Peace River
Cumulative Impact Study
2007

DEPARTMENT OF ENVIRONMENTAL PROTECTION
FLORIDA

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

PBS&J

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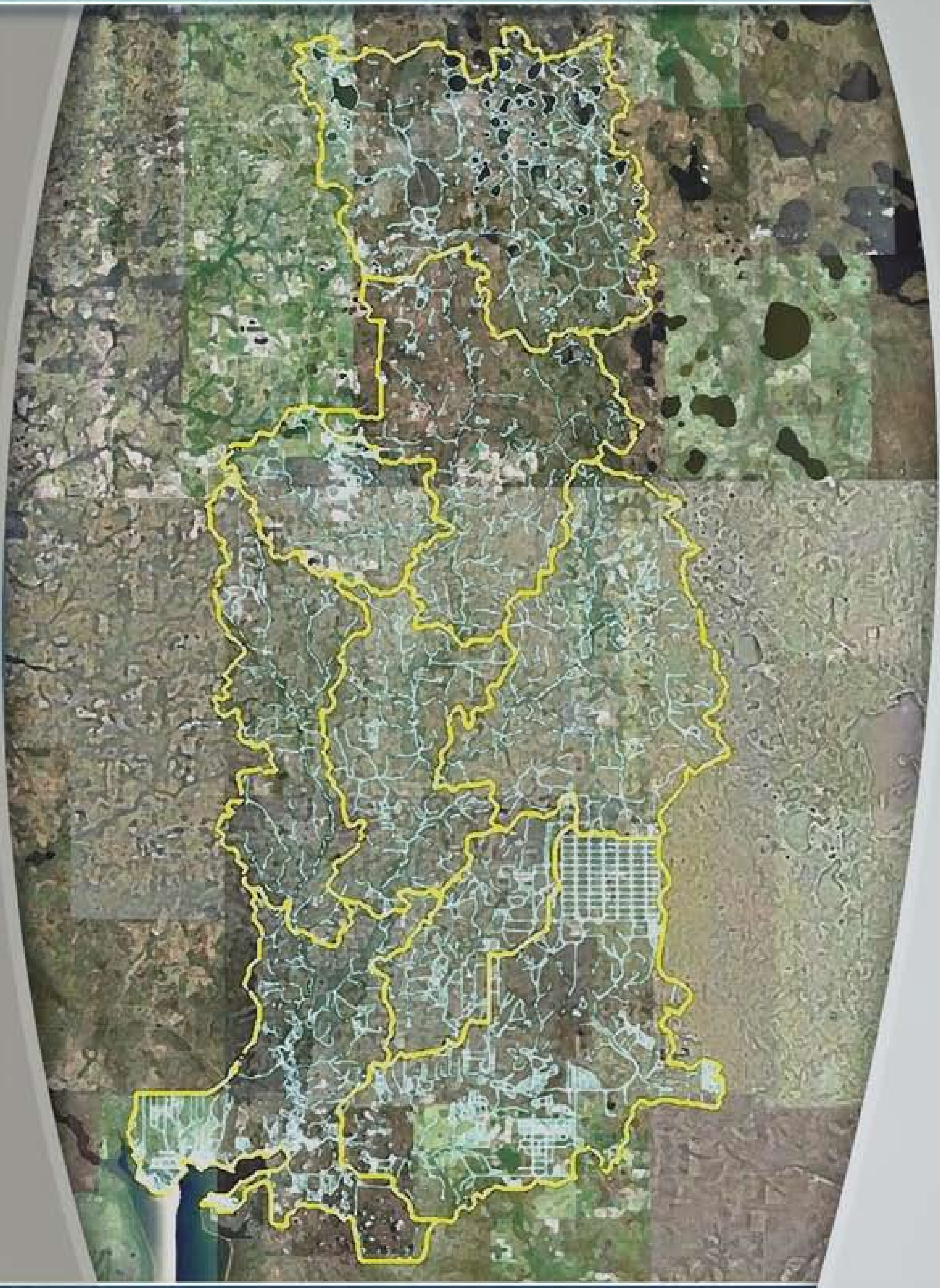

Final Report

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FINAL REPORT
for the

Peace River Cumulative Impact Study
Prepared for

Florida Department of Environmental Protection
Bureau of Mine Reclamation

and the

Southwest Florida Water Management District

Prepared by

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As with any undertaking of this complexity and magnitude, this final report reflects the work and input from a large number of individuals having a wide variety of expertise. The PBS&J team would like to express its thanks to the individuals who both worked on this effort and provided comments during its development. In addition, we would also like to acknowledge the comments and contributions of the many individuals who attended the series of public workshops during the development of the Peace River Cumulative Impact Study. Key contributors to the preparation of the Peace River Cumulative Impact Study report are shown in bold.

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Main Text					
Chapter 1 – Introduction	√				
Chapter 2 – Stressors and Indicators in the Watershed	√				
Chapter 3 – Peace River Basins	√				
Chapter 4 – Cumulative Impacts to the Peace River Watershed	√				
Chapter 5 – Overview of History and Evaluation of Regulatory Effectiveness		√			
Recommendations	√	√			
Appendices					
Appendix A – Literature Review	√				
Appendix B – Hydrologic and Water Quality Data	√				
Appendix C – Arc/GIS Project File	√				√
Appendix D – Analyses of Long-term Changes and Trends in Hydrology	√				
Appendix E – Analysis of Long-term Changes and Trends in Water Quality in the Peace River Watershed/Lower Peace River/Upper Charlotte Harbor Estuary	√				
Appendix F – Development of the 1940s Baseline GIS Land Use Layer					√
Appendix G – Change Analyses of Historic Land Use	√				√
Appendix H – Basin Water Budgets and Watershed Conceptual Models	√		√		
Appendix I – Regulatory History and Effectiveness		√			
Appendix J – Fishes in the Peace River Watershed				√	
Map Portfolio	√				
Access Reference Database	√				

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1.0 Introduction

1.1 Purpose and Objectives

Many portions of the Peace River watershed have been considerably altered from their natural state by agriculture, urban development and phosphate mining. In addition, considerable volumes of ground water, and to a lesser extent surface water, are withdrawn each day to support these land uses. It has become evident that these land and water uses have cumulatively impacted both the hydrology and ecology of the Peace River watershed.

In recognition of these impacts, Senate Bill 18-E, enacted in 2003 by the Florida Legislature, directed the Florida Department of Environmental Protection (FDEP) to conduct a Cumulative Impact Study (CIS) and subsequently prepare a *Peace River Basin Resource Management Plan*. FDEP selected PBS&J as the prime consultant for preparation of the CIS and work formally began in December of 2004.

> *The purpose of the Peace River CIS is to objectively assess the individual and cumulative impacts of certain anthropogenic and natural stressors in the Peace River watershed with respect to historical changes in stream flow, ambient water quality, and various ecological indicators.*

The purpose of the Peace River CIS is to objectively assess the individual and cumulative impacts of certain anthropogenic and natural stressors in the Peace River watershed with respect to historical changes in stream flow, ambient water quality, and various ecological indicators. Key selected stressors specifically assessed in this study include:

- Urban development
- Phosphate mining
- Agriculture
- Natural climate variability

The *Peace River Basin Resource Management Plan*, prepared by FDEP, and *Chapter 5.7* in the CIS, identify potential regulatory and non-regulatory means to minimize future impacts and mitigate past impacts to the Peace River watershed. In support of the Resource Management Plan, the CIS documents and evaluates the historic hydrologic and land use changes in the Peace River watershed. Several objectives were established to evaluate the potential cumulative impacts of the observed changes on the natural resources of the watershed and downstream estuarine system and are outlined below.

- Assess historical changes in the Peace River watershed with respect to the following indicators:
    - Acres of wetlands lost
    - Acres of native upland habitats lost
    - Miles of streambed lost
    - Changes in rainfall
    - Changes in streamflows
    - Changes in ground water elevations
    - Changes in the concentrations of indicator water quality constituents
    - Changes in the abundance, distribution, and diversity of indicator fish communities
- Discern, and quantify where possible, the relative and absolute contribution of each of the four stressors to documented historical changes in each of the nine major basins in the Peace River watershed.
- Develop a technical foundation for the subsequent preparation and adoption of the *Peace River Basin Resource Management Plan.*

1.2 Study Tasks

The CIS includes five primary tasks (listed below), as well as project management activities.

- Literature Review and Data Collection
- Description of Historical Changes
- Identification and Analysis of Factors Causing Changes
- Evaluation of Regulatory Effectiveness
- Final Report Preparation

Time periods used for comparisons among indicators varied, depending on data available. For example, the benchmark time period for land use data was circa-1940s based on the availability of quality high-resolution aerial photography. Spatial data were analyzed for three additional incremental time periods including 1979, 1990 (water budget only), and 1999. The absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins. Similarly, analyses of trends were conducted for incremental time steps appropriate to water quality and stream flow data. Data for these analyses (daily flows and rainfall, monthly water quality, quarterly ground water elevations spanned the period-of-record through 2004. Additional data were obtained from the mining industry to better differentiate among mining operations, for example, mandatory and nonmandatory reclaimed lands.

A variety of analytical techniques were used to determine and quantify, where feasible, the relative cause and effect relationships between the primary stressors and key indicators. Temporal changes in land uses and cover types associated with the anthropogenic stressors were directly assessed and quantified using various GIS spatial analytical methods. Temporal changes in hydrology attributable to the anthropogenic stressors and recent climate variability were assessed and quantified where possible using appropriate multivariate statistical procedures and modeling techniques.

An historical timeline of policy and regulatory programs implemented in the Peace River watershed from the benchmark period to the present was prepared. An attempt was made to relate historical changes in state and water management district policy and regulatory programs with documented temporal changes in key watershed indicators. From this analysis, inferences were developed regarding the effectiveness of current policy and regulatory programs. In addition, proposed potential changes to current regulatory and management programs were developed to reduce or reverse documented cumulative impacts.

1.3 Study Setting

The Peace River flows in a southerly direction about 105 miles from the confluence of the Peace Creek Drainage Canal and Saddle Creek in central Polk County to Charlotte Harbor. The Peace River watershed is approximately 2,350 square miles in area and includes large portions of Polk, Hardee, DeSoto, and Charlotte counties, and smaller portions of Hillsborough, Manatee, Highlands, Sarasota, and Glades counties (Figure 1.1). The Gulf Coastal Lowlands, the DeSoto Plain, and the Polk Upland are the three major physiographic provinces represented in the watershed. The headwaters region of the watershed lies within the Polk Uplands and is characterized by an upland, internally drained lake region that transitions to a poorly drained upland that extends south into Hardee County. The watershed gently slopes south through the DeSoto Plain in central Hardee and northern DeSoto counties, where surface drainage features are well developed. The Gulf Coastal Lowlands province dominates the watershed in central DeSoto County and Charlotte County. As in several previous studies, the Peace River Cumulative Impact Study (CIS) divides the watershed into nine basins.

1.3.1 Physiography

The Gulf Coastal Lowlands, the DeSoto Plain, and the Polk Upland are the three major physiographic provinces represented in the watershed and all or part of four sand hill ridge provinces occur in the northern watershed. The Peace River watershed begins in central Polk County, the Polk Uplands, as an internally drained lake region and transitions to a poorly drained upland. Within the DeSoto Plain of central Hardee and northern DeSoto Counties, the watershed becomes a gently sloping plain with well-developed surface drainage features. Downstream of central DeSoto County, the watershed includes the Gulf Coastal Lowlands province. The elevations decrease to less than 30 feet towards the coast as the floodplain broadens.

Figure 1.1 Location of the Peace River Watershed in Southwest Florida

1.3.2 Climate and Rainfall

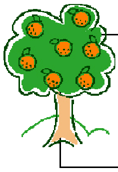
The climate in Peace River watershed is subtropical with an annual average temperature of about 73 degrees Fahrenheit. Annual rainfall in the watershed averages approximately 52 inches with about 60 percent of the rainfall occurring from June through September.

Long-term records indicated that annual rainfall during the last 30 years has been about five inches/year less when compared with the period 1940-1970.

Long-term records indicate that annual average rainfall during the 30-year 1970-2000 interval was about five inches/year less when compared with the preceding 1940-1970 period (Basso and Schultz 2003). Based on the monthly distribution, about 80 percent of this change was attributed to a decline in wet season rainfall during the months of June through October, with the largest monthly declines during the months of June, July, September, and October. This decline in wet season rainfall is consistent with conditions reported by Enfield (2001) and others who found a statistically significant change in wet season rainfall pre-1970 versus post-1970 for National Weather Service Region 4, which includes the Peace River watershed.

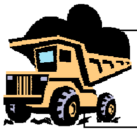
1.3.3 Land Use

During the 1940s baseline period, native uplands (60 percent) and wetlands (25 percent) comprised approximately 85 percent of the nearly 1.4 million acres of the Peace River watershed. By 1999, remaining native uplands accounted for only 17 percent, and wetlands only 16 percent, of the total Peace River watershed area. During the intervening six decades, combined developed land uses including agriculture (improved pasture, citrus and row cops), urbanization and phosphate mining increased from accounting for 13 percent to nearly 65 percent of the watershed area. The principal land use in the watershed in 1999 was agriculture, including 379,346 acres of improved pasture and 229,832 acres of intense agriculture making up 43.7 percent of the total area in the watershed.



The principal land use in the watershed in 1999 was agriculture, including 379,346 acres of improved pasture and 229,832 acres of intense agriculture making up 43.7 percent of the total area in the watershed.

Areas of urban and phosphate mining each increased from less than one percent of the watershed to approximately 10 percent of the watershed between the 1940s and 1999. Phosphate mining has moved from northern Peace River at Bartow and Zolfo Springs basins south into the Payne Creek and upper Horse Creek basins as a consequence of the commensurate increased depth to the ore and decreasing quality of the ore from north to south. Urbanized areas, by comparison, are largest in the northern portion of the watershed in Polk County (Peace River at Bartow basin) and at the southern end in Charlotte County in the Coastal Lower Peace River basin.



Urbanization and phosphate mining each accounted for about 10 percent of the land use in 1999.

Overall, the single largest change in developed watershed land use between the 1940s and 1999 was in improved pasture. Between the 1940s and 1979, acres of improved pasture increased from approximately 3 percent to 25 percent of the watershed. It has been suggested that much of this change occurred during the 1950s in response to rapidly increasing cattle prices.

Between 1979 and 1999, the change in improved pasture was much smaller and increased from 27 percent to 29 percent of the watershed.

As a result of these changes in land use, the natural drainage patterns in many parts of the watershed have undergone extensive alterations including ditching and connecting poorly drained wet prairies and isolated wetlands. Agricultural and urban alterations were made to improve water conveyance, lower the water table, and subsequently facilitate development. Phosphate mining alterations also altered drainage patterns and hydrological characteristics of mined lands and these changes often persist in spite of reclamation compliance with current regulations. As a result of these actions, the quantity, quality, and timing of surface runoff delivered to the tributaries the Peace River, and Charlotte Harbor estuary have also been affected. As a result of land use changes, 22 percent of the natural stream channels in the Peace River watershed were channelized or replaced by another land use between the 1940s and 1999. Percentage-wise, the greatest losses between the 1940s and 1999 of natural stream channels occurred in the Peace River at Bartow (60 percent) and the Payne Creek (52 percent) watershed basins, while the smallest losses took place in the relatively unimpacted Charlie Creek basin (5 percent).

As a result of land use changes, 22 percent of the natural stream channels in the Peace River watershed were channelized or replaced by another land use between the 1940s and 1999.

1.3.4 Hydrogeology

The Peace River watershed is underlain by three aquifer systems. The uppermost system is the unconfined surficial aquifer system. It consists of unconsolidated quartz sand, silt, and clayey sand. The depth of the surficial aquifer system varies from a few feet to over a hundred in the sand hill ridges. Underlying the surficial aquifer system is the confined intermediate aquifer system, consisting of thin, inter-bedded limestones, sands, and phosphatic clays of generally low permeability. The intermediate aquifer system is relatively thin in the upper reaches of the Peace River watershed and thickens to the south. Underlying the intermediate aquifer system, the confined Floridan aquifer system consists of limestone and dolostone formations. The Floridan aquifer is extremely permeable along some horizons. This is the principal water supply source of the basin. The Floridan aquifer system within the basin is a part of a much larger ground water basin, the Southern West-Central Florida Ground Water Basin. The Floridan aquifer is usually divided into upper and lower permeable units separated by a middle-confining unit. About 85 to 90 percent of all ground water is derived from the Upper Floridan aquifer. Depth to the lower Floridan aquifer and its relatively poor water quality currently preclude its use as a water supply.

In the vicinity of the Peace River proper, upstream of Fort Meade, the terrain and geology are of karst origin. During recent periods of low flows, the river has flowed into crevices of the streambed. Large sinks and solution features occur in the nearby floodplain. Kissengen Spring near Bartow was a significant local attraction in the early 1900s until it ceased flowing circa 1950. Average annual flows prior to the mid-1930s were about 30 cubic feet per second (cfs). Previous studies have attributed the historic decline of spring flow in the upper Peace River watershed to increasing ground water withdrawals (Peek 19951, Steward 1966, Hammett 1990, Basso 2003).

1.3.5 Water Use

Ground water use estimates were developed as part of the CIS (Appendix H) for each of the nine Peace River watershed basins for four reference periods (Table 1.3.1). Historically, ground water has provided the vast majority of the municipal, industrial, and agricultural water supplies used in the watershed. From the 1940s through the 1970s, the dominate ground water use in the upper watershed was for phosphate mining. However, in the late 1970s, the industry implemented water conservation practices, including greater reliance on capturing and recycling surface waters from mining areas. By the late 1990s, agriculture accounted for approximately 40 percent of the annual ground water use in Polk County, while domestic and industrial uses each accounted for just less than 30 percent of use (SWFWMD 2004). In the southern Peace River watershed basins, the majority of ground water withdrawals are associated with agricultural use.

Table 1.3.1. Estimated Watershed Basin Ground Water Use (mgd) for Four References Time Periods

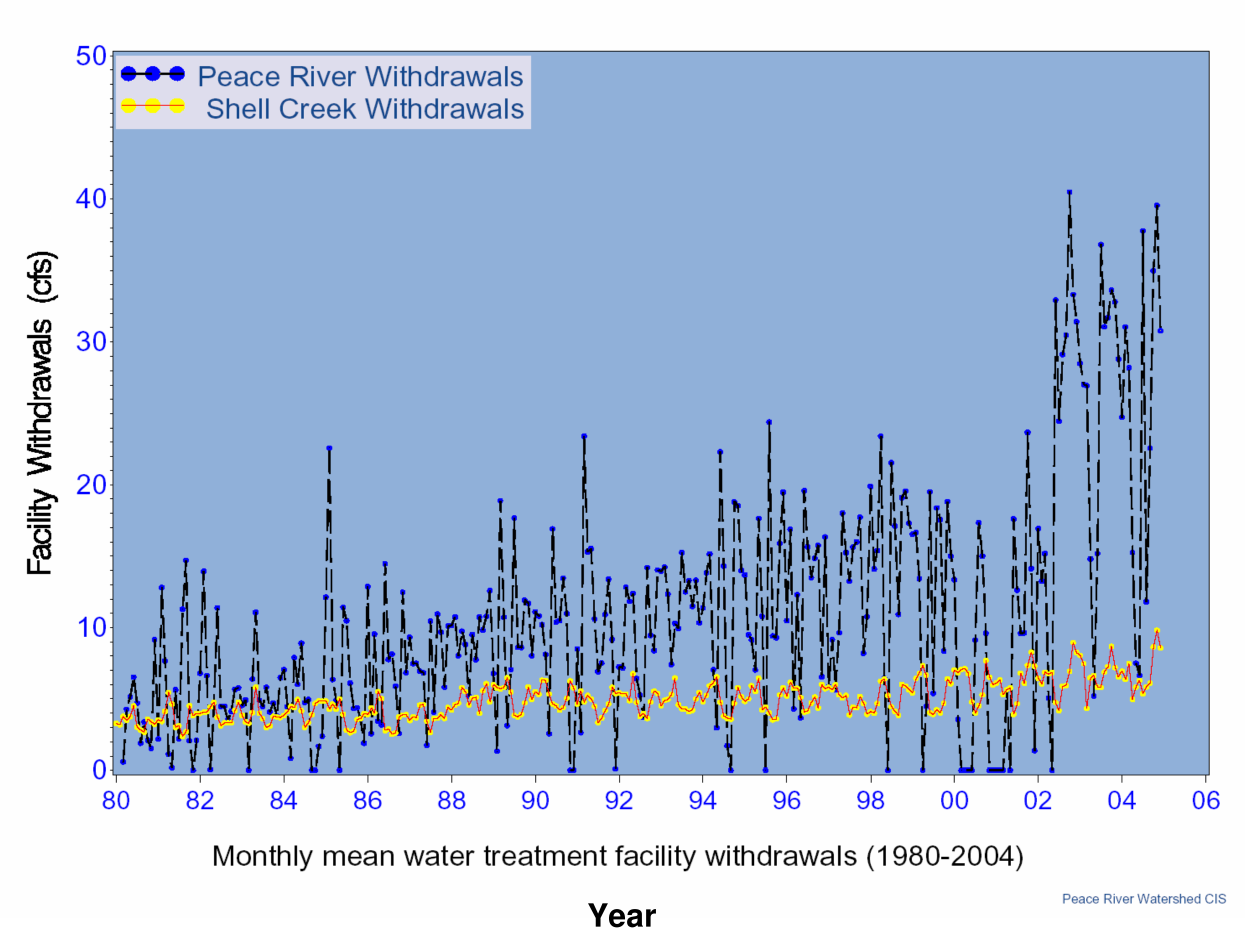
Peace River Watershed Basin	1941-1943	1976-1978	1989-1991	1997-1999
Peace River at Bartow	63	176	156	151
Peace River at Zolfo Springs	34	102	100	95
Payne Creek	7	24	24	24
Charlie Creek	11	49	57	62
Peace River at Arcadia	7	30	37	40
Horse Creek	6	27	34	37
Joshua Creek	9	27	33	36
Shell Creek	13	44	54	55
Lower Coastal	5	20	25	26

Agricultural practices in the watershed rely primarily on Upper Floridan aquifer ground water, rather than on surface water. Consequently, the conversion of undeveloped and range lands to more intensive forms of agricultural has resulted in increased irrigation and subsequent increases in annual dry season base flows in southern tributaries in the watershed (Appendix D). Dry season agricultural discharges resulting from the introduction of deep ground water from the well-confined Upper Floridan aquifer increases direct runoff as well as soil water in the surficial aquifer. These dry season discharges have resulted in increased conductivity and changes in other ground water quality characteristics in a number of several southern Peace River watershed tributaries (*Chapter 4* and *Appendix E*).

Like agriculture, phosphate mining ground water withdrawals and discharges have historically altered stream flows in the Peace River. The loss of flows from Kissengen Springs in 1950 was attributed to a progressive decline in the potentiometric surface of the Upper Floridan aquifer that was in turn associated primarily with historic ground water withdrawals for phosphate mining (Peek 19951, Steward 1966, Hammett 1990, Basso 2003). These withdrawals corresponded with mining discharges that historically obscured declining dry season spring base flows and altered the natural water quality in the upper river (Appendices D and E).

The major withdrawal of surface water for urban uses occurs in southern DeSoto County, where the Peace River/Manasota Regional Water Supply Authority (PRMRWSA) withdraws water from the Peace River to provide potable supplies for Charlotte, Sarasota and DeSoto counties. The City of Punta Gorda operates a smaller water treatment facility that withdraws surface water from behind the Hendrickson Dam on Shell Creek. A detailed description of these facilities, their history, and associated Hydrobiological Monitoring Programs (HBMPs) are presented in Chapter 5.4.4. Seasonal and long-term patterns of surface water withdrawals by these two public facilities are presented in Figure 1.3.1.

Figure 1.3.1. Monthly Mean Withdrawals from the Lower Peace River and Shell Creek for Public Supply



Total withdrawals at the Peace River facility from the first withdrawals in 1980 to 2004 have made up 1.15 percent of the corresponding gaged flows from the Peace River at Arcadia and 0.67 percent of the corresponding flows downstream of Shell Creek (PBS&J 2005).

A number of statistical models developed by the PRMRWSA and SWFWMD to predict the magnitude of the impacts of the Peace River Facility withdrawals on the salinity structure and movement of the freshwater/saltwater interface in the lower river (PBS&J 2006). These models have tested the relationships of lower river salinities and isohaline locations to both Peace River gage flows and facility withdrawal using HBMP data from the series of long-term “fixed” monitoring sites along the lower Peace River. Conclusions based on model results suggest that the predicted influences of facility withdrawals on salinity along the lower river typically range from 0.1 - 0.3 part per thousand (ppt). To date, these results have suggested that any facility salinity impacts probably could not easily be detected given the normal distributions or daily tidal ranges of salinity along the lower Peace River/upper Charlotte Harbor HBMP monitoring transect, and that the Peace River PRMRWSA facility has not significantly affected the seasonal or annual salinity structure of the estuarine reach of the lower Peace River. Thus, the measured and predicted changes in salinity and/or spatial locations of isohalines resulting from freshwater withdrawals have not been associated with pronounced or systematic changes in the salinity structure, water quality, or biological integrity of the estuarine communities of the lower Peace River/upper Charlotte Harbor.

> *The measured and predicted changes in salinity and/or spatial locations of isohalines resulting from freshwater withdrawals have not been associated with pronounced or systematic changes in the salinity structure, water quality, or biological integrity of the estuarine communities of the lower Peace River/upper Charlotte Harbor.*

1.3.6 Stream and Spring Flows

Hammett (1990) identified a statistically significant decline in annual mean discharge for the Peace River at Bartow, Zolfo Springs, and the Arcadia gaging stations from the 1930s to 1984. Lewelling and others (1998) updated this work by including the subsequent 10 year period and found the same declining trend from the 1930s to 1994. Results presented in the CIS (Appendix D) were similar and identified long-term declines in flows at these gaging locations over the period-of-record. However, more detailed trend tests indicated that seasonally adjusted flows at these same locations have remained statistically unchanged since 1970.

Historically, areas within the upper Peace basin exhibited artesian flow from the underlying confined aquifers. Between Bartow and Homeland, numerous sinks in the riverbed and the adjacent floodplain have periodically resulted in the loss of perennial flow during the dry season in the upper part of the river. Kissengen Spring and other minor springs previously discharged to the river, however, flow from Kissengen Spring declined steadily from the early

1930s, when flow was measured at greater than 30 cfs, until 1950 when continuous discharge ceased entirely. Cessation of flow from the springs is generally attributed to the decline in the hydraulic potential of the confined aquifers caused by the development of the ground water resource. The hydraulic potentials of the confined aquifers, previously observed above the riverbed, are generally tens of feet below the riverbed since the early-1960s. This has affected base flow to the upper portion of the river.

> *Cessation of flow from the springs (in the watershed) is generally attributed to the decline in the hydraulic potential of the confined aquifers caused by the development of the ground water resource.*

Base flow in the upper Peace River has also been affected by changes in discharges and drainage alterations associated with urbanization, phosphate mining, and agriculture. Phosphate mining and domestic waste discharges to the river have gradually declined since the mid-1980s (SWFWMD 2002). Historically these anthropogenic discharges augmented dry season base flow and until recently obscured the historic decline and cessation of spring flows in the upper watershed. Agricultural runoff, by comparison, has contributed to increased base flow in the Joshua, Prairie, and Shell Creek tributaries. In addition, urban land uses in the northern and southern areas of the watershed have increased impervious surface areas, altered natural hydroperiods, reduced stream stability, loss of in-stream habitat, degraded water quality, and reductions in biological diversity (Arnold and Gibbons 1996, Brant 1999, Shaver and Maxted 1996), and potentially impacted the ecology of the watershed ecology. Finally, median and high wet season flows have been affected by multidecadal changes in rainfall (Basso 2003). The analyses presented in the CIS (Appendix D), support previous findings that average annual wet season rainfall and flows (June through October) were greater prior to 1970 than since that time.

1.3.7 Ground Water Levels

The Upper Floridan aquifer is the principal source of water supply in the District and is divided into three ground water basins. The Southern West-Central Florida Ground Water Basin (SWCFGWB) covers most of the southern half of the District and saltwater intrusion is the principal constraint on the development of ground water in the coastal area of this basin. Ground water levels in the Southern West-Central Florida Ground Water Basin are open to the confined Floridan aquifer and have declined since the 1930s. This is generally the earliest period for which ground water level data exists. Ground water levels in Polk County reached their lowest levels in the mid-1970s when ground water withdrawals peaked. Ground water levels have increased somewhat since that time due primarily to water conservation efforts by the phosphate mining industry and agriculture. Demand for ground water in Hardee and DeSoto Counties was much less than in Polk County during the early and middle 1900s, however, water use data from the past decade indicate increasing ground water withdrawals by agriculture in these counties.

Ground water levels in the confined Floridan aquifer beneath the Peace River drainage basin are also affected by ground water withdrawals in other parts of the Southern West-Central Florida Ground Water Basin, particularly the Lake Wales Ridge area to the east and the areas of Manatee, southern Hillsborough, and northern Sarasota Counties to the west.

1.4 Importance of the Watershed and Estuarine System

The Peace River watershed and Charlotte Harbor estuary support a number of activities that contribute to the overall economy of the region. These include agriculture, urban development, phosphate mining, and tourism, as well as both recreational and commercial fishing. Regional economic assets also include natural habitats that provide direct and indirect economic benefits and represent significant regional environmental resources.

The diverse natural uplands, wetlands, riverine, and estuarine habitats in the Peace River watershed support a wide variety of flora and fauna as well as critical or essential habitat for a federally and state listed endangered and threatened species. The lower Peace River/Charlotte Harbor estuarine system is also important habitat for the larval, juvenile, and adult stages of a wide variety of recreationally and commercially important fish and invertebrate (crabs and shrimp) species.

The lower Peace River/Charlotte Harbor estuarine system is an important habitat for the larval, juvenile, and adult stages of a wide variety of recreationally and commercially important fish and invertebrate species.

However, expanding populations and development continue to present challenges at the local, regional, and state level to addressing impacts to these resources and developing management alternatives to reduce future threats and protect the current uses of these resources. Management goals include reducing future native wildlife habitat losses, reducing the impacts of point and nonpoint pollutants from growing development, securing additional water sources and improving the efficiency of freshwater use, protecting wetland areas for water storage, and maintaining ground water recharge.

In 1995 the U.S. Environmental Protection Agency (EPA) identified the Charlotte Harbor estuary and associated watershed as a system of national significance threatened by pollution, development, or overuse, and joined with local, regional, and state agencies to establish the Charlotte Harbor National Estuary Program (CHNEP). In addition, the Management conferences to develop Comprehensive Conservation and Management Plans (CCMPs) were convened under Section 320 of the Water Quality Act of 1987. The CHNEP is one of only 28 similar programs in the nation and represents the only program designated as "maintenance" rather than "restoration". To maintain the estuarine systems unique to Charlotte Harbor, the CHNEP has identified three priority problems that can be viewed as symptoms or consequences of more basic, causal processes.

1. **Hydrologic Alterations** – Adverse changes to volumes, locations, and timing of freshwater flows, the hydrologic function of floodplain systems, and natural river flows.

2. **Water Quality Degradation** – Pollution from several sources, including, but not limited to, agricultural and urban runoff, point source discharges, septic tank system loadings, atmospheric deposition, and ground water.

3. **Fish and Wildlife Habitat Loss** – Degradation and elimination of headwater streams and other habitats caused by development, conversion of natural shorelines, cumulative impacts of docks and boats, invasion of nonnative species, and cumulative and future impacts.

1.5 Overview of the Structure and Organization of the CIS Report

An overview of the integrated format for the Peace River CIS report, its associated technical appendices, and the additional accompanying portfolio of GIS based figures are provided below. The goal of the CIS report is to summarize the major findings of the study in a manner that will provide a comprehensive overview to a wide audience. The general findings and conclusions presented in the report are then supported through a series of technical appendices constructed around specific project tasks.

Chapter 1 – Introduction

The objective of this introductory section is to provide the reader with a brief overview of the items outlined below.

- The need for the study
- The primary objectives and goals of the PRCIS
- The report organization and structure

Chapter 2 –Watershed Stressors and Key Indicators of Change

This section provides general descriptions of the primary stressors identified as causes of long-term changes in important ecosystem components in the Peace River watershed. In addition, the means by which the key indicators of change are used to assess historic and cumulative impacts of the stressors are presented.

Stressors – The primary mechanisms of the influence of individual stressors and the characteristics of principal stressors associated with historic hydrologic alterations, changes in water quality, and lost of natural habitats within the Peace River watershed are reviewed. Stressors specifically addressed in this study include:

- Natural variability in long-term climate patterns
- Urban development
- Phosphate mining activities
- Agricultural conversions from more passive to intense practices

Indicators of Change – A discussion of the applicability of selected indicators to assessing long-term changes in key watershed characteristics is presented.

Chapter 3 – The Peace River Basins

This chapter of the report summarizes the primary findings of the CIS for each of the nine watershed basins, listed below.

- Peace River at Bartow
- Peace River at Zolfo Springs
- Payne River Creek
- Peace River at Arcadia
- Charlie Creek
- Joshua Creek
- Horse Creek
- Shell Creek
- Coastal Lower Peace

The general topics addressed for each of the basins include:

- Topography and geology
- Primary hydrologic features
- Time series changes in:
  - Rainfall
  - Stream flows
  - Water quality characteristics
  - Ground water levels
  - Land use - summary of change analyses and comparisons among the 1940s, 1979, and 1999 Peace River watershed GIS land use layers:
    - Agriculture activities and intensity
    - Urbanization
    - Mining activities and reclamation
    - Changes in extent of native upland habitats
    - Wetland losses
    - Losses of natural stream and river channels
- Overview of basin specific hydrologic water budget and differences between the 1940s, 1979, 1990 and 1999 reference periods.

Chapter 4 –Cumulative Impacts to Peace River Watershed

The primary objective of this chapter is to evaluate cumulative impacts at the watershed level with regard to previously presented historic changes in:

- Hydrology
- Water quality
- Wetland and in-stream habitat
- Native upland habitat

Relevant information and analyses from additional sources are also presented and used to examine possible linkages and/or causal relationships among and between anthropogenic and natural stressors, as well as the key indicators of change. In addition, the relative magnitude of influence of each of the key identified watershed stressors is ranked.

Chapter 5 – Overview of History and Evaluation of Regulatory Effectiveness

The primary objectives of this section of the report are to summarize conclusions regarding the effectiveness of both historical and current governmental policies and regulatory programs. Potential changes to those programs, and/or new programs to enhance protection of key watershed ecological components in the future are also proposed.

A historical timeline dating back to the study benchmark period is presented that documents the long-term history of both governmental policies and regulatory programs implemented in the Peace River watershed. Based on previously described long-term changes in the watershed resources, regulatory effectiveness is assessed through comparisons of historical implementation of regulatory policies and programs, and documented changes in the selected watershed indicators. The report assesses “gaps” in regulations.

The chapter also presents inferences regarding the historical and current effectiveness of policy and regulatory programs, as well as proposes changes to those programs. In addition, the assessment of potential policy and/or regulatory changes is presented centering on the potential benefits of floodplain buffers for maintaining water quality, moderating stream flow extremes, and protecting the habitat of water-dependent wildlife. The chapter presents an evaluation with regard to the specific applications and prescribed uses of floodplain buffers as mitigation under applicable permitting programs, and provides an economic assessment of such implementation.

Peace River Cumulative Impact Study Technical Appendices

Detailed technical information used in the Peace River Cumulative Impact Study is contained in a series of technical appendices. The technical appendices provide comprehensive summaries of the information, methods, and analyses implemented for the CIS tasks. As such, these appendices provide the technical background information supporting the summary conclusions contained in the main chapters of the document outlined above.

Appendix A, Literature Review – This appendix summarizes the methodology used in developing the CIS literature database and details the use of various aspects of the developed Access^{TM} reference/literature database.

Appendix B, Hydrologic and Water Quality Data – Appendix B provides descriptions of data sources used in synthesizing the hydrology and water quality data that were analyzed in the report and provides descriptions of each database.

Appendix C, Arc/GIS Project File – Appendix C describes the CIS ArcView project file, the standardized GIS projections, and includes a description of the appropriate meta data file structure.

Appendix D, Time Series Analyses of Trends in Hydrologic Information – This appendix provides an overview and comparison of the statistical methods used to test for statistically significant, progressive changes (or trends) in each of the key hydrologic indicators (listed below).

- Rainfall
- Surface water flows
- Rainfall / flow interactions
- Ground water elevations

The appendix also includes results, including summary graphics and tables, of all analyses for each of the nine watershed basins.

Appendix E, Time Series Analyses of Trends in Water Quality Parameters – The specific methodologies used to analyze the status and changes in water quality in each of the watershed basins are presented. This appendix also include the results, in graphical and tabular formats, of statistical and other procedures used to characterize changes in both surface and ground water quality measurements.

Appendix F, Development of 1940s Baseline GIS Land Use Layer – The appendix presents a brief overview of the technical issues related to the development of circa 1940s benchmark land use GIS layer. Topics include the availability, quality, and resolution of watershed aerial photography covering the 1940s reference period, as well as compatibility and comparability issues associated with more recent GIS land use layers developed by SWFWMD.

Appendix G, Application of Change Analyses Methodologies in Comparisons of 1940s, 1979, 1990, and 1999 Peace River Watershed GIS Land Use Layers – This appendix addresses the methods applied to change analyses among the available historical Peace River watershed GIS land use layers. This section also provides tabular summaries for each of the nine basins for specific indicators of land use changes.

Appendix H, Basin Water Budgets and Watershed Conceptual Models – This appendix details the methods and rationale used to develop conceptual water budget models for the watershed basins. Conceptual models were developed and used to relate all flow related mechanisms in each basin systems. Each of these analytical water budgets included primary components accounting for the channel, overland, and subsurface budgets. These components were computed from measured rainfall, stream flow, and ground water elevations, as well as estimates of annual fluxes between these components and their respective changes in storage. The developed water budgets included representations accounting for both temporal and spatial basin processes. Similarities and differences among the key hydrologic processes and specific observed responses among the basins were assessed and discussed. These comparisons were then used to develop conceptual models for the surface water and ground water systems in the Peace River watershed.

Appendix I, Background Information Associated with Evaluation of Regulatory Effectiveness – This appendix provides supporting information for the each of the primary topics discussed in Chapter 5 of the CIS report.

Appendix J, Evaluation of Historical Changes in Fish Species Composition and Abundance – This appendix details the technical findings of the review of historical fish studies in the Peace River watershed. The report examines historical changes in fish species composition and abundance. Where data were available, comparisons were made among tributaries in the Peace River watershed. Species richness and abundance were examined by computed incidence based curves and/or on sample based curves. Historical changes in the abundance and distribution of key indicator species were quantified by tributary or river basin. Based on the available data, inferences were drawn relative to potential causes of apparent historical changes in the abundances and distributions of fish species in the Peace River watershed.

1.6 Summary of Primary Data Sources

The results and conclusions presented in the Peace River CIS were based on analyses of data compiled from a number of sources. An overview of the primary data sources used in the study is presented here. Specific details with regard to the data used in the various analyses for the study are presented in the series of report technical appendices outlined above

Land Use

- 1940s land use Graphical Information System (GIS) mapping in the watershed – this layer was developed as part of the CIS by Avineon, Inc. FDEP contracted directly with Pickett, Inc. to have prints of photographs from the U.S. National Archives scanned and digitized into a GIS compatible format. Uniform, synoptic aerials for the entire watershed for the same time period were not available, and the information compiled by Pickett covered a period from the early 1940s to approximately 1951. Avineon then digitally rectified these aerials developed a 1940s baseline land use GIS layer using the same methods they applied in developing the 1979 SWFWMD land use GIS layer.

- 1979 land use GIS mapping – this recently developed layer was provided by SWFWMD.

- 1990 land use GIS mapping – this older layer was also provided by SWFWMD. It was developed by the District from U.S. Geological Survey (USGS) Quadrangle maps, rather than directly from aerial photographs. As a result, Avineon was unable to include accurate, direct comparisons between this 1990 land use information and from the 1940s, 1979, and 1999 time periods as part of the change analyses. The 1990 land use information was, however, used to develop the watershed basin water budgets presented in the CIS.

- 1999 land use GIS mapping – data were also provided by SWFWMD. Avineon then coordinated with District staff to resolve issues with the more recent 1979 layer developed by Avineon for the District.

- Phosphate mining GIS mapping – a number of sources were used in compiling the historic and current information presented in the CIS. GIS layers were obtained from SDI, Inc., the phosphate mining industry, and FDEP Bureau of Mine Reclamation.

- Avineon then used GIS software to prepare the tabular comparisons of changes in land use between the 1940s, 1979, and 1999 GIS layers presented in the CIS.

Stream and River Channel Lengths

Members of the PBS&J GIS and sciences staff used the 1940s digitally rectified aerial photographs to develop a digitized layer of the natural stream channels in each of the nine CIS watershed basins. These 1940s aerials indicated that even at this early period, extensive channelization had already occurred in many areas throughout the watershed. However, the objective of the CIS was to include only those 1940s stream channels that appeared to have retained their natural characteristics during this baseline period. In addition, stream channels were not included in sloughs or other continuous wetland systems where no definitive stream channel could be identified from the aerials. Consequently, estimates of first and second order streams may have been conservative and therefore underestimated due to the limits of the 1940s aerial photography. The 1940s GIS stream layer was then compared with the 1999 District aerials, and the new 1999 layer included stream segments identified in the 1940s that had been channelized, filled, or were otherwise no longer apparent. The difference between the 1940s and 1999 natural stream segments was then compared with the 1999 land use layer to provide an indication of potential causes for the observed losses. In many instances, the actual underlying cause of the stream loss may have been due to changes which preceded the 1999 land use.

Hydrologic Data

- Stream flow – data were obtained directly from the Tampa USGS web site.

- Ground water levels – data were compiled from the USGS ground water level monitoring and ambient water quality monitoring web sites, as well as from available SWFWMD monitoring programs.

- Rainfall – data were compiled from long-term recorders at the USGS stream flow gages, the National Oceanographic and Atmospheric Administration (NOAA) network, and the SWFWMD watershed rainfall monitoring sites.

- NPDES Discharges – data were obtained from FDEP.
- NPDES Water Quality – data were obtained from FDEP.

Water Quality Data

- Surface Water – period-of-record water quality data from watershed stream flow gaging sites were obtained directly from the USGS web site. STORET water quality data compiled by FDEP were obtained from the Total Maximum Daily Load Program. SWFWMD surface water quality data were provided by the District's surface water ambient monitoring program, and long-term water quality data for the lower Peace River/upper Charlotte Harbor estuary were acquired from the Peace River/Manasota Regional Water Supply Authority and City of Punta Gorda's Hydrobiological Monitoring Programs (HBMPs).
- Ground Water – data were obtained directly from the USGS ground water monitoring data web site, and from the SWFWMD database.

Relevant Literature – both the Peace River CIS and the accompanying technical appendices extensively cite relevant literature in support of statements made beyond particular findings derived directly from the study. Where applicable, the report directs readers back to specific technical appendices in support of conclusions drawn from relevant analyses conducted as part of the CIS. In addition, an extensive Access^{TM} database was developed as part of this study and includes additional references that may be of both specific and general interests with regard to assessing potential impacts to the Peace River watershed and the Charlotte Harbor estuary.

Background Information – copies of extensive background information and data, as well as materials compiled and summarized as part of recent legal proceedings regarding the issuance of phosphate mining permits were provided by Charlotte County and its consultants, the FDEP Bureau of Mine Reclamation, and SWFWMD staff.

2.0 Stressors and Indicators in the Watershed

The Peace River Cumulative Impact Study (CIS) identifies changes in the watershed associated with both natural differences in long-term rainfall patterns, as well as the more direct impacts from anthropogenic stressors, including increasing urban development, expanding phosphate mining, and changes resulting from more intense agricultural uses.

Importantly, Chapter 2 first provides an overview of these watershed stressors and summarizes some of the potential adverse impacts of the stressors from other studies, with limited reference to key findings of the CIS. The goal is to provide a context in which to evaluate changes in hydrologic indicators including stream flow, water quality, and ground water levels, and assess the impacts of losses of native uplands, wetlands, and stream habitat. Descriptions of major watershed stressors identified by the CIS and associated impacts are summarized from previous studies from both within and outside the Peace River watershed. Consequently, not all the identified potential stressor effects presented in this general overview are specifically described in either Chapter 3 or Chapter 4, where the discussions of stressor impacts are limited to the scope of the information developed for the Peace River CIS. A second goal of this chapter is to briefly describe the key indicators of change used in the CIS to document historical changes in the watershed that have resulted both from natural climatic variability as well as anthropogenic stressors.

Chapters 3 and 4 of the CIS subsequently assess impacts to individual basins as well as cumulative impacts to the watershed that are the result of natural and anthropogenic stressors with respect to historical changes in stream flow, ambient water quality, and selected ecological indicators.

2.1 Stressors

Historic hydrologic alterations, changes in water quality, and loss of natural habitats in the Peace River watershed have occurred due to natural variability in long-term rainfall patterns, increasing urban development, expanding phosphate mining activities, and agriculture. Each of these mechanisms, or “stressors”, has associated indicators that can be used to assess long-term changes in watershed characteristics. The CIS presents comparisons of land use changes between the 1940s, 1979, and 1999 that indicate the expansion of urban development, phosphate mining, and more intense agriculture activities in the watershed. These land use changes have altered natural drainage patterns, affected surface water runoff and infiltration rates, lowered ground water levels in the upper watershed, and complicated the analyses of the effects of natural long-term variations on seasonal rainfall patterns. Some of the potential impacts of natural variability in rainfall patterns and changes in land use on hydrology, water quality, and natural habitats are summarized below.

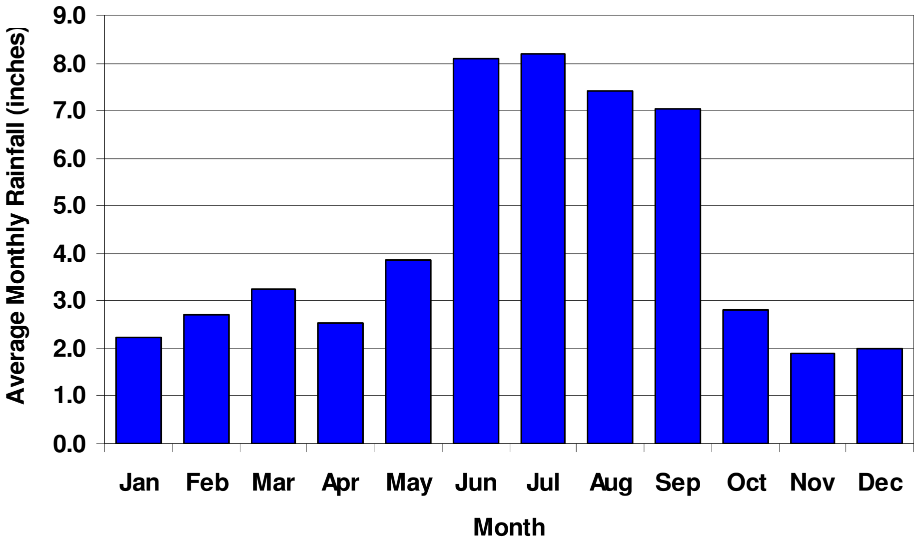
2.1.1 Influences of Natural Long-term Climatic Variability

Natural variability in long-term seasonal rainfall patterns and associated hydrologic (ground water and surface water) changes are potential watershed stressors in addition to anthropogenic influences. An objective of the CIS was to compile, summarize, analyze (see Appendix D), and subsequently identify the potential influences that long-term natural climatic cycles may or may not have had on surface water flows and ground water levels in both the overall Peace River watershed and individual basins.

2.1.1.1 Seasonal Rainfall Patterns Typical of Southwest Florida

The Peace River watershed occurs predominately in the National Weather Service (NWS) Florida South-Central Region Four. Annual monthly Peace River watershed rainfall averaged for the Bartow, Wauchula, Arcadia, and Punta Gorda gages over the historic 1932-2004 period is graphed in Figure 2.1.1.1. As indicated, the southwest peninsula of Florida is characterized by a summer wet season that accounts for approximately 59 percent of the 52 inches of total average annual precipitation. During this summer wet season, rainfall patterns are influenced by both frequent localized convective thunderstorms activity and periodic, widespread heavy rains associated with less frequent tropical cyclonic events. In contrast, the remainder of the year in southwest Florida is characterized by rainfall patterns associated with frontal systems from the northwest.

Figure 2.1.1.1. Monthly Average Peace River Watershed Rainfall at Bartow, Wauchula, Arcadia, and Punta Gorda Gages (1932-2004)



Typically, the four month summer wet season extends from June through September in southwest Florida, while the driest three months of the year are November through January. The transition from convection wet season rainfall to frontal dry season rainfall patterns occurs during October. Low precipitation, combined with higher temperatures and increasing evapotranspiration, precede the dry spring months and, as a result, streams, wetlands, and surficial ground water levels are typically at their lowest during May just prior to the beginning of the four month summer wet season. Conversely, during September and October, at the end of the summer wet season, hydrologic systems are usually near or at their annual peaks.

Seasonal influences of rainfall on watershed hydrology are therefore directly linked to the preceding hydrologic conditions. At the beginning of the summer wet season, a large proportion of rainfall is incorporated into surface and ground water storage (Basso and Schultz 2003). Conversely, later in the summer wet season, soil moisture content is highest, ground water levels are near the surface, wetlands and lakes are full, and a large proportion of rainfall contributes directly to runoff (Ross *et al.* 2001).

The four month wet season typically extends from June through September, while the driest three months of the year are November through January.

While these conditions are typical, there is a wide degree of both seasonal and annual variability in patterns of both rainfall and resulting river flow (see Appendix D). Deviations from the normal pattern can span periods of months up to several years. Intense El Niño/Southern Oscillation (ENSO) events, such as those that occurred in 1982-1983 and 1997-1998, can result in atypical extended periods of heavy rainfall during the usually drier winter/spring months and dramatically alter the annual watershed hydroperiod. In both instances these unusually wet periods were following by La Niña events and associated periods of extended drought. While short-term extremes of high and low flows influence the water budget in a watershed over periods of years, superimposed over these may be larger cyclic periods that can occur over a number of decades (Kelly 2004). Understanding the duration and magnitude of long-term regional rainfall cycles is important to assessing historic natural and anthropogenic hydrologic changes stream flow and ground water level records in Peace River watershed (Basso and Schultz 2003).

2.1.1.2 Potential Influences of Atlantic Multidecadal Oscillation Phases

Climate researchers (Gray *et al.* 1997, Enfield *et al.* 2001) have suggested that natural climate cycles or phases can persist over multiple decades. One of these cycles, the Atlantic Multidecadal Oscillation (AMO) refers to long-term cool and warm phase differences of only about 1°F (0.6°C) in average North Atlantic Ocean surface temperatures. An analysis of Atlantic Ocean surface temperatures suggests that warm AMO phases occurred during 1869-1893, 1926-1969, and to date since 1995, while cooler phases occurred predominately during the 1894-1925 and 1970-1994 time periods (Landsea *et al.* 1999). Climatological data indicate that differences between relatively warm and cool AMO periods affect both air temperature and rainfall patterns over North America and Europe (Gray *et al.* 1997, Enfield *et al.* 2001). It has been suggested that slight increases in average sea surface temperature in the Atlantic Ocean and Caribbean Sea during warmer AMO periods produce more summer rainfall across peninsular Florida, while cooler AMO phases result in decreased summer rainfall (Enfield *et al.* 2001, Basso and Schultz 2003, Kelly 2004).

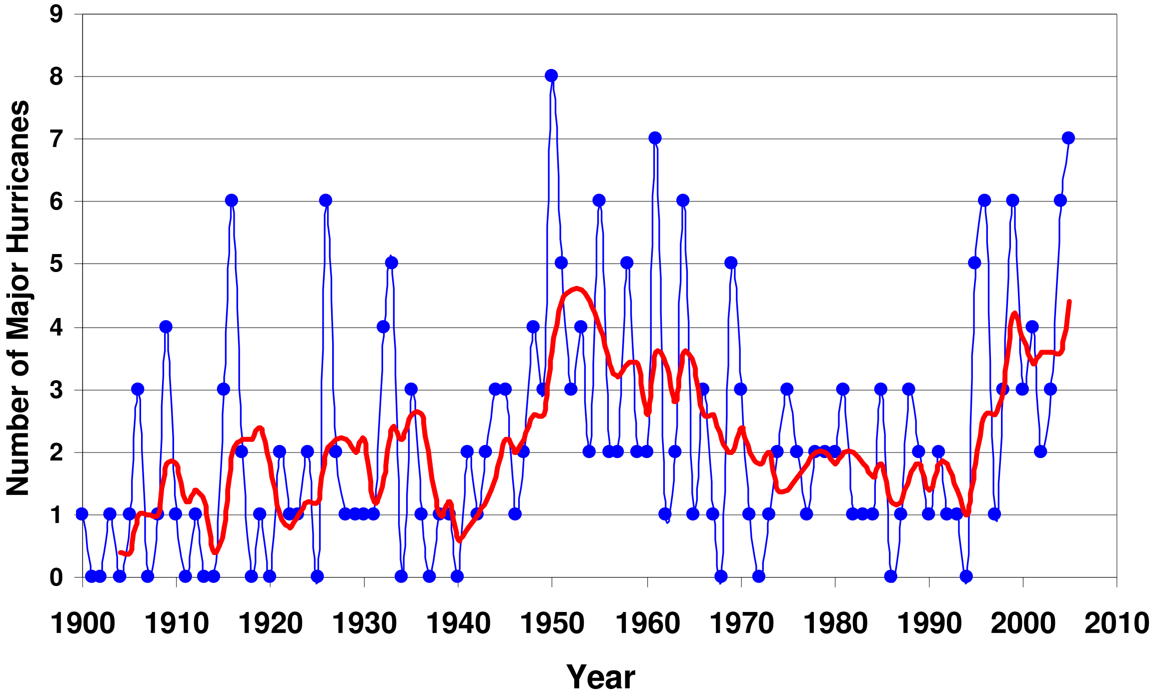
Studies of paleoclimatic proxies, including tree rings and ice cores, indicate that oscillations similar to those measured from Atlantic Ocean surface temperatures commonly occurred over 15-60 year intervals for at least the last thousand years. These changes predate modern era of anthropogenic climate influences and indicate that the AMO is a natural climate oscillation. It has also been suggested that during the 20th century, cyclical AMO climate changes have alternately camouflaged or exaggerated the potential effects of global warming making it more difficult ascertain recent changes.

Research suggests that past warm AMO cycles have corresponded with major droughts in the midwest and the southwest regions of the U.S., while during cooler AMO phases, rainfall has been more plentiful. Two of the most severe droughts of the 20th century in these western U.S., including the Dust Bowl of the 1930s, occurred during the extended warm AMO phase between 1925 and 1965. Conversely, rainfall patterns in both peninsular Florida and along the northwest Pacific Coast were opposite with increased wet season rainfall occuring during warmer AMO periods.

An analysis of Atlantic Ocean surface temperatures suggests that warm AMO phases occurred during 1869-1893, 1926-1969, and to date since 1995, while cooler phases occurred predominately during the 1894-1925 and 1970-1994 time periods.

Small increases in average surface water temperature in the Atlantic Ocean and Caribbean Sea during warmer AMO periods result in increased wet season rainfall across peninsular Florida, while cooler AMO phases correspond to decreased summer rainfall (Enfield *et al.* 2001, Basso and Schultz 2003; Kelly 2004). During warm AMO phases, Atlantic and Caribbean atmospheric circulation patterns flow predominantly from the southeast across the southern Florida peninsula, increasing summer afternoon convective thunderstorm activity, and resulting in higher wet season rainfall. At the same time, higher North Atlantic water surface temperatures also create atmospheric circulation patterns that tend to increase the frequency and intensity of storms, including those originating in the Sahel region of northwest Africa, while decreasing high level wind shear in the tropical Atlantic Ocean. During warm AMOs, these factors result in a higher frequency and duration of major tropical cyclones (Figure 2.1.1.2) in the Gulf of Mexico and Atlantic and Caribbean Basins (Gray *et al.* 1997, Landsea *et al.* 1999). These tropical systems can produce extremely high rainfall events as they move near (or across) Florida and a single storm event can account for as much as a third of the normal wet season rainfall. These storm events are more frequent toward the end of the summer wet season in August and September and hurricane associated rainfall events can dramatically influence annual stream flows and patterns in the watershed.

Figure 2.1.1.2. Annual Number of Major Hurricanes (1900-2005) (five-year moving average)



Several studies (Hickey 1998, Basso and Schultz 2003, Kelly 2004) have recently expanded upon previous work (Hammett 1990) in which changes in rainfall and/or stream flow patterns and relationships in Peace River watershed were examined. Hickey (1998) attributed observed declines in rainfall and flows to a reduction in the frequency of tropical storms events prior to and following 1970. Basso and Schultz (2003) found that while annual rainfall has not significantly changed over the last century, partitioning the data into shorter time intervals revealed cyclical decadal periods with rainfall above or below average rainfall. Using graphical and statistical methods, including 5-year moving averages, mean and median statistics, cumulative departure analyses, single mass techniques, and time series plots, they were able to demonstrate that the decades between the 1930s and 1960s were wetter than recent periods. Measures of mean and median rainfall at six gaging locations in the Peace River watershed indicated average declines of 4.5 and 5.5 inches/year between the two thirty-year periods 1936-1965 and 1966-1995. Changes in wet season rainfall, primarily linked to the AMO, were found to account for approximately 80 percent of the observed differences between the two periods.

An analysis of rainfall changes associated with an observed decline in tropical cyclone activity during 1970-1994 found that approximately one-third of the measured decline in wet season rainfall was associated with the observed decrease in these storms events. A total of 47 documented tropical cyclones (includes subtropical systems, depressions, tropical storms, and hurricanes) have impacted the Peace River watershed during the period 1930-2001. During the warmer AMO phase (1930-1969), 33 tropical storm events affected the basin. In comparison, during the subsequent cooler 1970-1994 AMO period, only 10 tropical systems impacted the watershed. This analysis indicated that the frequency of such intense rainfall storm events influencing the Peace River watershed during the warm AMO phase was approximately double of that which occurred during the cooler period.

> *Small increases in average surface water temperature in the Atlantic Ocean and Caribbean Sea during warmer AMO periods result in increased wet season rainfall across peninsular Florida, while cooler AMO phases correspond to decreased wet season rainfall.*

During warm AMO phases, the average number of tropical storms that become major hurricanes is significantly greater (at least double) when compared with cooler periods. Since 1995, when the AMO shifted from the preceding cooler period of approximately 26 years (1969-1994) to a warmer phase, the frequency of major hurricanes (category 3 or above on the Saffir-Simpson scale) has again increased (Figure 2.1.1.2). Based on the typical duration of alternating AMO phases, the current warm phase may persist for 10-30 more years. To date, models capable of predicting the AMO shifts from one phase to another are unavailable. However, it is possible is to determine the probability that a change in the AMO cycle will occur within a given future time frame (Enfield and Cid-Serrano 2005.) Such probability-based projections may be useful with regard to long-term water management planning since the availability of potential surface water supplies can vary considerably between warmer and cooler AMO periods.

2.1.1.3 Analyses of Long-term Variations in Watershed Rainfall Patterns

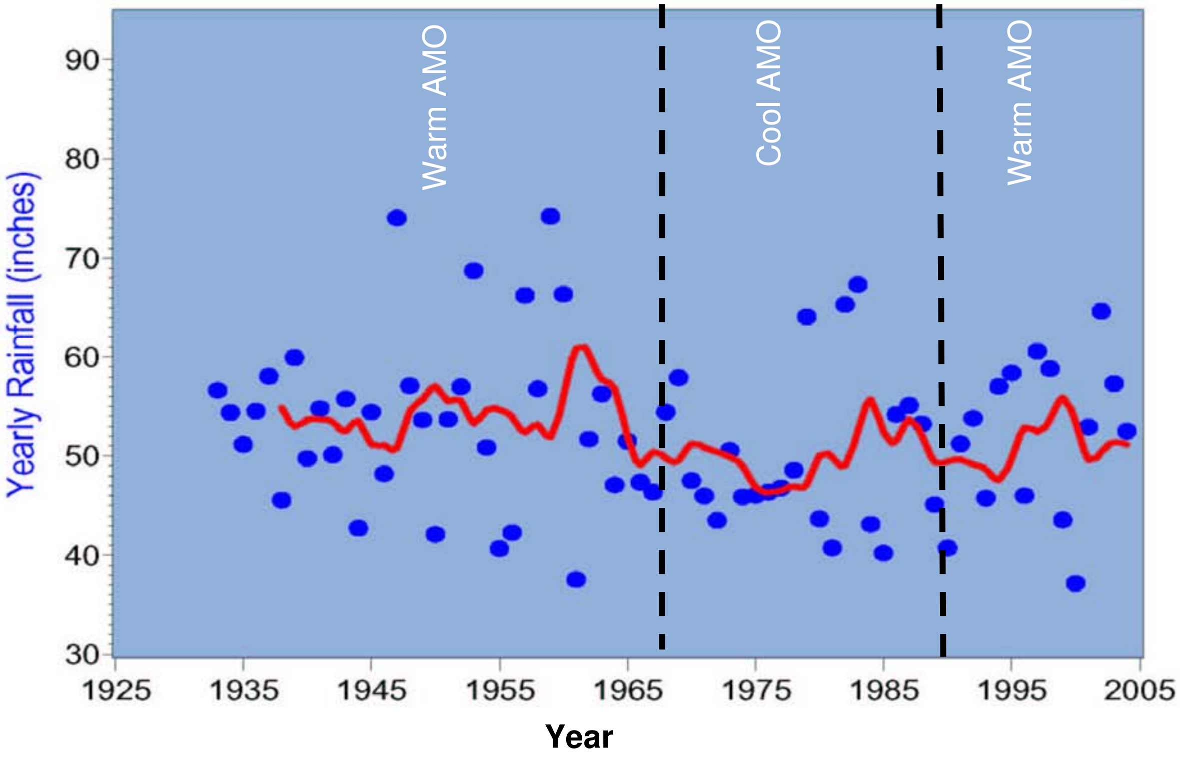
A series of statistical and graphical analyses were conducted as part of the Peace River CIS to assess potential long-term variability in rainfall patterns in the Peace River watershed. Detailed results of these analyses are presented in Appendix D and further summarized in Chapters 3 and 4. Some of the key results of these analyses are summarized here to provide a context for the preceding discussion of natural long-term climatic rainfall patterns.

- The variability in total monthly rainfall is sufficient to obscure small changes over time when data available from long-term rainfall monitoring sites in the Peace River watershed are examined on a monthly basis. However, when these data are viewed as either annual totals or as five-year moving averages (Figure 2.1.1.3), historically wetter and drier periods are both indicated.

- Total annual rainfall was slightly higher prior to the 1960s when compared with the years following. Seasonally, annual wet season (June-September) average rainfall was slightly higher from the 1930s through the 1950s when compared with the following interval from the 1960s through the 1980s. No similar long-term patterns were apparent in comparisons of dry season (January-May and October-December) rainfall, although rainfall was high during typically dry season months corresponding to the occurrences of El Niño events.

- Analyses of both yearly and cumulative total deviations from the long-term annual average rainfall supported the observations that historic rainfall patterns are generally consistent with the time intervals of the AMO theory. Averaged over the watershed, annual rainfall was generally above average from the early 1920s through approximately the early 1960s and then below average until the early/mid-1990s. Annual rainfall in the watershed prior to the 1960s averaged about 54 inches per year, compared with about 50 inches per year from the 1960s to the early/mid-1990s, and about 53 inches per year since the mid-1990s. The analyses indicated that decadal differences were primarily due to historically higher (four to five inches) wet season rainfall during the earlier period.

Figure 2.1.1.3. Yearly Total and Five-Year Moving Average Rainfall in the Peace River Watershed



2.1.1.4 Corresponding Long-term Patterns in Watershed Surface Flows

Comparisons of land use between the 1940s, 1979, and 1999 (Chapter 4 and Appendix G) indicate the degree to which the watershed has historically been modified by the expansion of urbanization, phosphate mining, and more intense agriculture activities. These landform changes have altered natural drainage patterns, affected surface water runoff and infiltration rates, and lowered ground water levels in the upper watershed, which subsequently eliminated natural spring discharges in the upper watershed (Basso 2003, Lewelling and Wylie 1993, Lewelling *et al.* 1998, URS 2005). These anthropogenic hydrologic changes associated with changing land use patterns complicate evaluation of the effects of cyclical rainfall variability on watershed flow patterns.

- Natural spring discharges that historically contributed base flow in the upper reaches of the Peace River were lost due predominately to the effects of historical ground water withdrawals by phosphate mining that lowered the water levels in the underlying intermediate aquifer and the Upper Floridan aquifer systems (Hammett 1990). However, these losses in natural base flow during the 1940s-1950s were historically masked by high ground water discharges from mining activities that substantially augmented river base flow. These augmented base flows were subsequently eliminated from the upper river during the late 1970s and early 1980s with the implementation of new regulatory measures and changes in phosphate mining practices, which eliminated direct mining and urban discharges to surface waters. Declines in dry season base flows in the upper river, therefore, are distinct from the influences of the observed natural cyclical rainfall patterns.

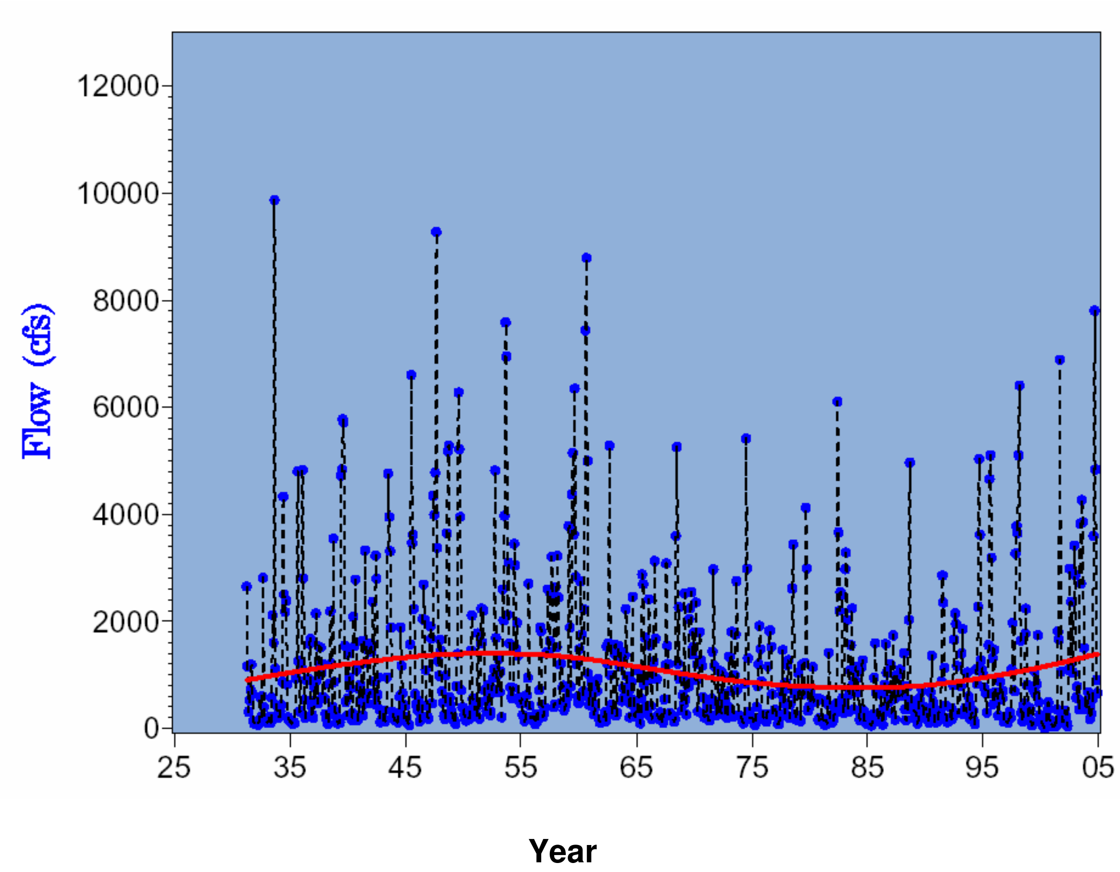
- Land use changes in the southern watershed basins represent cumulative losses of wetlands and native upland habitats due to a progressive shift in agriculture from predominately unimproved pasture to improved pasture, and then to larger areas of more intense agriculture such as citrus and row crops. Commensurate with increases in more intense agricultural land uses, ground water withdrawals (Appendix H) and discharges of ground water surface waters (Appendix E) have increased. The result has been recent marked increases in base flows and dry season flows from ground water in many of the Peace River tributaries that are again unrelated to natural long-term variations in seasonal rainfall patterns.

- The results of graphical and statistical analyses (Appendix D) indicate that historical median, mean, and high long-term flows were generally higher during the 1930-1960 time interval, declined during the 1960s and early 1970s, and suggest increases following the mid-1990s (Figure 2.1.1.4). These differences in flows generally coincide with three AMO oscillations, including the warmer wet phase prior to 1969, the cooler dry interval between 1969 and 1994, and the recent warmer wet period since 1995.

- Further analyses indicated that variation in annual total flows at the long-term river gages downstream of Bartow coincided with similar long-term flow patterns outside the Peace River watershed at the Withlacoochee River at Croom USGS gaging station. These results indicate similar variations in total annual flows within and outside the Peace River watershed due to natural long-term variations in rainfall that influenced southwest Florida (Kelly 2004). The Withlacoochee River at Croom gaging site was selected for comparison due to the proximity to the northern portion of the Peace River watershed and flows that are not strongly influenced by major spring flows, phosphate mining, extensive intense agriculture, or urban development.

- Combined, these analyses indicate that median, mean, and high flows in the Peace River have been affected by long-term, decadal patterns in rainfall that have influenced flows both inside and outside the watershed, and that these patterns generally correspond with the AMO theory, which has been suggested as a possible mechanism to explain changes in regional historic rainfall patterns. Declines in base flows, however, are not explained by changes in rainfall.

Figure 2.1.1.4. Monthly Means Flow at the Peace River at Arcadia (2296750) Gage (1931-2004)



2.1.2 Effects of Urban Development on Hydrology, Water Quality, and Natural Habitats

Urbanization, including both residential and commercial / industrial development as well as associated transportation infrastructure has increased from less than one percent of the Peace River watershed in the 1940s to accounting for approximately 10 percent of the watershed area by 1999. Urban lands more than doubled in the Peace River at Bartow basin between 1979 and 1999. Watershed urbanization influences the hydrology, stream geomorphology, water quality, and habitat associated with streams and rivers. Traditional development replaces pervious lands such as forests and prairies with impervious surfaces that include roads, parking lots, and buildings, storm sewer systems, and other anthropogenic features. These changes increase the amount of stormwater runoff from a site, decrease infiltration and ground water recharge, and alter natural drainage patterns (Figure 2.1.2.1). Under developed conditions, native vegetation and soils are disturbed and may be removed, and the natural mechanisms for removing pollutants from stormwater runoff are altered. Development can also introduce new sources of pollutants associated with residential, commercial, and industrial land uses.

In general, the greater the amount of impervious surface in a watershed, the greater the stream impacts, including reduced stream stability, habitat, water quality, and biological diversity.

Impervious surface has emerged as a measurable, integrating concept used to describe the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (CTFDEP 2004 after Schueler 1995, Arnold and Gibbons 1996, Brant 1999, Shaver and Maxted 1996). The increased impervious surface of urban areas results in loss of vegetation and top soils, which subsequently reduces rainfall interception by canopy vegetation, as well as evapotranspiration and interflow, and increases surface water runoff (Figure 2.1.2.2). In general, the greater the amount of impervious surface in a watershed, the greater the stream impacts to a watershed are, including reduced stream stability, habitat, water quality, and biological diversity (NRDC 1999). For comparison, typical total impervious surfaces of medium density residential areas ranges from 25 to nearly 60 percent of the developed area (Schueler 1995).

The impacts of urbanization on streams and watersheds can be placed in four categories (listed below). The extent of these impacts is a function of climate, level of imperviousness, and change in land use in a watershed (WEF and ASCE 1998).

- Hydrologic impacts
- Stream channel and floodplain impacts
- Water quality impacts
- Habitat and ecological impacts

2.1.2.1 Effects of Urban Development on Watershed Hydrology

Development can dramatically alter the hydrologic regime of a basin as a result of increases in impervious surfaces. Even before natural surfaces are replaced with impervious surfaces and structures, the natural hydrology of local streams is often changed due to initial site clearing and grading. Vegetation that once intercepted rainfall is removed and natural depressions that temporarily held water are often graded to a uniform slope. The soil and associated litter and humus in floodplain forests that previously absorbed rainfall are usually removed or eroded away. Even before impervious surfaces are constructed, much of the natural storage capacity of the developing area is often eliminated and rainfall subsequently flows off site as stormwater runoff.

Figure 2.1.2.1. Impacts to Watershed due to Conversion from Natural Landscapes to Urban Development

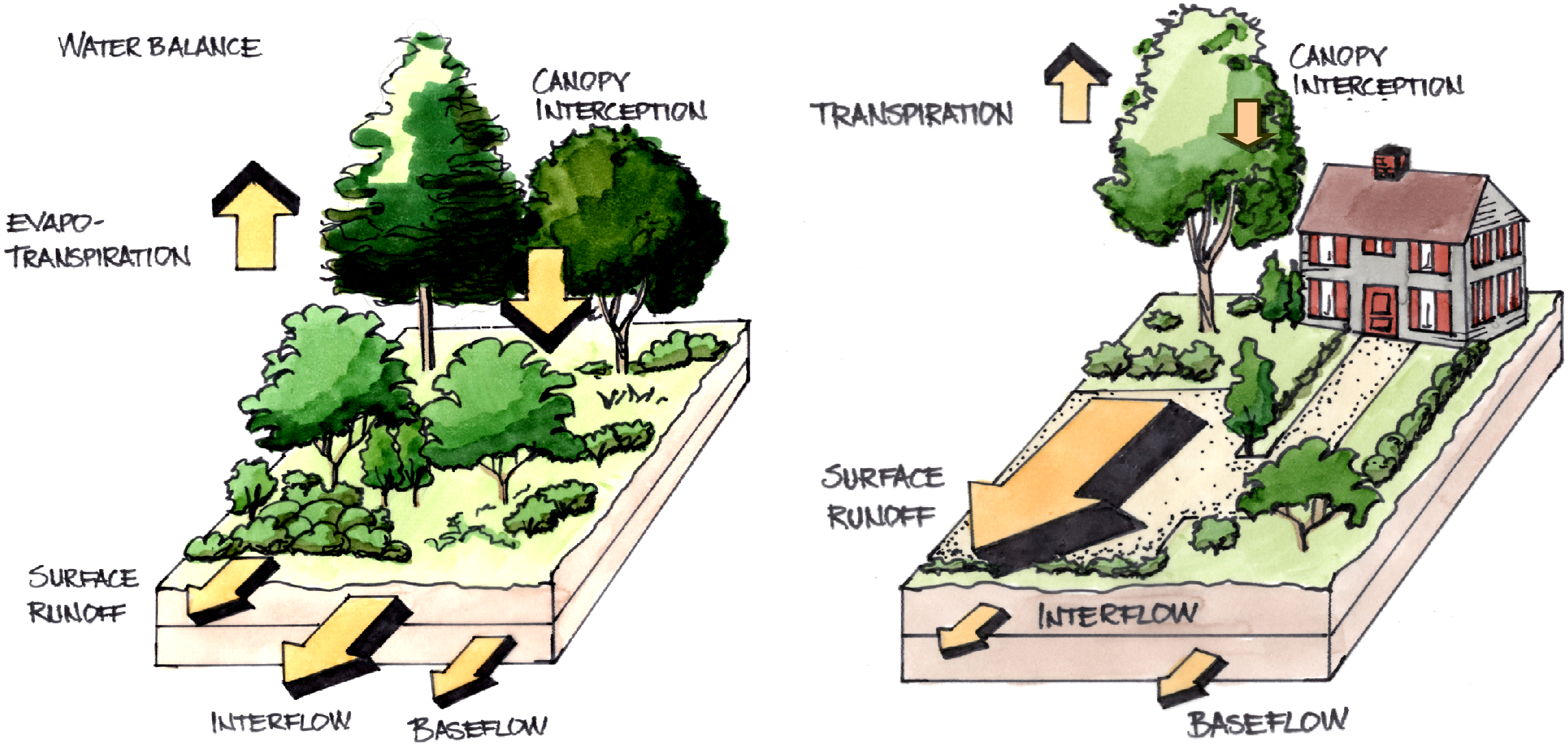
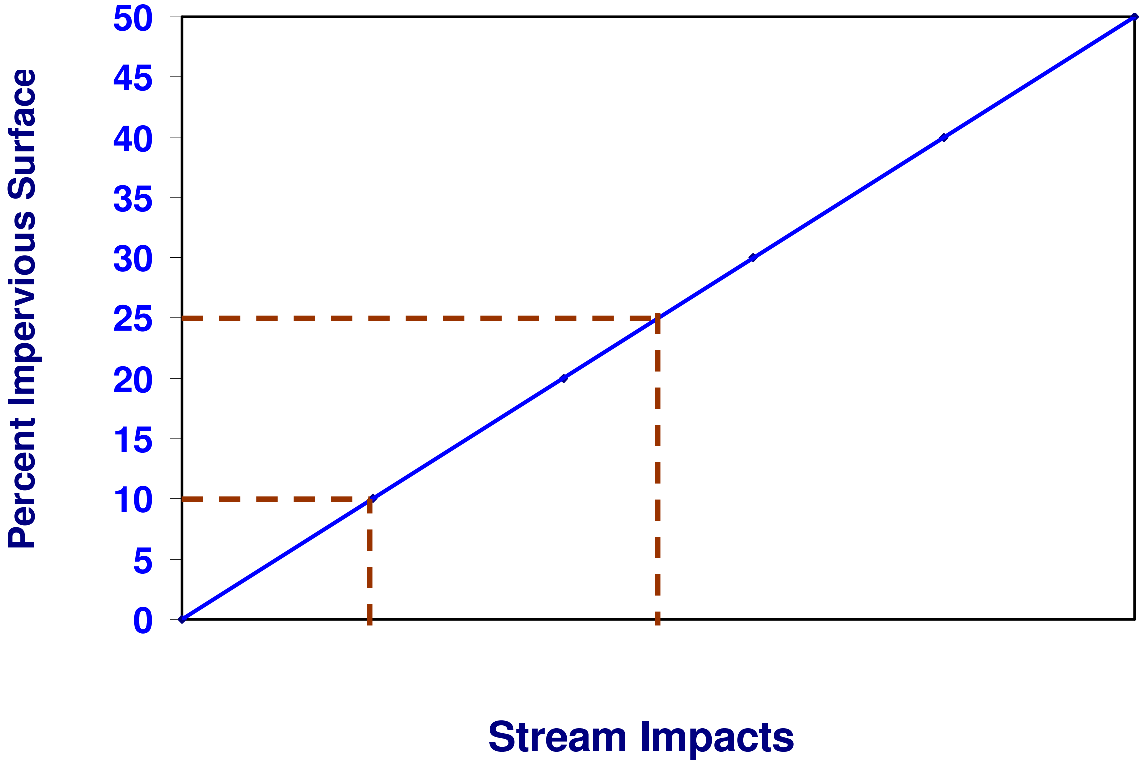


Figure 2.1.2.2. Relative Impact of Increases in Impervious Surface on Streams



Construction of buildings, roads, parking lots, sidewalks, and driveways all increase the amount of impervious area, decrease rainfall percolation into the ground, and subsequently increase the amount of stormwater runoff. The resulting excess runoff may be too large for the natural drainage system to manage and the existing drainage must be "improved" to convey the increased amounts of runoff away from the site by installing culverts, curbs, gutters, storm sewers, or lined channels. The impacts of development on hydrology may include:

- Increased runoff volume
- Increased peak discharges
- Decreased runoff travel time
- Reduced ground water recharge
- Reduced stream base flow
- Increased frequency of bankfull and over-bank floods
- Increased flow velocity during storms
- Increased frequency and duration of high stream flow

The channel of an urbanized stream often changes in response to altered hydrological conditions associated with urbanization. The severity and extent of stream alterations is generally a function of the degree of increased imperviousness (WEF and ASCE 1998). Some of the impacts of development on stream channels and floodplains are described below.

- The greatest changes in a stream channel subjected to increased stormwater flows are channel scour, widening, and down cutting. Numerous surveys (Robinson 1976, Fox 1974, Hammer 1972) and anecdotal evidence (Ragan and Dietmann 1976) have documented increases in stream widths two to four times their original size in the absence of effective, post-development runoff controls.

- Development elevations in the stream floodplain must be raised to accommodate resulting higher peak discharges. As a result, the actual floodplain may expand and property and structures which had not previously been subject to flooding may become so, often resulting in further channelization.

- Increased flows can undercut stream banks and erode banks into the channel. Trees that had previously stabilized the banks are exposed at the roots, and are more likely to be wind thrown, triggering even more bank erosion.

- Increased sediment loads from eroded stream banks and upland areas are seldom completely exported. Much of this load often remains in the form of sandbars and other sediment deposits before gradually being transported downstream as bed load. However, for many years following initial urbanization, stream channel benthic substrate habitat can be subject to covering by shifting erosional deposits.

2.1.2.2 Effects of Urban Development on Water Quality

Urbanization typically results both in new sources of pollutants, as well as the collection and concentration of pollutants from increased impervious areas. Stormwater runoff from urbanized areas consequently both increases pollutant loads and discharges. Urban stormwater collection and conveyance systems can rapidly wash pollutants to downstream and adversely impact the water quality of receiving waters. In contrast, the natural processes of infiltration, interception, depression storage, filtration by vegetation, and evaporation that characterize undeveloped landscapes both reduce the quantity of stormwater runoff and often provide some degree of pollutant removal. Urban stormwater runoff may occur as both point and nonpoint sources of pollution.

- **Point Source Pollutants –** Stormwater that flows into a conveyance system that is discharged through a pipe, ditch, channel, or other structure is considered a point source discharge under the US Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) permit program, as administered by Florida Department of Environmental Protection (FDEP) (additional urban point sources may also include wastewater and/or industrial discharges).

- **Nonpoint Source Pollutants** – Stormwater runoff that flows over the land surface and is not concentrated in a defined channel is considered nonpoint source pollution.

Stormwater runoff generally begins as a nonpoint source and then becomes a point source discharge as a result of urban stormwater conveyances. Both point and nonpoint sources of urban stormwater runoff have been targeted as causes of water quality impairment (US EPA 2000).

Pollution from nonpoint sources presently account for the majority of water quality problems in the State of Florida (DeBusk 2002). Typically, nonpoint source pollution is associated with stormwater runoff from residential, urban, and agricultural activities and the associated transport of sediments, nutrients, pathogens and pesticides. Typical soluble pollutants and associated concentrations that are found nationally in urban stormwater are listed in Table 2.1.2.1. A summary of urban stormwater pollutants, potential sources, impacts to receiving waters, and components that promote the removal of the pollutant, is provided in Table 2.1.2.2. Factors that promote removal of most stormwater pollutants include:

- Increasing hydraulic residence time
- Low turbulence
- Fine, dense, herbaceous plants
- Medium-fine textured soil

Conventional pollutants, metals and parameters that result in low dissolved oxygen levels (Meeter and Niu 2000) are often used to measure the health of surface water bodies. Typical examples of conventional pollutants include chlorides, fecal coliform, nitrates, phosphorus, and total suspended solids. Metals typically associated with urban stormwater runoff include arsenic, aluminum, copper, iron, lead, and mercury. The State of Florida has developed an *impaired waters* list and criteria used to assess whether a certain pollutant or metal level restricts a water body from meeting its designated use or “Class”. Designating thresholds for metals, which are anthropogenically linked, is generally less controversial than doing the same for naturally occurring pollutants.

Urban land uses and associated activities can also result in degraded ground water quality if stormwater with high pollutant loads and/or discharges from onsite treatment systems (septic tanks) are directed into the soil without adequate treatment. Intense land uses such as commercial parking lots, vehicle service and maintenance facilities, and industrial rooftops, result in higher loads of pollutants such as metals and toxic chemicals due to increased impervious areas and subsequent increases in surface water runoff. Soluble pollutants can then contaminate shallow wells in ground water supply aquifer areas.

Nutrients – Nutrients play a vital role in promoting excessive algae growth, which is indicated by increased amounts of chlorophyll *a*. However, nutrients are naturally occurring elements and surface water bodies contain a certain amount of background nutrients. In reference to eutrophication, two different dynamics need to be considered. First, in strictly scientific terms, eutrophication in closed water bodies can describe the natural aging process as loadings and increases in sedimentation occur over time. However, in terms of evaluating water quality, eutrophication has typically come to represent human induced increases in the rate of the “natural aging process” of lakes and/or increased chlorophyll *a* levels in open systems such as streams, rivers and estuaries (McFarland *et. al.*, 2000). Algal blooms caused by excessive nutrients often cause rapid diurnal changes in dissolved oxygen and other water quality changes that negatively affect the composition and diversity of aquatic communities. However, nutrients levels are not the only limiting factors to be considered, since resulting chlorophyll *a* levels are also dependent on factors such as light availability, water residence time, water velocity (for streams) and substrate factors (turbulence).

Sections 62-303.350 through 62-303.353 of Chapter 62-303 F.A.C., deal with the interpretation of the narrative nutrient criteria for the State's surface waters. Specifically, Section 62-303.350 F.A.C. states that "Trophic State Indices (TSIs) and annual mean chlorophyll *a* values shall be the primary means for assessing whether a water body should be assessed further for nutrient impairment. Other information indicating an imbalance in flora or fauna due to nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings, shall be considered".

Table 2.1.2.1. Principal Pollutants in Urban Stormwater Runoff

Constituent	Concentration	Units
Total Suspended Solids[1]	54.5	mg/l
Total Phosphorus[1]	0.26	mg/l
Soluble Phosphorus[1]	0.10	mg/l
Total Nitrogen[1]	2.00	mg/l
Total Kjeldahl Nitrogen[1]	1.47	mg/l
Nitrite and Nitrate[1]	0.53	mg/l
Copper[1]	11.1	ug/l
Lead[1]	50.7	ug/l
Zinc[1]	129	ug/l
BOD[1]	11.5	mg/l
COD[1]	44.7	mg/l
Organic Carbon[2]	11.9	mg/l
PAH[3]	3.5	mg/l
Oil and Grease[4]	3.0	mg/l
Fecal Coliform[5]	15,000	Colonies/100 ml
Fecal Strep[5]	35,400	Colonies/100 ml

Adapted from CSQM 2004, after NYDEC 2001. Original sources are: [1]Pooled Nationwide Urban Runoff Program/USGS (Smullen and Cave 1998), [2]Derived from National Pollutant Removal Database (Winer, 2000); [3]Rabanal and Grizzard 1995, [4]Crunkilton *et al*. 1996, [5]Schueler 1999. [6]Oberts 1994. mg/l = milligrams per liter. µg/l= micrograms per liter.

Table 2.1.2.2. Summary of Urban Stormwater Pollutants

Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Components that Promote Removal
Excess Nutrients Nitrogen, Phosphorus (soluble)	Animal waste, fertilizers, failing septic systems, landfills, atmospheric deposition, erosion and sedimentation, illicit sanitary connections	Algal growth, nuisance plants, ammonia toxicity, reduced clarity, oxygen deficit (hypoxia), pollutant recycling from sediments, decrease in submerged aquatic vegetation (SAV)	Phosphorus - High soil exchangeable aluminum and/or iron content, vegetation and aquatic plants Nitrogen - Alternating aerobic and anaerobic conditions, low levels of toxins, near neutral pH
Sediments Suspended, Dissolved, Deposited, Sorbed Pollutants	Construction sites, streambank erosion, washoff from impervious surfaces	Increased turbidity, lower dissolved oxygen, deposition of sediments, aquatic habitat alteration, sediment and benthic toxicity, decreased SAV	Low turbulence, increased residence time
Pathogens Bacteria, Viruses	Animal waste, failing septic systems, illicit sanitary connections	Human health risk via drinking water supplies, contaminated swimming beaches, and contaminated shellfish consumption	High light (ultraviolet radiation), increased residence time, media/soil filtration, disinfection
Organic Materials Biochemical Oxygen Demand, Chemical Oxygen Demand	Leaves, grass clippings, brush, failing septic systems	Lower dissolved oxygen, odors, fish kills, algal growth, reduced clarity	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Hydrocarbons Oil and Grease	Industrial processes; commercial processes; automobile wear, emissions, and fluid leaks; improper oil disposal	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Low turbulence, increased residence time, physical separation or capture techniques
Metals Copper, Lead, Zinc, Mercury, Chromium, Aluminum (soluble)	Industrial processes, normal wear of automobile brake linings and tires, automobile emissions and fluid leaks, metal roofs	Toxicity of water column and sediments, bioaccumulation in food chain organisms	High soil organic content high soil cation exchange capacity, near neutral pH (7)
Synthetic Organic Chemicals Pesticides, VOCs, SVOCs, PCBs, PAHs (soluble)	Residential, commercial, and industrial application of herbicides, insecticides, fungicides, rodenticides; industrial processes; commercial processes	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Aerobic conditions, high light, high soil organic content low levels of toxicants, near neutral pH (7), high temperature and air movement for volatilization of VOCs
Trash and Debris	Litter washed through storm drain network	Degradation of aesthetics, threat to wildlife, potential clogging of storm drainage system	Low turbulence, physical straining/capture

Table 2.1.2.2. Summary of Urban Stormwater Pollutants

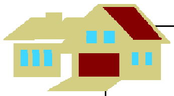
Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Components that Promote Removal
Freshwater Impacts	Stormwater discharges to tidal wetlands and estuarine environments	Dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites	Stormwater retention and volume reduction
Thermal Impacts	Runoff with elevated temperatures from contact with impervious surfaces (asphalt)	Adverse impacts to aquatic organisms that require cold and cool water conditions	Use of wetland plants and trees for shading, increased pool depths

Source: Adapted from CT DEP 1995; Metropolitan Council, 2001; Watershed Management Institute, Inc. 1997.

Nutrient criteria designations in Florida, like Texas and other states, have been based largely on narrative abstracts and are open to some matter of debate. Better links between chlorophyll *a* and nutrient concentrations are needed to develop quantifiable nutrient targets that would link biological and anthropogenic factors to algal growth and provide meaningful targets for implementation. Since water bodies naturally exhibit some degree of trophic variation, target objectives must be based on accurately assessed differences between natural occurring and culturally induced changes. “The difficult problem in water quality assessment is defining the appropriate trophic state for a given waterbody and the factor or factors that can be controlled to limit the production of algae if a lower trophic status is desired” (McFarland *et al.* 2000). Culturally induced eutrophication is in most instances caused by excessive nutrients. In general, phosphorus is the limiting nutrient for freshwater systems, while nitrogen is usually the limiting nutrient in estuarine systems (Gibson 1997). However, in the Peace River watershed, the Bone Valley geologic formation results in naturally higher phosphorus concentrations and freshwater/ estuarine aquatic systems are generally nitrogen-limited.

The major origins of nonpoint sources of nitrogen in surface water bodies are fertilizer, animal manure, atmospheric deposition and urban runoff. Dissolved nitrogen from agricultural runoff enters surface water bodies as nitrate, which is a very mobile form of nitrogen. In this form, nitrogen can very easily reach surface water bodies. Approximately 11.5 million tons of nitrogen are used as commercial fertilizer for agricultural purposes throughout the United States annually (Puckett 1994). Nitrogen contained in the manure of farm animals accounts for approximately 6.5 million tons of nitrogen annually (Puckett 1994). The atmospheric deposition of nitrogen originates from combustion processes (power plants, industries and transportation) and results in an estimated 3.2 million tons of nitrogen per year reaching surface waters (Puckett 1994). While the problems of excess nutrients in estuarine environments are well understood (excessive algae growth, reduced amounts of submerged aquatic vegetation, reduced amounts of dissolved oxygen, to name a few), tracking the exact source and form of the nitrogen imbalance is often difficult.

Estimates of the comparative loads of nitrogen and phosphorus from point source and nonpoint source discharges have been made using pollutant-loading models for Tampa Bay, Lemon Bay, and Charlotte Harbor. There are uncertainties associated with appropriate runoff coefficients and event mean coefficients (EMCs) for stormwater loads, appropriate uptake and/or dentrification rates for septic tank systems, appropriate techniques for base low calculations, and appropriate methodology for measurement of direct and indirect loads of wet and dry atmospheric deposition" (Tomasko 2000).



> *Point sources account only for about two percent of the nitrogen exported from the Peace River watershed. Nonpoint agriculture sources account for 68 percent of the nitrogen exported to Charlotte Harbor and nonagricultural runoff accounts for 17 percent of the nitrogen exported into Charlotte Harbor from the watersheds.*

Studies have suggested that point source account only for about two percent of the total nitrogen exported from the Peace River watershed, while atmospheric sources account for an estimated 13 percent of the total nitrogen exported from the watershed to Charlotte Harbor (Valigura *et al.* 2000). Correspondingly, it is estimated that nonpoint agriculture sources account for 68 percent of exported nitrogen and nonagricultural nonpoint runoff accounts for 17 percent of the nitrogen exported into Charlotte Harbor from the watershed.

Outside of the natural phosphate deposits, the primary sources of phosphorus in southwest Florida are generally similar to those previously described for nitrogen, and phosphorus rather than nitrogen is more likely to create eutrophic conditions in freshwater systems. Often under phosphorus limiting conditions, blooms of cyanobacteria (formerly called blue green algae) are the major sign of eutrophication. Excessive phosphorus inputs to such freshwater system are fairly well understood, but often with so many potential causes of phosphorus loading from nonpoint sources, the problem is accurately tracking the actual source.

Sediments – Sediment loading to water bodies occurs from stormwater runoff carrying particles that were deposited on impervious surfaces such as roads and parking lots, soil erosion associated with construction activities, mining, agriculture, and streambank erosion. Although some erosion and sedimentation is natural, excessive sediment loads can be detrimental to aquatic life including phytoplankton, algae, benthic invertebrates, and fish, by interfering with photosynthesis, respiration, growth, and reproduction. Solids can either remain in suspension or settle to the bottom of the water body. Suspended solids can make the water cloudy or turbid, detract from the aesthetic and recreational value of a water body, and harm submerged aquatic vegetation (SAV), finfish, and shellfish.

The models described above have also been used to estimate TSS contributions from point and nonpoint sources of discharges. Sediment transported in stormwater runoff can be deposited in a stream or other water body or wetland and can adversely impact fish and wildlife habitat by smothering bottom dwelling aquatic life and changing the bottom substrate. Sediment deposition in water bodies can result in the loss of deep-water habitat and can affect navigation, often necessitating dredging. Sediment transported in stormwater runoff can also carry other pollutants such as nutrients, metals, pathogens, and hydrocarbons. The greatest sediment loads are exported during the construction phase of any development site and are consequently exported from larger, intensively developed watershed basins in which Best Management Practices (BMPs) for erosion have not been implemented.

Consequences of high concentrations of suspended sediments in streams include increased turbidity, reduced light penetration, reduced prey capture among sight feeding predators, clogged gills/filters of fish and aquatic invertebrates, reduced spawning and juvenile fish survival, and reduced angling success.

Pathogens – Pathogens in stormwater runoff include disease-causing bacteria, protozoa, and viruses, and often exceed public health standards for water contact recreation and shell fishing. Sources of pathogens in stormwater runoff include animal waste from pets and wildlife, as well as from sewers, failing septic systems, and illegal sanitary sewer cross connections. The presence of bacteria such as fecal coliform or enterococci is used as an indicator of pathogens and of potential risk to human health (US EPA 2000).

The use of indicator bacteria is controversial for stormwater, as is the assumed time of typical exposure of swimmers to contaminated receiving waters, but recent epidemiological studies have shown significant health effects associated with stormwater-contaminated marine swimming areas (Burton and Pitt 2001). Protozoa pathogens, associated with sewage-contaminated stormwater, are also public health concern. Evaluating a receiving water and understanding the potential role that urban stormwater runoff may have on its beneficial uses is a complex and time consuming activity.

Organic Materials – Organic substances such as grass clippings, leaves, animal waste, and street litter are found in stormwater and decomposition of these substances can deplete oxygen levels. Low dissolved oxygen concentrations may have adverse impacts on a water body similar to those described for excessive nutrients. Organic substance decomposition is of concern in water bodies where oxygen is not easily replenished or is already low, such as in slower moving streams, lakes, and estuaries. An additional concern for unfiltered water supplies is the formation of trihalomethane (THM), a carcinogenic disinfection byproduct generated by combining chlorine with water high in organic carbon (CT DEP 2004).

Although bacteria levels exported from nearly every urban and suburban land use violate public health standards, older and more intensively developed urban areas produce the greatest export.

Hydrocarbons – Urban stormwater runoff can transport a large number of hydrocarbon compounds to receiving waters, some of which are toxic to aquatic organisms at very low concentrations (Woodward Clyde 1990). The primary sources of hydrocarbons in urban runoff are transportation related. Roads, parking lots, gas stations, vehicle service stations, residential parking areas, and bulk petroleum storage facilities are hydrocarbon sources due to high runoff coefficients that rapidly transport these substances to receiving waters.

Metals – In addition to hydrocarbons, copper, lead, zinc, mercury, cadmium, chromium, nickel, and other metals occur in urban stormwater runoff (US EPA 1983). The primary sources in stormwater runoff are vehicular exhaust residue, fossil fuel combustion, corrosion of galvanized and chrome-plated products, roof runoff, stormwater runoff from industrial sites. Architectural copper associated with building roofs, flashing, gutters, and downspouts has been shown to be a source of copper in stormwater runoff in some areas of the country (Barron 2000, Tobiason 2001). Marinas have also been identified as a source of copper to inland and marine waters (Sailer Environmental Inc. 2000). Removal of salt and barnacles from boat hulls also removes some of the bottom paint, which contains copper and zinc additives designed to protect hulls from deterioration.

Trace metals are primarily a concern because of toxic effects on aquatic life and potential contamination of drinking water supplies.

Roads and highways are often cited as the largest contributors of metals and hydrocarbons in stormwater runoff (see above). The most common contaminants in highway runoff are heavy metals, inorganic salts, aromatic hydrocarbons, and suspended solids that accumulate on the road surface as a result of regular highway operation and maintenance activities. Engine and tire wear from vehicles results in the dropping of oil, grease, rust, hydrocarbons, rubber particles, and other solid materials on the highway surface. These materials are often washed off the highway during rain events. The primary sources of highway runoff constituents are listed in Table 2.1.2.3 (US EPA 1993).

Recent findings are not definitive as some studies indicate a positive relationship between average daily traffic and pollutant concentrations, while others point to antecedent rainfall conditions, rainfall amount, and percent imperviousness as the primary factors affecting roadway runoff (Kayhanian *et al.* 2000, Davies *et al.* 2000, Drapper *et al.* 2000). However, pollutant concentrations are generally higher in deceleration/acceleration zones of roads (Table 2.1.2.4) due to increased brake and tire wear and idling conditions.

Pollutant concentrations were particularly low along urban highways with higher traffic speeds, and therefore less idling and greater emissions (Davies *et al.* 2000). Idling and slow moving vehicles have more time to release more oil and grease on the road. Based on the sources of roadway pollutants, activities that decrease brake and tire wear should result in a decrease in pollutant loading. In many cases, pollutant concentrations are related to total suspended solids (TSS) concentrations since heavy metals and some nutrients bind to larger particulate matter and are then transported by stormwater runoff to receiving waters. Higher concentrations of copper and zinc therefore may be exacerbated by rapid deceleration of heavy vehicles approaching the traffic lights (Davies *et al.* 2000).

As Table 2.1.2.4 indicates, deceleration areas exhibited the highest zinc concentrations, which are consistent with findings (US EPA 1993) that zinc is linked to tire wear, oil, and grease. Acceleration areas, by comparison, typically have the highest metal and dissolved metal concentrations of lead, which is a by-product of tire wear and exhaust (US EPA 1993).

Table 2.1.2.3. Primary Sources of Major Highway Runoff Constituents

Constituent	Primary Source
Particulates	Pavement wear, vehicles, atmosphere
Nitrogen, phosphorus	Atmosphere, roadside fertilizers
Lead	Tire wear, automobile exhaust
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, moving engine parts
Copper	Metal plating, brake lining wear, moving engine parts, bearing and bushing wear, fungicides and herbicides
Cadmium	Tire wear, roadside insecticide application
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Moving engine parts
Petroleum	Spills, leaks, blow by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate

Although metals generally attach themselves to the solids in stormwater runoff or receiving waters, recent studies (Mas *et al.* 2001, New England Bioassay, Inc. 2001) have demonstrated that dissolved metals, particularly copper and zinc, are often the primary toxins in stormwater runoff from urban industrial facilities. Metals previously attached to sediments can also become bioavailable under conditions where the bottom sediments become anaerobic (without oxygen), as often occurs during the summer in deeper lake and estuarine areas of southwest Florida. Metals can be toxic to aquatic organisms, can bioaccumulate, and can potentially contaminate drinking water supplies.

Synthetic Organic Chemicals – Synthetic organic chemicals, including pesticides, phenols, polychlorinated biphenyls (PCBs), and polynuclear or polycyclic aromatic hydrocarbons (PAHs) can also occur at low concentrations in urban stormwater. Such chemicals can exert varying degrees of toxicity on aquatic organisms and can bioaccumulate in fish and shellfish. Toxic organic pollutants occur most commonly in stormwater runoff from industrial areas, pesticides are commonly found in runoff from lawns and rights-of-way (NYDEC 2001), and PAHs are the most common organic toxicants found in roof runoff, parking area runoff, and vehicle service area runoff (Pitt *et al.* 1995).

Table 2.1.2.4. Pollutant Concentrations Associated with Primary Road Uses

Parameter	Highway	Deceleration	Acceleration
Conventional Measures			
TSS	94.4	64.9	123.1
TDS	84.8	89.5	97.6
DOC	14.7	15.9	14.2
TOC	17.7	21.5	17.9
Nutrients			
Nitrate as N	1.2	0.9	0.8
TKN	1.8	1.8	1.9
Total Phosphorus	0.3	0.2	0.3
Orthophosphate	0.2	0.1	0.2
Total Metals			
Arsenic	1.4	1.2	1.3
Cadmium	0.7	0.6	0.6
Chromium	7.8	5.6	5.7
Copper	22.3	22.1	22.0
Lead	21.9	21.7	52.2
Nickel	10.9	5.8	5.4
Zinc	129.8	199.9	165.1
Dissolved Metal			
Arsenic	0.9	0.7	N/A
Cadmium	0.4	0.4	N/A
Chromium	2.6	3.2	2.4
Copper	11.4	12.4	10.4
Lead	3.2	2.1	9.6
Nickel	4.4	3.5	3.1
Zinc	59.4	107.8	55.5

Trash and Debris – Trash and debris are washed off of the land surface by stormwater runoff and can accumulate in storm drainage systems and receiving waters. Litter detracts from the aesthetic value of water bodies and adversely impacts aquatic life directly (by being mistaken for food) or indirectly (by habitat modification). Sources of trash and debris in urban stormwater runoff include residential yard waste, commercial parking lots, street refuse, sewers, illegal dumping, and industrial refuse.

Freshwater Impacts – Discharge of fresh water, including stormwater, into brackish and tidal wetlands can decrease salinities and alter the hydroperiod in these environments. While freshwater discharges to estuaries and bays are important, excessive freshwater flows, with commensurate nutrients and toxins from urban runoff, can disturb existing plant communities and provide a foothold for invasive and nonnative species such as giant reed (*Phragmites australis)* and torpedo grass (*Panicum repens*). Invasive plant species like hydrilla (*Hydrilla* *verticillata*) and water lettuce (*Pistia stratiotes*) are a major problem in some springs and can replace native eelgrass (*Vallisneria americana)* and eliminate the open areas of the spring. Nuisance algae, such as green algae (*Spirogyra sp.)* and blue green algae (*Lyngbya sp.)*, grow quickly in response to the elevated nitrate levels, forming mats that smother the native aquatic vegetation on the spring floor. Control of these invasive species requires labor-intensive manual removal in some cases.

Thermal Impacts – Impervious surfaces may increase temperatures of stormwater runoff and receiving waters. Roads and other impervious surfaces heated by sunlight may transport thermal energy to a stream during storm events. Direct exposure of sunlight to shallow ponds and impoundments as well as unshaded streams may further elevate water temperatures. Elevated water temperatures can exceed fish and invertebrate tolerance limits, reducing survival and lowering resistance to disease. Elevated water temperatures also contribute to decreased oxygen levels in water bodies and dissolution of solutes. Concentrations of pollutants in stormwater runoff vary considerably between sites and storm events.

Urban Wastewater – Prior to the enactment of Clean Water Act and subsequent amendments to the Act in the early 1970s, wastewater discharges from municipal sewage and smaller package plant facility were largely unregulated, and streams, lakes and estuaries were often used to dilute and transport wastes from their sources. While increasingly stricter environmental regulations have resulted in both substantial improvements in wastewater treatment and the elimination of most direct discharges, currently NPDES-regulated wet weather wastewater discharges from percolation ponds and spray fields still contribute to increased stream flows and pollutant loadings, potentially adversely impacting water quality of receiving waters.

2.1.2.3 Effects of Urban Development on Natural Systems

The aquatic ecosystems in urban headwater streams are particularly susceptible to impacts of urbanization. Changes in hydrology, stream morphology, and water quality that are associated with the urbanization process can also impact stream habitat and ecology. Habitat and ecological impacts may include:

- A shift from external (leaf matter) to internal (algal organic matter) stream production
- Reduction in the diversity, richness, and abundance of the stream community (aquatic insects, fish, amphibians)
- Destruction of freshwater wetlands, riparian buffers, and springs
- Creation of barriers to fish migration
- Adverse impacts to health and reproduction of fish and other species

Impacts of urban stormwater runoff on biological communities are primarily the result of habitat destruction and long-term exposures to contaminants (especially to macroinvertebrates via contaminated sediment). Documented effects associated from acute exposures of toxicants in the water column are rare (Burton and Pitt 2001). Pitt (1997), Field and Pitt (1990), Pitt (2004), and others provide good reviews of the biological impacts of stormwater runoff. Typical laboratory bioassay test results have not indicated many significant short-term receiving water problems, although acute toxicity problems have been associated with moderate-term (about 10 to 20 day) exposures to adverse toxicant concentrations in urban receiving streams (Crunkilton *et al.* 1996). The most severe receiving water problems are likely associated with chronic exposures to contaminated sediment and to habitat destruction, although some studies have shown important aquatic life impacts for streams in watersheds that are less than ten percent urbanized (Pitt and Bozeman 1982).

Relationships between biological effects and possible causes are especially difficult to identify, let alone quantify. Several researchers have identified a wide variety of possible causative agents, including sediment contamination, poor water quality (low dissolved oxygen, high toxicants), and factors affecting the physical habitat of the stream (high flows, unstable streambeds, absence of refuge areas). However, the relative importance of these factors depends on the basin and receiving water conditions. Horner (1991, after Pitt 2004) notes that many basin, site, and organism specific factors must be evaluated before the best combination of runoff control practices to protect aquatic life can be determined. Diamond *et al.* (2001, after Pitt 2004) found that the effects of toxins depended on a combination of both chemical and flow characteristics and conventional laboratory testing of toxins with constant exposure concentrations are not very applicable to wet weather flow conditions. They concluded that it is possible to predict the chronic effects of fluctuating exposures of fast-acting contaminants using available acute toxicological models.

The time scale of biological impacts to receiving waters due to stormwater is also an important factor. Snodgrass *et al*. (1997) reported that ecological responses to basin changes may take between 5 and 10 years to equilibrate. Therefore, receiving water investigations conducted soon after disturbances may not accurately reflect the long-term conditions. The first changes caused by urbanization are to stream and ground water hydrology, followed by fluvial morphology, then water quality, and finally the aquatic ecosystem. They also reported that it is not possible to accurately predict biological responses from in stream habitat changes or conditions, although they, along with many other researchers have found that habitat changes are among the most serious causes of the aquatic biological problems associated with urbanization of a watershed.

The effects of large discharges of relatively uncontaminated sediment on the receiving water aquatic environment were summarized by Schueler (1997). Schueler listed the following impacts that can be associated with suspended sediment:

- abrades and damages fish gills, increasing risk of infection and disease
- scouring of periphyton from streams (plants attached to rocks)
- loss of sensitive or threatened fish species when turbidity > 25 NTU
- shifts in fish communities toward more sediment tolerant species
- decline in sunfish, bass, chub, and catfish at monthly turbidities > 100 NTU
- reduces light penetration that causes reduced plankton and aquatic plant growth
- reduces filtration efficiency of zooplankton in lakes and estuaries
- adversely impacts aquatic insects which are the base of the food chain
- slightly increases stream temperature in summer
- suspended sediments are a major carrier of nutrients and metals

He also listed the impacts that can be associated with deposited sediment:

- physical smothering of benthic aquatic insect community
- reduced survival rates for fish eggs
- destruction of fish spawning areas
- imbedding of stream bottom reduces fish and macroinvertebrate habitat value
- loss of habitat when fine sediments are deposited
- increase in sediment oxygen demand can deplete dissolved oxygen in lakes or streams
- significant contributing factor in the alarming decline of freshwater mussels
- reduced channel capacity, exacerbating downstream bank erosion and flooding

Many of the observed biological effects associated with urban runoff may be caused by polluted sediments and subsequent benthic organism impacts. Published pollutant criteria are usually not applicable to urban runoff because of the pulse nature of urban runoff and the unique chemical nature of its components. The US EPA (1998) prepared a four volume report to Congress on the incidence and severity of sediment contamination in the surface waters of the U.S. This report was required by the Water Resources Development Act of 1992. In the national quality survey, the US EPA examined data from 65 percent of the 2,111 watersheds in the United States and identified 96 areas of probable concern. In most cases, local reference conditions have been most effectively used to indicate if the observed conditions constitute a problem.

The majority of research on the ecological impacts of urbanization has focused on streams. However, urban stormwater runoff has also been shown to adversely impact other receiving environments such as wetlands, lakes, and estuaries (Table 2.1.2.5). Development alters the physical, geochemical, and biological characteristics of wetland systems. Lakes, ponds, wetlands, and submerged aquatic vegetations (SAV) are impacted through deposition of sediment and particulate pollutant loads, as well as accelerated eutrophication caused by increases in nutrient loadings. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings caused by increased runoff and reduced baseflow.

Snodgrass et al. (1997) reported that ecological responses to watershed changes may take between 5 and 10 years to equilibrate. Therefore, receiving water investigations conducted soon after disturbances may not accurately reflect the long-term conditions.

Studies in which trends in fish diversity and abundance were monitored over time in streams in urbanizing areas have indicated that fish communities become less diverse and are composed of more species with wider ranges of environmental tolerance following watershed development (Dietmann 1975, Ragan and Dietemann 1976, Klein 1979 and Metropolitan Washington Council of Governments 1982). Sensitive fish species either disappear or occur very rarely. In most cases, the total number of fish in streams in urbanizing areas may also decline.

Similar trends of reduced diversity and abundance have been noted among aquatic insects, which are the major food resource for fish. Many species cling to substrate or woody debris and feed on the passing flow of leaf litter and organic matter. Species' abilities to obtain food may be hindered by higher post-development increases in sediment loads and trace metal concentrations. Changes in water temperature, dissolved oxygen levels, and substrate composition resulting from urban development can also further reduce the species diversity and abundance of the aquatic insect communities.

In summary, no single factor is typically responsible for the progressive degradation of urban stream ecosystems. Rather, observed impacts are probably the cumulative result of many individual factors such as sedimentation, channel scouring, increased flooding, lower dry season flows, higher water temperatures, and increased pollution.

Table 2.1.2.5. Effects of Urbanization on Other Receiving Environments

Habitat	Impacts
Wetlands	• Changes in hydrology and hydrogeology • Increased nutrient and other contaminant loads • Compaction and destruction of wetland soil • Changes in wetland vegetation • Changes in or loss of habitat • Changes in the community (diversity, richness, and abundance) of organisms • Loss of particular biota • Permanent loss of wetlands
Lakes and Ponds	• Impacts to biota on the lake bottom due to sedimentation • Contamination of lake sediments • Water column turbidity • Aesthetic impairment due to floating debris and trash • Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity • Contaminated drinking water supplies
Estuaries	• Sedimentation in estuarine streams and SAV beds • Altered hydroperiod of brackish and tidal wetlands, which result from larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced baseflow • Hypoxia • Turbidity • Bioaccumulation • Loss of SAV due to nutrient enrichment • Scour of tidal wetlands and SAV • Short-term salinity swings in small estuaries caused by increased runoff volume that can impact important productivity areas for aquatic organisms

Source: Adapted from WEF and ASCE 1998.

2.1.3 Effects of Mining on Hydrology, Water Quality, and Natural Habitats

The Peace River watershed includes approximately 143,487 acres of lands classified as "extractive" under the Florida Land Use Classification, Forms, and Cover System (FLUCFCS)

(Florida Department of Transportation 1999). The extractive land use class includes phosphate mining, which makes up approximately 10 percent of the watershed, as well as small areas of sand and gravel mining in the southern basins that include about one percent of the watershed. Phosphate mined lands can be grouped into three general categories, described below.

- Phosphate mined lands and associated beneficiation and fertilizer manufacturing operations for which reclamation is mandatory, pursuant to Florida law that requires reclamation of lands mined after July 1, 1975.
- Reclaimed mined lands, which have not been fully converted into a distinct alternative land use classification based on available aerial photographic interpretation.
- Phosphate mined lands and areas associated with ore beneficiation and fertilizer manufacturing mined prior to July 1, 1975, for which reclamation is not mandatory.

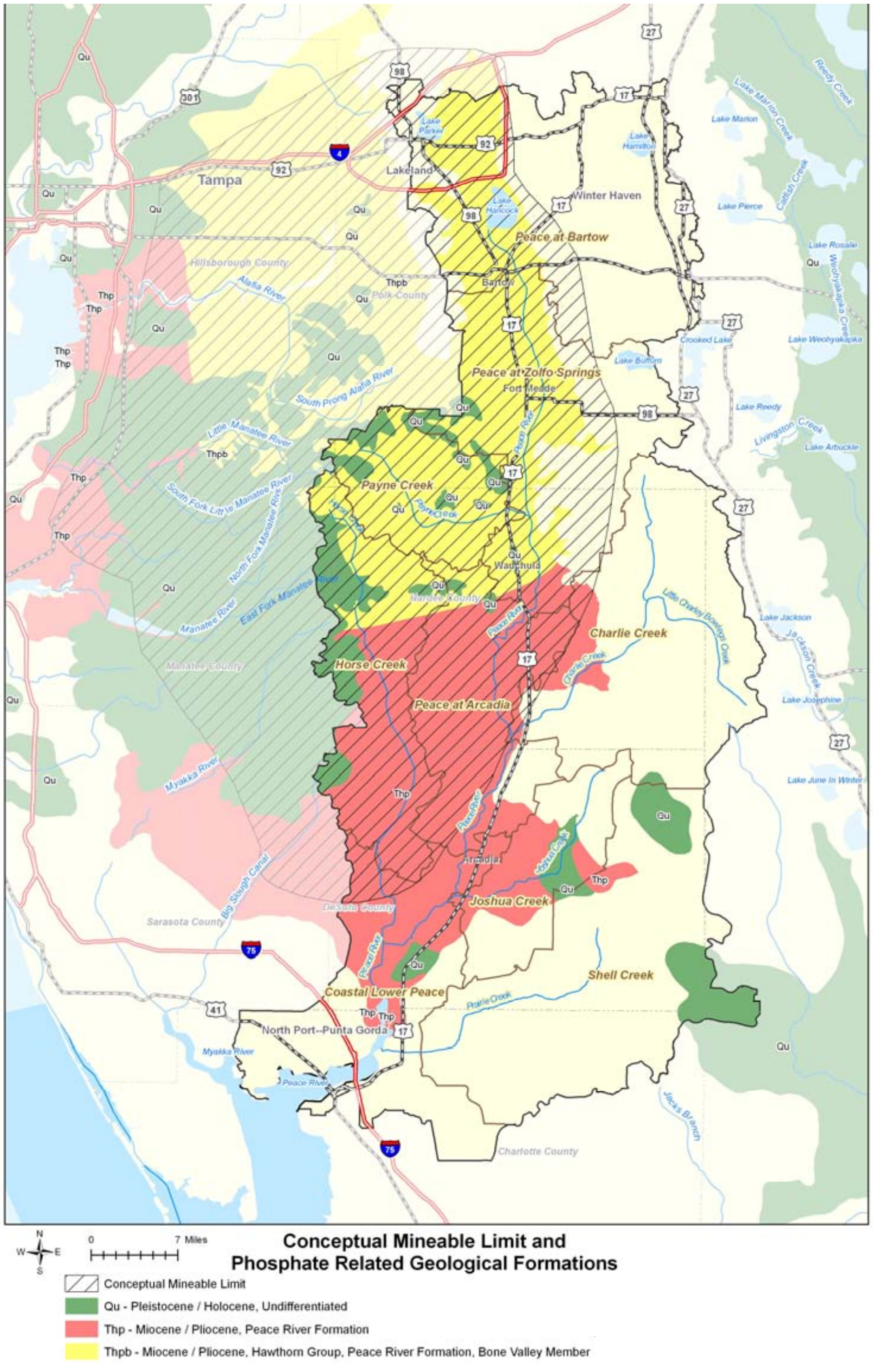
Active phosphate mining is an intensive land use that includes mine cuts (which may be subsequently filled with overburden, or remain as open water), clay settling areas (CSAs), beneficiation and fertilizer manufacturing facilities, and associated gypsum stacks. The physical effects of phosphate mining on natural habitats, hydrology, and water quality are readily evident, while long-term phosphate mining impacts require further examination.

Mineable phosphate deposits in southwest Florida occur primarily along the western half of Peace River watershed and extend west into the Hillsborough, Alafia, Little Manatee, Manatee, and Myakka river watersheds (Figure 2.1.3.1). These phosphate deposits provide almost 75 percent of the phosphate supply in the U.S. and 25 percent world-wide (CHNEP 2000).

Phosphate Mining in Florida and Southwest Florida – Florida ranks first in the nation in phosphate rock production and in 1992 produced about 30 percent of world total (Randazzo and Jones 1997). The classic central Florida phosphate district consists of phosphate deposits that are highly reworked and weathered marine and estuarine sediments that occur along the southern and eastern flanks of the Ocala Arch. The main ore zone belongs to the Peace River Formation and Bone Valley Member of the Hawthorne Group geologic formation (Figure 2.1.3.1). The Bone Valley formation in southwest Florida has been the source of high grade, easy to process phosphate since the beginning of phosphate mining in the State.

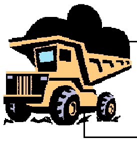
Prior to the 1930s, the mined ores were coarse enough to be beneficiated by simple washing and sizing. As the demand for higher-grade concentrates increased, cationic flotation was introduced to remove the last vestiges of impurities. Since about 1970, manufacturers of diammonium phosphate, the main ingredient in most solid fertilizers, have been working to remove magnesium deposits from phosphate concentrates. Several technically feasible processes have been developed, although none are widely used commercially in Florida due to economic constraints. Most of the mined phosphate rock (90 percent) is used to make fertilizer, while five percent is used in livestock feed supplements, and the remainder is used in the manufacture of food products, chemicals, and ceramics.

Figure 2.1.3.1. Central Florida Phosphate Mining District, Consisting of the Bone Valley Member and Peace River Formations of the Hawthorne Group



The earliest phosphate mining activity in Florida dates back to the 1880s, when hard rock phosphate deposits were found in Alachua County (FIPR 2004). The later discovery of high grade deposits near the town of Dunellon gave rise to the Dunnellon Phosphate Company in 1890. In the Peace River watershed, the discovery of river pebble phosphate deposits is usually credited to Captain J. Francis LeBarron, of the U.S. Army Corps of Engineers, who reported on his findings in 1881. Five years later, the Peace River Phosphate Company was formed to purchase and mine land along the Peace River. In 1888, the Arcadia Phosphate Company was the first full time operation to mine phosphate from the Bone Valley Formation (FIPR 2004). Early on, phosphate mining was done by hard rock mining (common in the Dunnellon area), river pebble mining, and land pebble mining. The least costly technique was land pebble mining and the same basic approach to phosphate mining is used today. Technology and economics allowed mining to move from the river pebble to the land-pebble and hard rock phosphates, and then on to mining the finer grained phosphate matrix that occurs over a wide area of west central Florida. In the 1970s, the central Florida phosphate companies began moving mining operations south into parts of DeSoto, Hardee, and Manatee counties.

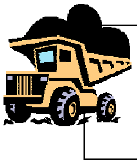
Phosphate Mining Techniques - Phosphate mining begins with clearing vegetation from the land to be mined and removing the soil that covers the phosphate rich deposits. These surface soils, or “overburden” are typically less than 30 feet deep (FIPR 2004) and are usually piled to the side of the mining operation to be later used during the reclamation phase of mining operations. Since July 1975, “mandatory” mined lands must be subsequently “reclaimed” to a beneficial land use following mining.



The earliest phosphate mining activity in Florida dates to the 1880s, when hard rock phosphate deposits were found in Alachua County.

Large cranes called “draglines” remove the phosphate rich matrix comprised of roughly equal portions of phosphate rock, clay, and sand. The underlying phosphate matrix is then removed and transferred from the mine cut to a pit where it is mixed with water from a high pressure hose to form a slurry, which is then subsequently pumped some distance to a more centralized beneficiation facility for further processing.

Physical and chemical processing at the beneficiation facility are next used to separate clay and sand from the phosphate rock. Typically, the resulting clay slurry is pumped to large clay settling ponds, while the separated sand is returned to the mine site and used to fill previous mine cuts. In some cases, sand is combined with accumulated overburden to create substrates for post-mining reclamation activities. The separated phosphate rock is transported to a fertilizer manufacturing, or processing, facility. At the facility, the phosphate rock is treated with sulfuric acid to produce phosphoric acid, or liquid phosphate, and calcium sulfate, commonly known as phosphogypsum. The phosphoric acid is mixed with ammonia to create diammonium phosphate (DAP). DAP is the primary form of fertilizer produced and marketed. Phosphogypsum, like its naturally occurring counterpart, gypsum, is mildly radioactive, and its use in road surface preparations was prohibited by the U.S. EPA in 1993. Consequently, waste phosphogypsum associated with fertilizer production forms “gypsum stacks” common in Mulberry, Piney Point, and Riverview in central and west Florida. There are approximately two dozen gypsum stacks in the central Florida phosphate mining region, each of which may exceed 100 feet in height. Until an alternative disposal method becomes available, approximately 30 million tons of waste phosphogypsum material continues to be produced annually.



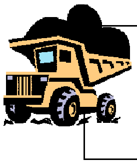
There are approximately two dozen gypsum stacks located in the central Florida phosphate mining region.... (and) approximately 30 million tons of waste phosphogypsum material continues to be produced to annually..

Mulberry Phosphates, Inc., filed for bankruptcy in 2001 and abandoned phosphate facilities at Piney Point on Tampa Bay and another facility in Mulberry. FDEP was forced to take over maintenance and clean-up of these two sites at an estimated cost in excess of $160 million. Efforts by the State of Florida to manage the estimated 1.2 billion gallons of acidic wastewater left behind at Piney Point and prevent potential contamination of Tampa Bay used up most of the State's trust fund that had been established for the reclamation of nonmandatory lands mined prior to July 1, 1975. A revised rule was subsequently adopted in 2005 that strengthened the financial assurances for phosphate processing companies to cover the future cost of clean-up and subsequent closing of phosphogysum stacks

2.1.3.1 Effects of Mining on Hydrology

Phosphate mining activities can alter surface and ground water hydrology by changing soil and land surface composition and structure, and subsequently alter the way the water flows over and through the land. In active mining areas, clay settling areas, mine cuts, and ditch and berm systems can alter the hydrology of mined and proximate areas by acting as holding ponds, decreasing flows to stream channels, replacing uplands that may act as recharge areas, or replacing natural streams and wetlands. Consequently, many phosphate mining activities can affect the relationship of rainfall to stream flow. Mining generally disturbs soils to a depth of 30 and 45 feet below land surface and recombined soils can potentially alter rainfall-runoff relationships during wet periods, as well as the contribution of base flow from surrounding uplands during dry periods.

Clay settling areas can also alter the hydrology of mined and proximate areas by acting as holding ponds and decreasing flows to stream channels. They can also replace uplands that may function as recharge areas or replace wetlands. Presently, CSAs cover approximately 100,000 acres of the phosphate mining lands in Florida (FIPR 2004) and can make up to 30 percent of mined areas. Consequently, these areas remain a long-term challenge to both hydrologic and habitat restoration.



Phosphate mining activities can alter surface and ground water hydrology by changing soil and land surface composition and structure, and subsequently alter the way the water flows over and through the land.

Like other developed uses such as agriculture and urban activities, ground water withdrawals for mining processes can alter watershed stream flows. Historically, phosphate mining/beneficiation relied heavily on ground water use, which led to both localized and regional declines in the potentiometric surface of the Upper Floridan aquifer. In the upper Peace River watershed, flows from Kissengen Spring, which previously discharged an average of approximately 19 mgd, ceased flowing in the 1950s. The loss of spring flows in the Peace River watershed was attributed to wider regional declines in the potentiometric surface of the Upper Floridan aquifer, which has been primarily associated with historically high levels of ground water withdrawals for phosphate mining. It has been estimated that phosphate mining withdrawals accounted for 75 mgd of the 110 mgd of total water withdrawals in southwest Polk County during the years preceding the cessation of flows from Kissengen Spring. Since the late 1970s, the phosphate industry has relied more heavily on recycling and storing surface runoff. These practices have markedly reduced industry ground water consumption. In Polk County, mining and industrial withdrawals accounted for 81 mgd in 2000, compared with 207 mgd in 1985 (Basso 2006).

Water conservation practices in both mining and agriculture have reduced the use of ground water in Polk County by 100 mgd since the 1970s. However, ground water is still used by the mining industry and withdrawals are higher during seasonal and extended dry periods. The storage of surface water by the phosphate industry can also seasonally alter basin hydroperiods.

2.1.3.2 Potential Effects of Mining on Water Quality

The impacts of phosphate mining on water quality can be associated with permitted and anticipated discharges from mining, beneficiation or fertilizer manufacturing activities, or with accidental and/or unanticipated discharges (spills). The magnitude of the impacts depends on whether the discharges are from mining, beneficiation, or fertilizer manufacturing operations. Waters used in mining, beneficiation, and fertilizer manufacturing are normally recycled many times over, and therefore discharges are associated with periods of excess rainfall where the additional water generated through rainfall exceeds water storage capacity. Under normal rainfall conditions, discharges can be controlled through NPDES permitting and are relatively minor (on a watershed scale). Discharges from phosphate mining and beneficiation activities typically consist of excess stormwater runoff.

The process water contained in phosphogypsum stacks and cooling ponds at fertilizer manufacturing plants, however, has a low pH (about 1 to 2) and contains a dilute mixture of phosphoric, sulfuric, and fluorosilicic acids. It is saturated with calcium sulfate and contains numerous other ions found in the phosphate rock used as a raw material as well as ammonia from the solid fertilizer manufacturing process. Process water has pH values far below that found in Florida surface waters and it is much higher mineral content (Table 2.1.2.1). The typical conductivity value for process water (22,100 µmhos/cm) corresponds to approximately 13 ppt, a salinity value similar to those found in the mesohaline, tidal estuaries. In terms of nutrient availability, process water has nitrogen and phosphorus levels that are at least two orders of magnitude higher than in a typical Florida stream. Large volumes of rainfall due to tropical storms, hurricanes, or El Niño events can preclude adequate management of process water discharged offsite.

Table 2.1.3.1. Water Chemistry of Process Water and Florida Streams

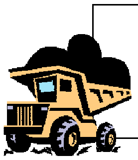
Water Quality Parameter (with units)	Typical Value for Process Water	Median Value for Florida Streams
Lab pH	2.1	7.1
Specific Conductivity (µmhos / cm)	22,100	335
Lab Turbidity (NTU)	0.9	5
Color (Pt-Co units)	300	71
Calcium (mg / liter)	538	NA
Magnesium (mg / liter)	223	NA
Sodium (mg / liter)	2,260	NA
Potassium (mg / liter)	210	NA
Iron (mg / liter)	59	NA

Table 2.1.3.1. Water Chemistry of Process Water and Florida Streams

Water Quality Parameter (with units)	Typical Value for Process Water	Median Value for Florida Streams
Manganese (mg / liter)	15	NA
Chloride (mg / liter)	140	NA
Fluoride (mg / liter)	4,120	0.2
Sulfate (mg / liter)	6,200	NA
Total Phosphorus (mg / liter)	6,600	0.09
Ammonia Nitrogen (mg / liter)	1,240	1.2*
Total Dissolved Solids (mg / liter)	39,800	NA
Total Suspended Solids (mg / liter)	22	7

* Value shown here is for Total Nitrogen, not only Ammonia Nitrogen. Florida streams water quality data from FDEP (2000). NA = data not available. Process water data from FIPR (2004).

Process water discharges (spills) into a stream and/or river can dramatically affect water quality, while a spill from a clay settling area associated with mining and beneficiation operations can transport millions of pounds of sediments to receiving waters. Consequently, these releases can result in massive and persistent (greater than 2 years) impacts to both water quality and biota. Such catastrophic impacts have previously occurred in both the Peace and Alafia River watersheds due to spills from phosphate mining, beneficiation or processing, that have affected both Charlotte Harbor and Tampa Bay.



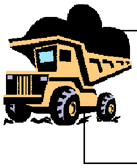
> … catastrophic impacts have previously occurred in both the Peace and Alafia River watersheds due to spills from phosphate mining, beneficiation or processing …

Since the 1960s there have been at least five spills from phosphate mining and beneficiation activities into the Peace and Alafia Rivers. In 1997, a spill of up to 50 million gallons of process water from a Mulberry Phosphate facility resulted in a massive fish kill along more than 30 miles of the Alafia River. A gypsum stack breach at a Cargill Crop Nutrition stack in Riverview during Hurricane Frances in 2004 spilled about 65 million gallons of process water into Archie Creek.

2.1.3.3 Effects of Mining on Natural Habitat

Active mining disturbs and/or eliminates natural habitats when lands are cleared of vegetation in preparation for mining. However, due to the subsequent conversion of natural marshes, lakes, and swamps to agriculture and residential uses, a number of birds, mammals, reptiles, amphibians, and fish species use some mined areas such as reclaimed lands, mine pits, clay settling areas as alternative habitat. Although some voluntary land reclamation occurred from the

1940s to the 1960s, Florida law now requires reclamation of lands mined after July 1, 1975. This law also created the Nonmandatory Land Reclamation Trust Fund to support reclamation efforts for lands disturbed prior to July 1, 1975. The mandatory and nonmandatory programs allow for reclamation to beneficial societal uses or rudimentary wildlife habitat.



Although some voluntary land reclamation occurred from the 1940s to the 1960s, Florida law now requires reclamation of lands mined after July 1, 1975.

Importantly, "reclamation" does not necessarily mean that disturbed land is restored to its pre-disturbance condition. Although restoration is now required for wetlands, uplands can be reclaimed to conditions suitable for agriculture, industry, or housing. A large proportion of the Florida lands mined for phosphate between 1975 and 2002 were designated as reclaimed. However, an estimated 50 percent of the reclaimed area was converted to lands reserved for industrial uses

In cases where habitat restoration is the goal, there is debate on the functional value of these restored areas. In a broad-scale and multi-year study examining the habitat value of reclaimed lands (Mushinksy 2001), significant differences in soil characteristics, vegetation composition, and the abundance and diversity of vertebrate species were found between reference sites (unmined mesic flatlands) and sites that were mined and subsequently reclaimed. The need to connect restored habitats via wildlife corridors and better integrate restoration efforts for upland and wetland areas was identified as part of their findings. A major implication of the report was a need for a regional habitat restoration plan for the Bone Valley area rather than parcel by parcel habitat restoration activities that are likely to continue to have less than optimal results.

2.1.4 Effects of Agricultural Land Uses on Hydrology, Water Quality, and Natural Habitats

Although there are exceptions, most of the available literature indicates that conversions of undeveloped land uses such as native uplands and wetlands to agricultural land uses both increases annual surface water runoff and anthropogenically augments base stream base flow volumes, In addition to increased water quantities, nitrogen concentrations are usually higher in runoff from agricultural land uses, and depending on the type of agriculture, area-normalized nitrogen loads may be 100 to 500 percent higher when compared with corresponding undeveloped uplands. In contrast, phosphorus concentrations in runoff from agricultural areas are more variable. However, such potential increases in phosphorus concentrations is typically not considered a problem in southwest Florida systems (such as the Peace River/Charlotte Harbor estuary) since algal productivity is primarily nitrogen, rather than phosphorus, limited (Montgomery *et al.* 1991, Turner *et al.* 2006.)

2.1.4.1 Effects of Agricultural Land Uses on Hydrology

In a review for the International Water Management Institute, Smakhtin (2002) concluded that "agriculture leads to changes in vegetation in floodplains, and this alters (flood plain) hydraulic characteristics that, in turn, may lead to changes in the flood regime." Different crop types can also alter the water budget of the catchment and affect flow rates during periods of low flow. The direction and magnitude of a hydrologic response to agricultural practices is a function of both prior and existing land uses.

Bosch and Hewlett (1982) suggest that loss of forest cover leads to increased surface water runoff, or hydrologic yield, at the watershed level. However, other studies have not found predictable changes in hydrologic yields following large scale modifications to watershed characteristics. In a study of forested basins in Thailand with canopy cover ranging from 30 to 80 percent, Wilk (2002) found no differences among basins in annualized hydrologic yields and base flow, and concluded that differences in forest cover were less important than variation in rainfall in predicting flows.

Results from pollutant loading models developed for the Charlotte Harbor Watershed indicate that changes in watershed level hydrologic yields depend upon the type of land use modification and soil (Coastal Environmental 1995). The model was based on the approach applied earlier to Tampa Bay (Zarbock *et al.* 1994) in which a "jackknife" analysis was used. In this analysis, one of three basins was removed from the calibration effort and rainfall and streamflow coefficients from the other two basins were used to predict flows for the single basin. The predicted flows were compared to flows modeled for the single basin. This process was then repeated for all three basin groups. Model r^2 values ranged from 46.2 to 58.7 percent, which may support the contention that "…the hydrologic model should provide adequate prediction of flow for basins in the watershed."

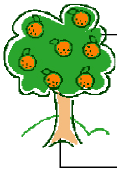
Stormwater runoff coefficients for land uses (after Florida Land Use Cover and Forms Classification System (FLUCFCS)) and hydrologic soil groups (HSG) (after United States Department of Agriculture 1972) are listed in Table 2.1.3.1. HSG designations indicate drainage potential of soils, (well-drained soils with low runoff potential (A) and poorly drained soils (D) with greater runoff potential, respectively).

Table 2.1.4.1. Stormwater Runoff Potential for Different Land Uses and Hydrologic Soils Groups

Land Use	Hydrologic Soil Group	Dry Season Runoff Coefficient	Wet Season Runoff Coefficient
Forested Uplands	A D	0.10 0.19	0.15 0.24
Medium Density Residential	A D	0.15 0.24	0.25 0.34
Commercial	A D	0.25 0.35	0.35 0.50
Rangeland	A D	0.10 0.22	0.18 0.30
Pasture land	A D	0.10 0.22	0.18 0.30
Groves	A D	0.20 0.29	0.26 0.33
Row Crops	A D	0.20 0.35	0.30 0.45

Using these results, annualized runoff (inches) was estimated for different land uses and is graphed in Figure 2.1.4.1. These estimates are based on 52 inches of annual rainfall, apportioned to the wet season (62 percent) for June to September and to the dry season (38 percent) for October to May, after DelCharco and Lewelling (1997). Based on these results, a conversion from forested uplands to commercial land use would result in the largest proportional increase in runoff, particularly in poorly drained soils. The second and third largest proportional increases in runoff (assuming an original landscape of forested uplands) would be conversions to row crops and groves, respectively.

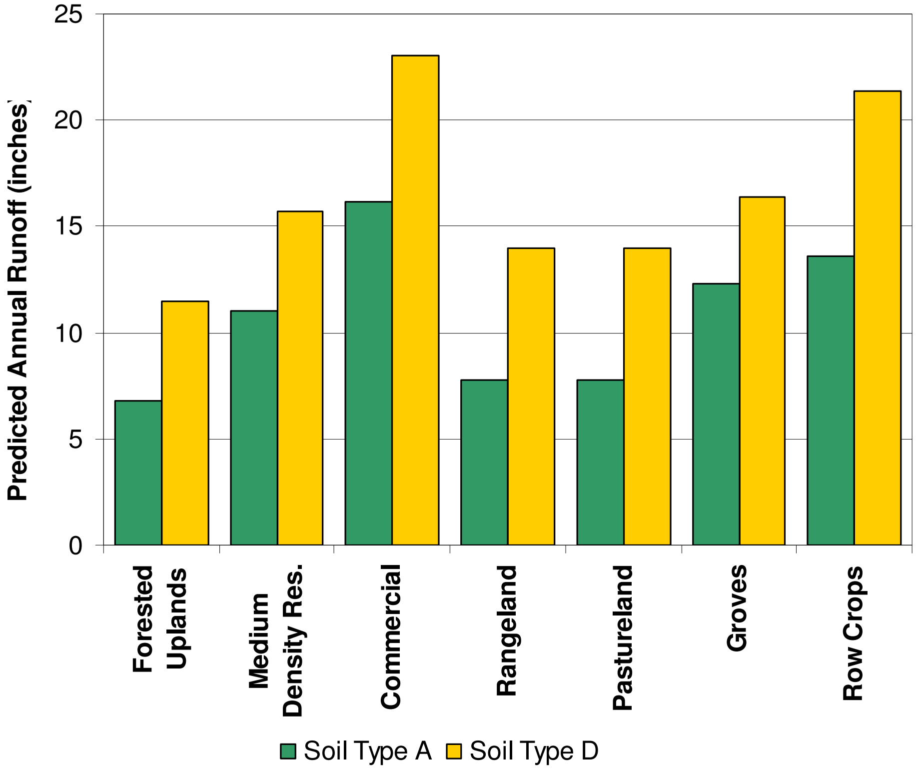
Converting forested uplands to a medium density residential landscape would increase runoff slightly more when compared with a change to groves. Conversions of forested uplands to rangeland and pasture land would increase runoff, but to a lesser degree than any of the other land use types illustrated. Most watersheds are a combination of land use types and changes are a function of both the type and proportional change of such modifications. Nonetheless, this summary allows for a comparison of the relative impacts, on a parcel level or higher, that would be expected with the conversion of landscapes from one land use type to another.



The conversion of forested uplands to agricultural land uses results in widely varying impacts on hydrological yields, depending on the agricultural practice and type of soil.

The conversion of landscapes from forested uplands to agricultural land uses results in widely varying impacts on hydrologic yields, depending upon both the agricultural practice and type of soil. Conversion of forested uplands to rangeland and/or pasture land results in a smaller increase in runoff when compared with a conversion to medium density residential land use (Bosch and Hewlett 1982). In contrast, the conversion of forested uplands to groves or row crops results in a substantial increase in predicted runoff. This increase is second only to that expected from a conversion to commercial land uses. Therefore, a conversion of lands from groves and/or row crops to medium density residential would be expected to result in decreased runoff.

Figure 2.1.4.1. Estimated Runoff from Land Uses and Soil Groups



In addition to altering hydrologic yields on an annual basis, information from both the Peace and Myakka rivers suggests that various agricultural land uses can have effects on stream base flow that exceed that which occurs naturally on an annual basis. In an assessment of the causes of tree mortality in Flatford Swamp (located in the headwaters of the Myakka River) the primary cause of the increased mortality of trees was attributed to a combination of higher seasonal water elevations and longer periods of seasonal flooding (PBS&J 1998). Anthropogenic increases in base flow were proposed as the basis for this hydrologic stress, due mostly to conversion of large portions of the contributing watershed from upland forests and rangeland/pasture land to a combination of row crops and groves that require intense irrigation.

In addition to the Myakka River, a similar supplementation of base flows has been reported for portions of the Peace River. Upon examining yearly ninety percent exceedance flows over the period of 1951 to 1996, Flannery and Barcelo (1998) concluded that for Joshua Creek in particular, "…agricultural irrigation waters pumped from the Floridan aquifer supplement the surficial aquifer resulting in greater base flow and runoff."

> *Agricultural fields in a catchment or wetland may hold back flood waters more than more sparsely vegetated areas and reduce downstream flood peaks.*

Most studies associate increased annualized flow and base flow with the conversion of landscapes from undeveloped to agricultural land uses. However, agricultural land use practices can also be associated with decreased flows in those locations where the surficial aquifer is in contact with sources of water used for irrigation. Agricultural practices rely on ground water, primarily the intermediate or Upper Floridan aquifers, more so than on surface water for irrigation supplies. The 2002 Estimated Water Use Report (SWFWMD 2002) indicates ground water withdrawals for agriculture were more than ten times the amount of surface water withdrawals. Consequently, most hydrologic models indicate increases in surface water runoff and base flow as a result of ground water withdrawals for agricultural irrigation.

> *Hydrologic models generally indicate increases in surface water runoff and base flow as a result of ground water withdrawals for agricultural irrigation.*

Typical agricultural practices in southwest Florida have also historically included the extensive ditching and connecting of wetlands, as well as the channelization natural streams to increase drainage. The expansion of more intense row crop and citrus agricultural production has resulted in further ditching to reduce seasonally high (near surface) surficial water table levels in many agricultural areas. Combined, these reductions in natural surface, wetland and surficial aquifer storage have seasonally altered the natural hydroperiods of the affected streams by increasing wet weather discharges, and reducing subsequent dry season flows.

2.1.4.2 Effects of Agricultural Land Uses on Water Quality

When considering the potential effects of agricultural land uses on water quality, a number of concepts should be considered. First, available information suggests that conversions from forested uplands to agricultural land use types (rangeland/pasture land, groves, and row crops), result in concurrent increases in surface water hydrologic yields. Consequently, even in the absence of differences in the stormwater runoff pollutant concentrations, pollutant loadings would increase since they are a function of both concentrations and flow. To remain unchanged following conversions to greater intensity land uses, decreases in pollutant concentration would have to be large enough to offset the increase in runoff volume. Most studies of the agricultural land use effects on pollutant loads have identified greater concentrations of nitrogen, phosphorus, and total suspended solids in stormwater runoff when compared to forested upland landscapes.

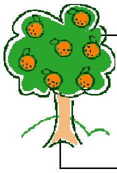
Pollutant Load Potential - A common approach to estimating the watershed level pollutant load potential of land uses is to combine estimates of stormwater runoff with estimates of pollutant concentrations in that runoff. In the previously described Charlotte Harbor watershed study (Coastal Environmental 1995), local rainfall data were used to estimate stormwater runoff for land uses in the Charlotte Harbor watershed. The estimated stormwater runoff per unit land area was then multiplied by Event Mean Concentration (EMC) values calculated from previous studies. Estimates of EMC values represent the concentration associated with a measured loading, with a given amount of runoff. In that sense, the term "EMC value" is often used interchangeably with the term "flow weighted concentration." EMC values for total nitrogen and total phosphorus for the described Charlotte Harbor pollutant loading model are listed in Table 2.1.3.2.

Table 2.1.4.2. Event Mean Concentration (EMC) Values for Land Use Classes

Land Use	Total Nitrogen (mg / liter)	Total Phosphorus (mg / liter)
Forested Uplands	1.02	0.16
Medium Density Residential	2.05	0.38
Commercial	1.95	0.28
Rangeland	1.24	0.01
Pasture land	2.66	0.81
Groves	1.67	0.27
Row Crops	2.91	0.54

The variability in EMC estimates can be quite large, even within a single land use. The total phosphorus EMC value determined for forested uplands by Camp, Dresser & McKee, Inc. (1992) for example was 0.16 mg/liter, while other researchers (Harper 1991) have found EMC total phosphorus values for the same landscape to be as low as 0.007 mg / liter. In general, the variability in calculated EMC values for total nitrogen tends to be less than the variability in calculated EMC values for total phosphorus, perhaps due to significant regional differences in the availability of phosphorus from sediments in different geological formations in Florida. Thus, estimates of watershed level phosphorus loads are probably compromised by the high variability in EMC values for phosphorus, due to the variability in phosphorus content in land surface soils. However, as previously discussed, studies (Montgomery *et al.* 1991, Turner *et al.* 2006) have shown that Peace River and Charlotte Harbor estuary are nitrogen limited systems, and variability in phosphorus estimates is probably not an issue when compared with variability in nitrogen loads.

Nutrients - Conversion of forested upland landscapes to intense agricultural land uses typically results in increased concentrations of both nitrogen and phosphorus in stormwater runoff, while conversion of forested uplands to rangeland result in estimates that indicate a decrease in phosphorus loads. Figure 2.1.4.2 illustrates the pattern of response for nitrogen loading expected as forested uplands are converted to various land use types.



Conversion of forested upland landscapes to intense agricultural land uses typically results in increased concentrations of both nitrogen and phosphorus in stormwater runoff.

These same land use conversions would result in larger phosphorus loads when compared with loads from an undeveloped landscape of forested uplands (Figure 2.1.4.3). The greatest anticipated increase in stormwater related phosphorus loads would be a conversion of forested uplands to an intense agriculture use, such as commercial row crops. The second greatest increase in stormwater related phosphorus loads would be expected with a conversion from forested uplands to improved pasture land.

In addition to nutrients, there is a wide variety of chemicals commonly associated with agricultural applications that potentially pose a risk for environmental contamination to both surface and ground waters (EPA 2003). The broader term *pesticides* can be used to include a range of substances and/or mixtures intended for preventing, destroying, repelling, or mitigating pests or used as a plant regulator, defoliant, or desiccant. These commonly include insecticides, herbicides, fungicides, miticides, nematicides as well as their persistent degradation products. Depending on a range of factors, these chemicals can potential cause impairments to surface and ground waters. Some classes of pesticides are particularly resistant to degradation. Historically, widely used compounds such as chlorinated hydrocarbons (including the now banned DDT and Chlordane) were found to persist and accumulate in aquatic food webs.

Conductivity - Increases in conductivity are often linked to an increased influence of water from highly mineralized aquifers on otherwise low-conductivity surface waters. In the headwaters of the Myakka River, increased conductivity was linked to off-site seepage of irrigation water that originated from the more highly mineralized intermediate and Upper Floridan ground water aquifers and reflects a commensurate increase in the amount of intensively farmed agricultural land uses (PBS&J 1998). In the Peace River watershed, irrigation with ground water also brings high conductivity water to the surface that subsequent seeps or flows into surface waters.

Specific conductance, or conductivity, is directly linked to the amount of dissolved salts in a water body and is an indirect measure of the presence of inorganic dissolved solids such as chloride, bicarbonate, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron. Importantly, changes in conductivity in surface water and/or ground water can indicate changes in the mineral content of that water. The potential impact of high conductivity water is recognized and addressed in the water quality standard for specific conductance (Chapter 62-302.530(23)) for Class III waters in the State of Florida, which stipulates that:

> *"Specific conductance (micromhos/cm) shall not be increased more than 50 percent above background or to 1,275, whichever is greater."*

In response to agricultural ground water discharges, one of the goals of the *Shell, Prairie and Joshua Creeks Watersheds Management Plan* (SWFWMD 2004) is to reduce specific conductance levels to no more than 775 µmhos/cm (below the existing State standard "never to exceed" value of 1,275 µmhos/cm) at all times, reduce chloride levels to below 250 mg/l, and reduce total dissolved solids levels to below 500 mg/l. This apparent discrepancy in conductivity threshold values between the State water quality standard and the SWFWMD Plan is an indication of concerns relative to whether or not the existing State water quality standard for conductivity is sufficiently protective.

Increased conductivity of waters in stream and river channels can result in changes in habitat and biota. For example, studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates (EPA 2006).

Increased conductivity can also impact macroinvertebrate communities. In a report to the Triennial Review Committee, FDEP (2005) used a bioassessment approach, wherein the specific conductance of various water bodies was compared to the health of indicator benthic macroinvertebrate communities. A key component to this approach was the use of "Florida Sensitive Taxa", defined as species that demonstrate "…. a statistically significant decrease in abundance with increases in human disturbance in the Peninsula, Panhandle and Northeast Bioregions". These organisms become proportionately less abundant in Florida streams as a function of increases in the specific conductance of those streams.

Pesticides - Pesticides with higher levels of toxicity and persistence are generally more likely to pose potential environmental risks. Short-term acute effects usually occur soon after application, such as in the case of a fish kill caused by drift or runoff, while chronic effects can occur when a pesticide persists in the environment over months or years at toxic concentrations, or increases in concentration through bioaccumulation in a food web.

Most currently licensed pesticides generally have relatively few reported chronic effects at levels commonly found in the environment. However, studies (EPA 2003) have found evaluated to acute pesticide levels in runoff and streams near agricultural sites soon after application, with significant reductions both downstream and over time. The potential for environment harm is generally dependent on the combination of a number of factors including:

- Toxicity and persistence
- Method of application
- Potential for drift
- Volatilization and subsequent atmospheric deposition

Figure 2.1.4.2. Estimated Percent Change in Nitrogen Load per Unit Area for Various Land Uses

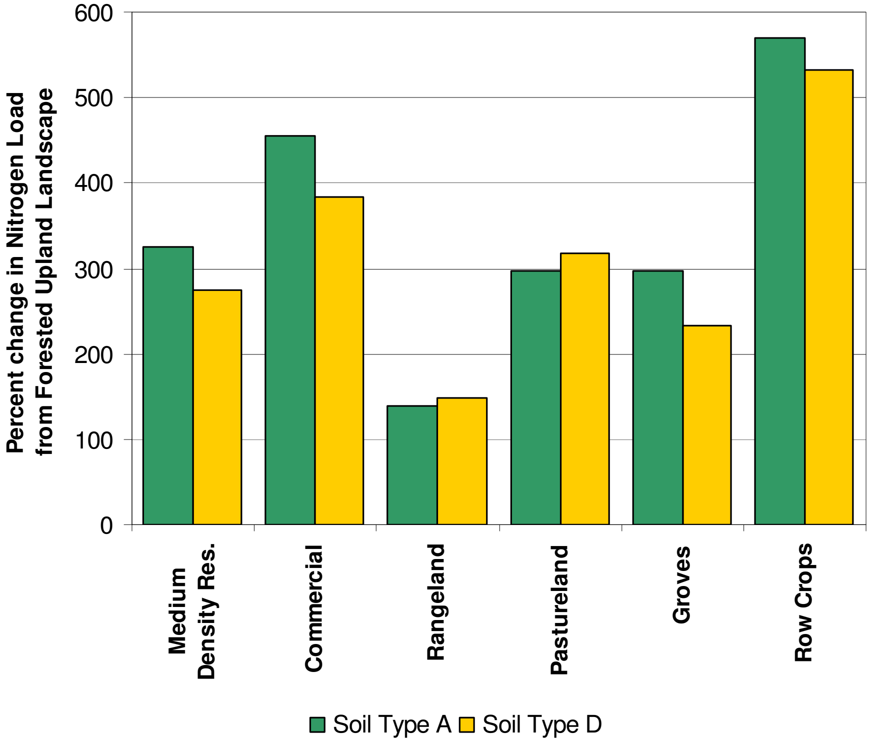
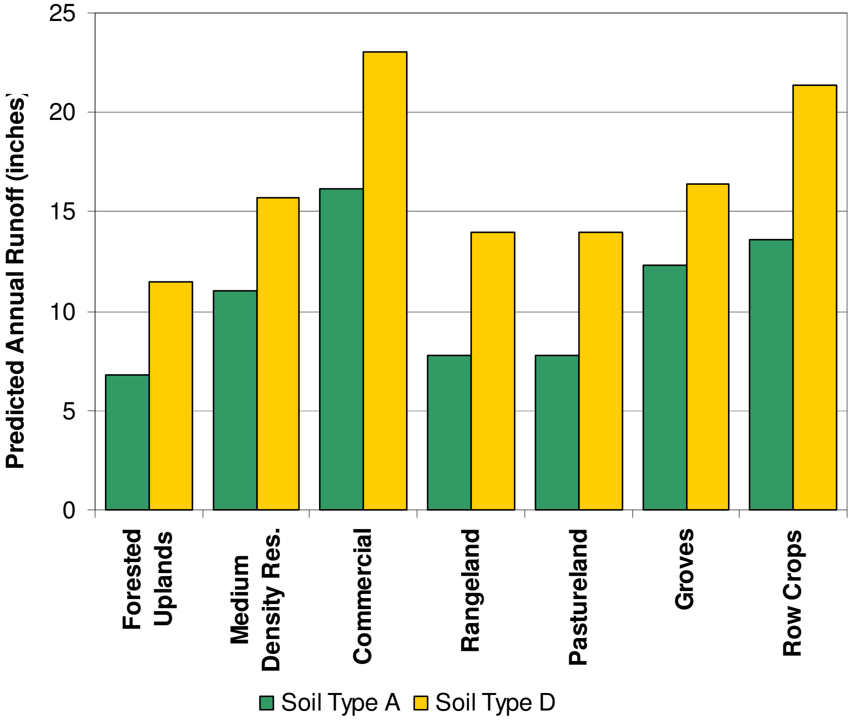


Figure 2.1.4.3. Estimated Percent Change In Phosphorus Load per Unit Area for Various Land Uses



- Soil characterization and organic content
- Leaching and runoff
- Duration of subsequent irrigation or rainfall
- Proximity to nearby receiving waters
- Biotic uptake and accumulation in the food web

2.1.4.3 Effects of Agricultural Land Uses on Natural Systems

Agriculture comprises the largest developed land use in southwest Florida. Historically, agriculture was dominated by cattle grazing on unimproved pasture. However, strong economics in the cattle industry in the 1950s led to increased land clearing for the expansion of improved pasture. This was followed by further, more recent reductions in native habitats with increasing conversions to more intense forms of agriculture, including row crops and citrus. The deforestation of uplands and draining of wetlands due to these changes in agricultural practices have resulted in fragmentation and reduced wildlife habitat values of natural communities in many areas, resulting in reductions in wildlife abundances and diversity.

As previously discussed under hydrologic changes, agricultural practices have historically included the extensive ditching and connecting of wetlands, as well as the channelization of natural streams to increase drainage. The expansion of more intense row crop and citrus has also resulted in further ditching to reduce seasonally high (near surface) surficial water table levels in many agricultural areas. These hydrologic changes have resulted in changes wetland habitats relative to both the frequency and duration of inundation, which have both affected wetland dependent species and allowed the invasion of upland plant species into previous wetland areas.

Agricultural changes also have the potential to degrade riparian bank and stream habitats. Livestock grazing can alter bordering vegetation, resulting in changes in banks and shorelines, resulting in changes or the elimination of important fish habitat. Changes in wetland and stream riparian plant communities can also occur due to lowering of the water table, allowing more xeric plants to replace previous riparian stream shorelines.

Like other developed anthropogenic land uses, such as urbanization and mining, the relatively loss of habitat value due to agricultural development is generally directly related to the intensity of uses. Outside of publicly owned lands, the majority of remaining native uplands and wetlands are located on lands with relatively low intensity agricultural use.

2.1.5 Impacts of Urban, Mining, and Agricultural Consumptive Uses

The expansion of more intense agriculture, urban development, and phosphate mining in southwest Florida has increased the demand for water, which has historically been accommodated by ground water withdrawals. While the relative levels of demand among these uses have varied over time and regionally, the combined impacts have been primarily associated with the historic decline in the potentiometeric surface elevation in the Upper Floridan aquifer. These changes have resulted in increases in saltwater intrusion in the Eastern Tampa Bay Region (SWFWMD 2002) and lower lake levels in the Northern Tampa Bay and Highland Ridge Regions. In areas such as the Northern Tampa Bay Region, deeper ground water withdrawals have further reduced ground water levels in the surficial aquifer and reduced the stage (surface water elevation) and the frequency and duration of inundation of water levels in nearby wetlands (Haag 2005). Effects of decreased depth and duration of inundation on wetland vegetation can range from minimal to severe, resulting in changes in wetland vegetation community composition and associated wildlife habitat value. Increased wetland soil exposure can also oxidize and compact wetland soils, causing loss of root support and subsequent tree fall, which may subsequently open the canopy and facilitate the encroachment of upland species.

In addition to influencing lake and wetland water levels regionally, declines in the potentiometeric surface of the Upper Floridan aquifer have eliminated historical spring discharges in the upper Peace River watershed (Basso 2003). The reduced base flows subsequently became evident following regulatory and other means of reducing anthropogenic discharges which had previously masked losses of natural base flow in the upper river.

In response to existing and potential future impacts associated with consumptive uses, the Southwest Florida Water Management District has established Minimum and Guidance Levels for lakes throughout the District and is in the process of establishing Minimum Flows and Levels (MFLs) for the rivers, including:

- The Alafia River
- Hillsborough River
- Tampa Bypass
- Upper Peace River
- Middle Peace River
- Lower Peace River/Shell Creek (expected early 2007)

2.2 Key Indicators of Change

The primary objective of the Peace River CIS was to document and evaluate the historic hydrologic and land use changes in the Peace River watershed. The CIS presents assessments of historical changes at the level of individual watershed basins (Chapter 3) and evaluates the cumulative impacts of changes to the watershed (Chapter 4). Changes associated with both natural differences in long-term rainfall patterns, as well as anthropogenic impacts, including increasing urban development, expanding phosphate mining, and changes resulting from more intense agricultural uses, are also described in the CIS. The analyses presented in the CIS focus primarily on the following key indicators of change.

Hydrologic Changes

- Variability in rainfall
- Changes in streamflows
- Changes in ground water elevations
- Changes in the concentrations of indicator water quality constituents

Land Use Changes

- Acres of wetlands lost
- Acres of native upland habitats lost
- Miles of streambed lost
- Changes in the abundance, distribution, and diversity of indicator fish communities

Long-term decadal patterns in regional rainfall patterns in southwest Florida, primarily associated with wet season differences have been documented in previous studies (Basso 2003, Coley and Waylen 2006). A goal of the CIS was to further investigate these long-term differences in rainfall patterns and examine potential relationships between rainfall patterns and gaged flows in the Peace River watershed and nearby basins. Relatively small changes in seasonal or annual rainfall can result in much larger proportional changes in stream flows (deWit and Stankiewicz 2006) since the majority of rainfall is returned to the atmosphere through either evaporation or transpiration.

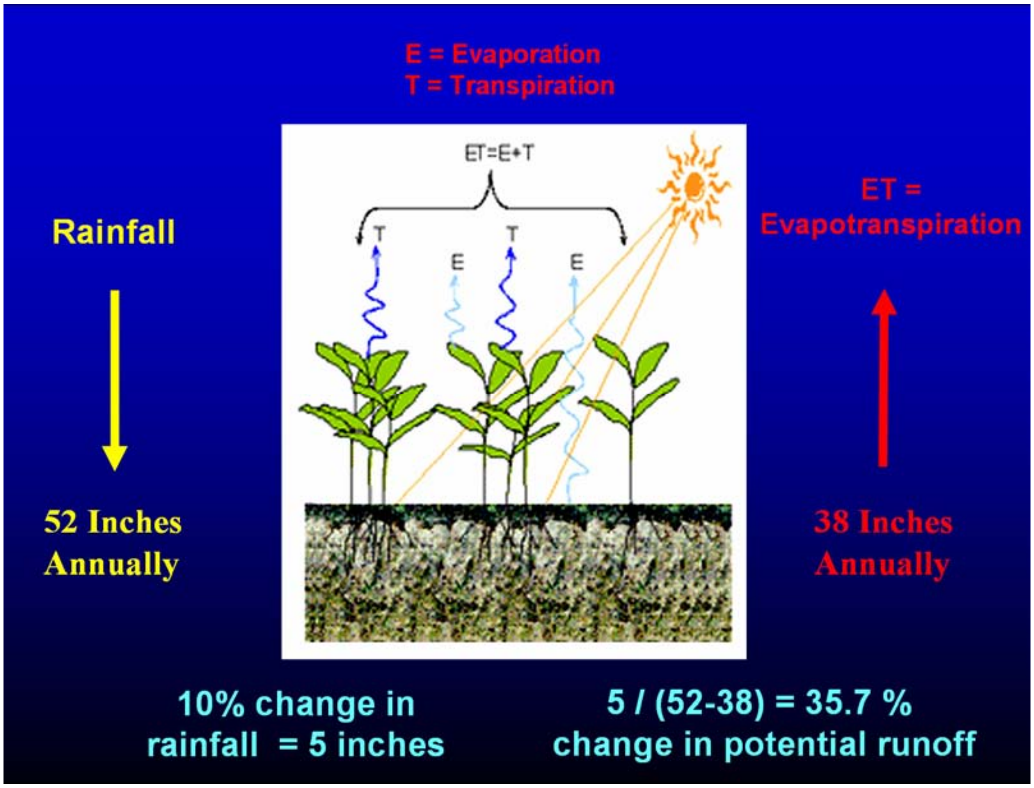
This relationship among rainfall, evaporation, and transpiration (release of water from plants) is presented graphically in Figure 2.2.1.. An annual rainfall of approximately 52 inches/year and a corresponding rate of evapotranspiration (evaporation and transpiration combined) of approximately 37 inches/year (both of which are close to the long-term averages for the Peace River watershed). At a maximum, this would leave only about 15 inches/year for both soil infiltration and runoff to occur as stream flow. A 10 percent change in rainfall in this simplified example could result in up to a 33 percent change in corresponding flow. In reality, factors such as evaporation, transpiration, recharge, and runoff are influenced by land use, land cover, soil type, temperature, humidity, and preceding rainfall. However, the general principle that relatively small changes in total annual rainfall are often reflected in substantially larger changes in flows applies.

Natural climate variability and anthropogenic changes can influence stream flows differently. Therefore, trends were evaluated to test for differences in mean and median gaged flows, as well as statistical percentiles ranging from monthly minimum to monthly maximum flows. The resulting observed patterns were then compared for difference among both the long-term gages within the Peace River watershed, as within adjacent reference basins.

A number of studies have concluded that change in flow regime is the primary variable influencing a vide variety of river ecosystem components both directly and indirectly. These components include fish abundance and community structure, floodplain forest composition, and nutrient cycling (Poff *et al.* 1997, Richter *et al.* 2001). Anthropogenic modifications of natural flow regimes have been shown to degrade river ecosystems and lower instream biodiversity (Postel and Carpenter 1997, IUCN 2000, Richter *et al.* 2001). Such modifications may result in perturbations of stream food web and biotic community structure and function (Poff *et al.* 1997). Populations of native species adapted to particular characteristics of natural variability may be impacted by induced changes to normal seasonal flow patterns, such as fish that require particular levels of flow to gain access to floodplain feeding and spawning areas (Figure 2.2.2).
Flow alterations may also interrupt the timing of inundations required for other taxa, including insects and other invertebrates, amphibians, and birds. Other flow studies focusing on instream

macroinvertebrates have recommended that measurable habitat losses should not exceed 15 percent and emphasized the importance of maintenance of seasonal base flows (Gore and Mead 2001).

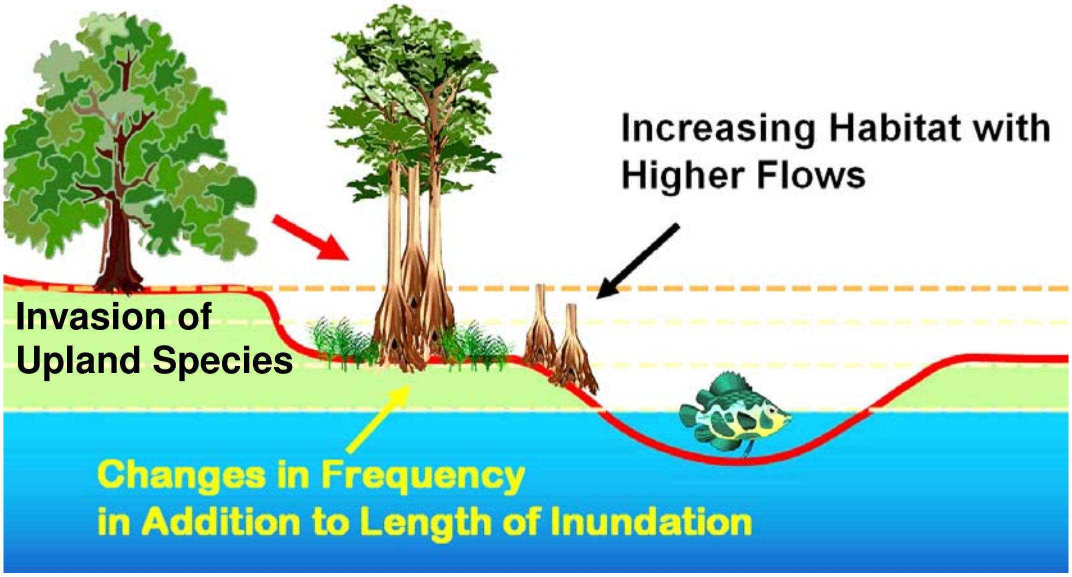
Figure 2.2.1. Potential Effects of Differences in Rainfall



Changes in the types and amount of wetland habitats result in further changes in biotic communities (Gorman and Kar 1978, Baker *et al*. 1991, Light *et al.* 2002). Light *et al*. (2002) found that swamp habitat in the Suwannee River was generally isolated during periods below median flows, and reconnected to other floodplain habitat at higher flows. Flow reductions below median flow values in most reaches of the Apalachicola River were also found to predict decreases the area of most types of connected aquatic habitat in the floodplain (Light *et al.* 1998). The physiological tolerances of plant species generally determine the distribution of wetland vegetation. Light *et al.* (2002) summarized inundation and saturation characteristics of a number of taxa and found that periods of 14 and 21 days of floodplain inundation, at depths up to approximately one meter, and at two and five year intervals, were important in limiting the invasion of wetland plant communities by more characteristically upland species, as presented in Figure 2.2.2. Natural long-term variability in climate patterns and anthropogenic influences can alter available instream and floodplain habitat. Changes in flows may interrupt the seasonal timing of inundations required for the life cycles of fish, amphibian, insects and other invertebrate species. Reductions in frequency and duration may also change wetland plant community structure by allowing encroachment of more upland species into the wetland.

In conjunction with natural and anthropogenic hydrologic changes in surface waters, the CIS also evaluated seasonal, decadal, and even longer term patterns in regional ground water levels in the surficial, intermediate, and Upper Floridan aquifers. While ground water levels respond to natural variations in rainfall, patterns generally reflect historical and regional changes in consumptive uses by agriculture, phosphate mining, and urban consumptive demands.

Figure 2.2.2 Potential Impacts of Changes in Flow (after SWFWMD)



Long-term patterns and differences among the basins in water quality characteristics are another of the key indicators used to evaluate the impacts of anthropogenic changes in the Peace River watershed, as part of the CIS. Historically, water quality in the upper Peace River watershed has been affected by a number of activities. These have included point and nonpoint source discharges from phosphate mining and processing, point source municipal/industrial effluents, and nonpoint runoff from both expanding urban and agricultural land uses. Over the past several decades, agricultural land uses in many areas of the Peace River watershed have undergone marked conversions from unimproved grazing pasture to improved pasture and increasingly to intense agricultural practices such as citrus and row cops.

Some of the largest conversions to more intense agricultural uses have occurred in the southern watershed basins and have been associated with increased discharges of highly mineralized ground water and nonpoint source nutrient loadings (nitrogen). The two primary influences on water quality in the Peace River watershed have historically been: 1) nutrient inputs and the eutrophication of Lake Hancock and subsequent increased nitrogen loadings to the upper river; and 2) discharges to the river from phosphate mining and processing associated with extensive mining of large tracts of land in the upper basins (PBS&J 1999, Janicki Environmental 2003). More recently, increases in ground water discharges from agricultural practices in the southern basins have resulted in increases in both conductivity and associated water quality characteristics (SWFWMD 2004) and nitrogen levels (Janicki Environmental 2003).

Changes in water quality characteristic are a key indicator used widely to evaluate compliance with designated uses in water bodies and assess potential impairments to the biological communities of both freshwater and estuarine systems (FDEP 2003, 2005). Importantly, the historical abundance, distribution, and diversity of fish communities were evaluated as part of the CIS and examined in relation to historical water quality to determine if changes in fish communities could be directly linked to water quality impacts associated with changing basin land use.

The final series of indicators of change evaluated in the CIS included acres of wetland and native upland habitat losses in each of the nine Peace River watershed basins between the baseline 1940s reference period, 1979, and 1999. Changes in miles of natural stream habitat from relatively undeveloped conditions (1940s) to more recent conditions (1999) were also compared. Miles of natural stream channels (not ditched or channeled) visible in the 1940s were quantified and compared with the remaining natural stream channels visible in 1999. As previously discussed, each of these three indictors of change reflects impacts to natural systems, and is also indicative of hydrologic alterations potentially affecting the amount and timing of seasonal flows.

The evaluation of the relative impacts of historic hydrologic and land use changes on key indicators of change that is presented in the CIS supports the FDEP Peace River Resource Management Plan. Both the Watershed Resource Management Plan and the CIS (Chapter 5.7) identify potential regulatory and non-regulatory processes intended to minimize future impacts and mitigate past impacts in the Peace River watershed and the Charlotte Harbor estuary.

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3.0 Peace River Basins

The Peace River watershed covers approximately 2,350 square miles in southwest Florida and includes nine basins covering large portions of Polk, Hardee, DeSoto, and Charlotte counties, and smaller portions of Hillsborough, Manatee, Highlands, Sarasota, and Glades counties. The five largest basins in the watershed are the Peace River at Bartow, Peace River at Zolfo Springs, Charlie Creek, Shell Creek, and Coastal Lower Peace River basins. Each of these five basins makes up between 10 and 17 percent of the watershed, and combined, they make up 70 percent of the watershed. The remaining four basins are Payne Creek, Peace River at Arcadia, Horse Creek, and Joshua Creek, each of which represents between six and nine percent of the watershed.

The major urban areas in the Peace River watershed are the cities of Lakeland, Winter Haven, Bartow, Punta Gorda, Port Charlotte, and Arcadia. The Peace River flows into Charlotte Harbor, which include Charlotte Harbor Aquatic Preserve and Charlotte Harbor State Reserve, near Punta Gorda, Florida. Portions of the Peace River have been designated as a Recreational Canoe Trail, and Payne Creek, a tributary to the Peace River, has been designated a historic Special Feature Site by the FDEP Division of Recreation and Parks.

The Peace River watershed covers approximately 2,350 square miles in southwest Florida and includes nine basins and all or part of nine counties.

The upper headwaters of the Peace River form in the black water systems of the Green Swamp in northern Polk County. Flowing south from Lake Hancock, Saddle Creek joins Peace Creek flowing from the lake district to the east, to form the Peace River. Much of the surface water drainage to the river between Bartow and Bowling Green originates from outfalls and reclaimed channels constructed for previous phosphate mining (Lewelling 2004). From Bowling Green south to Charlotte Harbor, the major surface water flows to the Peace River are from well developed, naturally formed tributaries, including Payne Creek, Charlie Creek, Joshua Creek, Horse Creek and Shell Creek. The lower river is tidally influenced and during extended dry periods, brackish conditions extend upstream of the confluence of Horse Creek with the Peace River.

Changes in physical characteristics from basin to basin are generally gradual and frequently overlap. The common features that characterize the Peace River watershed, such as climate, physiography, topography, and soils, are presented in the first section of this chapter to provide a general overview. In addition to characterizing existing conditions in the basins in the Peace River watershed, changes in hydrology (stream flows and water budget), water quality, and land use over time are presented. Additional maps of many watershed and basin characteristics, including hydrology, water quality, and land use, are further included in the accompanying GIS portfolio. The primary objective of this chapter is to provide a context in which to evaluate the potential impacts of stressors, (increasing urban development, expanding phosphate mining, and conversions to more intense agricultural practices) in each basin.

3.1 Watershed Setting

3.1.1 Climate

Temperatures in the Peace River watershed range from an average of about 80° F during the summer to about 60° F in December and January. Freezing temperatures occur occasionally. The average daily temperatures in Polk County range from 50 ° F to 92 ° F. Farther south average daily temperatures range from 52 ° F to 91 ° F in Hardee County (Robbins *et al*. 1984) and from 49 ºF to 92 ºF in DeSoto County. Average relative humidity in DeSoto County ranges from 57 percent in the mid-afternoon to 87 percent at dawn and in Polk County ranges from 60 percent in the mid-afternoon to 90 percent at dawn (USDA 1990). The prevailing wind direction in the region is from the east-northeast and highest average wind speed (7.8 mph) is typically in March (1951-1980) (Cowherd *et al*. 1984).

Average annual rainfall in the Peace River watershed is about 52 inches over the long-term period-of-record (1915-2004) (USGS 2004), more than half of which occurs during localized thunder showers during the wet season (June - September) (Hammett 1990). Rainfall in the spring, winter, and fall is typically due to large frontal systems instead of local storms (Hammett 1990). Rainfall is highest in June, averaging 8.27 inches (USGS 2004), while November is typically the driest month of the year, averaging 1.77 inches from 1915 to 2004. The months of April and May are also characteristically dry, averaging 2.56 and 3.95 inches, respectively (USGS 2004). Dry conditions and high evaporation rates generally coincide with the lowest stream flows, lake levels, and ground water levels of the year (Hammett 1990). Rainfall and stream flow data and analyses are presented in detail in *Appendix D*.

3.1.2 Rainfall Patterns

Historical data from six rainfall monitoring stations spatially distributed across the Peace River watershed were analyzed to assess the potential presence of long-term rainfall patterns and evaluate identified patterns and/or seasonal changes in the context of the Atlantic Multidecadal Oscillation (AMO) theory. Greater detail is presented in *Chapter 4*. Conclusions based on the results of time series analyses of rainfall data detailed in *Appendix D* are summarized below.

- Long-term total monthly rainfall patterns were similar among all of the selected rainfall gages.

- The variability in total monthly rainfall was sufficient to obscure small changes such that there are no indications of any consistent changes (or patterns) when long-term Peace River watershed rainfall data are analyzed on a monthly basis.

- The analyses suggest, however, that total monthly rainfall at the more coastal Punta Gorda gage has been slightly higher when compared with the more interior gages in the Peace River watershed.

In comparison, when the long-term rainfall data are analyzed as annual totals, the data indicate increased variations among the watershed gages and greater indications of both historically wetter and drier intervals. Calculated five-year moving averages, used to further reduce short term background "noise", indicated relatively longer wet and dry intervals over the period-of-record.

- Long-term annual rainfall averaged for four gages at Lakeland, Bartow, Wauchula, and Arcadia indicated rainfall levels were about three to eleven inches greater prior to the 1960s.
- Annual average wet season (June-September) rainfall in the Peace River watershed was about 10 percent higher during the 1930s through the mid-1960s when compared with the interval between from the late 1960s through the early 1990s.
- No similar long-term patterns were apparent at any of the selected monitoring stations with regard to dry season (January-May and October-December) rainfall, although periodic high annual totals corresponded to El Niño events.

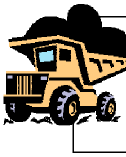
Annual average wet season rainfall in the Peace River watershed was about 10 percent higher during the 1930s through the mid-1960s when compared with the interval between from the late 1960s through the early 1990s.

3.1.3 Physiography

The Peace River headwaters flow between the Winter Haven and Lakeland ridges in the Polk Uplands of Polk and north Hardee counties before falling off into the DeSoto Plain in south Hardee and DeSoto counties and into the Gulf Coast Lowlands, where Horse Creek joins the main Peace River channel. The river continues south into Charlotte County and into Charlotte Harbor and the Gulf of Mexico.

The ridges, scarps, and plains through which the Peace River flows were formed during changes in global climate and sea level that occurred millions of years ago. Sea level fluctuations and erosion of the southeastern coastal plain and southern Appalachians eventually resulted in the deposition of the clayey sands over the limestone of the Florida peninsula (Randazzo and Jones 1997). Nearshore currents reworked and reshaped these deposits, leaving the system of upland ridges characteristic of central Florida. Subsequent deposition, exposure, and reworking and weathering of marine and estuarine sediments were also the source of phosphorite deposits in central and south Florida. The phosphorite deposits of the southeastern U.S. are the largest known Miocene deposits in the world.

The deposit that forms the primary phosphorite ore/ phosphate matrix in Florida is the Bone Valley member of the Peace River formation and overlays the larger Hawthorn group. These formations were developed during the Miocene epoch 23.8 to 5.3 million years ago, while the quartz sands that cover the phosphate matrix were deposited during the later Pleistocene epoch. The Bone Valley member has been the source of high grade, easy to process phosphate since the beginning of phosphate mining in the late 1800s. Polk County is the core of the Bone Valley mining region, although the mineable deposit stretches to Hillsborough, Hardee, Manatee, and DeSoto counties. The Hawthorne formation covers much of the Atlantic Coastal Plain of the southeastern U.S. and is mined in Hamilton County where the mineable area extends into Columbia and Suwanee counties. It is also the Hawthorne formation that is mined south of the central Florida phosphate district.



Polk County is the core of the Bone Valley mining region, although the mineable deposit extends into Hillsborough, Hardee, Manatee, and DeSoto counties.

The phosphate mining industry has moved to the southern extent of the Bone Valley formation as the mines in Polk County become depleted. However, the quality of the ore is lower beyond the Bone Valley area, with the ore bodies being higher in magnesium oxide, insoluble dolomite, clay and silica, and are lower in aluminum phosphate and phosphorus pentoxide. Mined lands encompass about 232 square miles (9.5 percent) of the Peace River watershed, 93 percent of which occurs in the upper Peace River above Zolfo Springs.

In Polk County, where the Peace River begins, the Polk Uplands characterize the physiography. The southern portion of the Peace River at Bartow basin occurs along the transition from the Polk Uplands to the DeSoto Plain. An inconspicuous but persistent outfacing scarp separates the Polk Upland from the DeSoto Plain and is about 75 to 80 feet NGVD. The effects of solution are not as pronounced in Hardee County as they are in most of peninsular Florida as a result of the Bone Valley Formation beneath the Polk Uplands and much of the DeSoto Plain, and stream branching is more prevalent (Robbins *et al*. 1984).

The Peace River at Bartow basin is located in the Central Highlands physiographic province, mainly on the Polk Uplands, with often gently rolling, sometimes hilly, terrain. With the exception of the ridges, land surface elevations along the Polk Upland generally range between 100 and 130 feet above mean sea level (White 1970). The Winter Haven Ridge lies just east of Lake Hancock and the Peace River, while the Lakeland Ridge lies just west of them. The Polk Upland is bounded by the Gulf Coastal Lowlands and the Western Valley on the west and north, by the DeSoto Plain to the south, and by the higher ground of the Lake Wales Ridge to the east. The Lakeland, Winter Haven, and Lake Henry ridges rise from the upland.

Surface and near surface sediments in Polk County consist of quartz sand, clay, phosphorite, limestone, and dolomite. These sediments range in age from Late Eocene to Holocene (40 million years ago to present). The marine origin of the river is apparent from the absence of ridges in Hardee County. About half of the Peace River at Zolfo Springs basin is in Polk County, on the Polk Uplands, and therefore adjacent to mined lands. In Hardee County, mining is not a dominant land use.

Occasionally, the river valley narrows and bluffs occur along the banks, most frequently between Zolfo Springs and Gardner in Hardee County. The Peace River at Arcadia basin extends across both the Polk Uplands to the DeSoto Plain. The basin has no relict shoreline features, evidence of the marine origin of the DeSoto Plain (Cowherd *et al*. 1989). The headwaters of the Horse Creek basin are in the Polk Uplands and flow across the DeSoto Plain into the Gulf Coast Lowlands where it enters the lower Peace River (Lewelling 1997). Joshua Creek flows across the DeSoto Plain and enters the Peace River just above Nocatee (Cowherd *et al*. 1989).

The upper Shell Creek basin is also within the DeSoto Plain in DeSoto County, while the lower basin drops off into the Gulf Coast Lowlands. The Coastal Lower Peace River includes parts of the De Soto Plain, the Gulf Coast Lowlands, and the Caloosahatchee Incline (White 1970).

3.1.4 Topography

Land surface elevations in the watershed reach about 200 feet above sea level near the headwaters of the Peace River in Polk County and decline to sea level at Charlotte Harbor (topography in individual basins is presented in the GIS map portfolio). Changes in elevation are most conspicuous along the ridges and scarps. The northwest portions of the Peace River at Bartow basin and the City of Lakeland have an average elevation of 200 feet NGVD. Elevations rise to approximately 150 feet NGVD north of Lake Hancock before gradually decreasing again into the Green Swamp. The upland elevations decrease from 160 feet NGVD near Auburndale in the north to 120 feet NGVD near Bartow in the south.

The Lakeland Highlands are a conspicuous landform in the basin along with the Winter Haven Ridges. Lakeland Highlands have an average elevation of 240 feet NGVD but exceed 260 feet NGVD at the highest points. Winter Haven Ridges are not of the same stature as the Lakeland Highlands, which only reach an elevation above 180 feet NGVD.

Land surface elevations in the watershed reach about 200 feet above sea level near the headwaters of the Peace River in Polk County and decline to sea level at Charlotte Harbor. Changes in elevation are most conspicuous along the ridges and scarps.

Lakes and other water features in the basin occur at elevations of about 120 to 135 feet NGVD. Elevations at Lake Hancock are less than 100 feet NGVD. At the confluence of Saddle Creek and Peace Creek the elevation is 100 feet NGVD. The elevation of the Peace River at the southern limits of the basin is about 95 feet NGVD.

The Peace River channel from Bartow to Fort Meade transitions from incised to poorly defined and channel elevations decrease from approximately 97.5 feet NGVD at S.R. 60 in Bartow to about 68.0 feet at U.S. Highway 98 at Fort Meade, over a distance of nearly 13 miles. Stream flow is diverted from the river channel via sinkholes and recharges the underlying aquifers. Phosphate reclamation landforms along much of the river corridor confine flood stages to the river channel. Channel elevations decrease by about 45 feet from Fort Meade to Bowling Green and decrease another 31 feet at Zolfo Springs, over a distance of about 19 miles.

The land surface elevation at Fort Meade is about 129 feet NGVD and elevations outside the river channel decrease downstream to the town of Bowling Green, which is at about 117 feet NGVD. Farther downstream and the town of Wauchula, just north of Zolfo Springs, the land surface elevation is 109 feet NGVD. The elevation of Zolfo Springs is 64 feet NGVD.

The elevation in the Peace River at its confluence with Payne Creek, just south of Bowling Green, is approximately 45 feet NGVD. Elevations along the Payne Creek corridor begin at about 65 feet NGVD where the creek flows into the Peace River. Extensive strip mining has altered the topography of this basin. Little Payne Creek flows southeast from 130 feet NGVD down to 50 feet NGVD at its confluence with Payne Creek. Elevations gradually decrease from northwest to southeast in the Payne Creek basin. Major municipalities within the basin fall along topographic highs. Wauchula has an average elevation of 115 feet NGVD while the Peace River, just to the east, is less than 45 feet NGVD.

Elevations in the Charlie Creek basin, outside the creek channel, range from 30 feet NGVD at the confluence of Charlie Creek and the Peace River to more than 80 feet NGVD north of S.R. 64. The elevation of the Peace River channel is at approximately 12 feet NGVD just above its confluence with Charlie Creek. Charlie Creek has extensive wetlands with an average elevation of less than 60 feet NGVD.

From Zolfo Springs to Arcadia, a distance of nearly 38 miles, channel elevations in the Peace River decrease from 32 feet NGVD to approximately five feet at the railroad bridge in Arcadia (Lewelling 2003). The town of Arcadia occurs at about 50 feet NGVD. Land surface elevations may exceed 80 feet NGVD in the north portion of the basin.

Land surface elevations are less than 40 feet NGVD across the Gulf Coastal Lowlands in the southern portion of the Horse Creek basin and 135 feet NGVD in the northern basin near the confluence of Horse Creek and the Peace River. Brushy Creek, Cypress Branch, Osborn Branch, and Elder Branch range in elevation from slightly less than 85 feet NGVD down to 65 feet NGVD before merging into Horse Creek. Horse Creek eventually meets the Peace River in Desoto County east of North Port. The confluence of the Peace River and Horse Creek is at an elevation of approximately five feet NGVD.

The upper reaches of the Joshua Creek reach elevations near 90 feet NGVD northeastern portion of DeSoto County, while wetlands are generally at elevations of about 55 feet NGVD. The largest municipality in the basin, Arcadia, is a 45 feet NGVD, while the elevation of the river bed just west of Arcadia is approximately 15 feet NGVD in the river channel. Joshua Creek meets Peace River in the southernmost portion of this basin at about 45 feet NGVD.

Elevations along Shell Creek and in the basin range from sea level to approximately 23 feet NGVD at the city of Punta Gorda, near the confluence of Shell Creek with the Peace River. The control elevation of Hendrickson Dam on Shell Creek, just upstream of Prairie Creek, is five feet above mean sea level. Prairie Creek headwaters in Telegraph Swamp in DeSoto County reach a maximum elevation of 35 feet NGVD. A few of the wetland systems in the northern portion of the basin, Sheep Pen Slough and Tiger Bay Slough, have elevations of 59 feet NGVD and 65 feet NGVD, respectively. The remaining sloughs and other wetlands in the northernmost portion of the basin have elevations between 55 feet NGVD and 75 feet NGVD.

Fort Ogden, south of the confluence of Horse Creek and the Peace River, and in upper to middle reaches of the river, occurs at about 50 feet NGVD. Port Charlotte, located on the north side of U.S. 41 at the mouth of the Peace River, and Punta Gorda, located on the south side of U.S. 41 at the river mouth, both occur at approximately 23 feet NGVD.

In the upper reaches of the Coastal Lower Peace River basin, elevations of the Peace River are less than 15 feet NGVD. The Peace River travels from the northeast to the southwest in this basin, where it reaches Charlotte Harbor.

3.1.5 Soils

Flatwoods soils are the most extensive natural soil type in the Peace River watershed. These soils are generally nearly level with zero to two percent slopes, poorly drained, sandy, and have a high water table. Throughout the watershed, these soils are often combinations of Myakka, Smyrna, and Immokalee soils series. Soils adjacent to the Peace River itself are generally of the Chobee series in combination with another of several wetland soil types. Soils in the Chobee series are deep, with nearly level slopes of zero to one percent, are very poorly drained, and are associated with depressions with high water tables. These soils often include mucky or loamy components, in contrast with the sandier flatwoods soils. Soils series making up more than three percent of the Peace River watershed are mapped in the GIS map portfolio.

Nearly 50 percent of Polk County is underlain by upland soils and upland soils such as Zolfo-Tavares sands are interspersed throughout the watershed. The Arents-Hydraquents-Neilhurst soils have been strip mined for phosphate or silica sands. Candler-Tavares-Apopka soils are characteristic of uplands and are moderately sloping, excessively to moderately well-drained, sandy, and underlain by loamy or clay material.

> *Flatwoods soils are the most extensive natural soil type in the Peace River watershed. These soils are generally nearly level soils with zero to two percent slopes, poorly drained, sandy, and have a high water table.*

Above Bartow, soils are predominantly nearly level, very poorly drained organic Nittaw-Kaliga-Chobee soils subject to flooding. Soils surrounding Lake Hancock are similar in slope and drainage, but are loamy and mucky Samsula-Hontoon soils, some of which over sands. Large strip mined areas drain into Saddle Creek, Lake Hancock, and the Peace River. Mined lands increase tremendously south of Bartow.

Just south of Bartow, the soils along the Peace River shift from loamy and mucky Nittaw-Kaliga-Chobee soils to more frequently flooded sandy and loamy Bradenton-Felda-Chobee soils. Beyond the river corridor, soils to the west are almost exclusively mined soils. Mined soils do not extend much farther than about two miles before uplands associated with the Winter Haven Ridge occur. South of Fort Meade, soils are still nearly level and poorly drained (Pomona-Myakka-Immokalee) or somewhat poorly drained (Smyrna-Myakka-Immokalee), but are generally sandy throughout as opposed to loamy or mucky. Upland sandy soils, such as Zolfo-Tavares, are typical from Fort Meade south to Zolfo Springs.

Upstream of Charlie Creek, Pomona-Floridana-Popash soils are the dominant soil series outside the river corridor. From Charlie Creek downstream to the confluence of Joshua Creek and the Peace River (at the town of Nocatee), flatwoods soils predominate.

Charlie and Horse creek corridors are also characterized by the more frequently flooded sandy and loamy Bradenton-Felda-Chobee soils that typify the Peace River corridor upstream to Bartow. Above S.R. 64, Horse Creek flows through flatwoods soils of the Immokalee-Pomello-Myakka series. The most extensive soils in the Horse Creek basin are the Smyrna-Myakka-Ona soils in Hardee County and Smyrna-Myakka-Immokalee soils in DeSoto County. Both these soils are nearly level, poorly drained, and sandy throughout, with a dark, sandy surface layer about five inches thick (Cowherd *et al*. 1989, Robbins *et al*. 1984). Ona soils may have one to five percent organic matter, and are dark reddish brown to brown, fine sand below. In contrast, Immokalee soils have one to two percent organic matter, a leached horizon, and a subsurface that is white fine sand.

Horse and Brushy creeks flow through Pomona-Floridana-Popash soils in the north portion of the basin. These soils characterize most of western Hardee County and are nearly level, poorly drained, and very poorly drained sandy soils. Subsoils may be dark to 30 inches in depth and occur over loamy material, or sandy to a depth of 20 - 40 inches and loamy below. Sandy Zolfo-Tavares ridges are infrequent in the basin, although they occur at Pine Level and where C.R. 665 intersects the creek channel. At the confluence of Horse Creek and the Peace River, the soils outside the creek corridor transition to Bradenton-Felda-Chobee soils, which are typical of wetlands and floodplains.

Joshua Creek flows through nearly level, poorly drained soils of flatwoods and sloughs. The downstream portion of the creek flows through predominantly sandy Malabar-Pineda-Felda soils with a loamy subsoil typical of sloughs and marshes. The middle reaches of the creek flow through Smyrna-Myakka-Immokalee soils of flatwoods typical of much of the Peace River watershed. Along the upper reaches of the creek where Lake Slough and Honey Run enter it, Valkaria-Basinger-Malabar soils lie beneath a large marshy area where the creek is poorly defined.

Flatwoods soils continue to typify the landscape outside Cypress Creek, Myrtle Slough, and the upper reaches of Shell Creek corridors. Oldsmar-Myakka, Immokalee-Myakka and Wabasso-Pineda-Boca soils outside the creek corridors make up the most extensive soils groups in Charlotte County and lack the mucky soil component that occurs farther downstream. Prairie Creek and lower Shell Creek, as well as other distributaries at the mouth of the river, flow through Peckish-Estero-Isles soils typical of tidal marshes and barrier islands and are mucky and sandy with a loamy subsoil. Low sandy ridges with 0-5 percent slopes near the mouth of the Peace River along Prairie Creek are composed of deep and moderately well-drained in thick beds of marine sands that characterize Orsino-Daytona soils. At the mouth of the Peace River, there are Matlacha soils of mixed sands and shell and limestone fragments in altered areas immediately landward the sand flats.

3.1.6 Hydrology and Hydrogeology

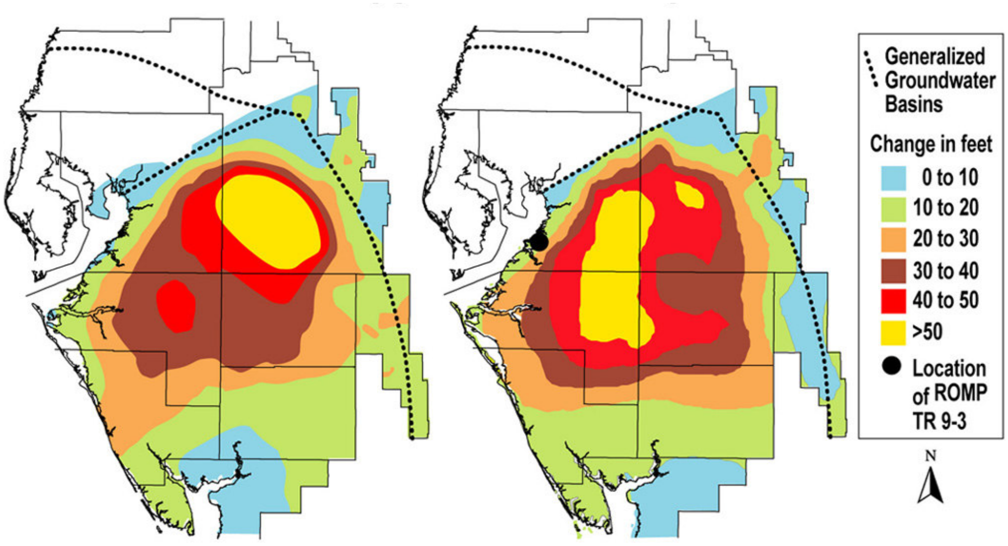
The Green Swamp in northern Polk County forms the headwaters of the Peace River. Flowing south from Lake Hancock just north of Bartow, Saddle Creek joins Peace Creek to form the Peace River. The other major surface water flows to the Peace River are from a series of five tributaries, including Payne Creek, Charlie Creek, Joshua Creek, Horse Creek and Shell Creek. Major control structures in the watershed are located at the headwaters on Saddle Creek south of Lake Hancock (P-11) and the Hendrickson Dam at the City of Punta Gorda's water supply reservoir on Shell Creek. Historic changes in hydrology in the Peace River watershed are detailed in *Chapter 4* and are also mapped in the GIS portfolio.

The Upper Floridan aquifer is the primary ground water supply in the Peace River watershed. Near the coast, water in the aquifer is highly mineralized and the surficial and intermediate aquifers are used for the primary ground water supply. The Floridan aquifer is separated into upper and lower aquifers by a "middle confining unit" (MCU II, after Miller 1986), and the confining unit and lower aquifer are usually saline. Throughout much of the watershed, the intermediate aquifer and the deeper Floridan aquifer are confined. However, where confining units are thin, absent, or breached by springs and uncased wells, water flows upward from the intermediate and Upper Floridan aquifers into the surficial aquifer and, subsequently, into the river and Charlotte Harbor (Wilson 1977, Wolansky 1983). The intermediate aquifer is recharged from the surficial aquifer, sinkholes, and abandoned mine pits that breach the confining units (Lewelling 1997). Although most ground water in the watershed is used for agriculture, other uses include industrial, commercial, phosphate mining, and dewatering (SWFWMD 2000).

The Upper Floridan aquifer is the primary ground water supply in the Peace River watershed.

As a result of potentiometric declines in the Upper Floridan aquifer and the demand placed on the aquifer by water withdrawals, the Southwest Florida Water Management District (1993) has designated *Water Use Caution Areas (*WUCAs*)* in southwest Florida to address water supply issues. The Peace River is within the Southern WUCA (SWUCA). Long-term changes in the potentiometeric surface of the Upper Floridan aquifer are mapped in Figure 3.1.1. Estimated declines in the potentiometeric surface of Upper Floridan aquifer between predevelopment and 1975 have exceed 50 feet in the northern region of the Peace River watershed. Since the mid-1970s, the area of greatest decline has moved southwest.

Figure 3.1.1. Long-term changes in the potentiometeric surface of the Upper Floridan Aquifer (SWFWMD, based on USGS data).



Predevelopment to 1975 **Predevelopment to 2000**

3.2 Peace River at Bartow

The headwaters of the Peace River are located in the Peace River at Bartow basin. This basin covers 233,761 acres (17 percent), of the watershed, making it the largest basin in the watershed. This basin also includes the largest number of acres (147,308 acres) and the largest percent (27 percent) of urban land use when compared with the other eight basins. The basin is mapped in Figure 3.2.1 and an aerial photograph of the basin (GoogleEarth 2006) is presented in Figure 3.2.2.

> *The headwaters of the Peace River are located in the Peace River at Bartow basin. This basin covers 233,761 acres (17 percent), of the watershed, making it the largest basin in the watershed.*

3.2.1 Hydrology

The major permanent streams and surface drainage systems associated with the Peace River at Bartow are the headwaters in the Green Swamp, Peace Creek (flows to Peace River just below Lake Hancock), Saddle Creek (flows from Lake Hancock), and Bear Branch. Many of the lakes in the headwaters area are linked by stems of canals, and many of these have fixed or operable control structures. Canals provide permanent surface water connections between some lakes, while connections occur only at high water in other lakes. The Peace River watershed above Bartow totals approximately 390 square miles, or 28 percent of the basin above Arcadia and contributes close to 22 percent of the average discharge at Arcadia (Estevez *et al*. 1984). The three surface water courses upstream of Bartow that have the most influence on the flow in the Peace River are Peace Creek, Saddle Creek, and Bear Branch.

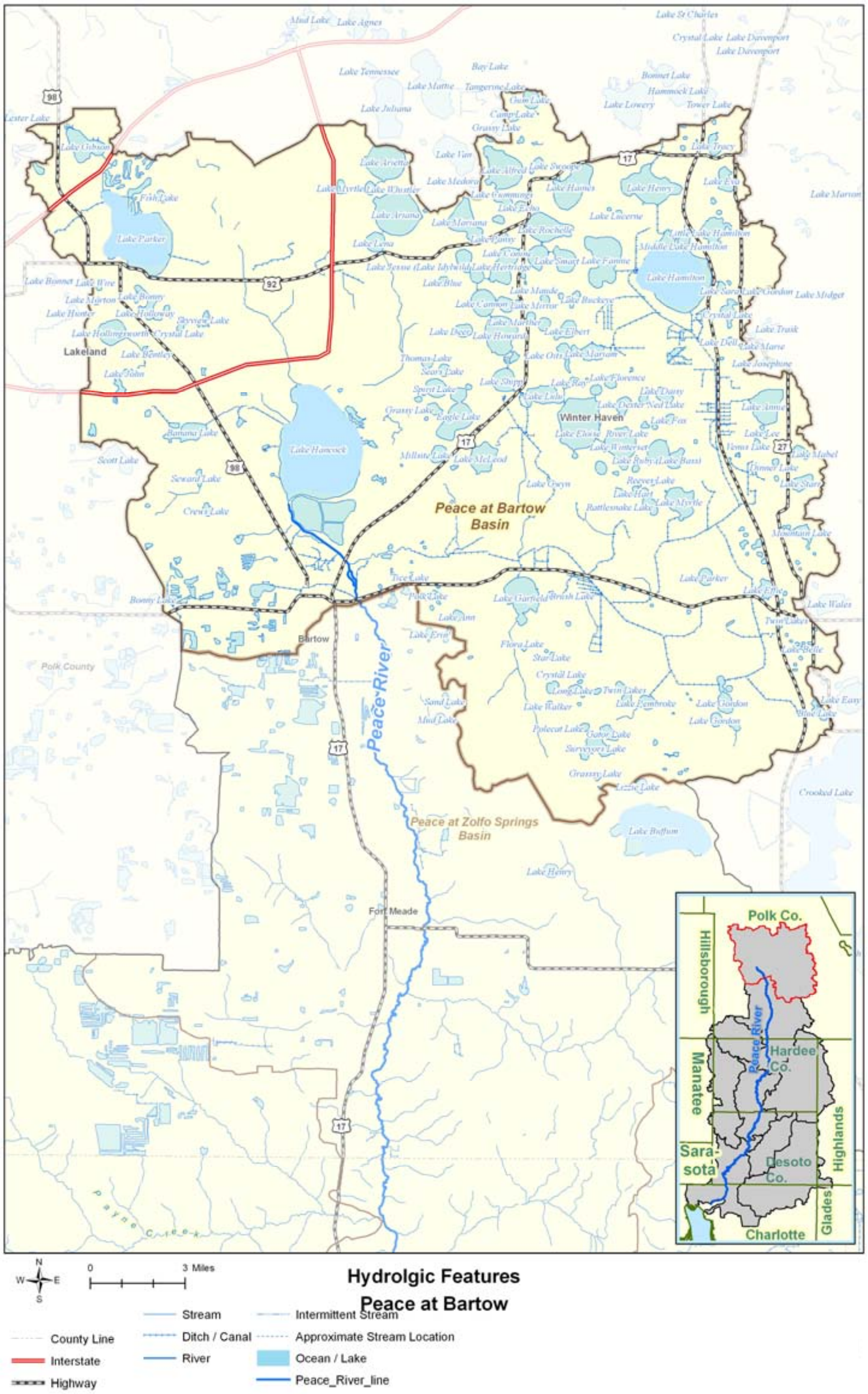
Along the upstream portion of the Peace River, the Upper Floridan aquifer is the primary source of water supply. Historically, the upper Peace River watershed appears to have been an area of widespread upward leakage and artesian flow from the intermediate Hawthorn layer (Hammett 1988).

> *In the upper watershed, declines in base flows along the main river channel historically occurred due primarily to phosphate mining ground water withdrawals and subsequent reductions in the potentiometric surface, which in turn resulted in cessation of spring flows and reduced natural ground water contributions.*

The surficial aquifer is composed primarily of quartz and includes surficial sand and clay with unconfined ground water. It is used for domestic and low volume irrigation that requires only low flows (Stewart 1966). The intermediate aquifer is composed of limestone and clay sediments and is in direct contact with the Upper Floridan aquifer, although it is confined. It is about 10 to 150 feet thick and used for domestic, truck farm, and some citrus irrigation. The Upper Floridan aquifer is the principal aquifer in Polk County and provides all major municipal, industrial and irrigation water supplies.

In the upper watershed, including the Peace River at Bartow, Peace River at Zolfo Springs, and Payne Creek basins, phosphate mining appears to have had an historical major influence on hydrology, water quality, and native upland and wetland habitats. Reduced base flows, as well as loss of spring flows, in the upper reaches of the Peace River reflect historic impacts to ground water associated primarily with phosphate mining withdrawals, and to a lesser extent agriculture and urban practices, from the intermediate and the Upper Floridan aquifers. Public supply water use (84 mgd in Polk County in year 2000) now contributes to the reduced base flows, along with phosphate mining and agricultural withdrawals.

Figure 3.2.1. Location of Peace River at Bartow Basin in the Peace River Watershed



A series of Seasonal Kendall Tau trend tests were run for each of the three basin USGS stream flow gages using standardized five-year intervals. The Peace River at Bartow gage data (Figure 3.2.3) have a long record starting in 1940, so trend tests were run sequentially in five year intervals (for example, 1940-2004, 1945-2004, 1950-2004). Since it usually requires six to eight years of monthly data to determine statistical significant trends in highly seasonal data, the last interval used for all gages was 1995-2004. Trend tests were conducted for three selected monthly flow metrics (listed below).

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

Trend tests indicate declines in flows at the Peace River at Bartow gage during the 1940s, 1950s and 1960s. However, none of the tested flow metrics show any statistically significant trends since the 1970s (35 years ago).

The trend tests indicate that since the 1970s and 1980s, there have been long-term increases in low flows in the upper Peace River at the Saddle Creek gage. Trend tests for low, median, and high flows at the Peace River at Bartow gage all show declines since the 1940s, 1950s and 1960s (Table 3.2.1). However, none of the tested flow metrics show any statistically significant trends in flows since the 1970s (35 years). Additional results of trend tests run over the individual periods-of-record for each of the three Peace River at Bartow basin flow gages are presented in Chapter 4.

Figure 3.2.2. Aerial Photograph of the Peace River at Bartow Basin

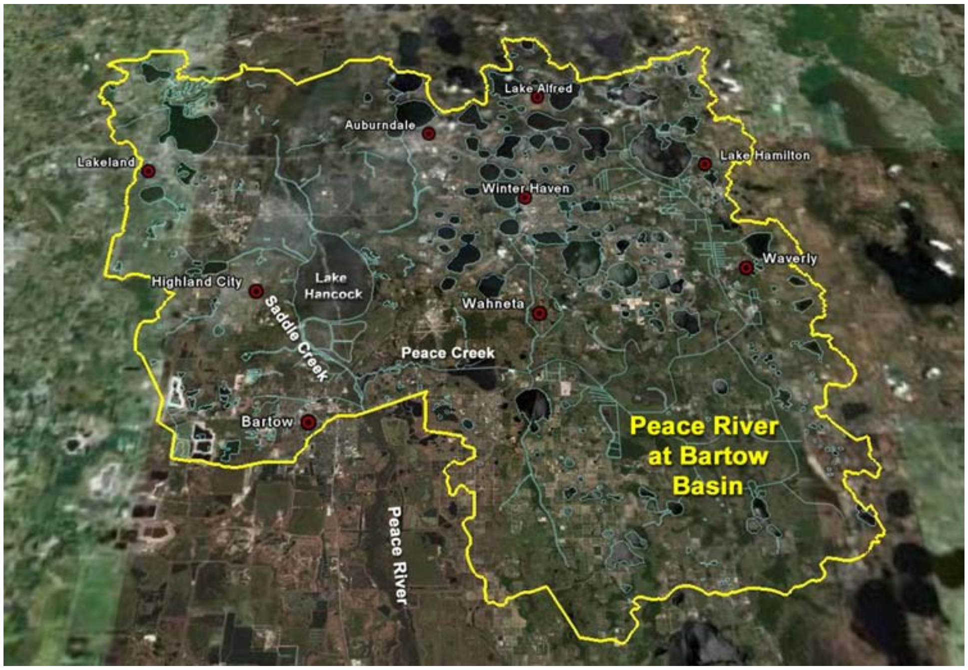


Figure 3.2.3. Monthly Minimum Flows over the Period-of-record for the Peace River at Bartow Gage (1939 – 2004)

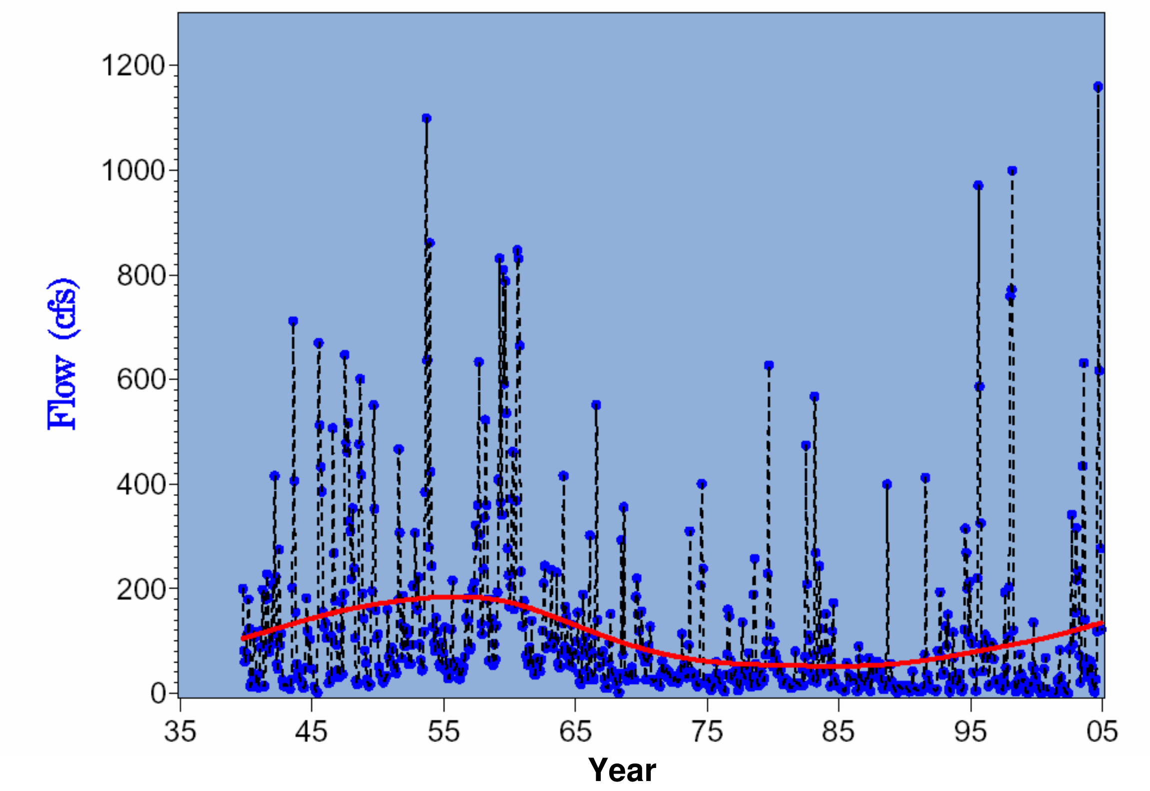


Table 3.2.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Peace River at Bartow Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Peace Creek Drainage Canal near Wahneta	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
	High (Q10)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Saddle Creek at Structure P-11 near Bartow	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▲		▲	▲		
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨						
	High (Q10)	▨	▨	▨	▨	▨	▨	▨						

Table 3.2.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Peace River at Bartow Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Peace River at Bartow	Low (Q90)	▨	🔻	🔻	🔻	🔻	🔻	🔻						
	Medium (Q50)	▨	🔻	🔻	🔻	🔻	🔻	🔽						
	High (Q10)	▨	🔻	🔻	🔻	🔻	🔽							

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location.

3.2.2 Water Quality

There are two water quality monitoring locations in the Peace River at Bartow basin with sufficient data to evaluate potential long-term changes. The first is the USGS/ SWFWMD Saddle Creek sampling site at Structure P-11 and the second is located downstream at the Peace River at Bartow gage. Important observed long-term changes in basin water quality are summarized below.

- Lake Hancock water quality has been characterized as “poor”, based on the Florida Trophic State Index, since at least 1970 and the poor water quality has been attributed to urban and agricultural impacts. The FDEP has verified the impaired condition of the lake and levels of total nitrogen, total phosphorus, and biological oxygen demand all exceeded the State threshold screening values.

- A large portion of the organic nitrogen exported from Lake Hancock is a result of nitrogen-fixation by high levels of blue green algae concentrations.

- Instances of low dissolved oxygen concentrations are conspicuous in the upstream portions of the Peace River, and both the frequency and downstream extent of low dissolved oxygen levels increase as discharges from Lake Hancock increase. Flows from the lake via Saddle Creek are characteristically high in total suspended solids, total Kjeldahl nitrogen, total organic carbon, and chlorophyll *a*. The high chlorophyll concentrations (algae) and organic material associated with these discharges result in extreme fluctuations in dissolved oxygen levels in the upper Peace River. During periods of high rainfall, discharges from the lake increase, and the low dissolved oxygen conditions are exacerbated.

- Historical changes in water quality at the Peace River at Bartow monitoring site reflect improving water quality following regulatory and phosphate mining changes that eliminated direct processing discharges and reduced other phosphate mining discharges to the Peace River.

- The most apparent improvements in water quality in the upper Peace River are the marked declines in both total phosphorus and orthophosphate levels in the 1980s and 1990s. It should be noted, however, that current phosphorus concentrations in the Peace River and the Charlotte Harbor estuary are extremely high relative to other freshwater and estuarine systems due to both natural deposits and the influences of mined lands.

- Historic improvements in fluoride and strontium levels in the upper Peace River also reflect reductions in phosphate mining water quality impacts.

- Levels of specific conductivity, total dissolved solids, calcium, magnesium, sulfate, and silica have declined in the upper river and are associated with reduced ground water discharges that historically occurred due to phosphate mining practices.

- Results of data analyses suggest that the loss of spring flows due to ground water withdrawals and the reductions in ground water discharges were historically so large that when discharges were reduced, color in the upper river increased, which may have been associated with the loss of the aquatic plant *Vallisneria americana* (tape grass) in areas of the upper river.

- These changes in water quality suggest that historically high ground water discharges predominantly from phosphate mining activities substantially augmented river base flow and that the supplementary base flow masked the declines of natural spring discharges that followed reductions in basin ground water levels.

- Conversely, increasing chloride and potassium levels, which were accentuated during the recent 1999-2001 drought, are similar to patterns reflecting increased ground water discharges in the southern watershed basins.

3.2.3 Water Budget

A water budget, or water balance, was developed for individual basins in the Peace River watershed to quantify the amount of water entering, stored within, and leaving the watershed during different time intervals. The water budget was then examined in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed. Water budgets for the Peace River watershed were completed on a basin scale for intervals of three years.

Importantly, the inter-annual variability of a major water budget parameter, such as rainfall, is often greater than the associated long-term change, and consequently, water budget trends may be obscured by variability in rainfall. The best approach to use when assessing cumulative hydrologic impacts is to first identify trends in time series data, such as rainfall or land use changes, and subsequently assess the impact of those trends on overall watershed functions using water budgets. In addition, water budgets are based on simplified conceptual models of complex watershed functions and should be used as a basis for understanding water fluxes at an order of magnitude scale. The results of the water budget for the Peace River at Bartow basin are summarized below.

1941-1943

- Rainfall during the 1941-1943 period was above the 100-year average.

- Total stream flow was above average during this period.

- From 1941-1943, recharge to the surficial aquifer was estimated to be 6-inches a year, which was the lowest estimate of all the budget intervals. This relatively low recharge rate is due in part to the high water table position in the surficial aquifer and the high potentiometric surface in the intermediate aquifer and Upper Floridan aquifer.

- By 1941-1943, ground water withdrawals in the basin were still low in comparison to modern levels. However the withdrawals had already reached a level where significant aquifer drawdown occurred.

1976-1978

- Rainfall during the 1976-1978 period was below the 100-year average.

- Total stream flow was below average during this period.

- Recharge to the surficial aquifer was estimated to be 12-inches a year, which was the highest estimate of all the budget intervals and nearly double the recharge estimated for the 1941-1943 period. The relatively high recharge rate is due in part to the depressed water table position in the surficial aquifer and the lowered potentiometric surface in the intermediate aquifer and Upper Floridan aquifer. The primary cause of the drawdown in these aquifers was the aquifer response to pumping withdrawals, although there was also a response to rainfall events.

- By 1976-1978 ground water withdrawals in the basin were at the maximum level of any of the four budget intervals. The related drawdown in the Upper Floridan aquifer exceeded 40-feet in some areas.

1989-1991

- Rainfall during the 1989-1991 period was below the 100-year average.

- Total stream flow was below average during this period.

- Recharge to the surficial aquifer was estimated to be 10 inches a year, which was elevated compared to the estimate for the 1941-1943 period. The relatively high recharge amount is due in part to the depressed water table position in the surficial aquifer and the lowered potentiometric surface in the intermediate aquifer and Upper Floridan aquifer.

- In the 1989-1991 ground water withdrawals were reduced from the maximum withdrawal levels of the mid-1970s. Significant drawdown in the Upper Floridan aquifer remained.

1997-1999

- Rainfall during the 1997-1999 period was above the 100-year average.

- Total stream flow was above average during this period.

- Recharge to the surficial aquifer was estimated to be 10-inches a year, which was still elevated compared to the estimate for the 1941-1943 period.

- In the 1989-1991 ground water withdrawals were reduced from the maximum withdrawal levels of the mid-1970s. Significant drawdowns in the Upper Floridan aquifer remained as a result of earlier ground water withdrawals and withdrawals that were ongoing during the 1997-1999 budget intervals.

- By the 1997-1999 budget interval significant declines in base flow had occurred relative to the base flow levels present in the 1940s. Base flow had declined by more than 35 percent between the 1941-1943 and the 1997-1999 water budget intervals. The reduction in base flow is related to the pumping-related aquifer drawdowns in the intermediate aquifer and Upper Floridan aquifer.

- Drawdown of the intermediate aquifer and Upper Floridan aquifer has also impacted the surficial aquifer by increasing leakage losses from the surficial aquifer to the deeper aquifers. The increased leakage has lowered the water table elevation in the surficial aquifer and has lowered the stage of some lakes in the basin. The drawdown of the surficial aquifer due to ground water extractions has been a contributing factor to base flow decline.

3.2.4 Land Use

The Peace River at Bartow basin is the largest basin in the Peace River watershed and includes 233,761 acres (17 percent) of the watershed. This basin includes the largest amount of urban land (147,308 acres or 27 percent of the total watershed) when compared with the eight other basins in the watershed and is one of the only two basins in the watershed with a large urban land use component.

In the 1940s, approximately 26 percent of the basin was developed and 19 percent of the basin was in intense agriculture. Urban, mining, and improved pasture combined accounted for about seven percent of the land use in the basin. Native upland habitats (31 percent), wetlands (30 percent), and lakes/open water (13 percent) made up the remaining 76 percent of the basin. Table 3.2.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another provided in *Appendix G*. Land use changes are graphed in Figure 3.2.4 and mapped in Figures 3.2.5 and 3.2.6.

Table 3.2.2. Land Uses 1940s – 1999: Peace River at Bartow Basin

Land Use Designation	**Time Period**					
	1940s		**1979**		**1999**	
	Acres	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**
Developed						
Mined Lands*	2,575	1	19,972	9	19,977	9
Urban Land Use	7,553	3	30,659	13	61,359	26
Improved Pasture	5,889	3	39,027	17	34,054	15
Intense Agriculture	44,682	19	43,857	19	31,919	14
Subtotal	**60,699**	**26**	**133,514**	**57**	**147,308**	**63**
Undeveloped						
Wetlands	69,874	30	37,736	16	33,169	14
Native Upland Habitats	72,279	31	31,715	14	20,380	9
Subtotal	**142,154**	**61**	**69,451**	**30**	**53,548**	**23**
Water						
Streams and River Channels	203	<1	171	<1	189	<1
Lakes and Open Water	30,705	13	30,624	13	32,715	14
Subtotal	**30,908**	**13**	**30,796**	**13**	**32,904**	**14**
Total	**233,761**	**100**	**233,761**	**100**	**233,761**	**100**

* Includes reclaimed (totally and partially) lands

By 1979, acres of developed land uses in the basin more than doubled due to increases in improved pasture, urban land uses, and phosphate mining, and urban land uses made up to 57 percent of the basin. There was very little change in the extent of intense agriculture in the basin and large areas of wetlands and native upland habitats were converted to developed land uses. These changes were greatest between the 1940s and 1979. For example, a total of about 32,000 acres of wetlands were converted to a developed land use by 1979, while acres of wetlands lost between 1979 and 1999 decreased by only about 4,500 acres (*Appendix G*). Approximately 40,000 acres of native upland habitat were lost between the 1940s and 1979.

Acres of phosphate mining in this basin increased from about 2,575 acres in the 1940s to 19,972 acres in 1979, and by 1999, the total change in mined lands was an increase of only five acres to

19,977 acres. In 1979, about 11,500 acres of mined lands were identified as totally or partially reclaimed. Conversions of wetlands (9,976 acres) and native upland habitat (7,052 acres) to mined lands totaled more than 17,000 acres in 1979. Post-1979, about 4,400 acres of wetlands and native uplands habitat and about 2,400 acres of agriculture were converted to phosphate mining. However, about 8,600 acres were identified as mined, but nonmandatory (no reclamation required) and only 232 acres were identified as mined with mandatory reclamation. There was a 2,010 acre increase in lakes and open water in this basin from the 1940s to 1999, due primarily to conversions of mined lands to open water bodies.

Conversions to urban land uses doubled from 1979 (30,659 acres) to 1999 (61,359 acres). Lands converted to urban uses during this time period were predominantly from intense agriculture (9,854 acres, improved pasture (7,491 acres), and native upland habitat (7,402 acres). Nearly two-thirds of the Peace River at Bartow basin was developed by 1999. Since 1979, acres of urban land use doubled, while acres of agriculture, wetlands, and native upland habitats declined. Acres of mining remained at about nine percent of the basin.

Acres of native upland habitat in the basin had decreased from approximately 72,279 acres in the 1940s to about approximately 20,380 acres in 1999 and represented the largest change in land use in this basin. Wetlands made up 34 percent of the basin in the 1940s and only 16 and 14 percent, respectively, in 1979 and 1999, a loss of about 33,000 acres. These conversions occurred predominantly before 1979.

Figure 3.2.4. Land Uses: Peace River at Bartow Basin

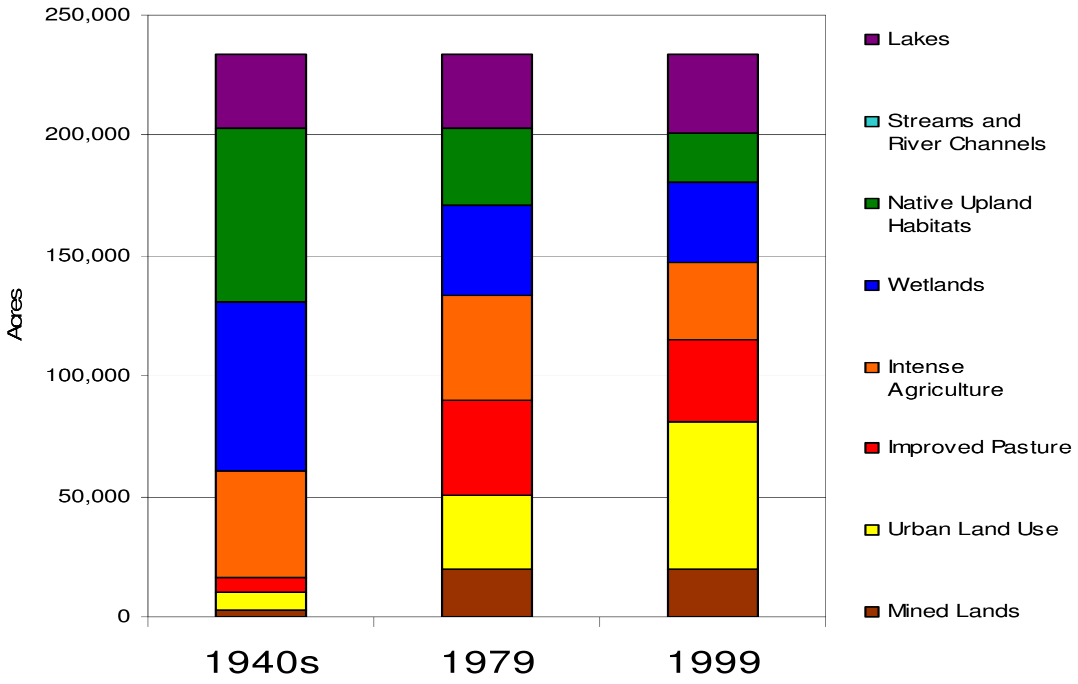


Figure 3.2.5. Changes in Undeveloped Land Use: Peace River at Bartow Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

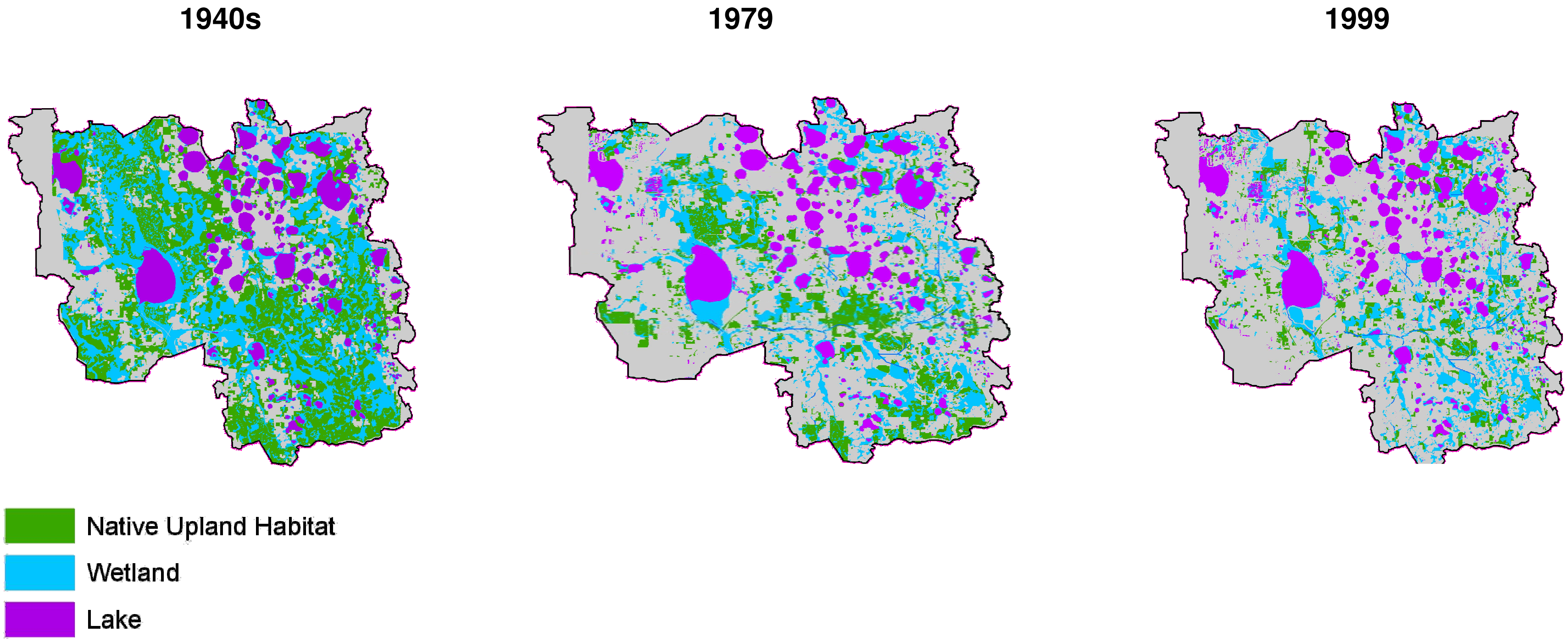
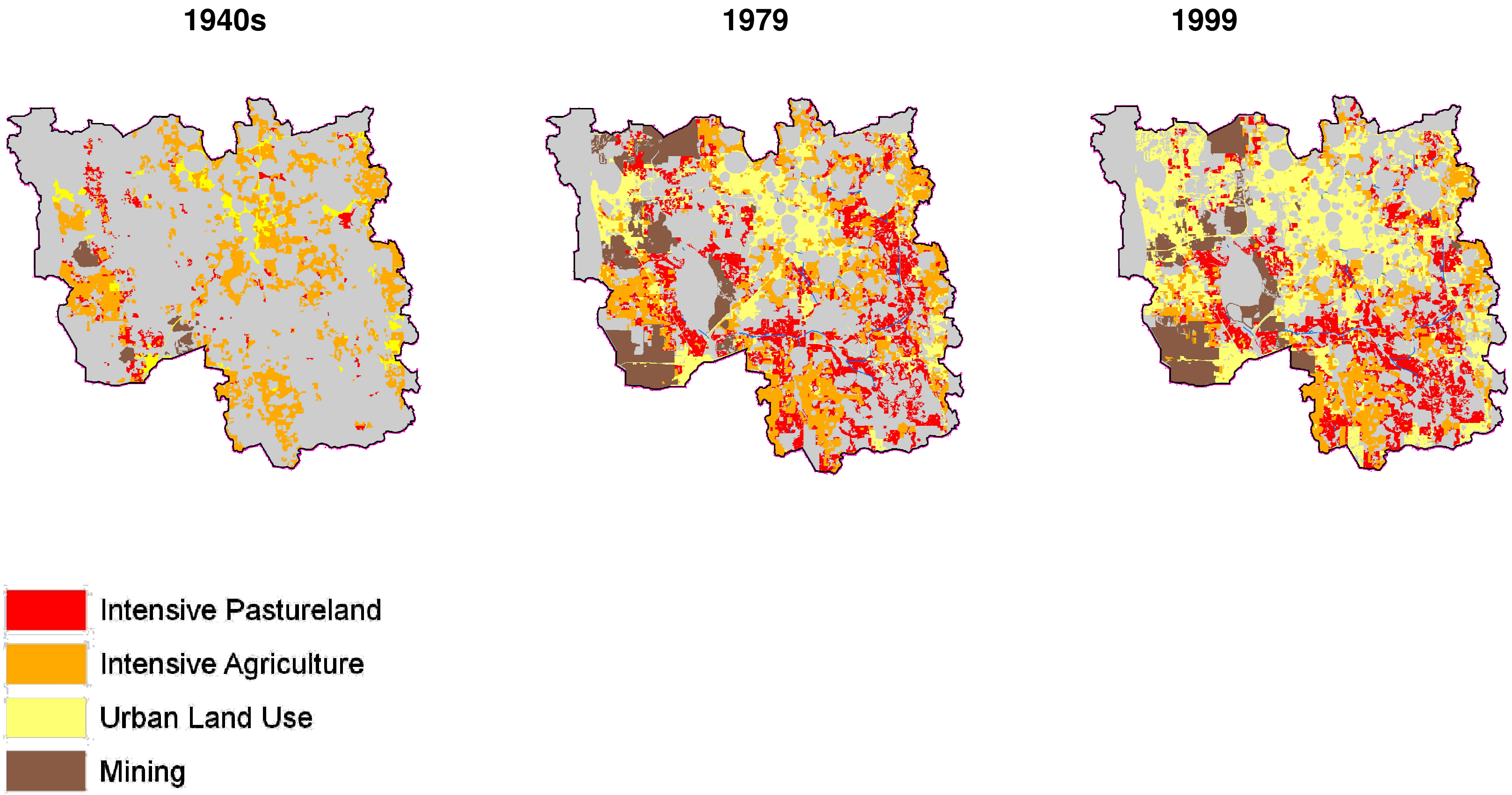


Figure 3.2.6. Changes in Developed Land Use: Peace River at Bartow Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



3.3 Peace River at Zolfo Springs

The Peace River at Zolfo Springs basin is approximately 196,668 acres in size. This basin includes the Peace River from Bartow in Polk County to Zolfo Springs, approximately 30 miles south on U.S. 17. The towns of Fort Meade, Bowling Green, and Wauchula also occur along this portion of the river. The basin is mapped in Figure 3.3.1 and an aerial photograph of the basin is presented in Figure 3.3.2.

> *The Peace River at Zolfo Springs basin is approximately 197,668 acres in size and includes approximately 14 percent of the watershed. Most of the basin (77 percent) is developed and mining makes up the largest single land use (33 percent).*

3.3.1 Hydrology

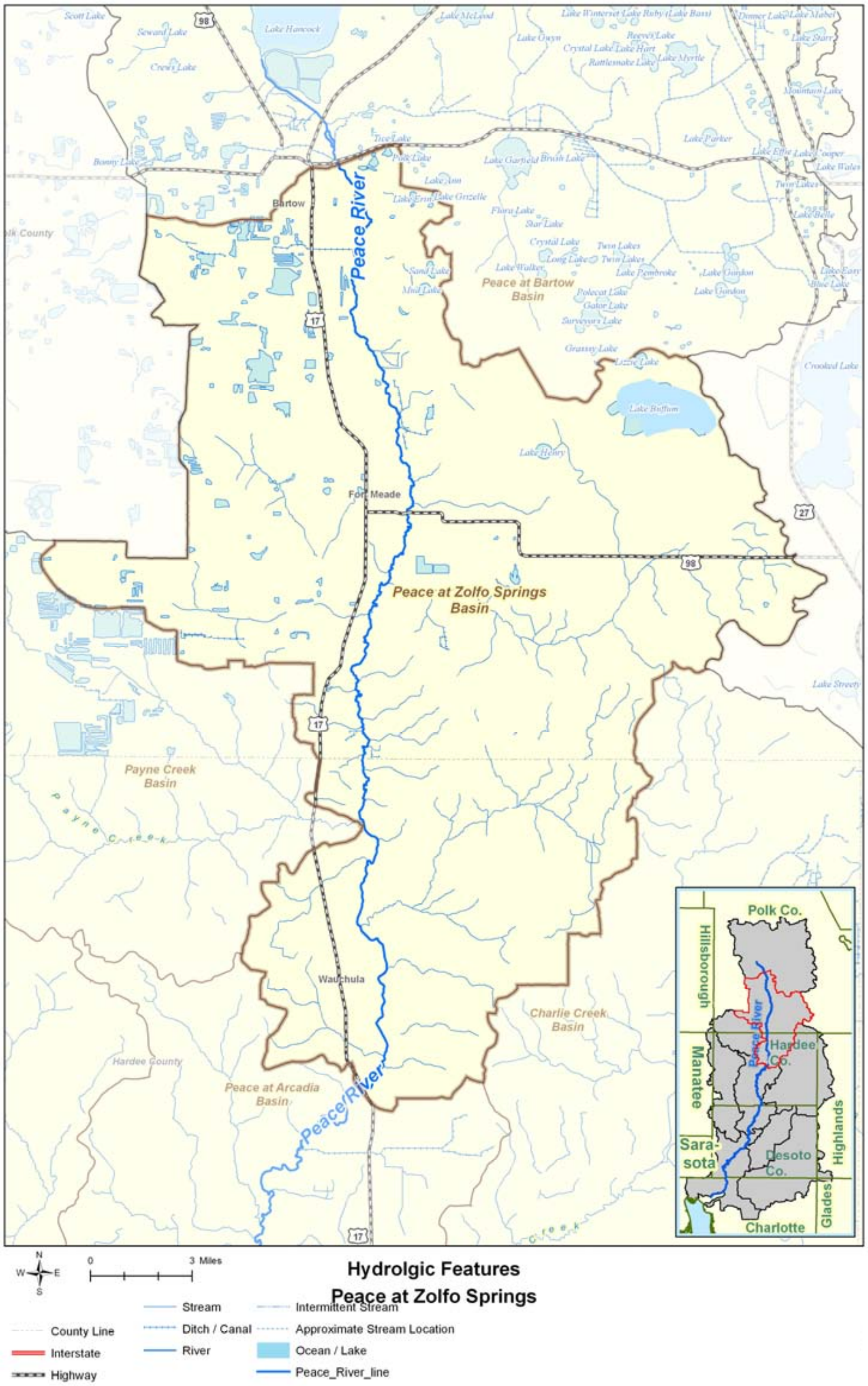
There are numerous creeks intersecting the Peace River between Fort Meade and Zolfo Springs, including Thompson Branch, Hog Branch, Little Charlie Creek, Payne Creek, Hickory Creek, Whidden Creek, Bowlegs Creek, and Sink Branch.

The Upper Floridan aquifer is the primary source of all ground water, although the surficial sands and upper portion of the Hawthorn Formation are secondary sources. Wells provide the water supply for towns, communities, and homes in Hardee County. The wells are generally 80 to 100 feet deep, dug and cased to the limestone.

There are numerous creeks intersecting the Peace River between Fort Meade and Zolfo Springs, including Thompson Branch, Hog Branch, Little Charlie Creek, Payne Creek, Hickory Creek, Whidden Creek, Bowlegs Creek, and Sink Branch.

Rivers typically gain flow downstream as the size of the contributing watershed increases. However, comparable flow data for the Bartow and Fort Meade USGS monitoring stations over the past 35 years have often indicated a net loss in flow. The number of days each year that flows at the upstream Bartow gage exceed those approximately 13 miles downstream at the Fort Meade gage is illustrated in Figure 3.3.3. This graphic indicates that, during drier years, upstream flows exceed downstream flows more than half the time. The following summarized the cause of the decline in flows in this reach of the upper river (Flannery and Barcelo 1998, Lewelling et al. 1998, Basso 2002, SWFWMD 2005).

Figure 3.3.1. Location of Peace River at Zolfo Springs in the Peace River Watershed



- Historically, the dry season potentiometric head was higher than the river bed and ground water flowed into the river channel even during the dry season. This resulted in the upper river having base flow throughout the year. However, potentiometric levels declined as a result of ground water withdrawals and flows in certain areas of the upper river flow into the ground during dry periods.

- Historically, surficial, intermediate, and Upper Floridan aquifers beneath the Peace River produced springs and seeps that maintained the natural base flow of the upper river, primarily between Bartow and Ft. Meade. Where the surficial aquifer is absent, the karst formations along the upper Peace River are exposed and are directly connected to the river. Where the surficial aquifer is present, it lies between the river and the lower karst formations. However, due to excessive ground water withdrawals, the connections are now a conduit for the direct loss of dry season flow into the aquifers.

- Ongoing USGS studies have indicated that most flows are lost from the Peace River to the aquifer in a five-mile interval between the Bartow gage and where flow from Kissengen Springs historically entered the Peace River. USGS recently measured dry season river losses in four seepage run studies with estimated losses to ground water ranging from 6-30 cfs.

Figure 3.3.2. Aerial Photograph of the Peace River at Zolfo Springs Basin

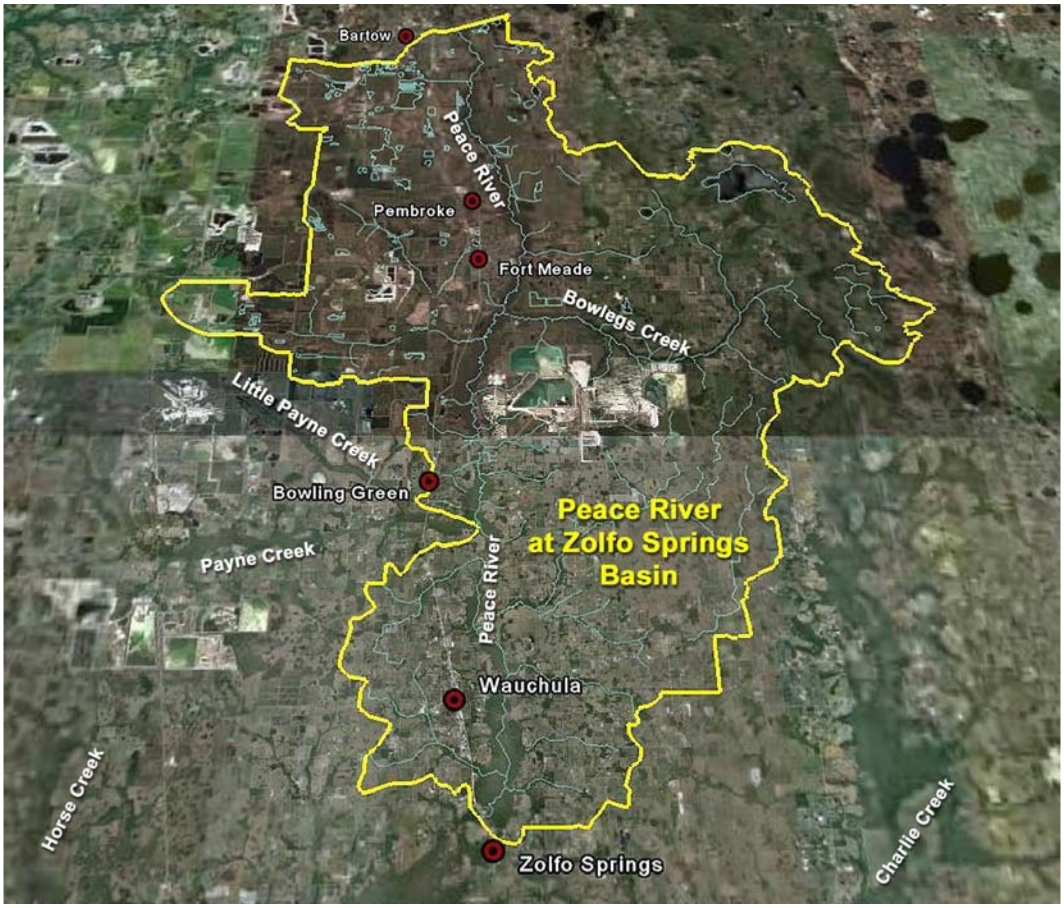
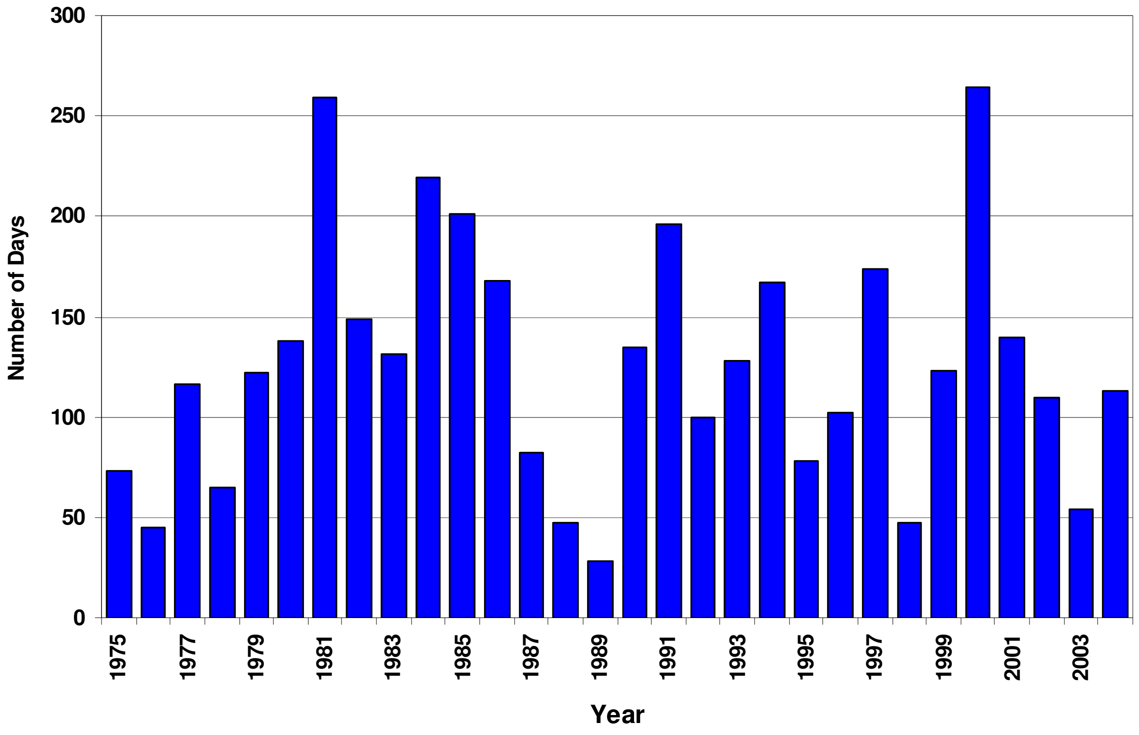


Figure 3.3.3. Number of Days Flows at Bartow Exceed Flows at Ft. Meade

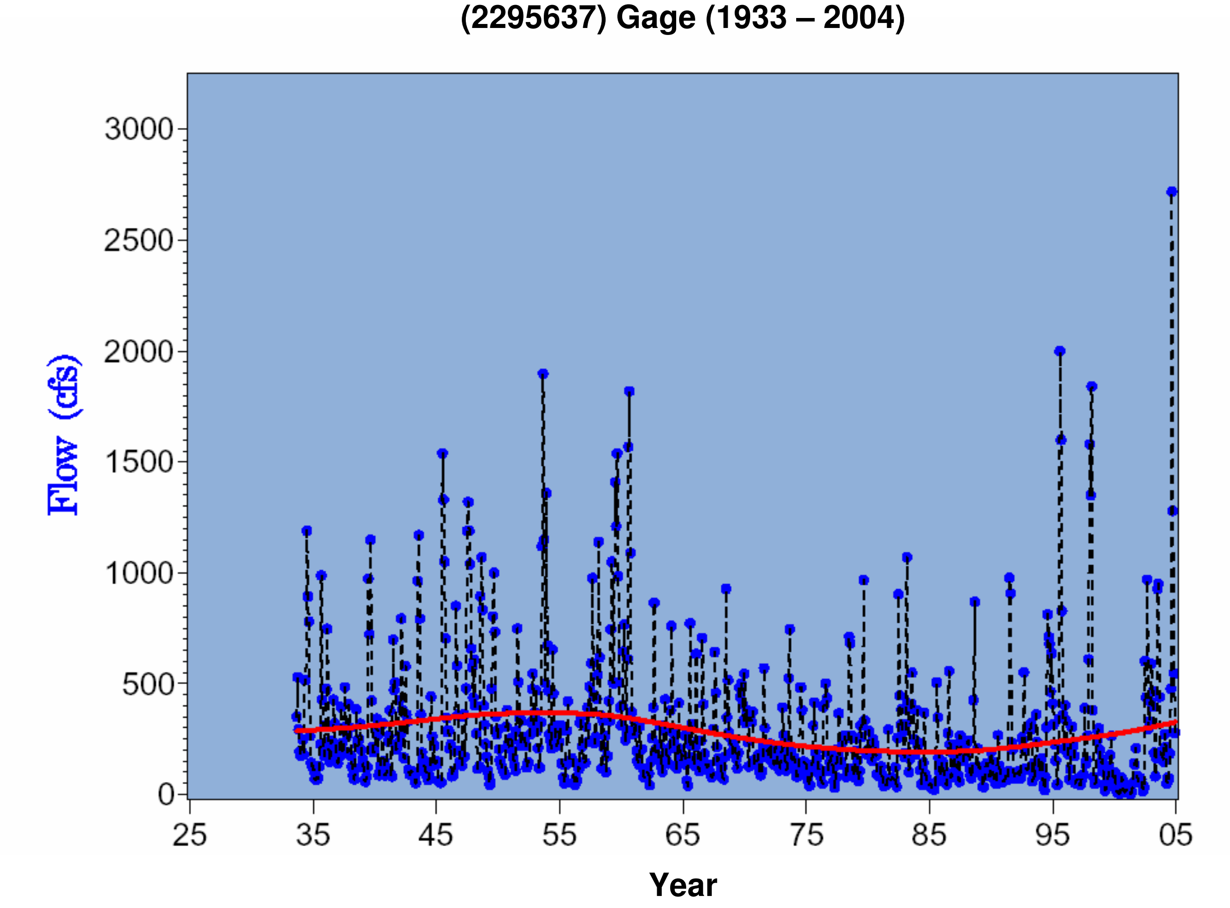


Seasonal Kendall Tau trend tests were run for each of the three basin USGS stream flow gages using standardized five-year intervals (Figure 3.3.4). The Peace River at Zolfo gage data have a long record starting in 1934, so trend tests were run sequentially in five-year intervals (for example, 1935-2004, 1940-2004, 1945-2004). Since it usually requires six to eight years of monthly data to determine statistical significant trends in highly seasonal data, the last interval used for all gages was 1995-2004. Trend tests were conducted for three selected monthly flow metrics (listed below).

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.
- Trend test for low, median, and high flows at the Peace River at Zolfo gage all show declines since the mid-1930s, 1940s, 1950s and early 1960s. However, none of the tested flow metrics show any statistically significant trends in flows since the 1970s (35 years).

Additional results of trend tests run over the individual periods-of-record for each of the three Peace River at Zolfo Springs basin flow gages (Table 3.3.1) are presented in Section 4.

Figure 3.3.4. Monthly Minimum Flow at Long-term Peace River at Zolfo (2295637) Gage (1933 – 2004)



3.3.2 Water Quality

There are three long-term USGS/ SWFWMD water quality monitoring locations in this basin with adequate periods-of-records to assess potential long-term changes. These are the Peace River at Fort Meade, Bowlegs Creek near Fort Meade, and the Peace River at Zolfo Springs sites. Available water quality data from all three of these locations historically dates back to the mid-1960s. However, potential changes over time are more apparent at the Zolfo Springs site due to the greater number of parameters and higher frequency of sampling observations. The following observations summarize several important water quality changes that have occurred in basin.

- Comparisons among the river monitoring sites indicate that the marked increases in water color observed following reductions of the historic large scale mining ground water discharges upstream in the Bartow basin were also apparent in the long-term Fort Meade data and to a lesser extent downstream at Zolfo Springs.

- Both of the basin mainstream river monitoring sites showed long-term declining patterns in total and orthophosphate levels similar to those previously observed upstream at the Peace River at Bartow monitoring location.

Table 3.3.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Peace River at Zolfo Springs Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Peace River at Fort Meade	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▨					
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨	▨					
	High (Q10)	▨	▨	▨	▨	▨	▨	▨	▨					
Bowlegs Creek near Ft Meade	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
	High (Q10)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Peace River at Zolfo Springs	Low (Q90)	🔻	🔻	🔻	🔻	🔻	🔻	🔻						
	Medium (Q50)	🔻	🔻	🔻	🔻	🔻	🔻							
	High (Q10)	🔻	🔻	🔻	🔻	🔻	▼							

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location.

- The historic declines in fluoride and strontium levels in the river observed upstream at Bartow were also reflected to a lesser extent at Zolfo Springs.

- On the other hand, measured levels of alkalinity, sodium, potassium, and chlorides at Zolfo Springs all indicated long-term increasing patterns with historically high levels measured during the 1999-2001 drought.

- Similar long-term increasing patterns of conductivity levels, and potassium and sulfate concentrations in Bowlegs Creek showed marked increases during the 1999-2001 drought. This indicates that these changes are also associated with increasing ground water discharges.

- The apparent declines at the Zolfo Springs monitoring site in the measured forms of nitrogen may reflect changes in domestic point source discharges in both the Peace River at Bartow and Peace River at Zolfo Springs basins.

3.3.3 Water Budget

The water budget was examined for the Peace River at Zolfo Springs basin in the context of changes in land use and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget are summarized below.

1941-1943

- Rainfall during the 1941-1943 period was above the 100-year average.
- Total stream flow was above average during this period.
- By 1941-1943, ground water withdrawals in the basin were still low in comparison to modern levels. However the withdrawals had already reached an unsustainable level where significant aquifer drawdown occurred.
- Discharge from Kissengen Spring was located within the Peace River at Zolfo Springs basin. Discharge had begun to decline in response to aquifer drawdown by the 1941-1943 budget interval relative to discharge levels through the 1930s. Discharge from Kissengen Springs would cease altogether by the mid-1960s.

1976-1978

- Rainfall during the 1976-1978 period was below the 100-year average.
- Total stream flow was below average during this period.
- By 1976-1978, ground water withdrawals in the basin were at the maximum level of any of the four budget intervals. Ground water withdrawals during and preceding this budget interval resulted in significant drawdown of the Upper Floridan aquifer in the basin (the intermediate aquifer is present only along the upper reaches of the river).

1989-1991

- Rainfall during the 1989-1991 period was below the 100-year average.
- Total stream flow was below average during this period.
- In the 1989-1991 ground water withdrawals were reduced from the maximum withdrawal levels of the mid-1970s. However, the effect of the earlier draw downs in the Upper Floridan aquifer persisted.

1997-1999

- Rainfall during the 1997-1999 period was above the 100-year average.

- Total stream flow was above average during this period.

- In 1997-1999 ground water withdrawals were reduced from the maximum withdrawal levels of the mid-1970s. Significant declines in the Upper Floridan aquifer persisted as a result of earlier ground water withdrawals and withdrawals that were ongoing during the 1997-1999 budget interval.

- By the 1997-1999 budget interval significant declines in base flow had occurred relative to the base flow levels present in the 1940s. The reduction in base flow is related to the pumping-related aquifer drawdowns in the Upper Floridan aquifer and the cessation of flows from Kissengen Spring.

- Drawdown of the Upper Floridan aquifer has also impacted the surficial aquifer by increasing leakage losses from the surficial aquifer to the deeper aquifers. The drawdown of the surficial aquifer due to ground water extractions has been a contributing factor to base flow decline.

- Loss of flows along segments of the upper Peace River channel in the Peace River at Zolfo Springs basin (between Bartow and Fort Meade) were documented during the spring of 2000, 2001, 2002, 2003, and 2006. Although there have been several anecdotal reports, the losses were first documented in 2000, and are a result of low overall stream flow coupled with stream flow losses to sinks and other karst features that provide connections of surface waters with deeper underlying layers.

- The pumping-related drawdown of the Upper Floridan aquifer has created losing conditions, where stream flow sinks into the subsurface, along much of the Peace River channel in this basin. The effects of the pumping-related draw downs in the Upper Floridan aquifer are the primary cause of the Peace River channel going dry in, 2001, 2002, 2003, and 2006, although rainfall events have also influenced water levels.

3.3.4 Land Use

The Peace River at Zolfo Springs basin is approximately 197,668 acres in size and includes approximately 14 percent of the watershed. Most (77 percent) is developed and phosphate mining makes up the largest (33 percent) single land use in the basin. Agriculture (improved pasture and intense agriculture) (37 percent) and urban land uses (seven percent) make up the remaining 44 percent of developed land in the basin.

In the 1940s, approximately 38,660 acres (20 percent) of the basin was developed and 12 percent was intense agriculture. Urban, phosphate mining, and improved pasture, combined, accounted for about eight percent of the land use in the basin. Native upland habitats (55 percent), wetlands (25 percent), and lakes/open water (one percent) made up the remaining 80 percent of the basin. Table

3.3.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.3.5, 3.3.6, and 3.3.7.

By 1979, areas of developed lands in the basin more than tripled to 120,092 acres (61 percent) in the basin, primarily due to increases in improved pasture and phosphate mining. Urban land uses remained relatively unchanged and made up only three percent of the basin. The increase in improved pasture, from 8,794 acres in the 1940s to 46,613 acres in 1999, was due primarily to the conversion of nearly 34,000 acres of native upland habitat to improved pasture. About 40,000 acres of native upland habitat were converted to developed land uses between the 1940s and 1979.

Acres of phosphate mining in this basin increased from 4,109 acres in the 1940s to 36,108 acres in 1979 and increased to over 65,000 acres by 1999. Nearly 20,000 acres of native upland habitat and 4,800 acres of wetlands were converted to mined lands during this period. Post-1979, about 4,000 acres of wetlands, almost 17,000 acres of native upland habitat, and about 11,600 acres of improved pasture and intense agriculture were converted to mining.

Table 3.3.2. Land Uses 1940s – 1999: Peace River at Zolfo Springs Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	4,109	2	36,108	18	65,324	33
Urban Land Use	2,642	1	6,292	3	14,105	7
Improved Pasture	8,794	5	46,613	24	43,360	22
Intense Agriculture	23,115	12	31,079	16	29,428	15
Subtotal	**38,660**	**20**	**120,092**	**61**	**152,218**	**77**
Undeveloped						
Wetlands	48,773	25	29,809	15	24,525	12
Native Upland Habitats	107,774	55	44,485	23	16,674	8
Subtotal	**156,547**	**79**	**74,295**	**38**	**41,199**	**21**
Water						
Streams and River Channels	211	<1	215	<1	129	<1
Lakes and Open Water	2,249	1	3,066	2	4,122	2
Subtotal	**2,460**	**1**	**3,281**	**2**	**4,251**	**2**
Total	**197,668**	**100**	**197,668**	**100**	**197,668**	**100**

* Includes reclaimed (totally and partially) lands

Conversions to urban land uses doubled from 1979 (6,292 acres) to 1999 (14,105 acres), although the number of acres converted was relatively small compared with phosphate mining and agriculture. Lands converted to urban during this time period were predominantly improved pasture (2,724 acres), and native upland habitat (3,484 acres).

More than three-quarters of the Peace River at Zolfo Springs basin was developed by 1999. Since 1979, the greatest increases were in phosphate mining, while acres of agriculture, wetlands, and native upland habitats declined.

Acres of native upland habitat in the basin decreased from 107,774 acres (55 percent of the basin) in the 1940s to about 16,674 acres (eight percent) in 1999 and represented the largest change in land use in the basin. Wetlands included 48,773 acres (25 percent) of the basin in the 1940s and only 15 and 12 percent, respectively, in 1979 and 1999. This amounts to a loss of about 14,000 acres, most of which occurred by 1979.

Figure 3.3.5. Land Uses: Peace River at Zolfo Springs Basin

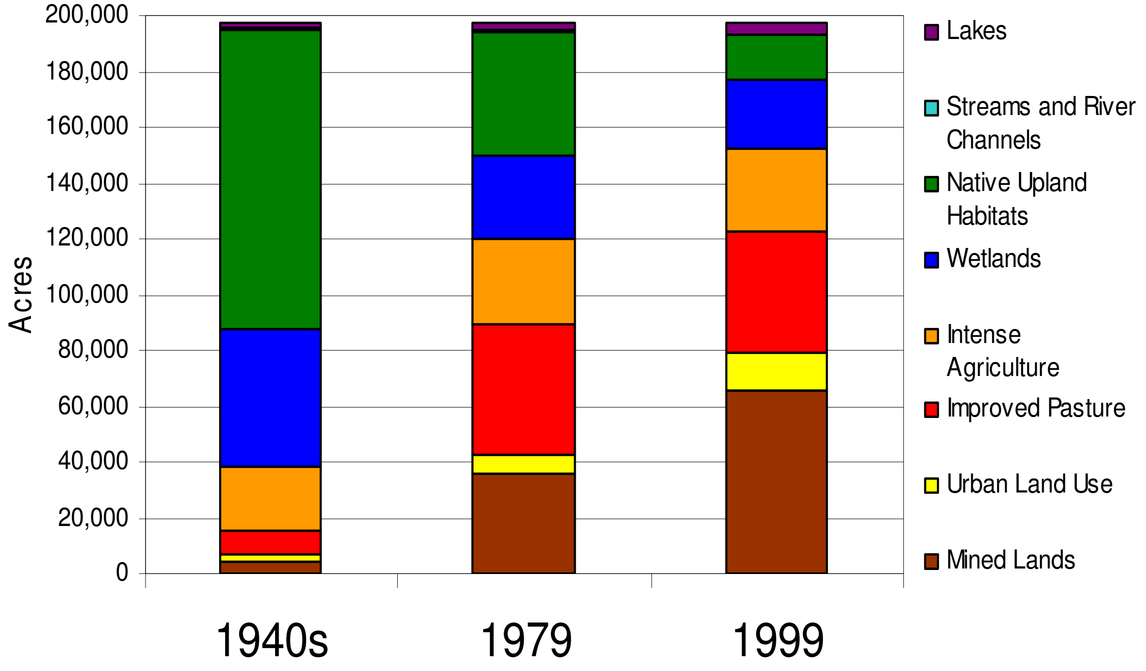


Figure 3.3.6. Changes in Undeveloped Land Use: Peace River at Zolfo Springs Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

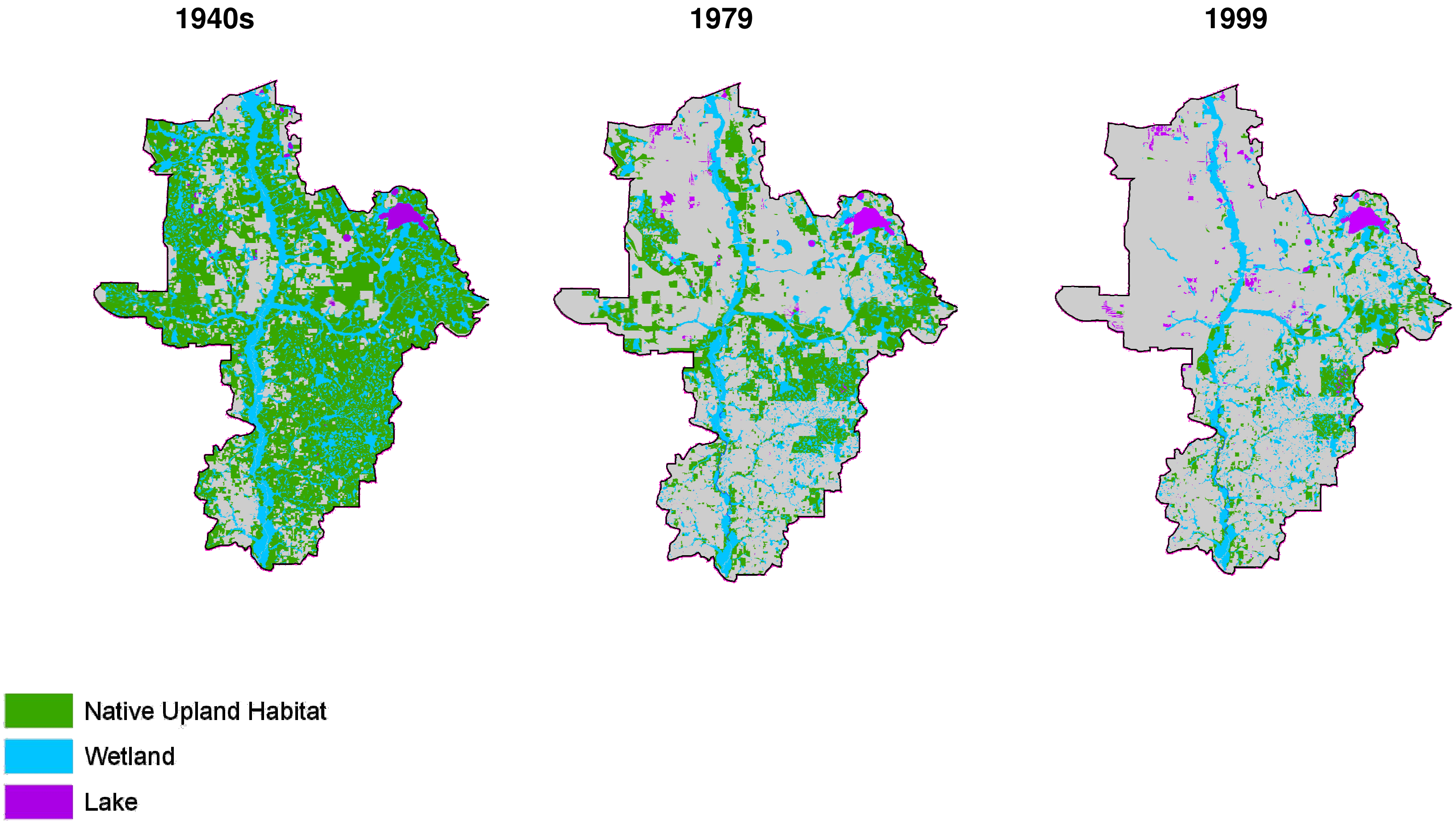
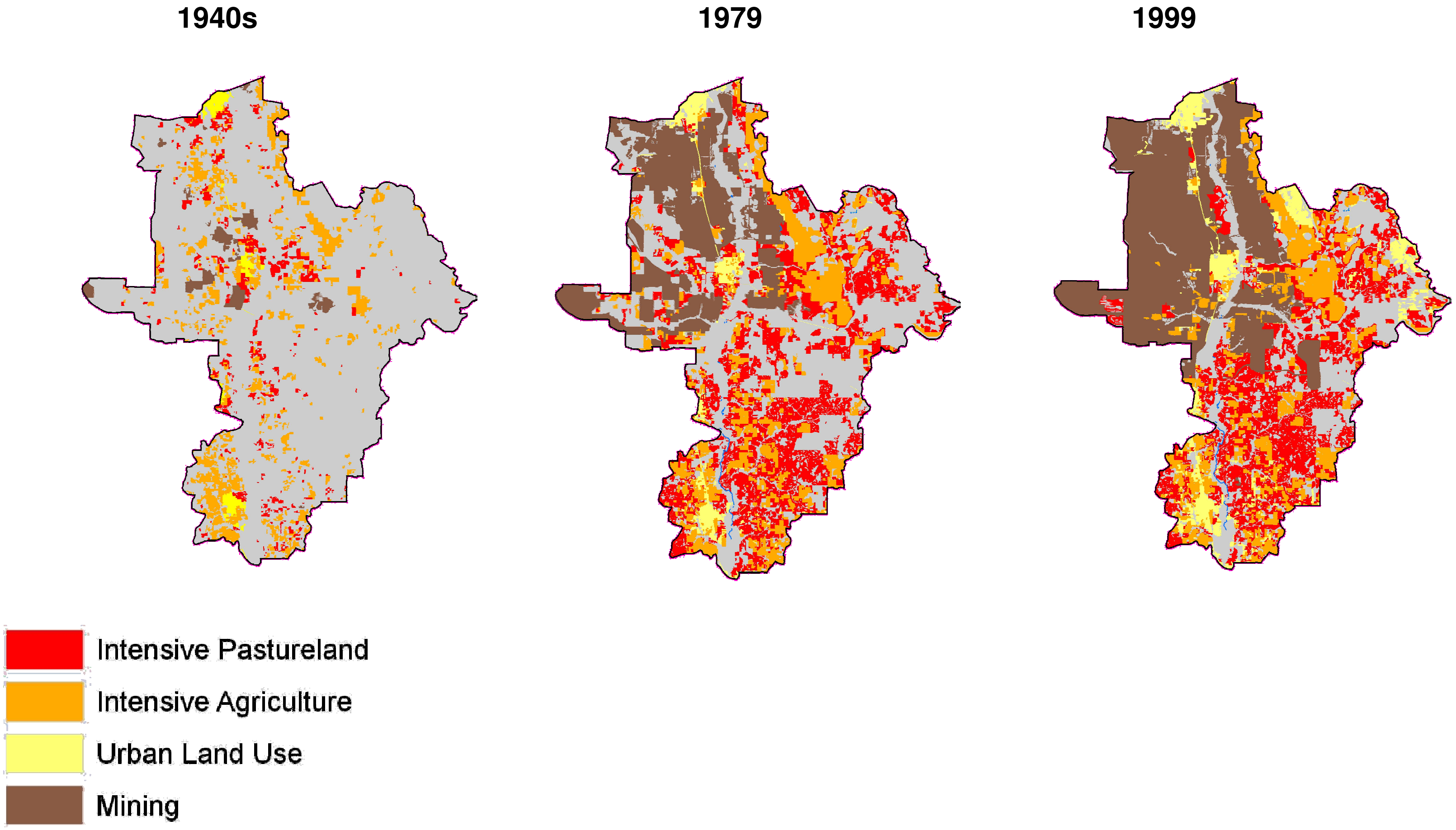


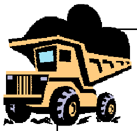
Figure 3.3.7. Changes in Developed Land Use: Peace River at Zolfo Springs Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



3.4 Payne Creek

The Payne Creek basin is 79,561acres in size, making it the second smallest basin in the watershed. The basin is in the northwest portion of the Peace River watershed and the Payne Creek itself begins just north of the Polk-Hardee counties boundary and flows southeast through Hardee County into the Peace River just south of Bowling Green. The basin is mapped in Figure 3.4.1 and an aerial photograph of the basin is presented in Figure 3.4.2.



The Payne Creek basin comprises only six percent (79,561 acres) of the Peace River watershed, making it the second smallest basin (next to Joshua Creek). In contrast, this basin includes 41 percent (50,238 acres) of the phosphate mined lands in the Peace River watershed.

3.4.1 Hydrologic Features

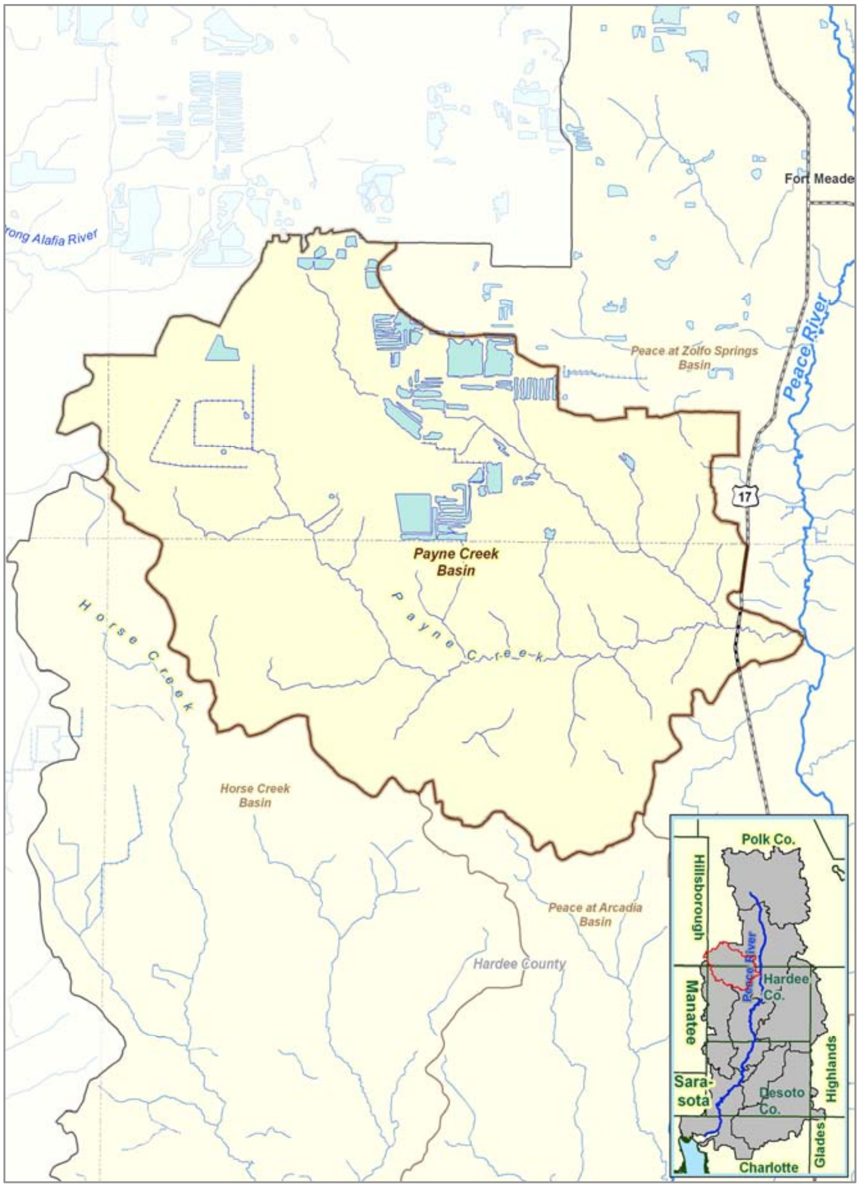
Hickey Branch, Shirtail Branch, Gum Swamp Branch, and Olive Branch are all tributaries to Payne Creek. Little Payne Creek and Payne Creek are the main tributaries of the Peace River from this basin. The number of wetlands associated with both the Little Payne Creek and Payne Creek are considerable.

Monthly minimum flows over the period-of-record for the Payne Creek near Bowling Green gage are plotted in Figure 3.4.3. Payne Creek base flow is augmented by phosphate mining, agriculture, and power facility National Pollutant Discharge Elimination System (NPDES) permitted discharges of ground water withdrawals used for mining operations, agricultural irrigation, and power facility cooling. Phosphate mining ground water withdrawals were more than double that of agriculture and power facility withdrawals for the years 1999-2001 (Table 3.4.1), although mining withdrawals declined dramatically in 2002 following the end of the previous three years of drought to volumes less than those of agriculture and power facilities. Further details of these withdrawals are presented in *Appendix D*.

Table 3.4.1. Mean Annual Ground Water Withdrawals (cfs) in the Payne Creek Basin

Year	Ground Water User		
	Agriculture	Phosphate Mining	Power Utilities
1999	4.36	9.52	4.31
2000	5.03	11.51	3.59
2001	5.13	11.47	4.44
2002	4.83	3.82	3.92

Figure 3.4.1. Location of Peace River at Payne Creek Basin in the Peace River Watershed



A 10-year break in the data record precluded the use of the Seasonal Kendall Tau trend test prior to 1980. Trend tests were run for 10 monthly flow metrics for the period 1980-2004 (Section 4 below) and sequentially in five-year intervals (for example, 1980-2004, 1985-2004, 1900-2004) for the following three monthly metrics (listed below).

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flow.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

The results of the trend tests support the graphical evidence that base flows in the basin have increased over time. However, due to the relatively short period-of-record and the high degree of monthly variability none of the increasing patterns in the monthly flow metrics were statistically significant after correcting for serial autocorrelation.

Figure 3.4.2. Aerial Photograph of the Peace River at Payne Creek Basin

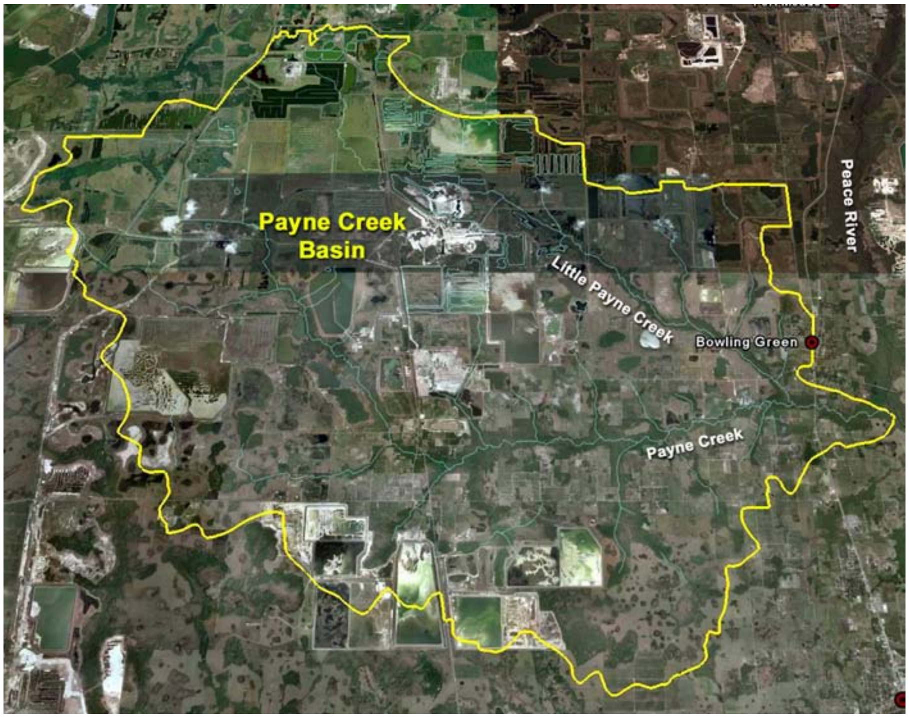
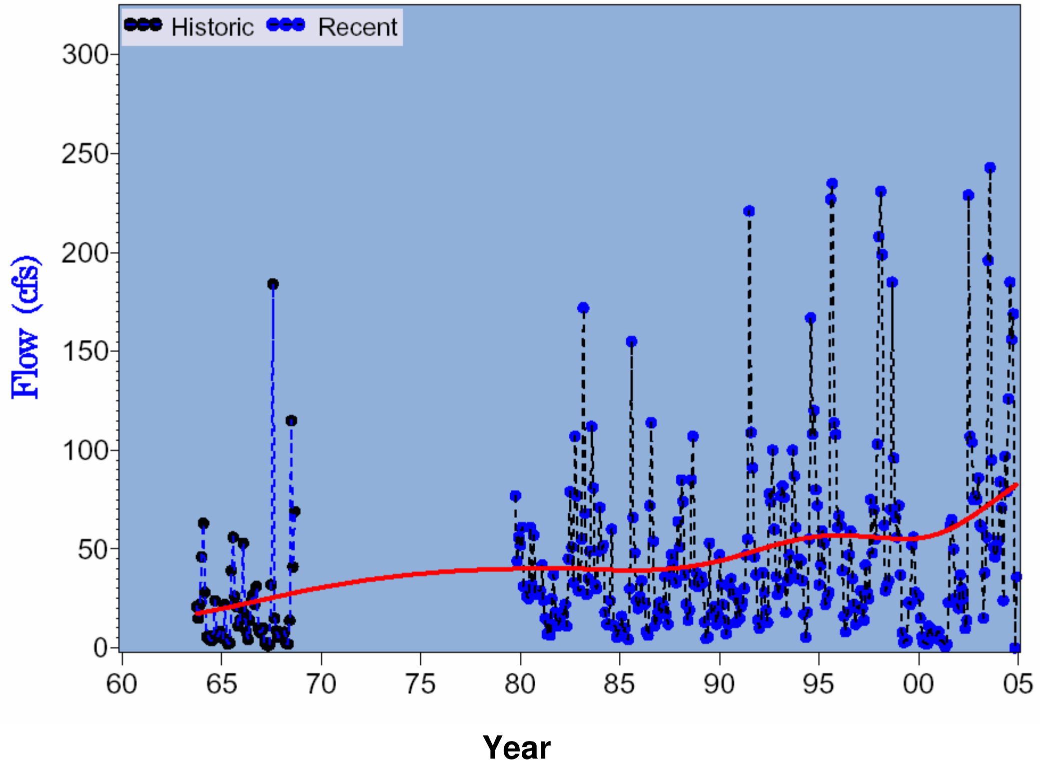


Figure 3.4.3. Monthly Minimum Flow at Long-term Payne Creek (2295420) Gage (1963 – 2004)



3.4.2 Water Quality

There is a single long-term USGS/SWFWMD basin water quality monitoring location at the Payne Creek site near Bowling Green. The Payne Creek basin is unique due to the extent of recent and active phosphate mining operations and reclamation. Water from Payne Creek enters the Peace River upstream of Wauchula. The following indicates patterns of historical water quality changes that have taken place in the Payne Creek basin.

- The water quality data from this long-term monitoring location indicates comparatively large historic increases in levels of measured total alkalinity, total dissolved solids, sodium, and sulfate over the period-of-record.

- Relatively smaller increases over the period-of-record in conductivity (specific conductance) and pH levels, as well as calcium and magnesium concentrations, were also apparent.

- Since the 1980s, both total phosphorus and orthophosphate levels in Payne Creek have increased.

- These observed long-term changes in water quality in the Payne Creek basin can be attributed primarily to the ground water withdrawals and subsequent discharges by agriculture and mining activities.

Data analyses, although not definitive, lead to several conclusions regarding potential sources of base flow and seasonal changes in water quality in the Payne Creek basin. These conclusions are listed below and relevant analyses are presented in *Appendix D*. Overall, analyses indicate that during typical wet seasons, phosphate mining discharges contribute a significant portion of the flows in Payne Creek. However, the data also suggest that much of the increase in dry season base flow in the creek may originate from agricultural discharges of ground water, similar to that observed in the southern basins that are characterized by predominantly agriculture.

- During typical dry months from the late fall to the beginning of the wet season, as well as unusually extended dry periods (for example, between January 1999 and mid-2001), NPDES permitted discharges by phosphate mining and power facilities generally make up a relatively small portion of the measured base flow in the lower Payne Creek basin at the USGS gage. This is not unexpected since withdrawal data indicate that mining uses much larger quantities of ground water during the dry season and NPDES discharges are limited when compared with wetter intervals. Mean monthly NPDES discharges and USGS gaged flow in the Payne Creek basin are graphed in Figure 3.4.4 and illustrate NPDES discharges by phosphate mining and power facilities.

- Seasonal patterns and relative amounts of ground water withdrawals by agricultural were similar between 1999 and 2002. However, phosphate mining ground water withdrawals in the Payne Creek basin were generally much higher than either agricultural or power facility uses throughout the 1999-2001 drought, and then declined sharply in 2002 following the return of more normal rainfall patterns. Agricultural withdrawals were highest from the late fall through the spring dry season each year, and power facility withdrawals were similar in magnitude to agriculture, but did not follow the same seasonal pattern. Phosphate mining ground water use also did not show a clear seasonal pattern.

Mean monthly ground water withdrawals among primary users in the Payne Creek basin are presented in Figure 3.4.5 to illustrate user volumes.

- The highest phosphate mining related NPDES discharges occur during the summer wet season and corresponding periods of high flows in Payne Creek. During wet conditions, NPDES discharges can contribute a significant portion of the mean monthly and 120 day estimated base flow of Payne Creek.

- Under low flow conditions, the measured water chemistry at the USGS Payne Creek gage is similar to that measured in the Upper Floridan aquifer in this area of the Peace River watershed. Water chemistry data suggest that ground water contributes to the augmented base flow of Payne Creek during dry periods.

- Observed seasonal water quality patterns (especially specific conductance and calcium) typically associated with ground water discharges were very similar to patterns in total monthly agricultural pumping.

- Ten percent of the area in the Payne Creek basin was in intense agriculture in 1999, similar to that in Horse Creek, where dry season agricultural ground water discharges have augmented base flow and resulted in marked increases in dry season specific conductance and other water quality characteristics.

- Increased flows (and NPDES discharges) result in decreases in concentrations of the water chemistry constituents typically associated with ground water and indicate that the wet season NPDES discharges originate from, or are diluted by, surface flows.

- Increased phosphorus and fluoride concentrations with increasing flows indicate that much of the flow into Payne Creek originates from mined lands and also support the previous conclusion.

Figure 3.4.4. Mean Monthly NPDES Discharges and USGS Gaged Flow in the Payne Creek Basin (both in cfs)

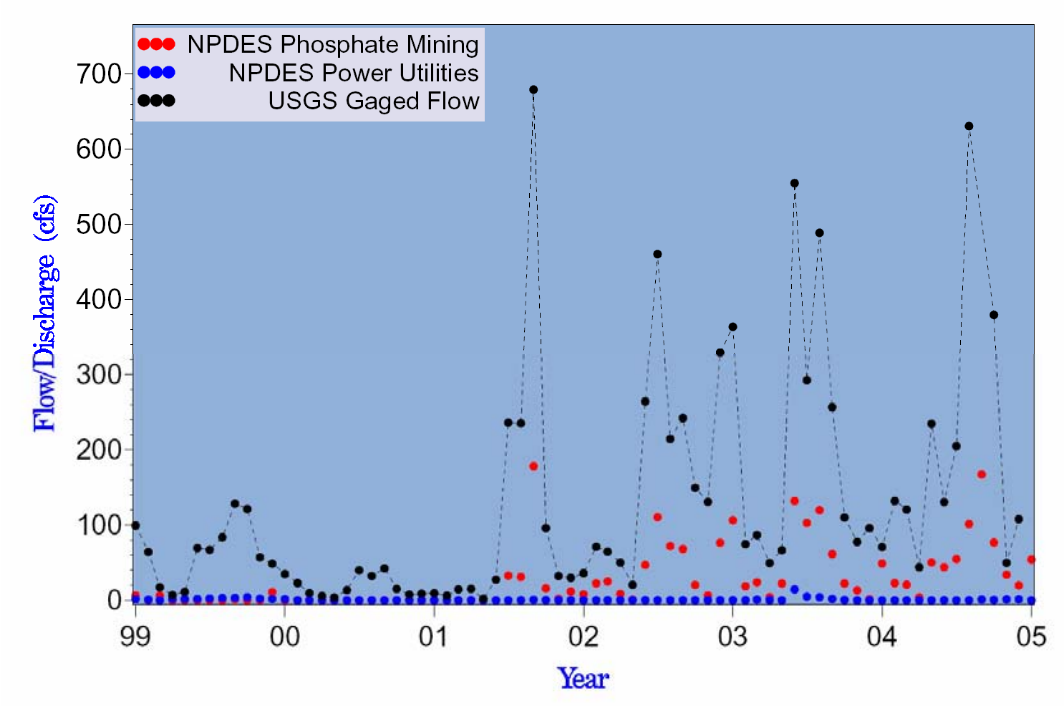
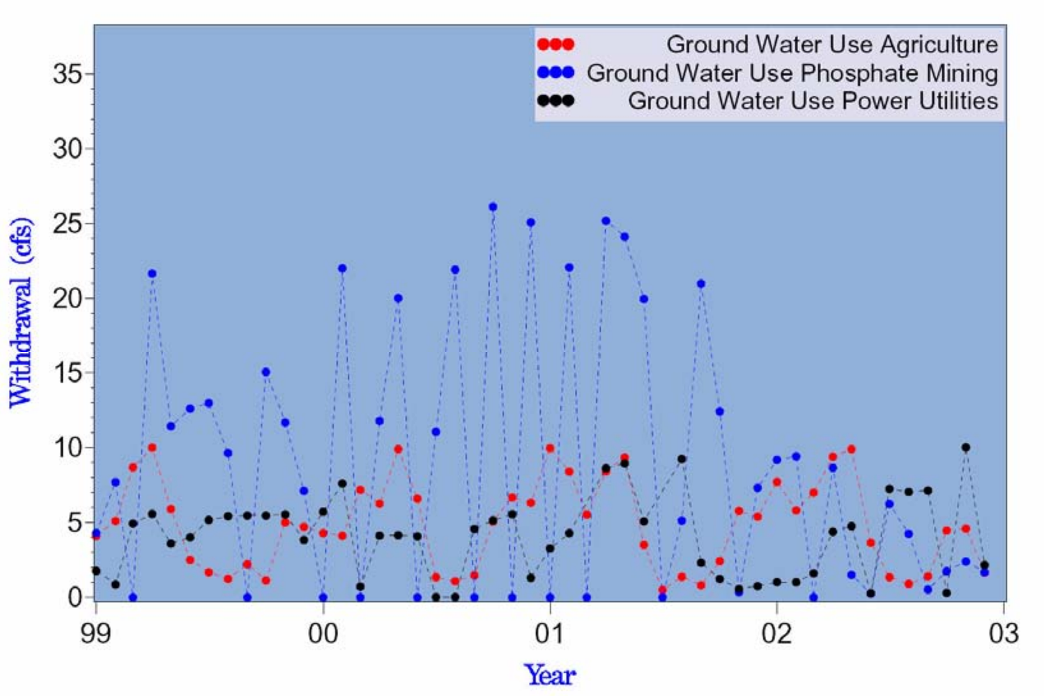


Figure 3.4.5. Mean Monthly Ground Water Withdrawals among Primary Users in the Payne Creek Basin (cfs)



3.4.3 Water Budget

The water budget was examined for the Payne Creek basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget are summarized below.

- A USGS stream gaging station is present in Payne Creek for the 1989-1991 and 1997-1999 budget intervals making it impossible to complete a budget for the two earlier periods, precluding the completion of a budget for the two earlier periods.

- With only two water budgets completed for this basin, trend analysis is limited.

- A USGS gage was placed on Payne Creek in 1963 but it stopped collecting data in 1968. A replacement gage was installed in 1979 leaving a data gap for the interval from 1968 to 1979. This early gage is the only record of stream flow characteristics prior to the onset of mining operations.

- Ground water extraction data were obtained for the time period between 1941 and 1943.

1989-1991

- The Payne Creek basin is intensely mined for phosphate. By the 1989-1991 budget interval phosphate mining operations had expanded over much of the basin.

- By the 1989-1991 budget interval ground water withdrawals were increased several fold over 1941-1943 levels. Aquifer drawdown within the basin was significant in response to pumping within the Payne Creek basin and adjacent basins including Peace River at Bartow and Peace River at Zolfo Springs.

- In the 1989-1991 budget interval Payne Creek had the highest total stream flow of any basins in the Peace River watershed on a per unit area basis.

- Base flow in Payne Creek is measured from two gages, one that was present from 1963 to 1968 and a replacement gage that was installed in 1979. A comparison of the data recorded at each of the two gages, reveals a significant and sustained increase in base flow in the 1989-1991 and 1997-1999 budget intervals compared to the base flow estimated from the gage data from 1963-1968.

1997-1999

- Base flow in Payne Creek was 21 percent of total stream flow in the 1997-1999 budget interval. This is the highest base flow percentage of all the basins modeled in the Peace River watershed. A temporary gage present on Payne Creek from 1963 to 1968 recorded much lower base flows at that time, prior to the broad expansion of mining activities in the basin.

- In the 1997-1999 budget interval Payne Creek had the highest total stream flow of any basin in the Peace River watershed on a per unit area basis.

- During the 1997-1999 budget interval, ground water withdrawals were nearly unchanged from the 1989-1991 budget interval.

3.4.4 Land Use

The Payne Creek basin comprises only six percent (79,561 acres) of the Peace River watershed, making it the second smallest basin (next to Joshua Creek). In contrast, this basin includes 41 percent (50,238 acres) of the phosphate mined lands in the Peace River watershed.

Mined lands currently make up the largest land use in the basin and only one basin, Peace River at Zolfo Springs (described previously), has more acres of mining (65,324 acres). Intense agriculture (7,799 acres) and improved pasture (6,527 acres) combined make up 18 percent of the basin. Urban lands, in contrast, comprise only one percent (1,002 acres) of the basin.

In the 1940s, approximately 8,675 acres (11 percent) of the basin was developed, primarily due to intense agriculture (14,062 acres). Urban and improved pasture land uses combined accounted for approximately three percent of the land use in the basin. Native upland habitats (65 percent), wetlands (24 percent), and lakes/open water (one percent) made up the remaining 89 percent of the basin. Less than 1,000 acres (one percent) were present in the basin during the 1940s. Table 3.4.1 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.4.6, 3.4.7, and 3.4.8.

By 1979, acres of developed lands in the basin increased from 11 to 43 percent, primarily due to agriculture, including improved pasture and intense agriculture, which made up 33 percent (about 26,000 acres) of the basin. Expansion of agriculture resulted in the loss of approximately 17,700 acres of native upland habitat and about 1,900 acres of wetlands. Phosphate mining increases were smaller prior to 1979 and increased in area from 774 to 8,357 acres (11 percent), commensurate with a loss of 6,027 acres of native upland habitat and 1,867 acres of wetlands. Urban land uses increased by about 300 acres.

Eighty-two percent (65,566 acres) of the Payne Creek basin was developed by 1999 and conversions to mining were the primary land use change post-1979. Acres of phosphate mining in this basin increased from 8,357 acres in 1979 to 50,238 acres in 1999. A total of 7,663 acres of wetlands and 22,866 acres of native upland hardwoods were converted to mining during this time period. An additional 12,500 acres of agriculture were converted to mining post-1979.

Table 3.4.2. Land Uses 1940s – 1999: Payne Creek Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	774	1	8,357	11	50,238	63
Urban Land Use	144	<1	454	1	1,002	1
Improved Pasture	1,821	2	11,693	15	6,527	8
Intense Agriculture	5,936	7	14,062	18	7,799	10
Subtotal	**8,675**	**11**	**34,566**	**43**	**65,566**	**82**
Undeveloped						
Wetlands	18,903	24	14,868	19	7,017	9
Native Upland Habitats	51,574	65	29,699	37	5,176	7
Subtotal	**70,478**	**89**	**44,567**	**56**	**12,193**	**15**
Water						
Streams and River Channels	0	0	1	<1	0	0
Lakes and Open Water	408	1	427	1	1,802	2
Subtotal	**408**	**1**	**429**	**1**	**1,802**	**2**
Total	**79,561**	**100**	**79,561**	**100**	**79,561**	**100**

* Includes reclaimed (totally and partially) lands

By 1999, about 16,152 acres of mined lands were identified as totally or partially reclaimed in the basin. Since most phosphate mining in the basin occurred subsequent to reclamation regulations, over 11,000 acres in the Payne Creek are also identified as mandatory reclamation lands and only about 3,500 acres are identified as nonmandatory reclamation. A total of 14,025 acres of mined lands are identified as clay settling areas. Post-1979, about 4,400 acres of wetlands and native uplands habitat and about 2,400 acres of agriculture were converted to phosphate mining.

Acres of native upland habitat in the basin decreased from over 51,574 acres in the 1940s to about 5,176 acres in 1999 and represented the largest change in land use in the basin. Wetlands made up 24 percent (18,903 acres) of the basin in the 1940s and only 19 and nine percent, respectively, in 1979 and 1999, a loss of about 10,000 acres. These conversions were greatest before 1979.

Figure 3.4.6. Land Uses: Payne Creek Basin

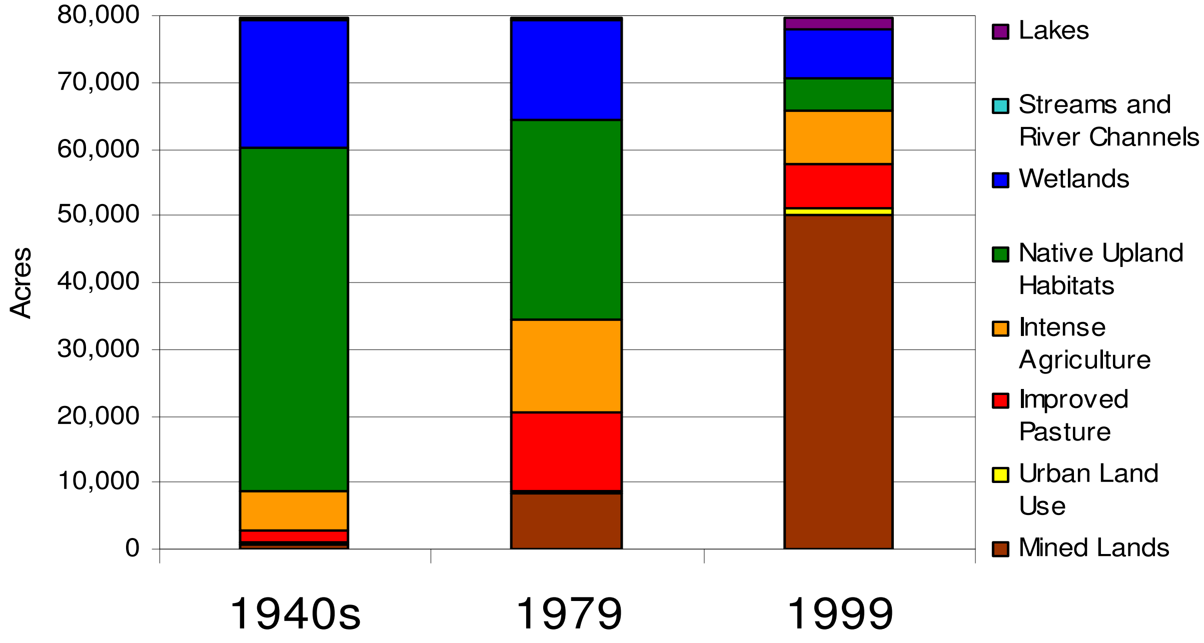
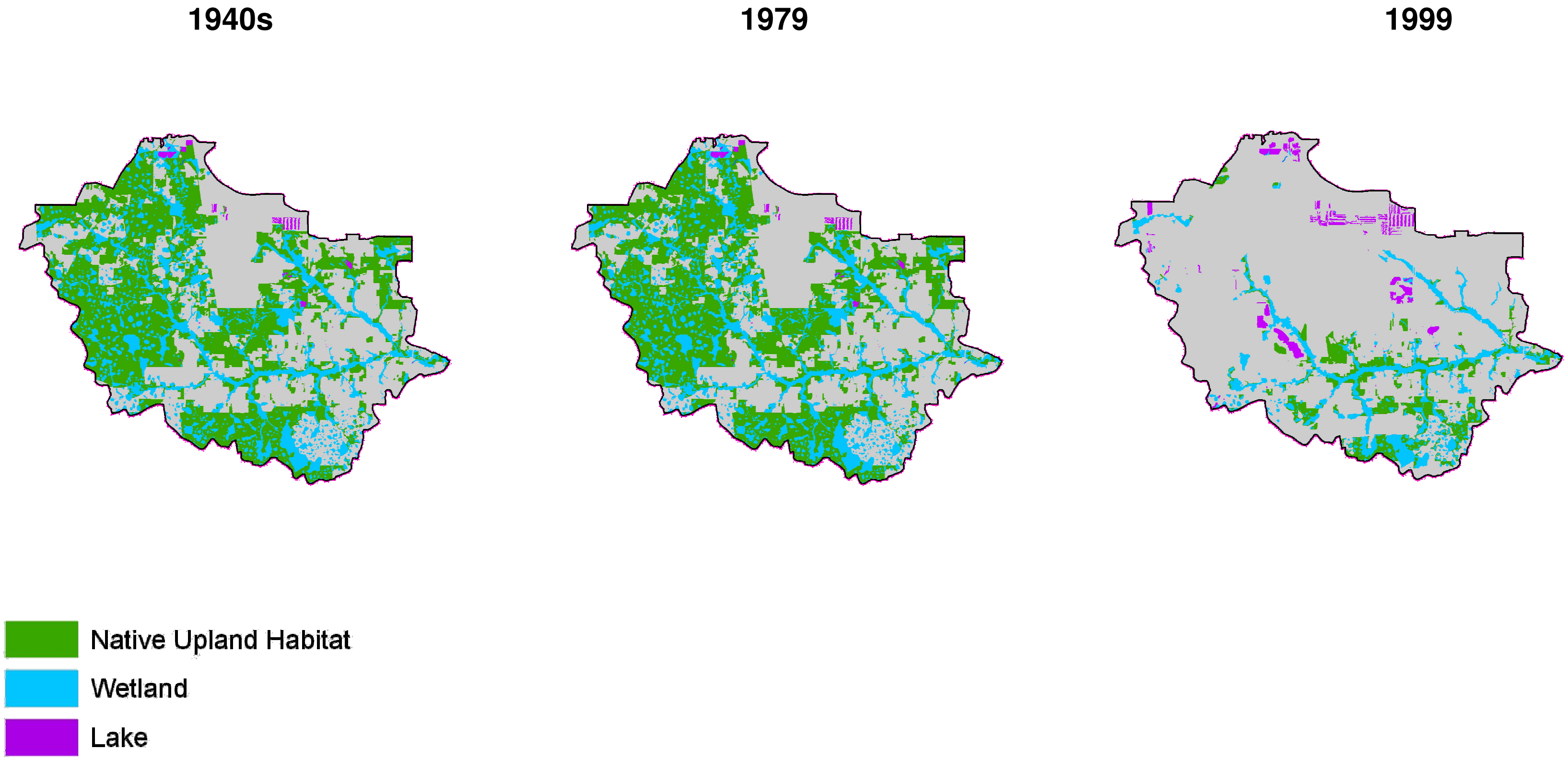


Figure 3.4.7. Changes in Undeveloped Land Use: Payne Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



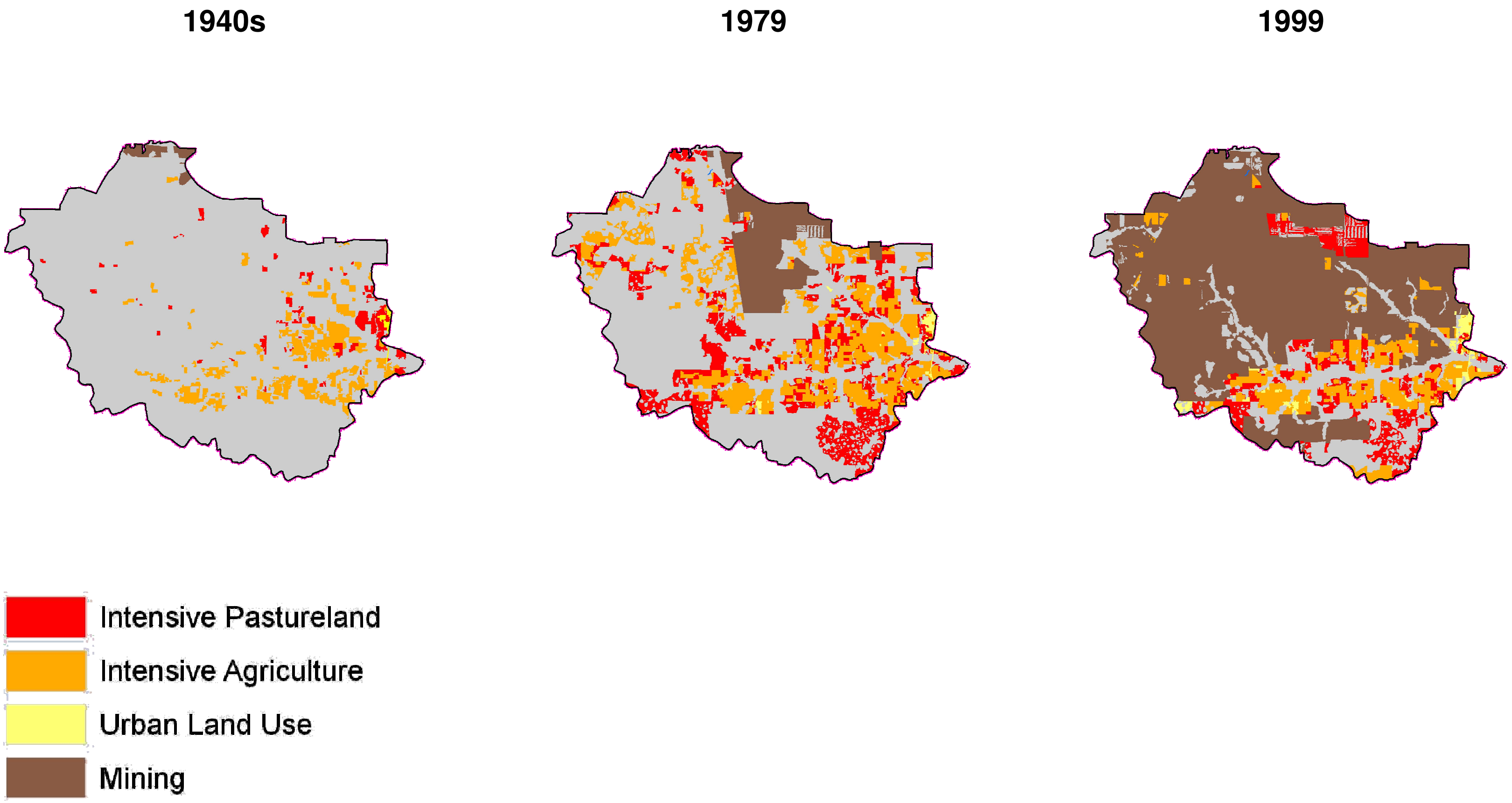
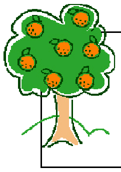


Figure 3.4.8. Changes in Developed Land Use: Payne Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

3.5 Charlie Creek

The Charlie Creek basin is 173,573 acres in size. The creek itself is the major tributary to the Peace River between Zolfo Springs and Arcadia and contributes over half of the intermediate annual inflow to this reach of the river. It has a drainage area of 330 square miles (Estevez *et al*. 1984). Original aerials for the land use analysis were obtained for Polk, Hardee, DeSoto, and Charlotte counties only. As a result, the portion of the Charlie Creek basin in Highlands County was not included in the land use analysis. All other analyses included the whole extent of the Charlie Creek basin. The basin is mapped in Figure 3.5.1 and an aerial photograph of the basin is presented in Figure 3.5.2.



The Charlie Creek basin includes 173,573 acres (12 percent) of the Peace River watershed. Agriculture lands make up the largest land use in the basin and account for 110,498 acres (70 percent) of the basin.

3.5.1 Hydrologic Features

Named creeks flowing into Charlie Creek include Oak Creek, Buckhorn Creek, Bee Branch, and Little Charlie Bowlegs Creek. Among the nine basins in the Peace River watershed, the Charlie Creek basin has relatively undergone the least amount of change since the 1940s. There is no phosphate mining, urbanization is limited, and there has not been the same degree of conversion to more intense forms of agriculture seen in the more southern basins. Figure 3.5.3 shows monthly minimum flows over the period-of-record for the USGS Charlie Creek stream flow gage. Trend tests were run for 10 monthly flow metrics for the period 1950-2004 (Section 4 below) and sequentially in five-year intervals (for example, 1950-2004, 1955-2004, 1960-2004) for the following three monthly metrics.

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

The results of these trend tests support the graphical evidence that base flows in the Charlie Creek basin have been relatively stable and have not significantly changed over time. The graphical results however do suggest a slight decline in minimum monthly flows during the 1960s and a slight increase again over the past decade. While these patterns aren't statistically significant, they are consistent with the timing of the wet and dry periods in southwest Florida proposed by the AMO theory.

Figure 3.5.1. Location of Peace River at Charlie Creek Basin in the Peace River Watershed

Figure 3.5.2. Aerial Photograph of the Peace River at Charlie Creek

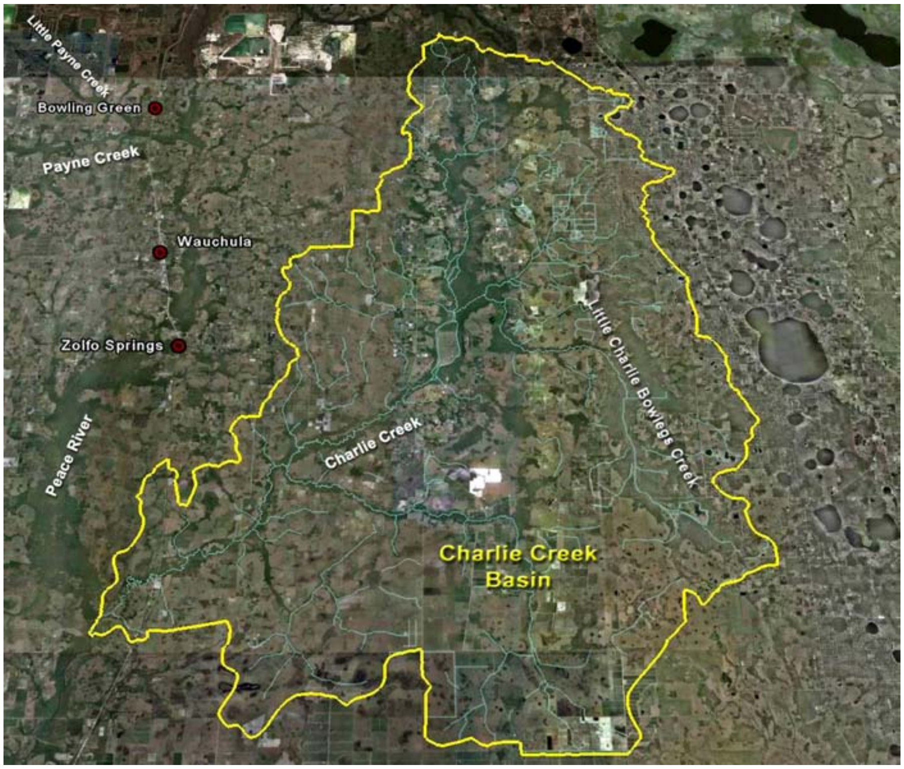
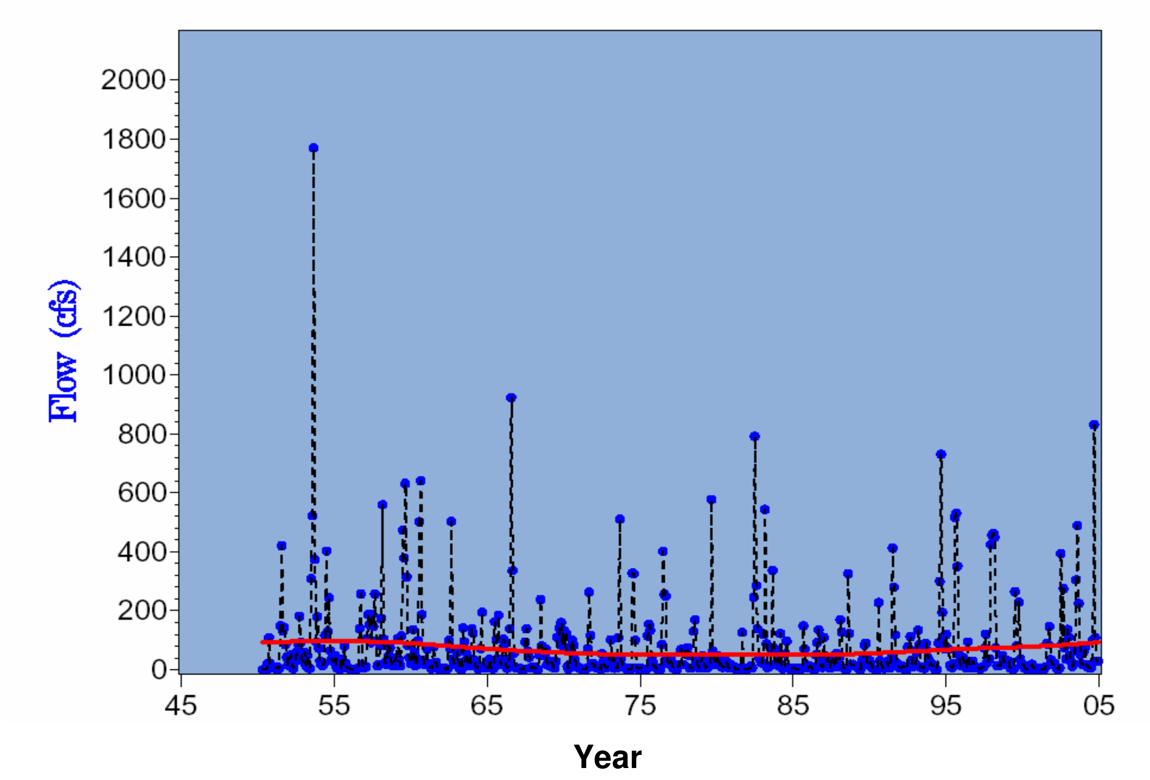


Figure 3.5.3. Monthly Minimum Flow at Long-term Charlie Creek (2296500) Gage (1950 – 2004)



3.5.2 Water Quality

Historic USGS/SWFWMD water quality data for the Charlie Creek basin are available from the long-term monitoring site near Gardner. The anthropogenic changes in the Charlie Creek basin have probably been the fewest of any of the basins in the Peace River watershed. There is no phosphate mining, only limited residential development, and there are comparatively less areas in intensive agriculture (such as citrus and row crops) relative to other agriculturally dominated watershed basins further to the south. Nevertheless, changes have occurred in a number of the measured water quality characteristics over the historic period-of-record. Water from Charlie Creek enters the Peace River upstream of Arcadia. The observed patterns of water quality changes that have taken place in the Charlie Creek basin are summarized below.

- The time series graphs show moderate increases in calcium, chloride, silica and sulfate concentrations over time. Corresponding, but smaller, increases are also apparent in conductivity levels and concentrations of total dissolved solids and magnesium. These observed water quality changes probably reflect increases in agricultural ground water discharges.

- Additional observed increases in potassium and inorganic nitrite+nitrate nitrogen also likely are a result of agricultural practices.

3.5.3 Water Budget

The water budget was examined for the Charlie Creek basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget are summarized below.

1941-1943

- Rainfall during the 1941-1943 period was above the 100-year average.

- Total stream flow was above average during this period.

- By 1941-1943 ground water withdrawals in the basin were still low in comparison to modern levels. During the 1941-1943 budget interval, ground water withdrawal totals in the Charlie Creek basin were among the lowest of any of the basins in the Peace River watershed.

1976-1978

- Rainfall during the 1976-1978 period was below the 100-year average.

- Total stream flow was below average during this period.

- By 1976-1978 ground water withdrawals had increased relative to 1941-1943 to irrigation for expanding agricultural operations.

1989-1991

- Rainfall during the 1989-1991 period was below the 100-year average.

- Total stream flow was below average during this period.

- In the 1989-1991 budget interval ground water withdrawals continued to increase relative to earlier budget intervals.

- Recharge to the surficial aquifer was estimated to be four inches per year during this budget interval.

1997-1999

- Rainfall during the 1997-1999 period was above the 100-year average.

- Total stream flow was above average during this period.

- In the 1997-1999 ground water withdrawals were reduced from the maximum withdrawal levels of the mid-1970s. Significant drawdowns in the Upper Floridan aquifer remained as a result of earlier ground water withdrawals and withdrawals that were ongoing during the 1997-1999 budget interval.

- Recharge to the surficial aquifer was approximately eight inches per year in the 1997-1999 budget, which was nearly double the estimated recharge in the 1989-1991 budget. The increased recharge is due to a combination of increased irrigation and rainfall.

- By the 1997-1999 budget interval a significant increase in base flow had occurred relative to the earlier budget intervals. The increase in base flow is related to increased rainfall and irrigation in the basin.

3.5.4 Land Use

The Charlie Creek basin includes 173,573 acres (12 percent) of the Peace River watershed. Agriculture lands in the form of improved pasture (78,180 acres) and intense agriculture (32,318 acres) make up the largest land use in the basin and account for 110,498 acres (64 percent) of the basin. The Charlie Creek basin has no phosphate mining, but does have approximately 1,409 acres (one percent) of excavation such as sand or shell mining. There are only 81 acres (less than one percent) of urban land uses in the basin. Native upland habitats (28,114) and wetlands (32,971 acres) make up 35 percent of the basin.

Developed land uses made up only 8,798 acres (five percent) of the basin in the 1940, most of which was intense agriculture (7,148 acres) and improved pasture (1,595 acres). Mining and urban land uses made up less than one percent of the remaining lands. The remaining 95 percent of the basin was comprised of 119,617 acres (69 percent) of native upland habitats and 44,995 acres (26 percent) of wetlands. Table 3.5.1 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.5.4, 3.5.5, and 3.5.6.

Between the 1940s and 1979, native upland habitats and wetlands decreased from 164,607 acres (95 percent of the basin) to 84,092 acres (48 percent of the basin). A total of 72,866 acres of native upland habitats and 7,987 acres of wetlands were converted to agriculture during this time period. Acres of developed lands in the basin increased from five to 51 percent from the 1940s to 1979 and were accounted for by large increases in intense agriculture (from 7,148 to 21,201 acres) and improved pasture (from 1,595 to 67,620 acres).

By 1999, an additional 22,780 acres of native upland habitats and 2,610 acres of wetlands were converted to agriculture (primarily improved pasture), making up 64 percent of the basin. Nearly 9,000 acres of improved pasture were converted to intense agriculture. Native upland habitats converted to agriculture totaled 18,830 acres and these habitats decreased from 48 percent to 35 percent of the basin. Sixty-five percent (111,998 acres) of the Charlie Creek basin was developed by 1999 and agriculture remained the primary land use from the 1940s to 1999. Large areas of wetlands (9,926 acres) and native upland hardwoods (92,614) were converted to agriculture during this time period, while urban and mined lands combined to make up only about one percent of the basin.

Table 3.5.1. Land Uses 1940s – 1999: Charlie Creek Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	18	<1	308	<1	1,409	1
Urban Land Use	36	<1	0	0	81	<1
Improved Pasture	1,595	1	67,620	39	78,180	45
Intense Agriculture	7,148	4	21,201	12	32,318	19
Subtotal	**8,798**	**5**	**89,129**	**51**	**111,988**	**65**
Undeveloped						
Wetlands	44,985	26	34,048	20	32,971	19
Native Upland Habitats	119,617	69	50,045	29	28,114	16
Subtotal	**164,602**	95	**84,092**	48	61,085	35
Water						
Streams and River Channels	154	<1	181	<1	59	<1
Lakes and Open Water	20	<1	171	<1	442	<1
Subtotal	**174**	**<1**	**353**	**<1**	**501**	**<1**
Total	**173,573**	**100**	**173,573**	**100**	**173,573**	**100**

* Includes sand and shell mining

Figure 3.5.4. Land Uses: Charlie Creek Basin

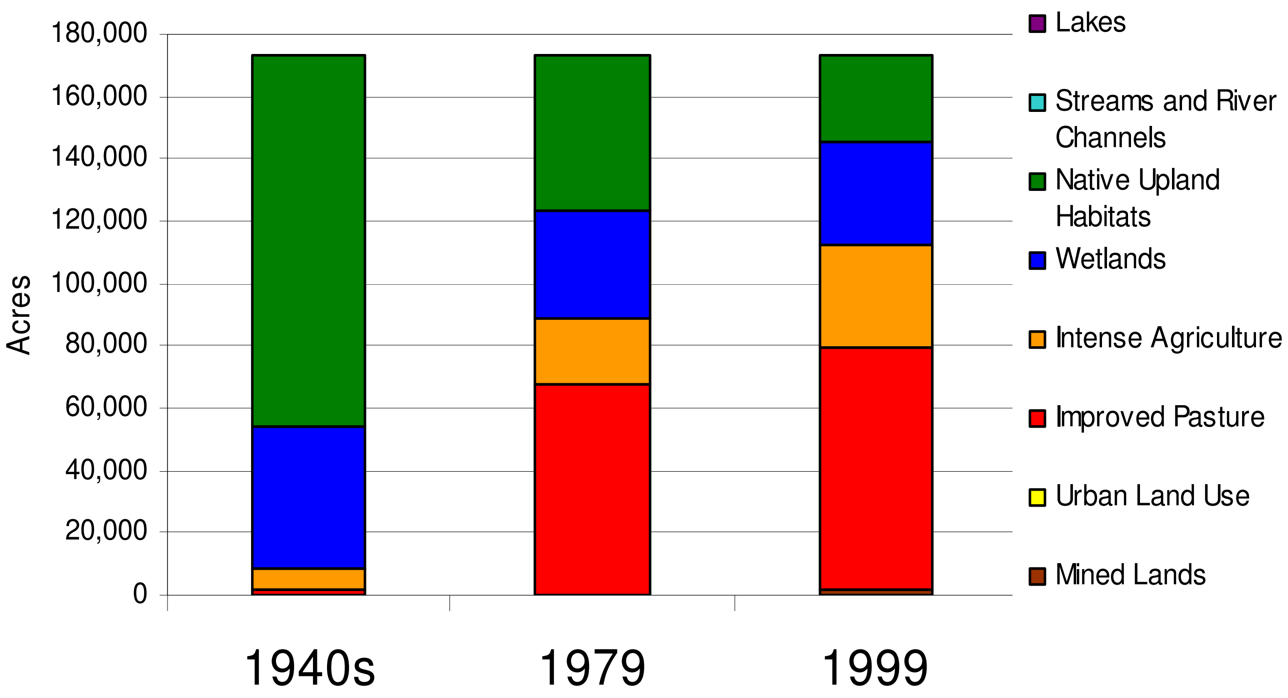


Figure 3.5.5. Changes in Undeveloped Land Use: Charlie Creek Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

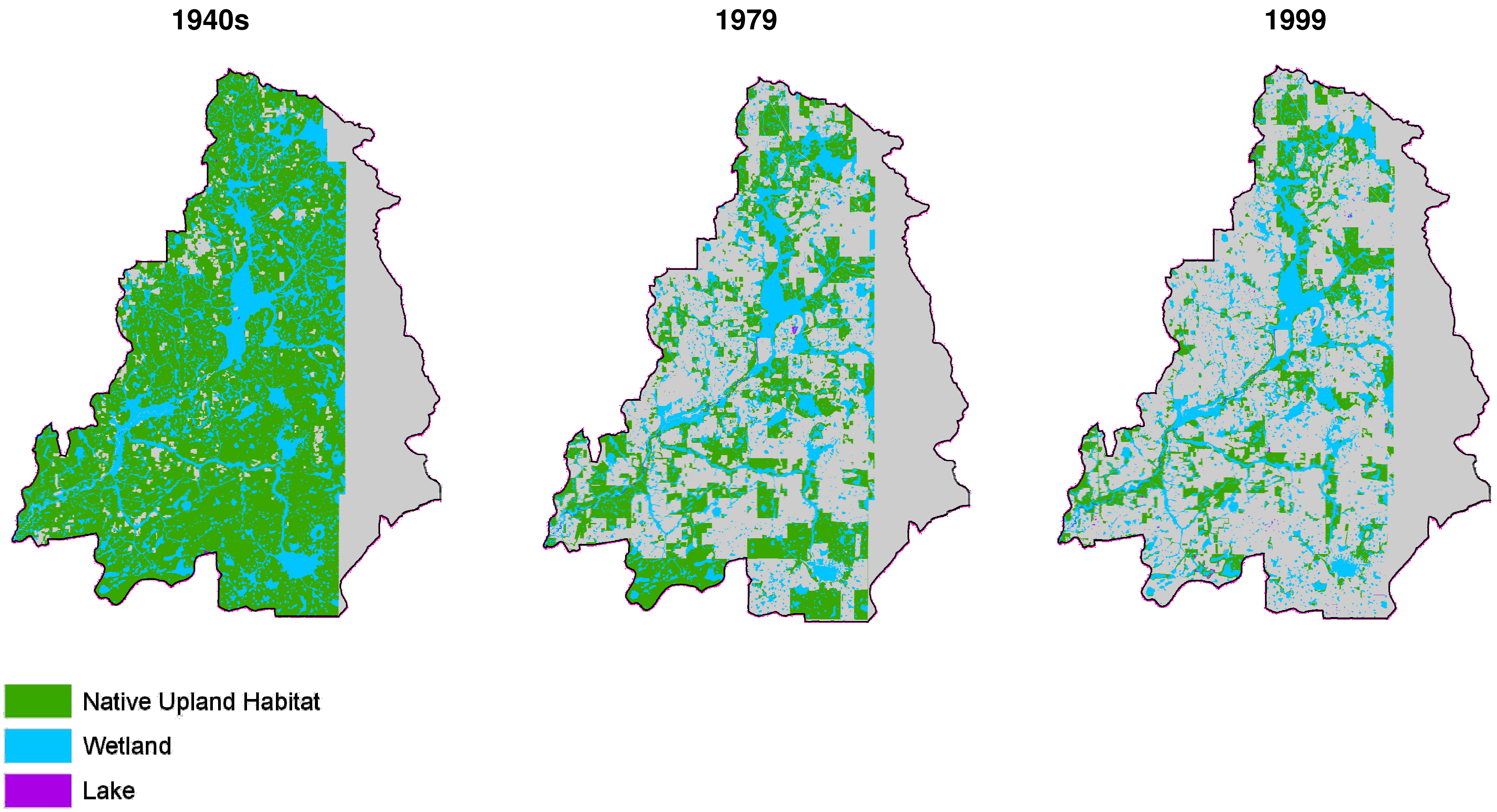
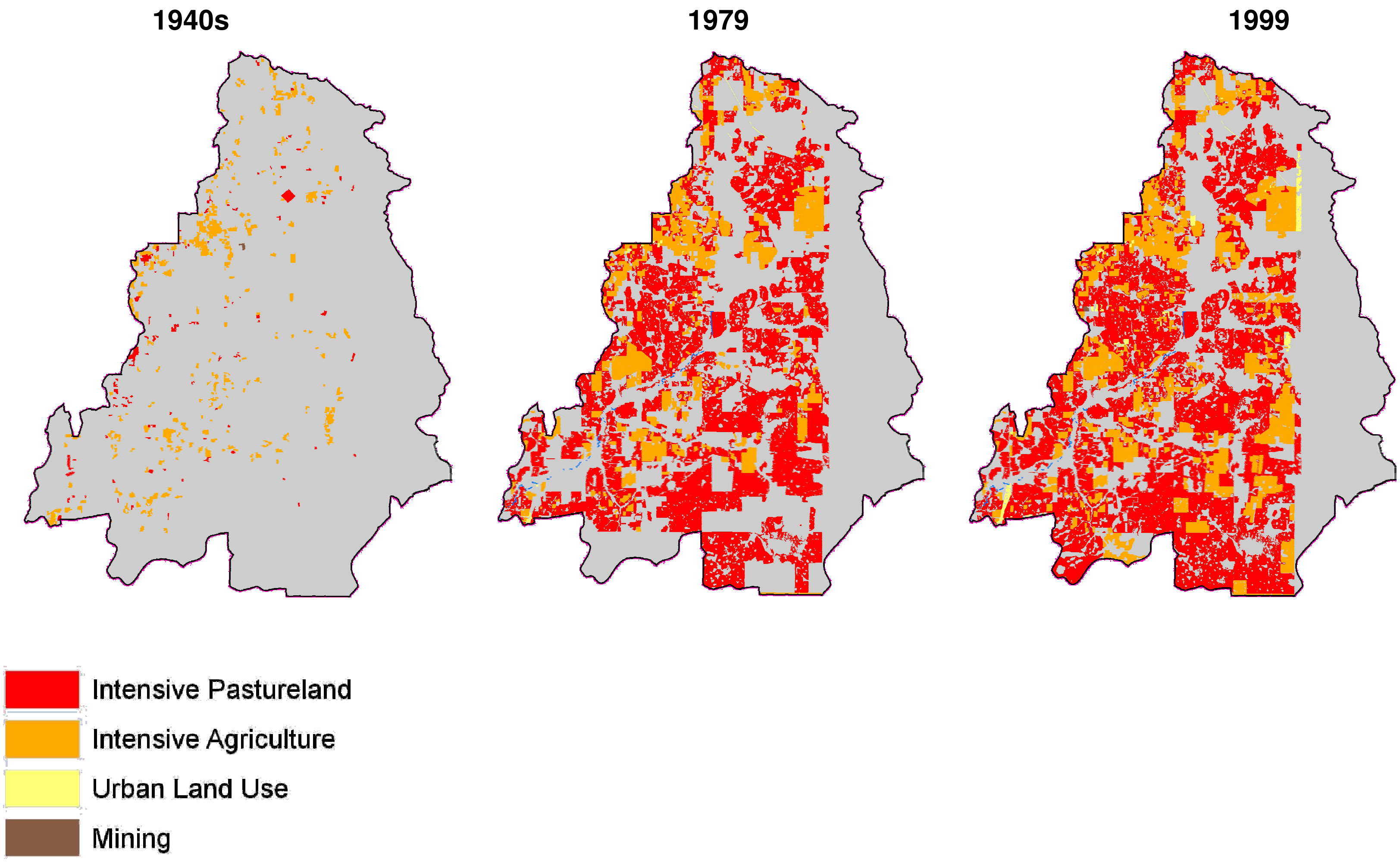


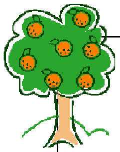
Figure 3.5.6. Changes in Developed Land Use: Charlie Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)


1940s
1979
1999

3.6 Peace River at Arcadia

The Peace River at Arcadia basin is 128,186 acres in size and is located almost directly in the center of the watershed. It includes the Peace River at Arcadia and upstream to just south of Zolfo Springs. Most of the basin is in Hardee County. The remainder of the basin is in DeSoto County, downstream of the confluence of the Peace River and Charlie Creek. Arcadia is the only municipality in DeSoto County, although the smaller community of Brownville is located upstream of Arcadia in DeSoto County. The basin is mapped in Figure 3.6.1 and an aerial photograph of the basin is presented in Figure 3.6.2.



The Peace River at Arcadia basin comprises nine percent (128,186 acres) of the Peace River watershed. This basin is characterized by large decreases in primarily native upland habitats due to conversions of these habitats to improved pasture and intense agriculture, a trend typical of the watershed in general.

3.6.1 Hydrologic Features

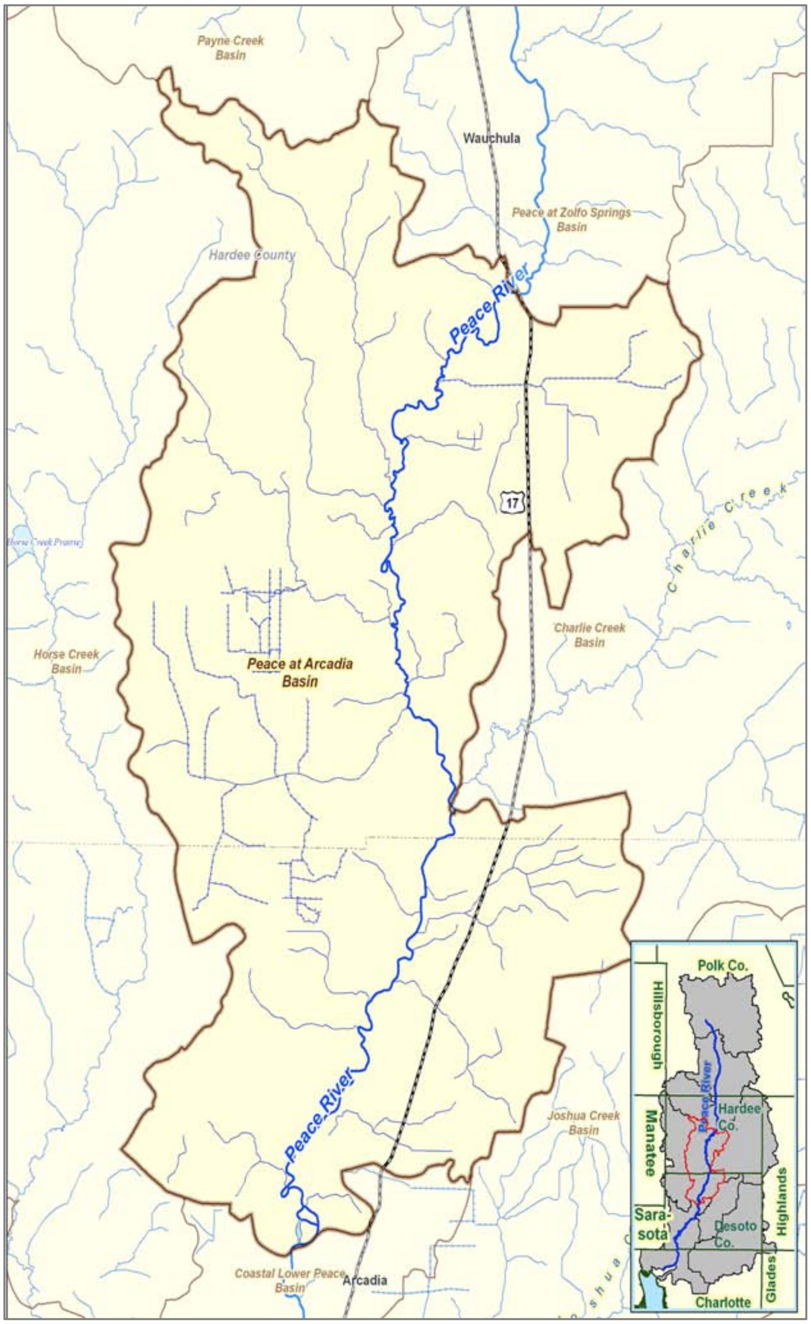
Ground water in DeSoto County is obtained from the surficial, intermediate, and Upper Floridan aquifers. The surficial aquifer is composed primarily of unconsolidated quartz sand and undifferentiated sand and shell. This aquifer underlies essentially all of DeSoto County and water from it is used primarily for lawns and livestock.

The confined intermediate aquifer is about 200 feet thick and wells, although variable, may provide several hundred gallons per minute and are used for domestic and public water supplies. The Upper Floridan aquifer consists of limestone and dolomite. Wells in the Floridan aquifer yield up to 1,000 gallons per minute and are used primarily for large scale agricultural irrigation. Water quality in the Upper Floridan and intermediate aquifer decreases southwest towards the coast.

Ground water in DeSoto County is obtained from the surficial, intermediate, and Floridan aquifers.

The Peace River at Arcadia USGS gage is the most downstream gage along the main stem of the river and includes flows not only from the immediate basin, but also the upstream river gages at Bartow and Zolfo Springs, as well as the Payne and Charlie Creek basins.

Figure 3.6.1. Location of the Peace River at Arcadia Basin in the Peace River Watershed



The Peace River at Arcadia gage has the longest historic record (1931 – present) of any of the gages in the watershed, which enabled trend tests to be run for 10 monthly flow metrics for the period 1932-2004 (Section 4 below) and sequentially in five-year intervals (for example, 1935-2004, 1940-2004, 1945-2004) for the following three monthly metrics.

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

Summary results of the trend test for low, median, and high flows at the Peace River at Arcadia gage (Table 3.6.1) all indicate declines since the 1930s, 1940s, and 1950s. However, none of the flow metrics tested indicated any statistically significant trends in flows since 1965, and median and high flows have not shown systematic trends since 1955. Monthly minimum (base) flows over the period-of-record for the Peace River at Arcadia gage (Figure 3.6.3) indicate both long-term anthropogenic upstream changes (see above discussion of Peace River at Bartow flows) as well as differences between the historic wet and dry AMO phases.

Table 3.6.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Peace River at Arcadia Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Peace River at Arcadia	Low (Q90)	🔻	🔻	🔻	🔻	🔻	🔻							
	Medium (Q50)	🔻	🔻	🔻	🔻									
	High (Q10)	🔻	🔻	🔻	▼									

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location

Figure 3.6.2. Aerial Photograph of the Peace River at Arcadia

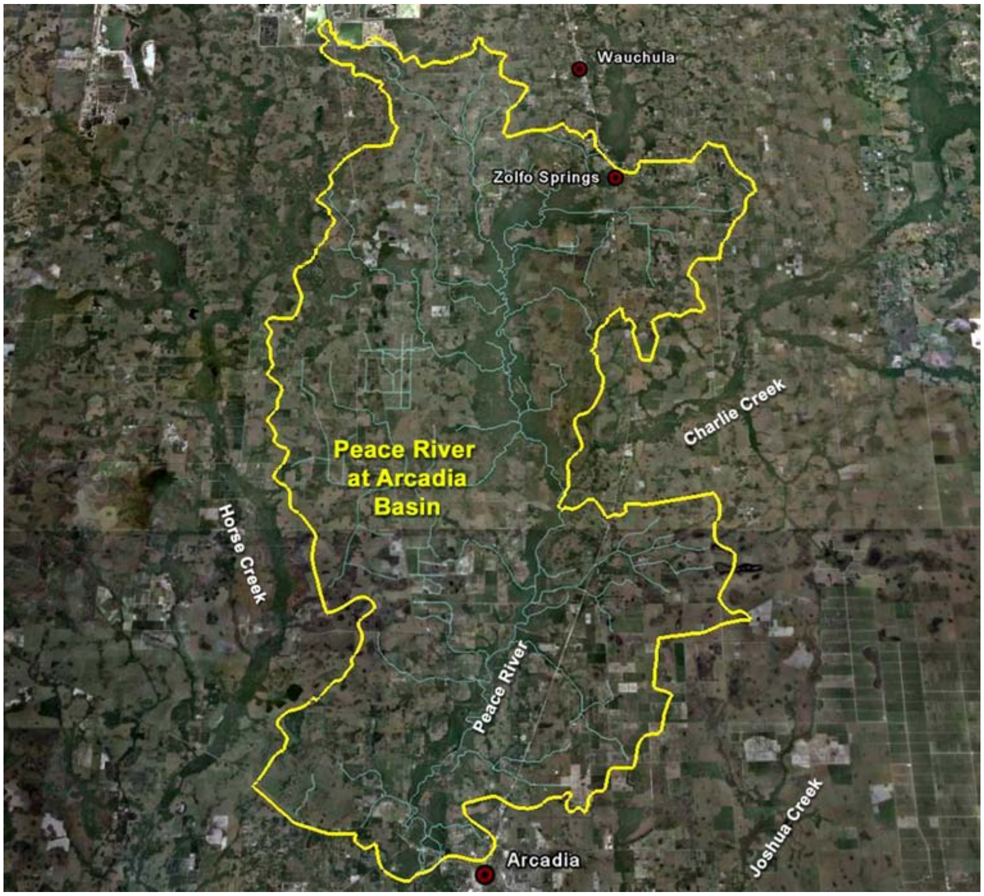
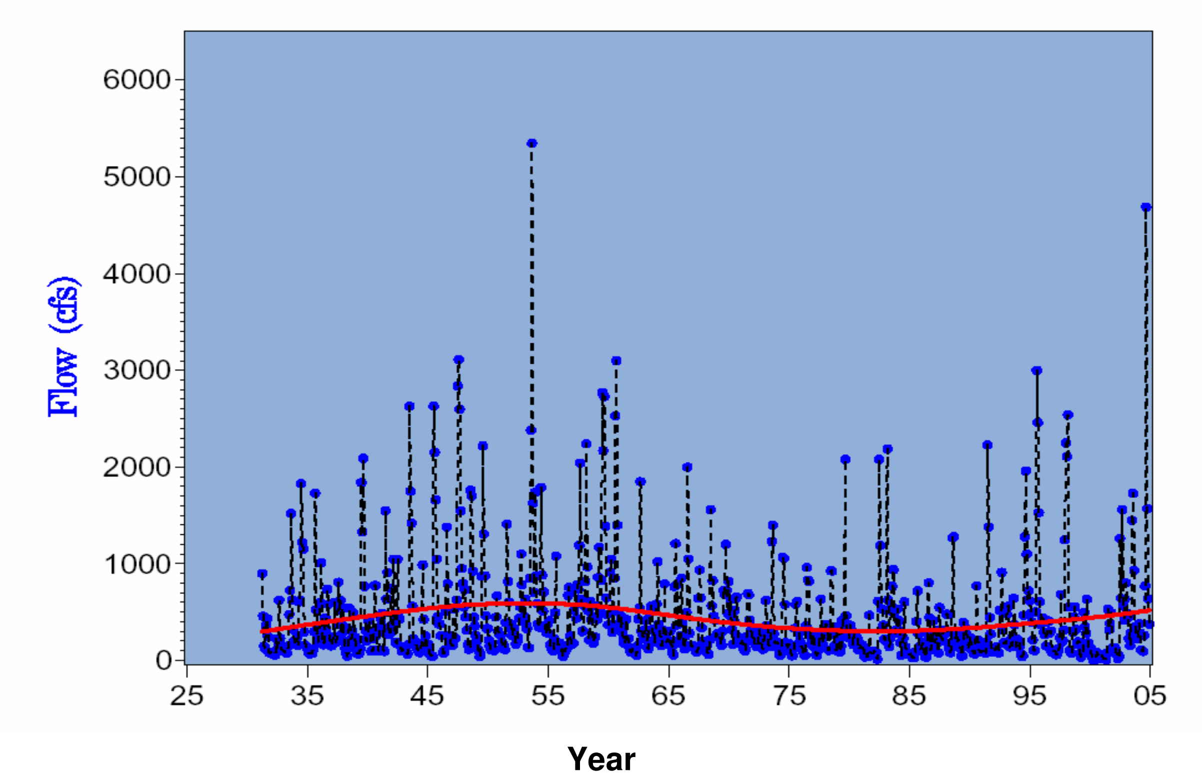


Figure 3.6.3. Monthly Minimum Flow at Long-term Peace River at Arcadia (2296750) Gage (1931 – 2004)



3.6.2 Water Quality

Relatively consistent data for a number of water quality parameters dating back to the early 1960s are available for this long-term USGS/SWFWMD monitoring location. This is the most downstream of the four monitoring sites along the main stem of the Peace River and water quality characteristics reflect changes in the adjacent basin, and to a potentially greater extent, the influences of all four of the upstream basins (Peace River at Bartow, Peace River at Zolfo Springs, Payne Creek, and Charlie Creek). Some of the important water quality changes observed in the Peace River at Arcadia basin are summarized below.

- Marked declines in total phosphorus, orthophosphate and fluoride levels in the Peace River at Arcadia are similar (after dilution) to the declines observed upstream at the Peace River at Zolfo Springs and Bartow gages, and are attributable to improvements in phosphate mining and processing practices.

- Observed declines in forms of inorganic nitrogen, also observed upstream, may reflect regulatory reductions in domestic point source discharges.

- In contrast, long-term increases in pH and total alkalinity, sodium, and chloride concentrations can be attributed to increasing ground water discharges both within the basin and upstream.

3.6.3 Water Budget

The water budget was examined for the Peace River at Arcadia basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget are summarized below.

- The total stream flow at Peace River at Arcadia is a composite of flows from several basins (Peace River at Bartow, Peace River at Zolfo Springs, Payne Creek, and Charlie Creek). The composition of flows has a moderating effect, and as a consequence the flow at Arcadia does not always clearly display the hydrologic trends of its contributing basins.

1941-1943

- Rainfall during the 1941-1943 period was above the 100-year average.
- Total stream flow was above average during this period.
- Ground water withdrawals were low within the Peace River at Arcadia basin relative to the intense withdrawals beginning to occur in other basins such as the Peace River at Bartow basin.

1976-1978

- Rainfall during the 1976-1978 period was below the 100-year average.
- Total stream flow was below average during this period.
- In the 1976-1978 budget interval ground water withdrawals continued to grow relative to the 1941-1943 time period. Significant drawdowns in the intermediate aquifer and Upper Floridan aquifer occurred by this period. This effect was partially due to the influence of drawdown in upgradient basins such as the Peace River at Bartow and Peace River at Zolfo Springs basins.

1989-1991

- Rainfall during the 1989-1991 period was below the 100-year average.
- Total stream flow was below average during this period.
- In the 1989-1991 budget interval ground water withdrawals continued to grow relative to the 1976-1978 and 1941-1943 time periods. Significant drawdowns in the intermediate aquifer and Upper Floridan aquifer remained.

1997-1999

- Rainfall during the 1997-1999 period was above the 100-year average.
- Total stream flow was above average during this period.
- In the 1997-1999 budget interval ground water withdrawals continued to grow relative to pervious budget intervals. Significant drawdowns in the Upper Floridan aquifer remained as a result of earlier ground water withdrawals and withdrawals that were ongoing during the 1997-1999 budget interval.

3.6.4 Land Use

The Peace River at Arcadia basin comprises nine percent (128,186 acres) of the Peace River watershed. Urban land uses (3,804 acres) make up about three percent of the basin and phosphate mining in this basin is negligible (187 acres). This basin is characterized by large decreases in primarily native upland habitats due to conversions of these habitats to improved pasture and intense agriculture, a trend typical of the watershed in general. Agricultural lands make up the largest land use in the basin and account for 71,212 acres (56 percent) of the area in the basin. Native upland habitats and wetlands still comprise 41 percent of the basin.

Developed land uses included approximately 13,823 acres (11 percent of the basin) in the 1940s and all but one percent of this was agriculture, including 10,457 acres of intense agriculture and 3,027 acres of improved pasture. Urban lands included only 339 acres of the basin. Native upland habitats (61 percent), wetlands (28 percent), and lakes/open water (16 percent) made up the remaining 89 percent of the basin. Table 3.6.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.6.4, 3.6.5, and 3.6.6.

By 1979, acres of developed lands in the basin increased from 11 to 48 percent, due to almost exclusively agriculture (primarily improved pasture), which made up 46 percent (59,483 acres) of the basin. Expansion of agriculture resulted in the loss of approximately 43,005 acres of native upland habitat and about 4,431 acres of wetlands. The percent of native upland habitats in the basin decreased from 61 percent to 31 percent. Approximately 954 acres of native upland habitat and 135 acres of wetlands were converted to urban land uses during this time period.

Fifty-nine percent (75,203 acres) of the Peace River at Arcadia basin was developed by 1999 and agriculture was the primary land use change both pre- and post- 1979. Large numbers of acres of wetlands (26,115 acres) and native upland hardwoods (26,257) were converted to agriculture during this time period. Urban land uses increased to about three percent (3,804 acres) of the basin.

Table 3.6.2. Land Uses 1940s – 1999: Peace River at Arcadia Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	0	0	0	0	187	<1
Urban Land Use	339	<1	1,652	1	3,804	3
Improved Pasture	3,027	2	39,851	31	45,836	36
Intense Agriculture	10,457	8	19,642	15	25,376	20
Subtotal	**13,823**	**11**	**61,145**	**48**	**75,203**	**59**
Undeveloped						
Wetlands	35,598	28	26,878	21	26,115	20
Native Upland Habitats	78,274	61	39,575	31	26,257	21
Subtotal	**113,872**	**89**	**66,452**	**52**	**52,372**	**41**
Water						
Streams and River Channels	474	<1	437	<1	355	<1
Lakes and Open Water	16	<1	152	<1	256	<1
Subtotal	**490**	**<1**	**589**	**<1**	**611**	**<1**
Total	**128,186**	**100**	**128,186**	**100**	**128,186**	**100**

* Includes reclaimed (totally and partially) lands

Figure 3.6.4. Land Uses: Peace River at Arcadia Basin

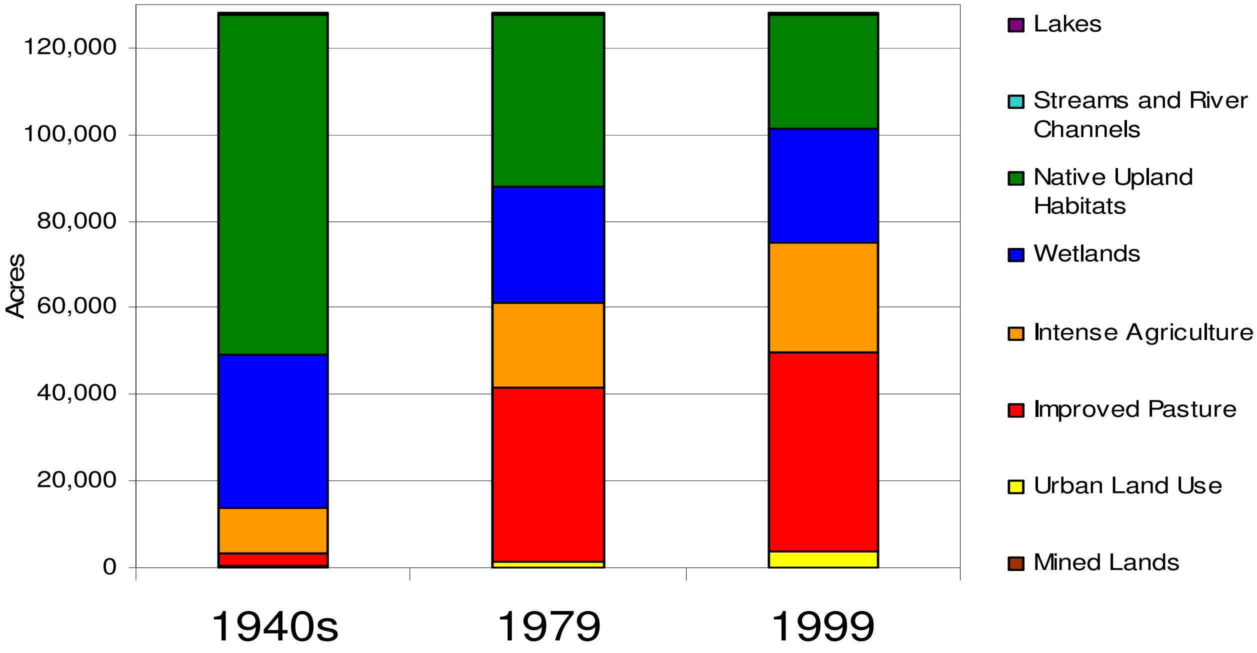


Figure 3.6.5. Changes in Undeveloped Land Use: Peace River at Arcadia Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

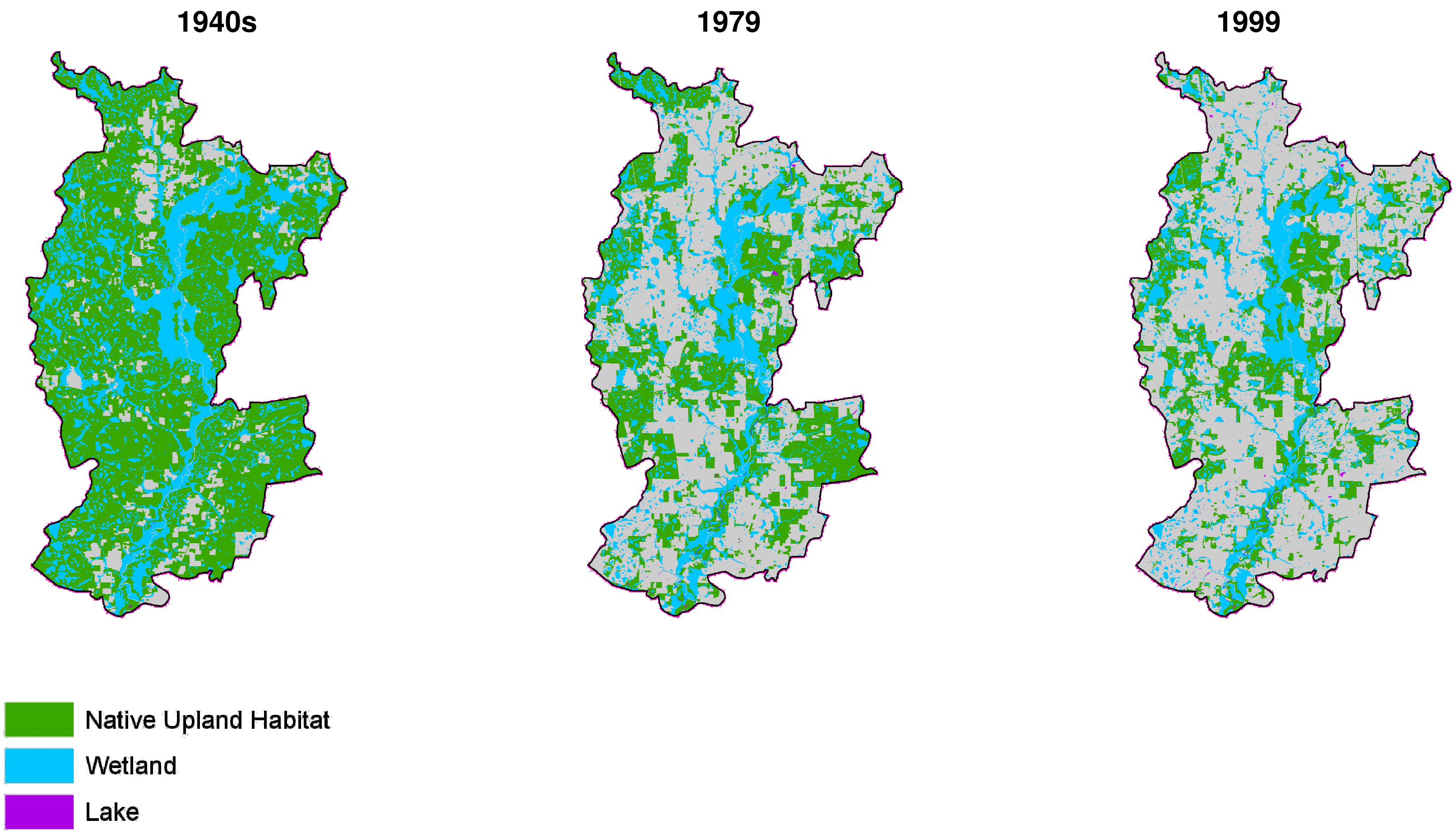
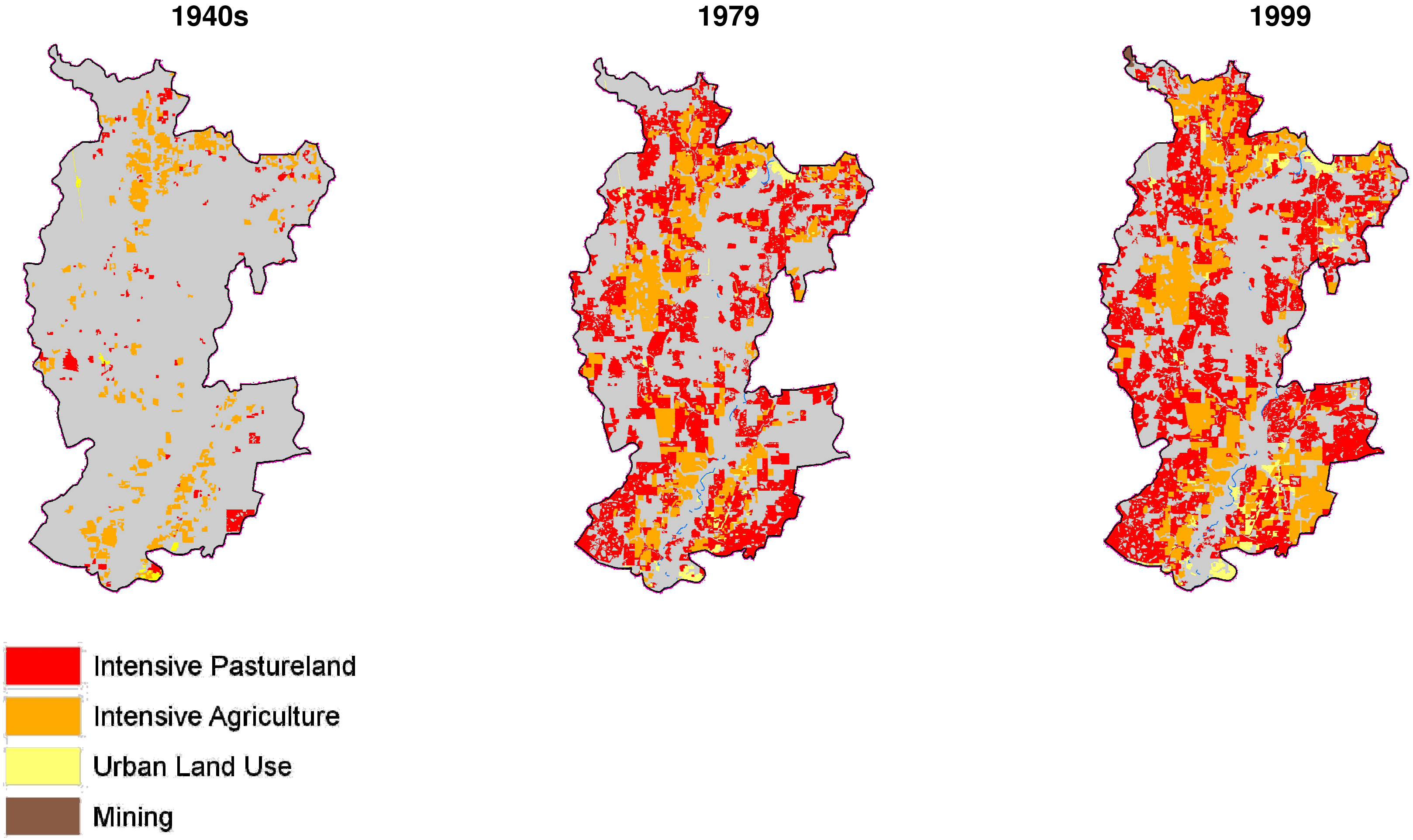


Figure 3.6.6. Changes in Developed Land Use: Peace River at Arcadia Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



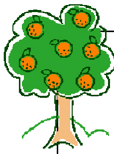
1940s

1979

1999

3.7 Joshua Creek

Joshua Creek is located in the southeast portion of the Peace River watershed in Desoto County and is the smallest basin (77,391 acres) in the Peace River watershed. Land use in the Joshua Creek basin was predominantly agricultural in 1999 (73 percent) and 29 percent of the basin was in citrus. Joshua Creek enters the Peace River downstream of the Peace River at Arcadia gage. The basin is mapped in Figure 3.7.1 and an aerial photograph of the basin is presented in Figure 3.7.2.



The Joshua Creek basin is the smallest basin in the Peace River watershed and includes only 77,391 acres (six percent) of the watershed. This basin has land use characteristics similar to the watershed in general, that is, agriculture is the primary land use (76 percent), most (81 percent) of which was converted from native upland habitats to improved pasture and intense agriculture.

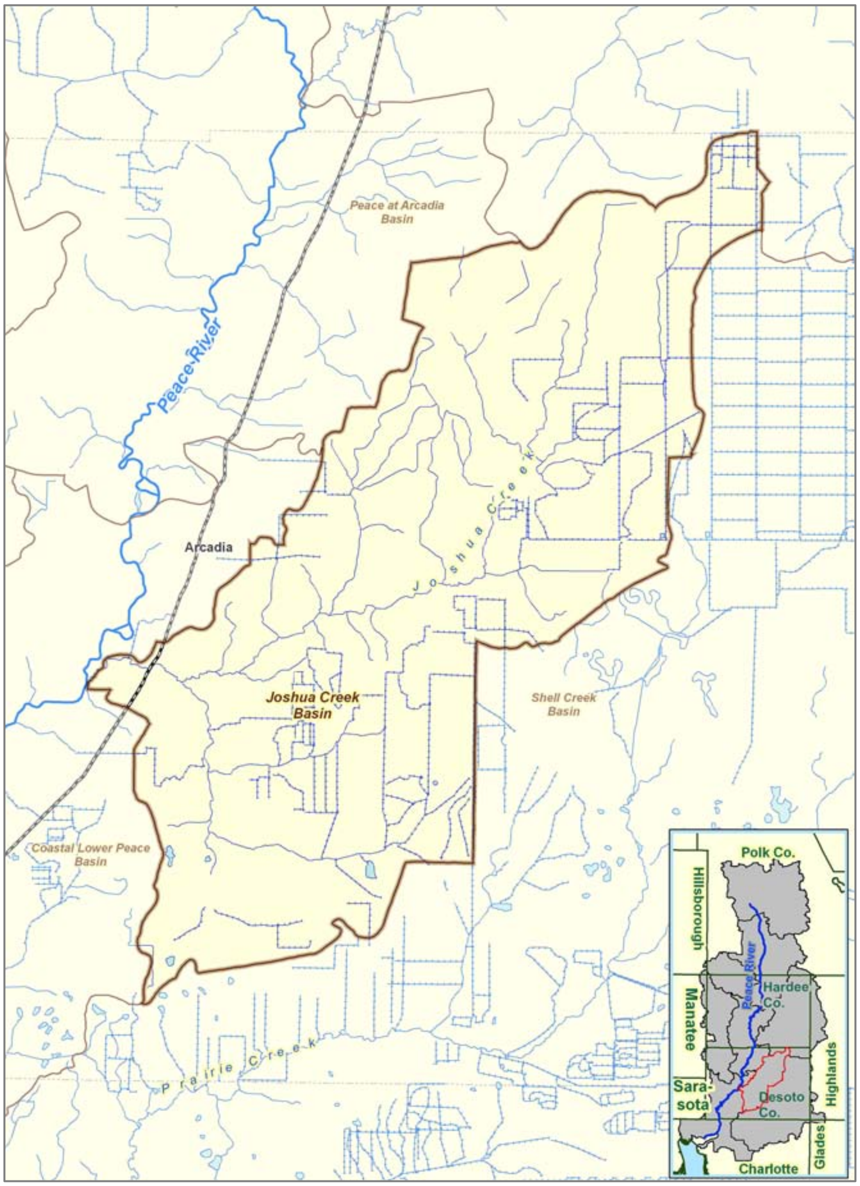
Joshua Creek begins in northeastern DeSoto County and flows southwest to the Peace River, 2.2 miles downstream of Nocatee in central DeSoto County (Estevez *et al*. 1984). It has a drainage area of approximate 132 square miles.

3.7.1 Hydrology

Hawthorne Creek and Hog Bay flow into the lower reach of Joshua Creek just upstream of its confluence with the Peace River. Above the town of Joshua, Lake Slough and Honey Run flow into the creek, although the creek channel is very poorly defined in this area.

Changes in land use in this basin are from native habitats and unimproved pasture in the 1940s to extensive areas of improved pasture and more intense forms of agriculture such as citrus and row crops by the late 1990s.

Figure 3.7.1. Location of Peace River at Joshua Creek Basin in the Peace River Watershed



Changes in land use in this basin are from native habitats and unimproved pasture in the 1940s to extensive areas of improved pasture and more intense forms of agriculture such as citrus and row crops by the late 1990s. These changes to more intense agriculture are also reflected in the water chemistry of Joshua Creek, which over recent decades has had large increases in concentrations of water quality parameters associated with Upper Floridan ground water discharges into the natural stream flows. The flow record for the USGS Joshua Creek near Nocatee gage record dates back to 1951, which enabled trend tests to be run for 10 monthly flow metrics for the period 1951-2004 (Section 4 below) and sequentially in five-year intervals (1955-2004, 1960-2004, 1965-2004, etc.) for the following three monthly metrics.

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

Summary results of the trend test for low, median, and high flows at the Joshua Creek near Nocatee gage shown in Table 3.7.1 indicate the degree to which agricultural ground water discharges have increased flows. Figure 3.7.3 depicts monthly minimum (base) flows over the period-of-record for the gage and indicates that increases in base flow resulting from ground water discharges became apparent in the early 1980s.

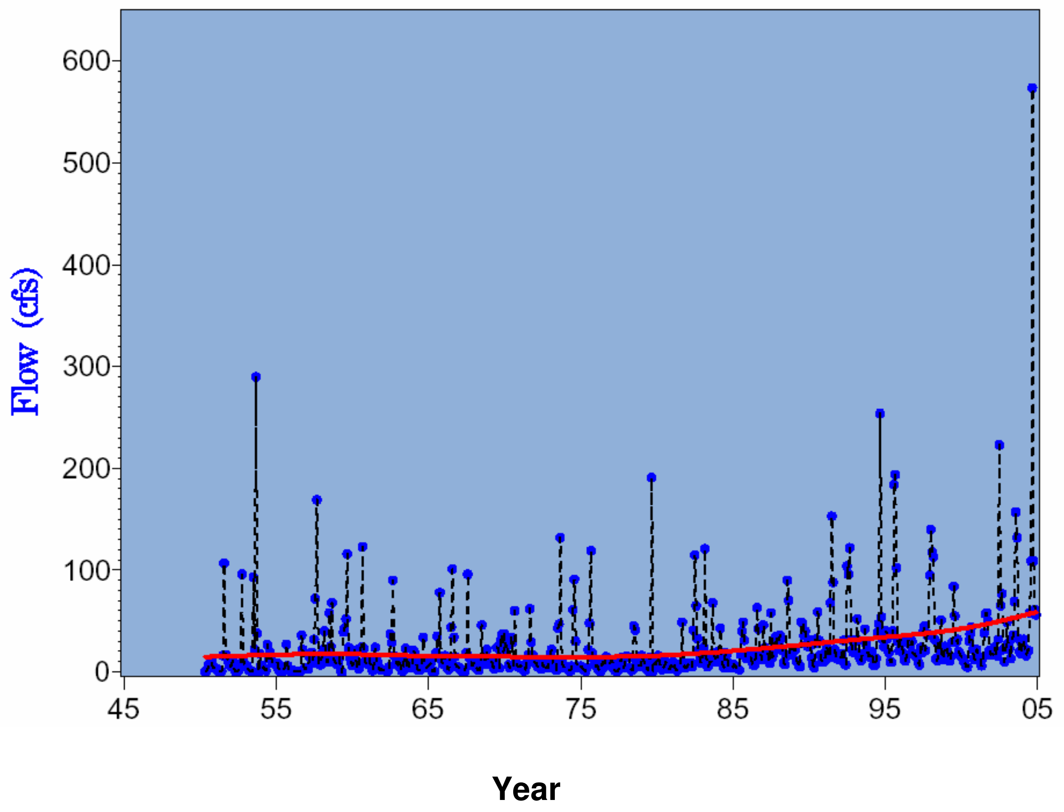
Table 3.7.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Joshua Creek Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Joshua Creek at Nocatee	Low (Q90)	▨	▨	▨	▨	🔺	🔺	🔺	🔺	🔺	🔺	🔺		
	Medium (Q50)	▨	▨	▨	▨	🔺	🔺	🔺	🔺	🔺	🔺	▲		
	High (Q10)	▨	▨	▨	▨	🔺	🔺	🔺	🔺	🔺	🔺			

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location

Figure 3.7.2. Aerial Photograph of the Peace River at Joshua Creek

Figure 3.7.3. Monthly Minimum Flow at Long-term Joshua Creek at Nocatee (2297100) Gage (1950 – 2004)



3.7.2 Water Quality

Joshua Creek flows into the lower Peace River downstream of Arcadia and upstream of the river's confluence with Horse Creek. This southern Peace River watershed basin has no phosphate mining and only modest residential/urban development. However, since the 1940s increasing extensive areas of the basin have been converted to more intense forms of agricultural use. The historical period-of-record of water quality information for the USGS/SWFWMD Joshua Creek at Nocatee sampling location extends back to the mid-1960s. Yet, only scattered information is available for a number of water quality parameters prior to the mid-1980s to early 1990s. This lack of regular, consistent historic sampling information is unfortunate, since water quality changes in the Joshua Creek basin are some of the largest observed throughout the watershed. Historic patterns of water quality changes in the Joshua Creek basin are summarized below.

- Available water quality data indicate comparatively large historic increases conductivity (specific conductance), total dissolved solids, sodium, chloride, and sulfate levels.

- Slightly smaller increasing patterns have also occurred in calcium, magnesium, and silica concentrations.

- Observed changes in water quality are attributable to agricultural discharges of mineralized ground water to basin surface waters. Correspondingly, many of these water quality parameters with long-term increasing patterns were near or at historically high levels during the recent 1999-2001 drought.

- The recent large increases observed in inorganic nitrite+nitrate nitrogen in the Joshua Creek basin are also likely attributable to changes to more intensive agricultural land uses.

3.7.3 Water Budget

The water budget was examined for the Joshua Creek basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget are summarized below.

- Ground water withdrawals in the Joshua Creek basin have steadily increased through each budget interval. The growth of intense agriculture has increased demand for irrigation supply water from the intermediate aquifer and Upper Floridan aquifer.

- Base flow has approximately doubled since the 1980s as a result of high intensity agricultural irrigation within the basin.

3.7.4 Land Use

The Joshua Creek basin is the smallest basin in the Peace River watershed and includes only 77,391 acres (six percent) of the watershed. This basin has land use characteristics similar to the watershed in general; that is, agriculture is the primary land use (76 percent), most of which (81 percent) was converted from native upland habitats to improved pasture and intense agriculture. The small increase in urban areas in this basin was also due primarily to a conversion from native upland hardwoods.

Nearly 7,500 acres (nine percent) of the Joshua Creek basin was developed as improved pasture (four percent) and intense agriculture (five percent) in the 1940s. Native upland habitats included 56,109 acres (73 percent of the basin) and 113,423 acres of wetlands (17 percent of the basin) made up 90 percent of the basin. Less than 500 acres (one percent) of the basin was in urban land use and mining never entered the basin. Table 3.7.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.7.4, 3.7.5, and 3.7.6.

By 1979, improved pasture expanded to include 36,576 acres, or 47 percent of the basin. Intense agriculture and urban land uses made up nine and one percent, respectively, of the basin. Native upland habitats decreased by nearly 34,000 acres due primarily to conversions to improved pasture (30,815 acres) and intense agriculture (3,667 acres). Wetland conversions to agriculture totaled 4,458 acres. The greatest conversions of native upland habitats and wetlands to agriculture occurred by 1979.

Post-1979 land use conversions in the basin were also predominantly native upland habitats to agriculture. Improved pasture decreased by almost 5,000 acres, mostly due to conversions to intense agriculture. Intense agriculture increased by almost 17,000 acres. In addition, nearly 17,000 acres of native upland habitats were converted to improved pasture and intense agriculture.

Acres of urban lands doubled to include 2,960 acres (four percent) in the basin. During this time period, losses of native upland habitats (13, 034 acres) and wetlands (903 acres) were far less than during the previous time period, but were still primarily a result of conversions to agriculture (13,726 acres). However, improved pasture declined during this period of time, while intense agriculture expanded from 7,179 acres (five percent) to 23,947 acres (31 percent) of the basin. Over 1,000 acres of previously agricultural lands were converted to urban lands, along with smaller numbers of acres of native upland habitats (606 acres) and wetlands (44 acres).

Over three-quarters of the Joshua Creek basin was developed by 1999, due almost exclusively to expanding agriculture. Urban land uses remained low and mining remained absent in the basin. The loss of native upland habitats and wetlands declined from 90 percent to 23 percent of the basin. Conversions to improved pasture were largest pre-1979, while intense agriculture had the greatest increase post-1979.

Table 3.7.2. Land Uses 1940s – 1999: Peace River at Joshua Creek Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	0	0	0	0	0	0
Urban Land Use	468	1	1,456	2	2,960	4
Improved Pasture	3,431	4	36,576	47	31,941	41
Intense Agriculture	3,918	5	7,179	9	23,947	31
Subtotal	**7,817**	**10**	**45,211**	**58**	**58,848**	**76**
Undeveloped						
Wetlands	13,423	17	9,251	12	8,349	11
Native Upland Habitats	56,109	73	22,863	30	9,829	13
Subtotal	**69,532**	**90**	**32,114**	**41**	**18,178**	**23**
Water						
Streams and River Channels	0	0	0	0	0	0
Lakes and Open Water	41	<1	65	<1	365	<1
Subtotal	**41**	**<1**	**66**	**<1**	**366**	**<1**
Total	**77,391**	**100**	**77,391**	**100**	**77,391**	**100**

Figure 3.7.4. Land Uses: Joshua Creek Basin

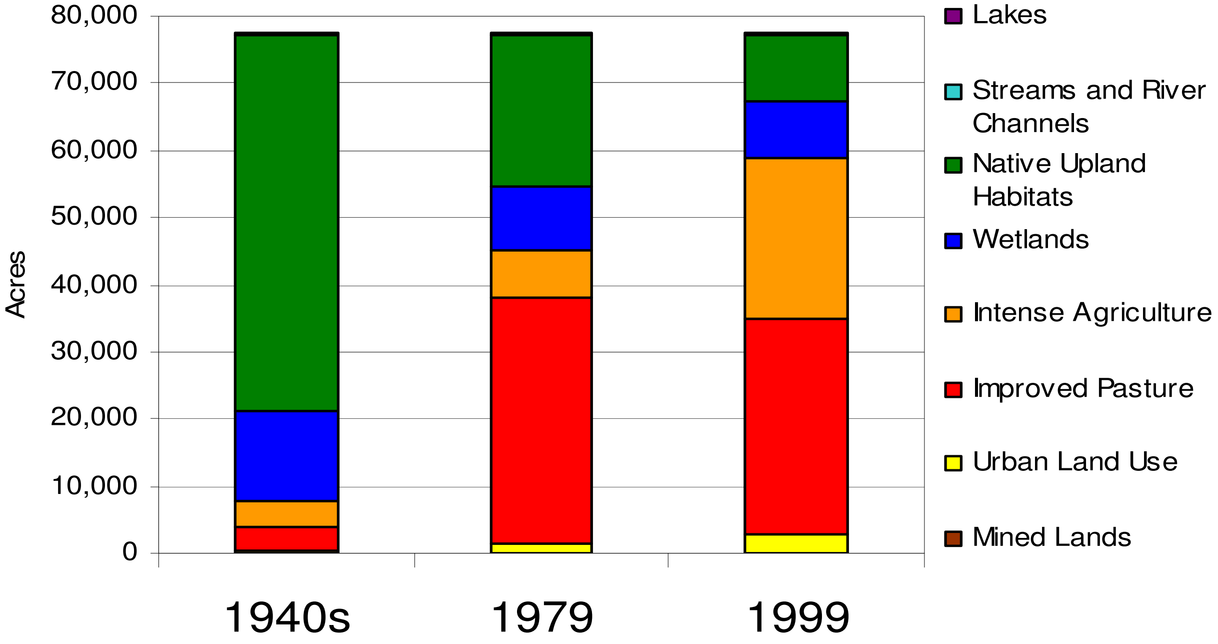


Figure 3.7.5. Changes in Undeveloped Land Use: Joshua Creek Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

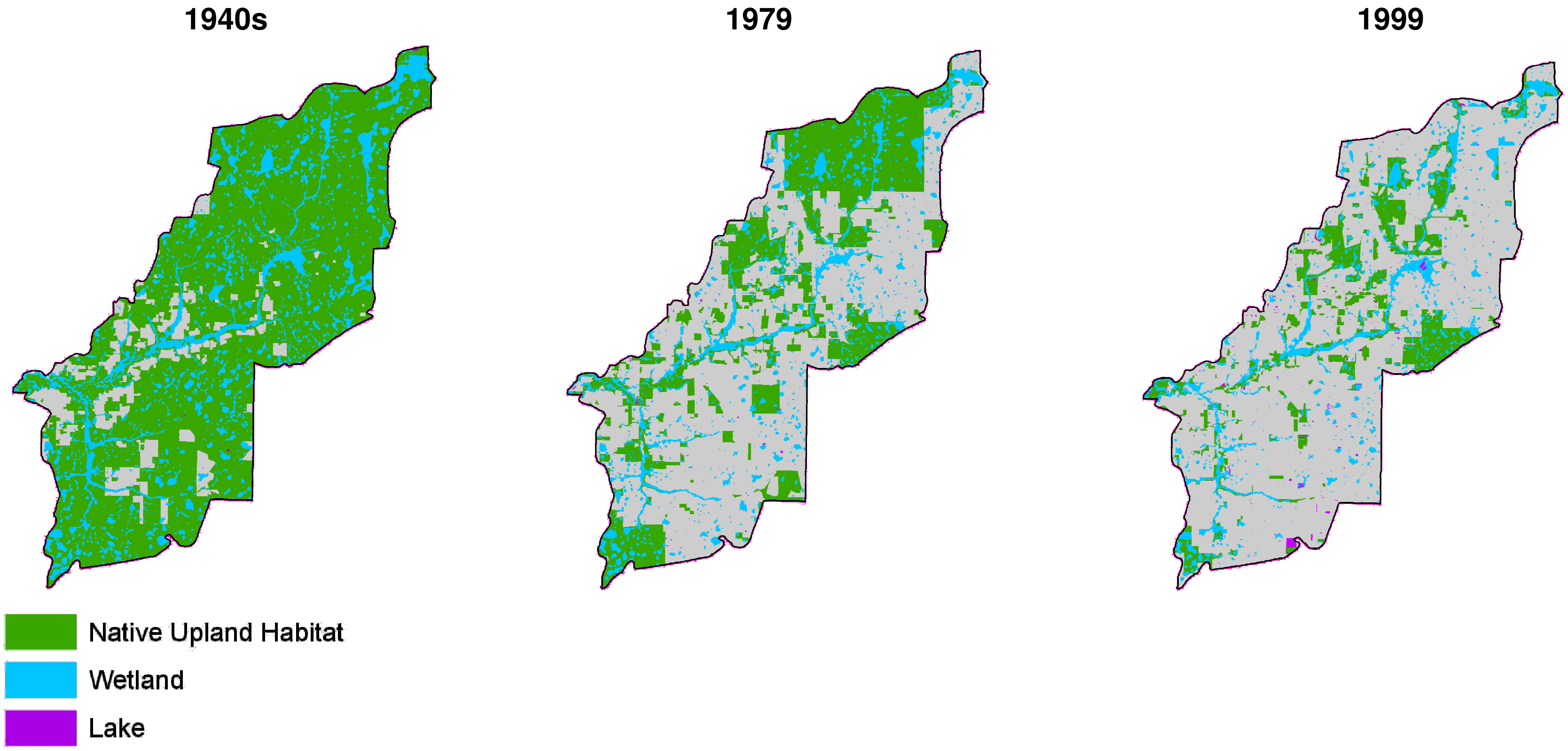
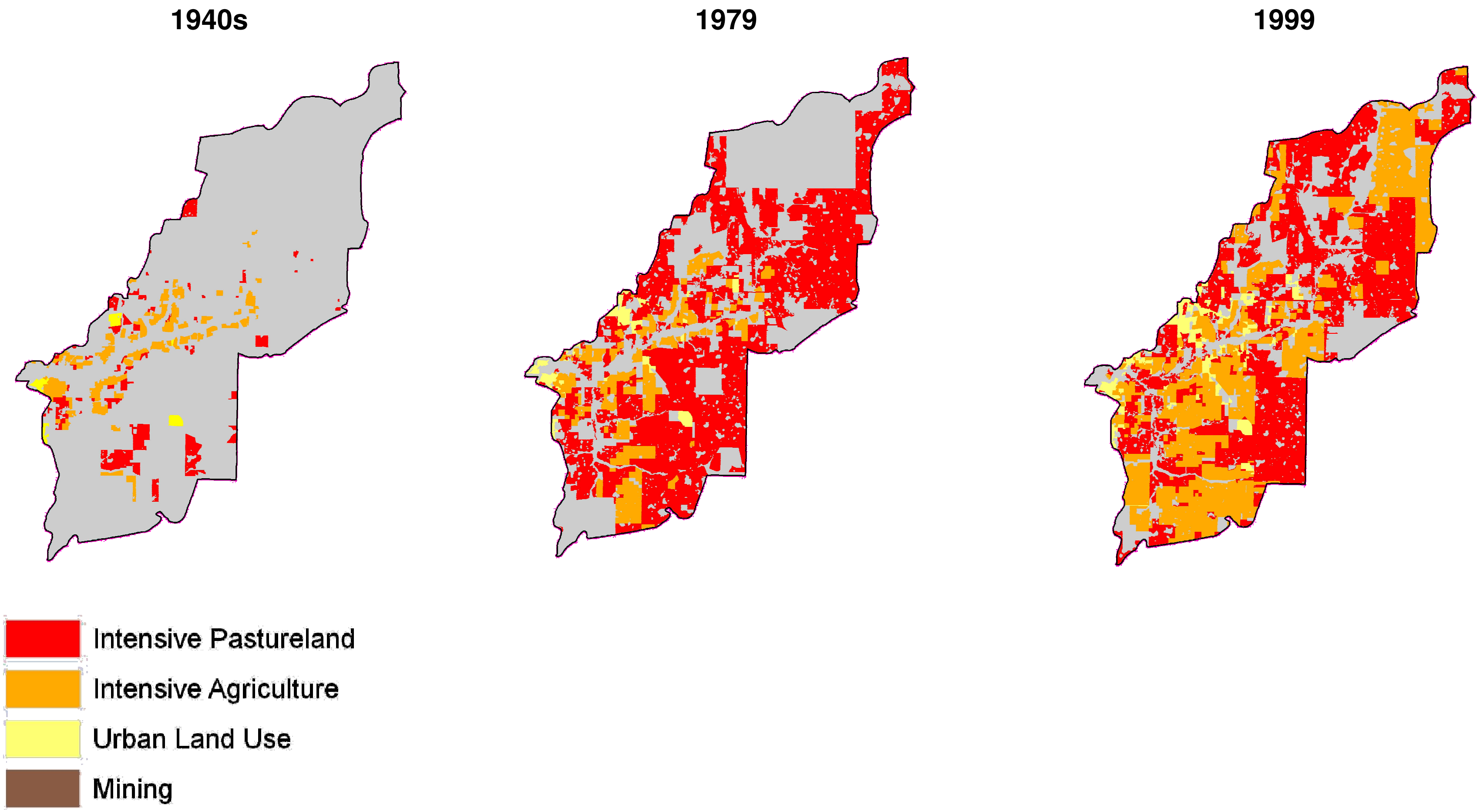
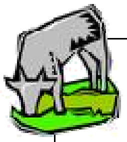


Figure 3.7.6. Changes in Developed Land Use: Joshua Creek Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



3.8 Horse Creek

The Horse Creek basin is approximately 128,435 acres in size. The creek itself drains approximately 241 square miles in the western portion of the Peace River watershed (Lewelling 1997) and flows approximately 43 miles south through primarily Hardee and DeSoto counties, although portions of the basin include Hillsborough, Polk, and Manatee counties. Horse Creek flows into the Peace River near Fort Ogden (SWFWMD 2000). The basin is mapped in Figure 3.8.1 and an aerial photograph of the basin is presented in Figure 3.8.2.



The Horse Creek basin is approximately 128,435 acres in size and includes approximately nine percent of the watershed. Developed land uses, primarily improved pasture, make up 69,097 acres (54 percent) of the basin and the remaining 59,053 acres (46 percent) is comprised of native upland habitats and wetlands.

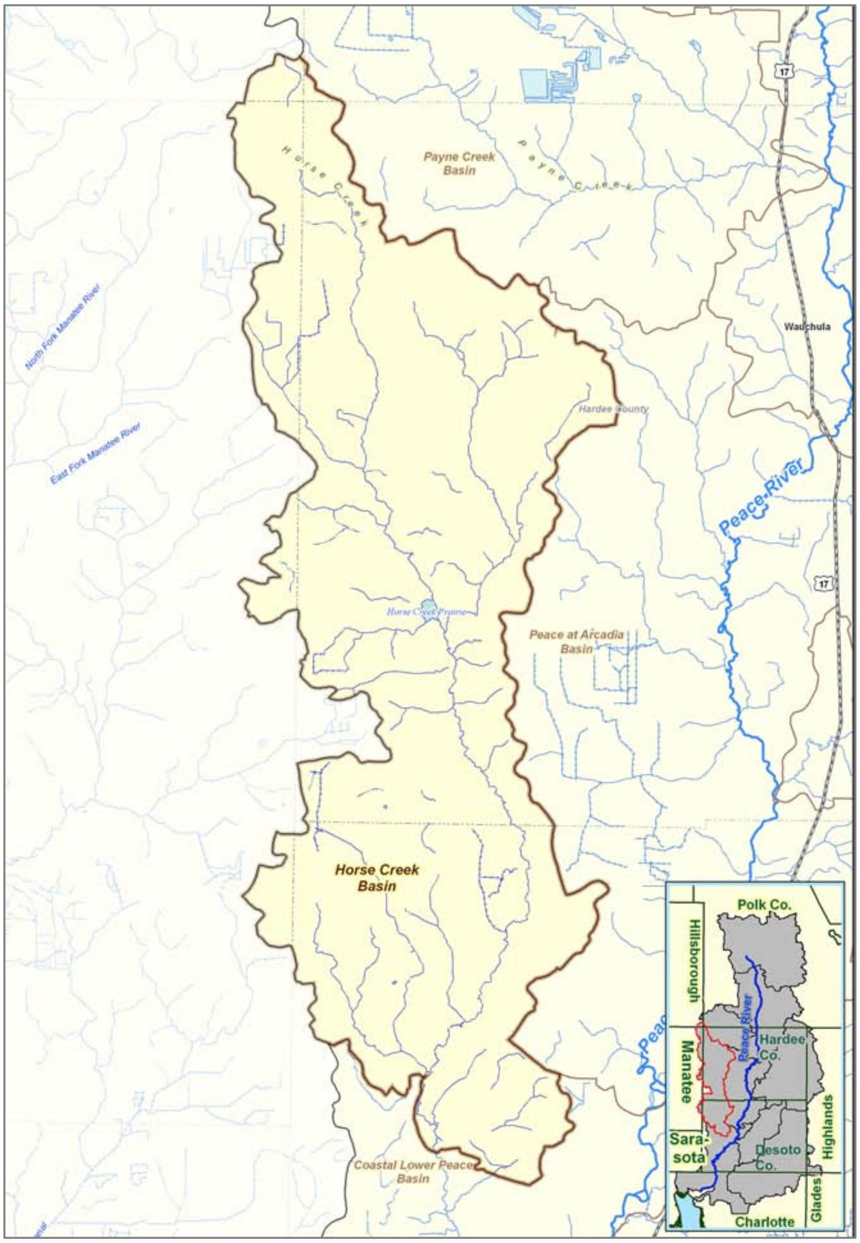
3.8.1 Hydrologic Features

West Fork Horse Creek and Brushy Creek originate in the Polk Uplands and are ditched, resulting in rapid flows (Lewelling 1997). The tributaries to Horse Creek occur in the DeSoto Plains/Gulf Coast Lowlands in the central and south portion of the Horse Creek basin. These tributaries include the Elder Branch and Cypress Branch which flow into Horse Creek in Hardee County. The slower, meandering Buzzard Roost Branch and Brandy Branch enter Horse Creek near Pine Level in DeSoto County.

Several land use changes have occurred in the Horse Creek watershed with the potential to influence basin flows. Phosphate mining has moved south from the Payne Creek basin into adjoining northern areas of the Horse Creek basin, and both intense agriculture and urban development have expanded toward the basin's southern end.

The northern portion of the Horse Creek basin has more natural vegetation when compared with the southern portion, which is characterized by large areas of pasture and row crops (SWFWMD 2000). The phosphate industry owns approximately 45,000 acres of land in the Horse Creek basin and roughly 7,295 acres of this were mined prior to 1999.

Figure 3.8.1. Location of Peace River at Horse Creek Basin in the Peace River Watershed



The unconfined surficial aquifer in the Horse Creek basin is permeable and contiguous with the land surface. The intermediate aquifer is recharged with water from the surficial aquifer, sinkholes, and abandoned mine pits that breach the confining units (Lewelling 1997). Both the intermediate and Floridan aquifers are under confined conditions in the Horse Creek basin and may contribute to the artesian flow in portions of the Horse Creek drainage area (Cowherd *et al.* 1984). According to Lewelling (1997), virtually all municipalities, industrial, and agricultural systems in the Horse Creek basin draw from the Upper Floridan aquifer.

The base flow in Horse Creek is due predominantly to agricultural ground water discharge from the surficial aquifer. In the south basin, the head of the intermediate aquifer is higher than the surficial, and ground water moves from the intermediate into the surficial aquifer before discharging into the creek.

Ground water flow is generally east to west in the Horse Creek basin, consistent with the downward slope of the land surface. Transmissivity values of the surficial aquifer in the Horse Creek basin range from 3,000 gallons per day (gpd)/foot to 40,000 gpd/foot. In the intermediate aquifer, transmissivity values range from 3,000 to 52,400 gpd/foot and lateral flow is generally west-southwest. The general direction of ground water movement in the Upper Floridan aquifer is to the west/ southwest, while transmissivity values are highly variable, typically ranging from 528,000 gpd/foot to 1,300,000 gpd/foot (SWFWMD 2000). Ground water from both the surficial and intermediate aquifers is suitable for potable use. However, ground water from the Floridan aquifer is potable only from the north Horse Creek basin. Although recharge to the surficial aquifer is high, recharge potential to the intermediate and Floridan aquifers is low as a result of artesian conditions and thick confinement (SWFWMD 2000).

Several land use changes have occurred in the Horse Creek watershed with the potential to influence basin flows. Phosphate mining has moved south from the Payne Creek basin into adjoining northern areas of the Horse Creek basin, and both intense agriculture and urban development have expanded toward the southern end. There are two USGS stream flow gages along Horse Creek. The upstream Horse Creek near Myakka City gage located toward the basin's northern end has a flow record extending back only to 1978. In comparison, the period-of-record for the downstream Horse Creek near Arcadia gage toward the southern end of the basin starts in 1951, which enabled trend tests to be run for 10 monthly flow metrics for the period 1951-2004 (Section 4 below) and sequentially in five-year intervals (for example 1955-2004, 1960-2004, 1965-2004) for the following three monthly metrics.

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

Summary results of the trend test for low, median, and high flows for the two USGS Horse Creek stream gages are shown in Table 3.8.1, while Figures 3.8.3 and 3.8.4 depict monthly minimum (base) flows over the period-of-records for each gage. While these data don't show statistically significant changes low flows at the upstream gage near Myakka City, the long-term water chemistry data collected from this location indicate that mineralized ground water discharges have increased, especially during the recent 1999-2001 drought. As both the flow and water chemistry data indicate, the influences of ground water discharges augmenting surface flows increases farther downstream at the Horse Creek near Arcadia gage.

Table 3.8.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Horse Creek Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Horse Creek near Myakka Head	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▨	▨				
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨	▨	▨				
	High (Q10)	▨	▨	▨	▨	▨	▨	▨	▨	▨				

Table 3.8.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Horse Creek Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Horse Creek near Arcadia	Low (Q90)	▨	▨	▨	▨				🔺	▲				
	Medium (Q50)	▨	▨	▨	▨				🔺	▲				
	High (Q10)	▨	▨	▨	▨				▲	▲				

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location

Figure 3.8.2. Aerial Photograph of the Peace Rive at Horse Creek Basin

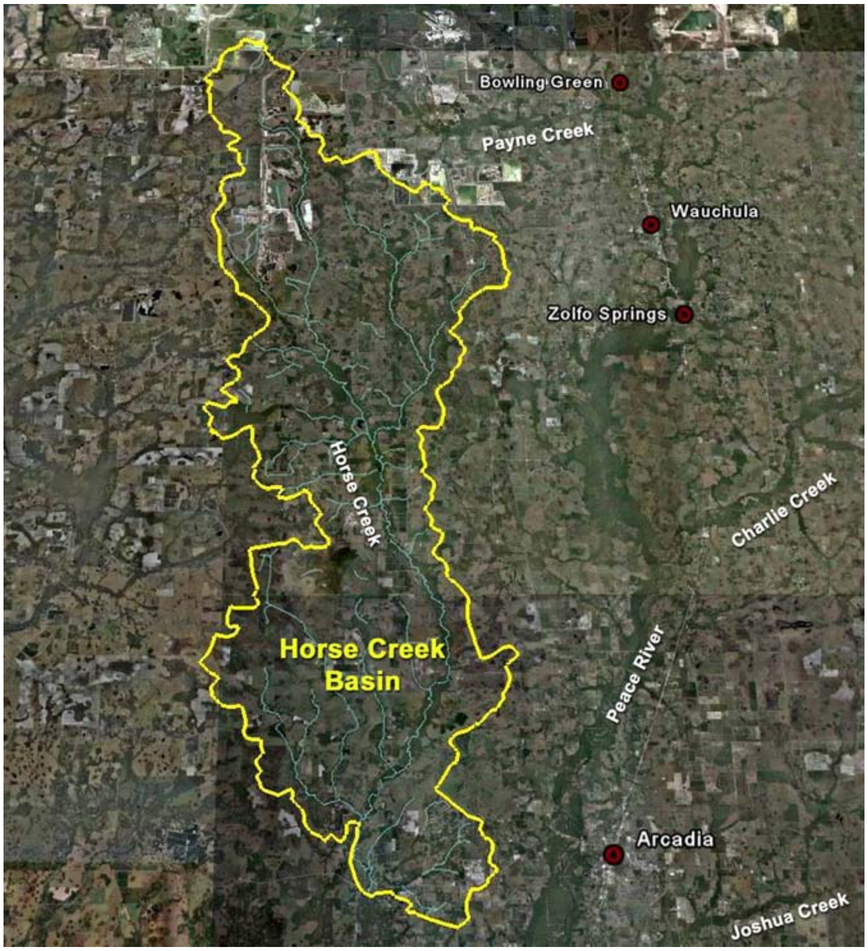


Figure 3.8.3. Monthly Minimum Flow at Long-term Horse Creek near Myakka (2297155) Gage (1977 – 2004)

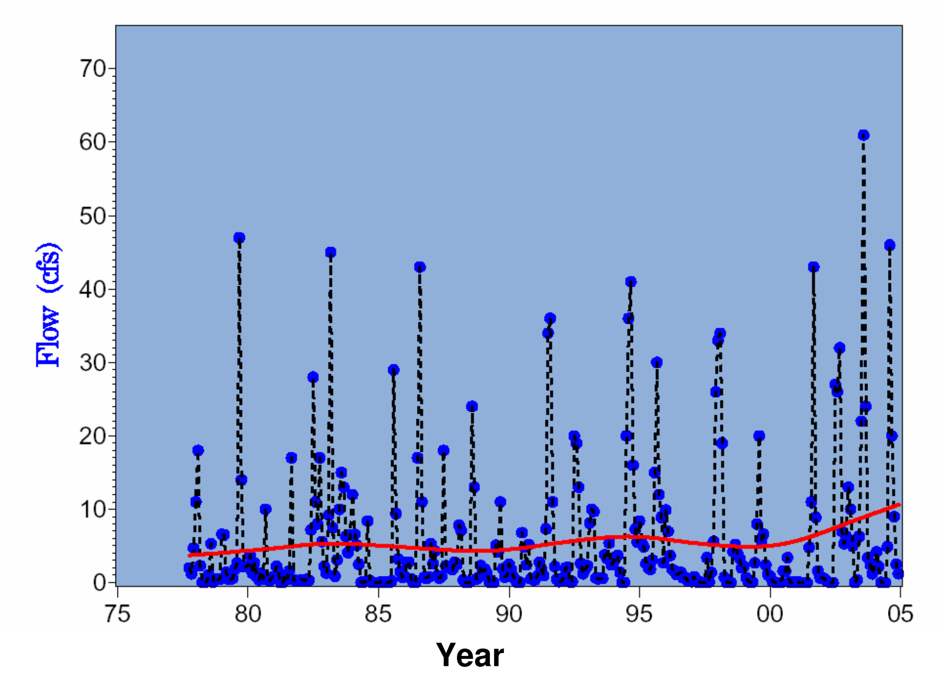
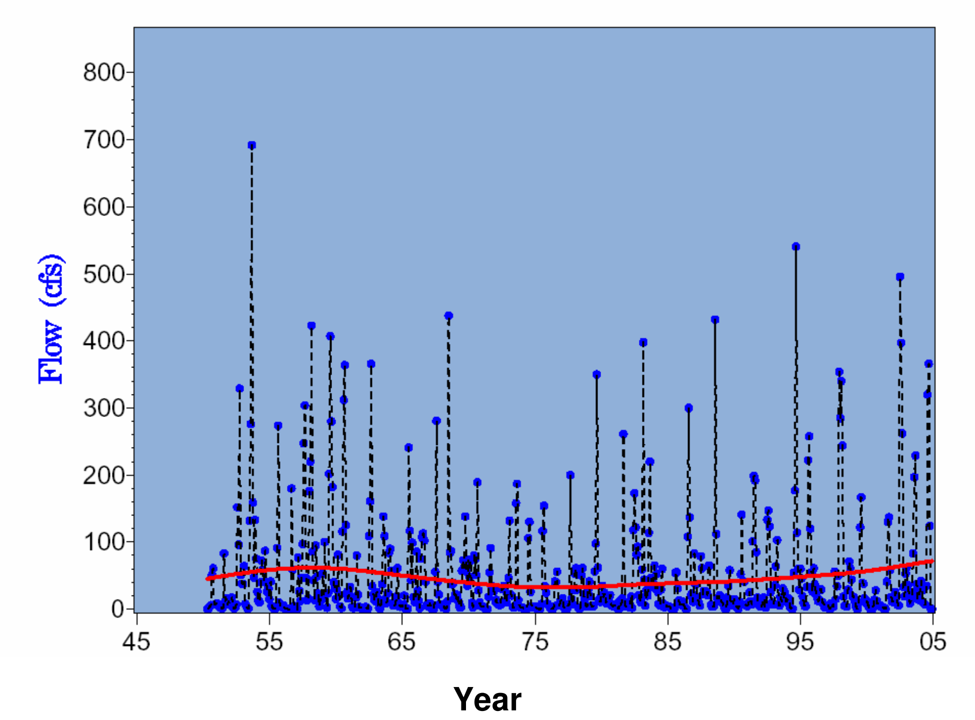


Figure 3.8.4. Monthly Minimum Flow at Long-term Horse Creek near Arcadia (2297310) Gage (1950 – 2004)



3.8.2 Water Quality

This basin spans the western side of the southern region of the Peace River watershed and includes two USGS/SWFWMD water quality monitoring sites. Most of the available water quality data for the Horse Creek monitoring location near Myakka Head only dates back to the early 1990s (although there are some scattered observations in the early 1980s). In comparison, the historic period-of-record for a number of water quality parameters measured at the southern Horse Creek monitoring site near Arcadia date back to the early 1960s. Subsequently, phosphate mining expanded south from the Payne Creek basin into the northern portion of the Horse Creek basin, while more intensive agriculture and residential/urban development expanded into the southern portion of the basin. Horse Creek enters the lower tidal Peace River approximately 3.5 miles upstream of the Peace River/Manasota Regional Water Supply Authority treatment facility. The overall patterns of water quality changes in the Horse Creek basin are summarized below.

- Time series plots for the upper Horse Creek near Myakka Head station are obviously strongly affected by the limited period-of-record and the influences of the 1999-2001 drought. The increases in phosphorus levels, for example, reflects high concentrations during the drought, and lower concentrations both prior to and following the drought. Similar influences of the drought on chloride and potassium levels are also apparent.

- Even with the relatively limited historic record, water quality data from the Horse Creek near Myakka Head monitoring sites indicate increases in levels of conductivity (specific conductance) and pH, and concentrations of total dissolved solids, calcium, magnesium, sodium, and sulfate.

- Similar, larger changes in these water quality parameters are apparent over the longer available historic period-of-record at the downstream Horse Creek near Arcadia monitoring site.

- These observed changes in water quality at both sampling locations are attributable to agricultural withdrawals of mineralized ground water and subsequent discharges to Horse Creek.

- The long-term data at the downstream site also indicate increases in inorganic nitrite+nitrate nitrogen concentrations during the mid-1980s.

3.8.3 Water Budget

The water budget was examined for the Horse Creek basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget revealed no significant trends in hydrology during the water budget intervals attributable to something other than variation in rainfall.

3.8.4 Land Use

The Horse Creek basin is approximately 128,435 acres in size and includes approximately nine percent of the watershed. Developed land uses, including urban (one percent), mining (six percent), intense agriculture (10 percent), and improved pasture (37 percent), make up 69,097 acres (54 percent) of the basin and the remaining 59,053 acres (46 percent) is comprised of native upland habitats and wetlands.

In the 1940s, only five percent of the basin was developed as agriculture with the exception of about 50 acres of urban land uses. Ninety-five percent (122,042 acres) of the basin was undeveloped and included 32,397 acres (25 percent) of wetlands and 89,645 acres (70 percent) of native upland habitats. There was no mining in the basin. Table 3.8.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.8.5, 3.8.6, and 3.8.7.

By 1979, acres of developed lands increased in area to encompass 47,090 acres (37 percent) of the basin due primarily to the conversion of 32,045 acres of native upland habitats to improved pasture and another 6,810 acres to intense agriculture. Wetland conversions to agriculture during this time period were small in comparison and totaled 2,572 acres. Urban area increases were negligible and no mined lands were present.

Between 1979 and 1999, agriculture expanded further to include a total of 60,206 acres (47 percent) of the Horse Creek basin, nearly 48,000 acres of which was improved pasture. About 16,179 acres of native upland habitats were converted to agriculture during this time period and the remaining 5,842 acres of native upland habitats were converted to phosphate mined and urban lands. About 2,036 acres of improved pasture were converted to mined lands and 1,209 acres were converted to intense agriculture. Approximately 40,000 acres of native upland habitat were lost between the 1940s and 1979.

Phosphate mining entered the Horse Creek basin post-1979 and included 7,295 acres (six percent) of the basin in 1999. Approximately 3,790 acres of native upland habitat and 1,363 acres of wetlands were converted to mined lands during this period, all of which are subject to mandatory reclamation. Conversions to urban land uses increased from 46 acres in the 1940s to 109 acres in 1979 and then to 1,596 acres in 1999 and still made up only one percent of the basin.

Nearly half (60,206 acres) of the Horse Creek basin was in agriculture by 1999, with most of the agricultural increases occurred pre-1979. Conversions of native upland habitats during this same period of time accounted for all but about 4,000 acres, which was actually due to changes between agriculture classes.

Table 3.8.2. Land Uses 1940s – 1999: Horse Creek Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	0	0	0	0	7,295	6
Urban Land Use	46	<1	109	<1	1,596	1
Improved Pasture	1,380	1	36,373	28	47,903	37
Intense Agriculture	4,672	4	10,609	8	12,303	10
Subtotal	**6,097**	**5**	**47,090**	**37**	**69,097**	**54**
Undeveloped						
Wetlands	32,397	25	26,895	21	24,089	19
Native Upland Habitats	89,645	70	54,257	42	34,964	27
Subtotal	**122,042**	**95**	**81,152**	**63**	**59,053**	**46**
Water						
Streams and River Channels	41	<1	75	<1	33	<1
Lakes and Open Water	255	<1	118	<1	253	<1
Subtotal	**296**	**<1**	**194**	**<1**	**286**	**<1**
Total	**128,435**	**100**	**128,435**	**100**	**128,435**	**100**

* Includes reclaimed (totally and partially) lands

Figure 3.8.5. Land Uses: Horse Creek Basin

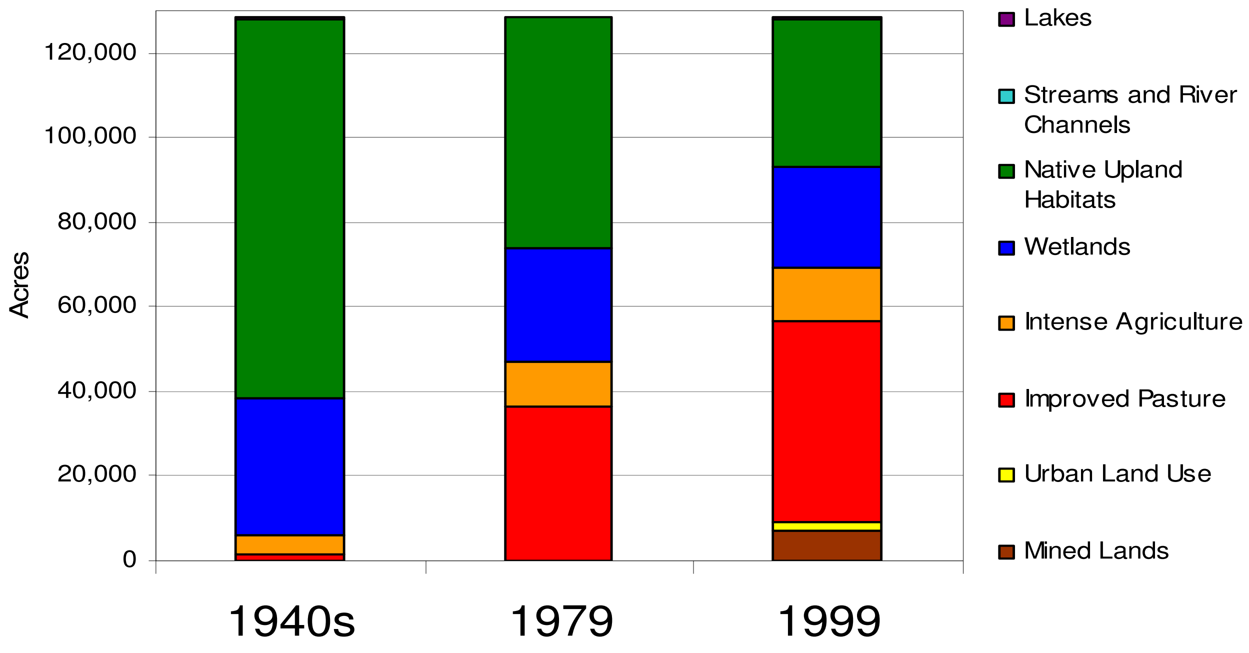


Figure 3.8.6. Changes in Undeveloped Land Use: Horse Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

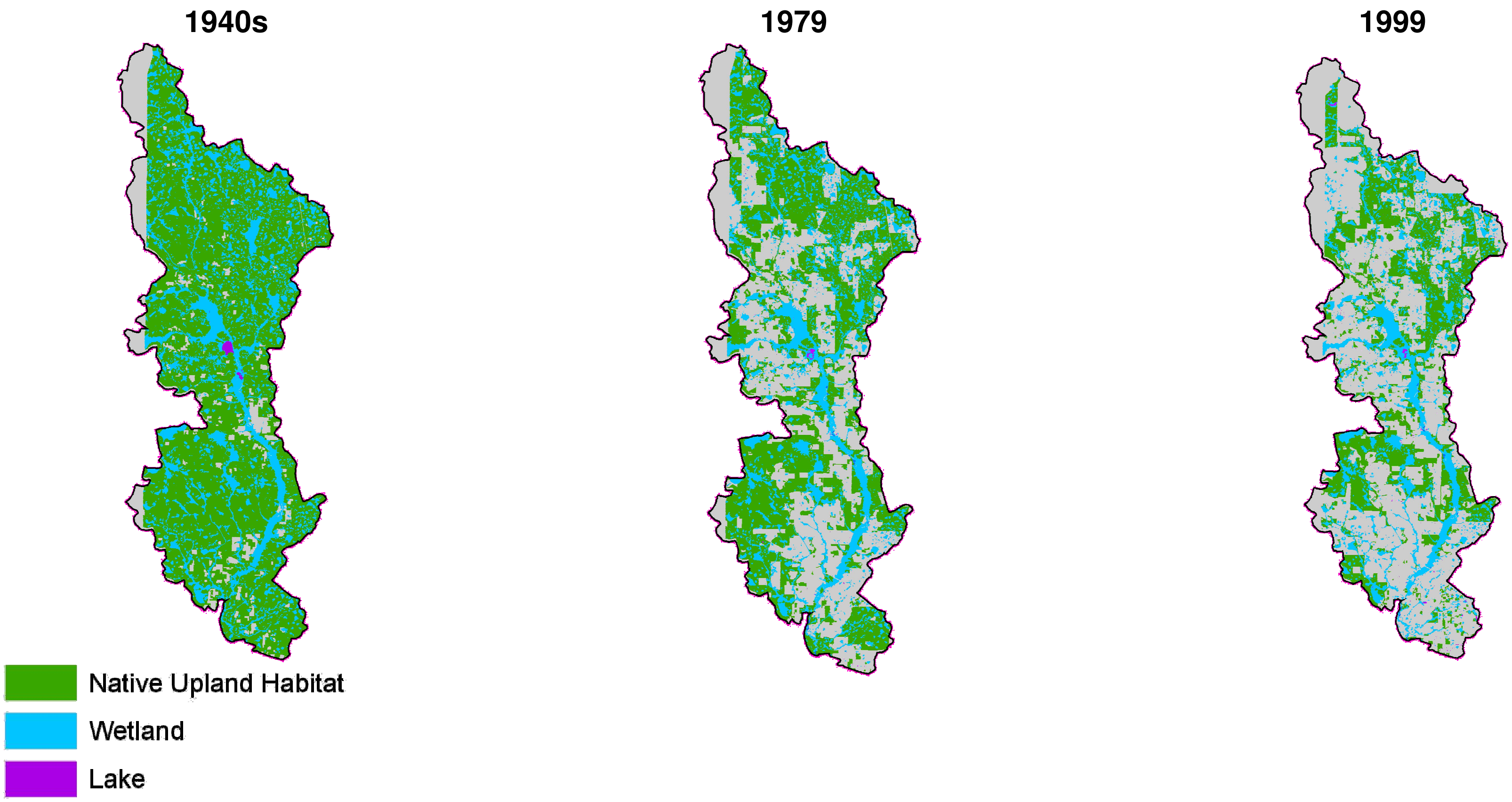
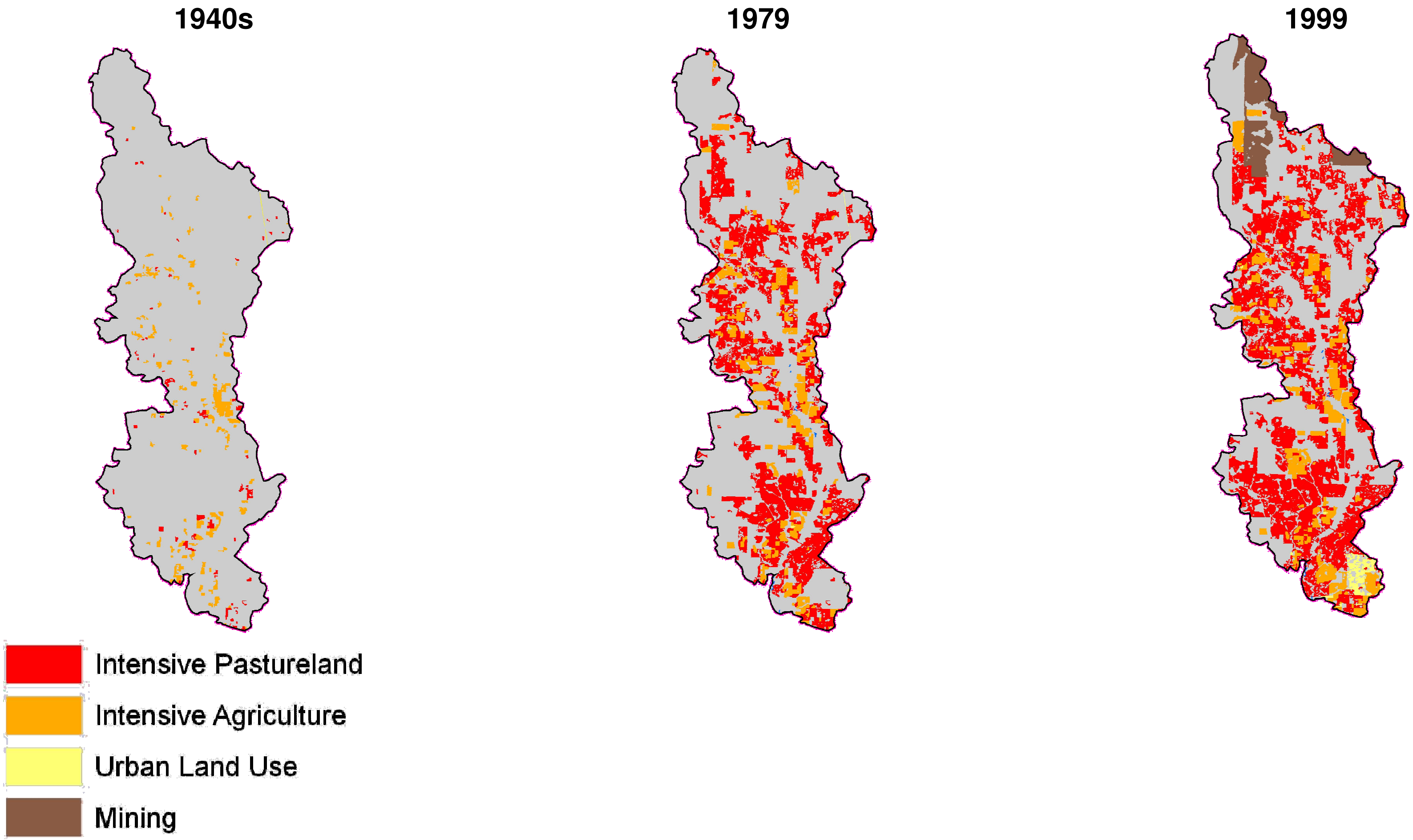


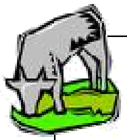
Figure 3.8.7. Changes in Developed Land Use: Horse Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for "missing" data at the edge(s) of some basins)



3.9 Shell Creek

The Shell Creek basin is approximately 213,537 acres in size, making it the second largest basin in the Peace River watershed. Agriculture (58 percent) was the dominant land cover in the basin in 1999 and a total of 22 percent was in citrus. Between 1972 and 1999, approximately 21 percent of the basin was converted from wetlands and uplands to agricultural uses. The Hendrickson Dam is located below the confluence of Prairie Creek with Shell Creek, and lower Shell Creek the flows into the lower tidal reach of the Peace River near Punta Gorda. The basin is mapped in Figure 3.9.1 and an aerial photograph of the basin is presented in Figure 3.9.2.



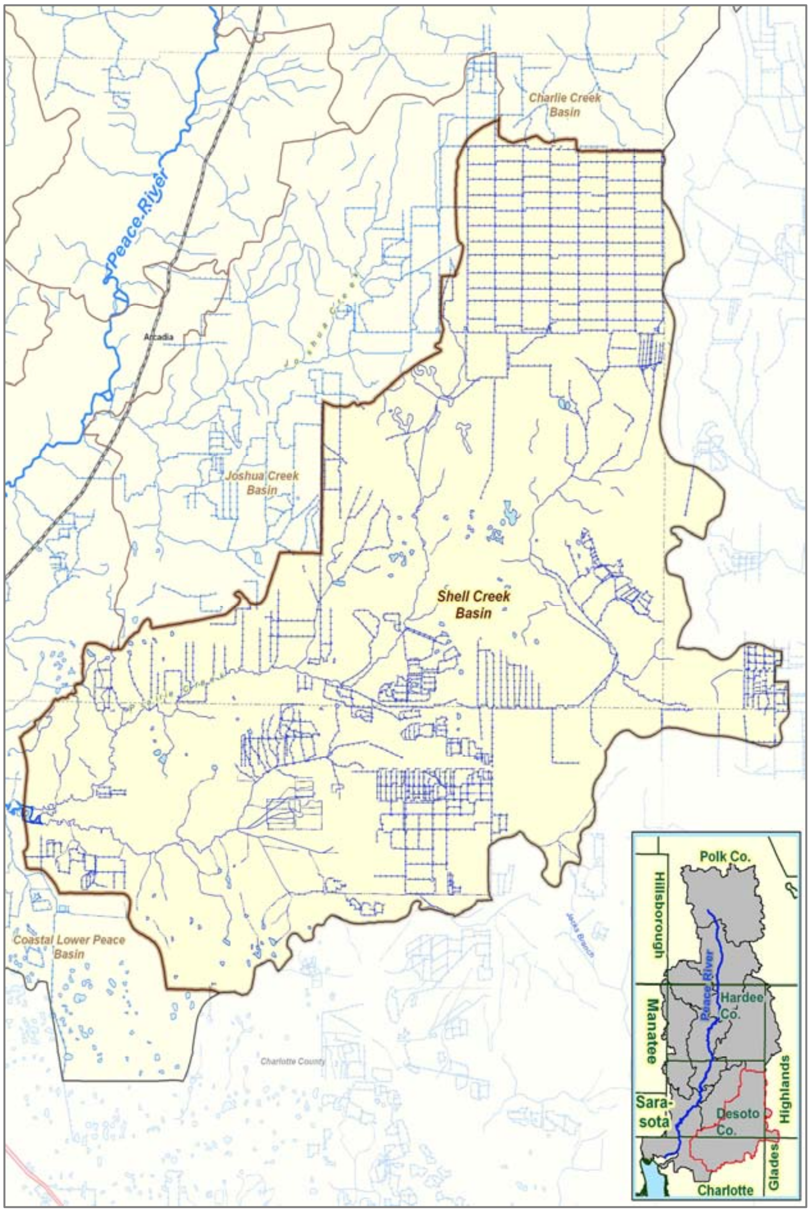
The Shell Creek basin is second only to the Peace River at Bartow basin in size and includes approximately 213,537 acres (15 percent) of the Peace River watershed. Improved pasture and agriculture, in general, comprise the largest land uses in the basin.

3.9.1 Hydrology

Prairie Creek, which drains the northeastern portion of the basin, and Shell Creek, which flows through more of the southeastern portion of the basin, are the two primary stream channels in the Shell Creek basin. These two creeks merge at the Shell Creek reservoir upstream of the Hendrickson Dam, and then flow downstream along tidal Shell Creek to join the lower Peace River just upstream of the I-75 crossing. Hendrickson Dam was constructed in 1965 on Shell Creek, below its confluence with Prairie Creek, near the City of Punta Gorda. The 800-acre reservoir is located approximately eight miles east of the city and provides water for domestic/ municipal/ industrial uses within the regional area of the city.

Prairie Creek, which drains the northeastern portion of the basin, and Shell Creek, which flows through more of the southeastern portion of the basin, are the two primary stream channels in the Shell Creek basin.

Figure 3.9.1. Location of Peace River at Shell Creek Basin in the Peace River Watershed



There are two USGS stream flow gages in the Shell Creek basin. The Prairie Creek gage near Fort Ogden has a flow record extending back to 1963. Continuous data, however, are only available since 1978. In comparison, the period-of-record for the Shell Creek near Arcadia gage (flows over the dam) starts in 1965, which enabled trend tests to be run for 10 monthly flow metrics for the period 1965-2004 (Section 4 below) and sequentially in five-year intervals (for example 1965-2004, 1970-2004, 1975-2004) for the following three monthly metrics.

- The low flow Q90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less than half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only 10 percent of the time.

Summary results of the trend test for low, median, and high flows for the two USGS Shell Creek stream gages are shown in Table 3.9.1, while Figures 3.9.3 and 3.9.4 depict monthly minimum (base) flows over the period-of-records for each gage. Even with a relatively short continuous record, the increasing patterns of flow in Prairie Creek have been of such a magnitude that statistically significant trends are readily apparent. Water chemistry data from Prairie Creek over the same time interval clearly indicate that these increases in flows are associated with agricultural discharges of highly mineralized Upper Floridan ground water reaching the creek. Flows at the dam show both long-term increases in low flows, as well as declines associated with the recent 1999-2001 drought.

Table 3.9.1. Summary Results of Seasonal Kendall Tau Trend Analyses of Monthly Flow Percentiles for Selected Periods through 2004 for the Shell Creek Basin

USGS Gaging Site	Flow Percentile	1935 - 2004	1940 - 2004	1945 - 2004	1950 - 2004	1955 - 2004	1960 - 2004	1965 - 2004	1970 - 2004	1975 - 2004	1980 - 2004	1985 - 2004	1990 - 2004	1995 - 2004
Prairie Creek near Fort Ogden	Low (Q90)	▨	▨	▨	▨	▨	▨	▨	▨	▨	🔺	🔺		
	Medium (Q50)	▨	▨	▨	▨	▨	▨	▨	▨	▨	🔺	🔺		
	High (Q10)	▨	▨	▨	▨	▨	▨	▨	▨	▨	🔺	🔺		
Shell Creek near Punta Gorda	Low (Q90)	▨	▨	▨	▨	▨	▨	▲					▼	
	Medium (Q50)	▨	▨	▨	▨	▨	▨							
	High (Q10)	▨	▨	▨	▨	▨	▨							

Note: The direction of an arrow denotes a significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, blue show trends significant at p=0.10, and blanks indicate no significant trends in Seasonal Kendall Tau tests corrected for serial correlations. Dashed lines indicate periods prior to USGS gaging data at each location.

Figure 3.9.2. Aerial Photograph of the Peace River at Shell Creek Basin

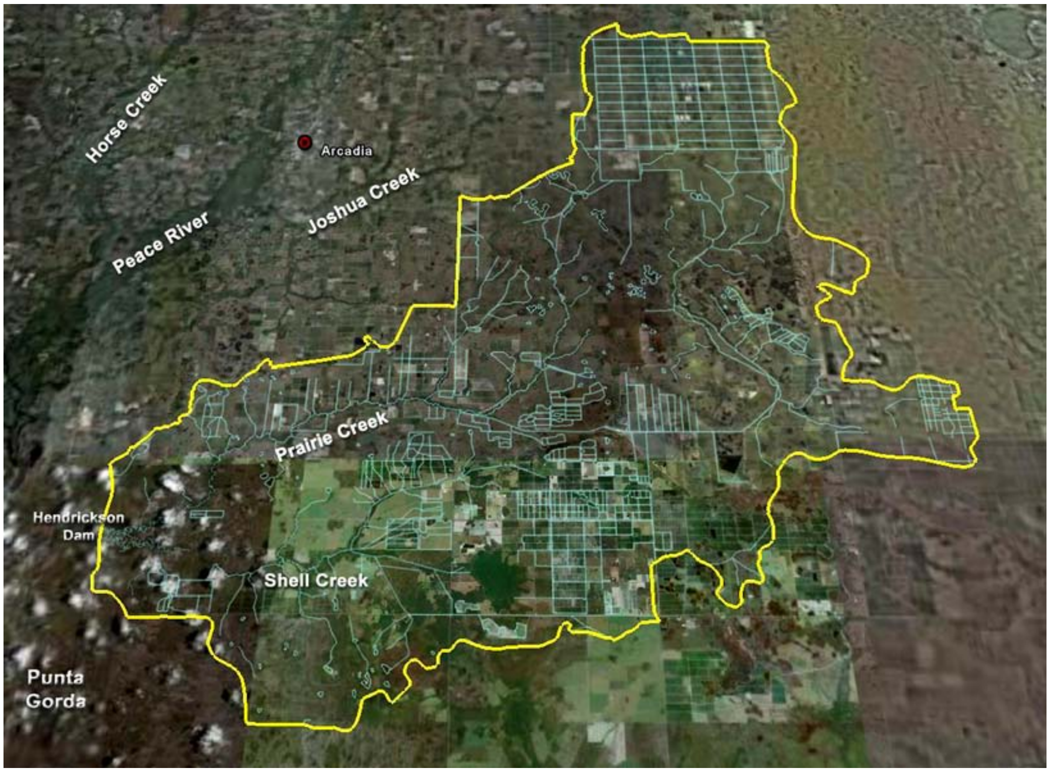


Figure 3.9.3. Monthly Minimum Flow at Long-term Prairie Creek (2298123) Gage (1963 – 2004)

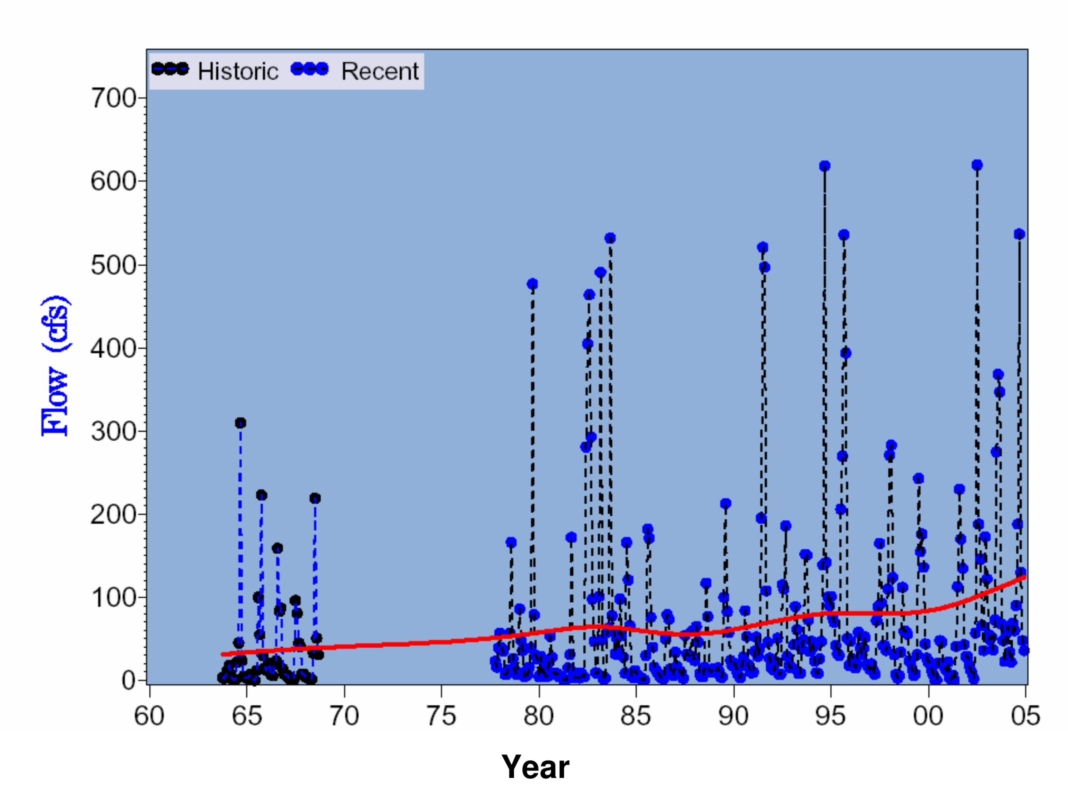
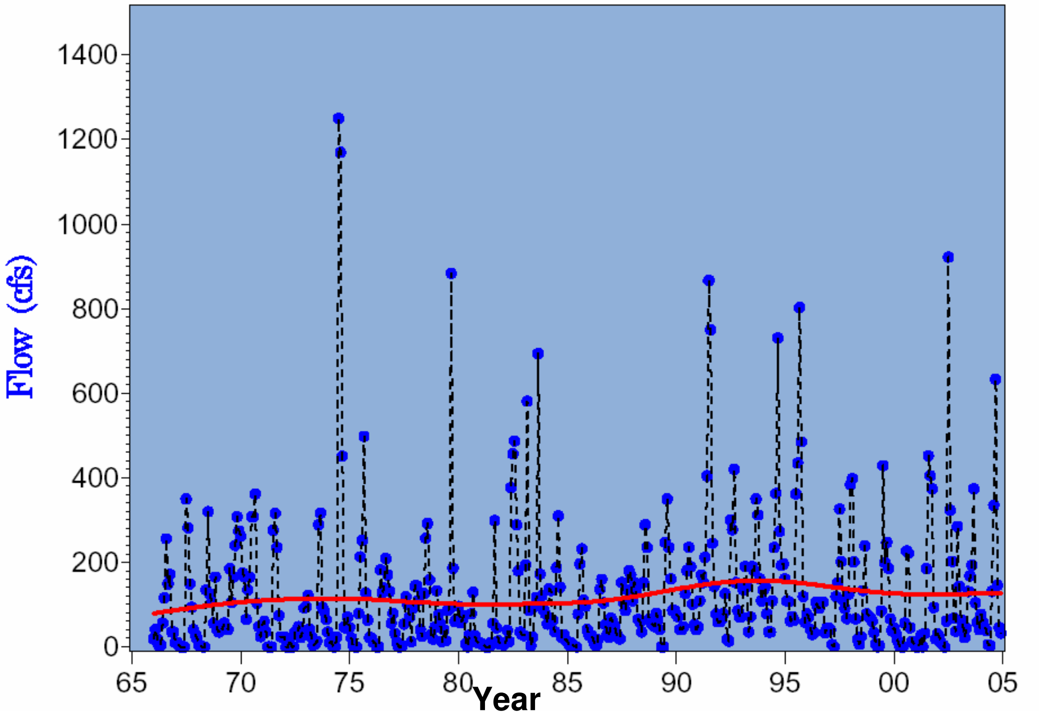


Figure 3.9.4. Monthly Minimum Flow at Long-term Shell Creek Gage (1965 – 2004)



3.9.2 Water Quality

This large basin in the southern portion of the watershed includes two major tributaries that join near Punta Gorda at the Shell Creek Reservoir. Water flowing from the reservoir over the dam enters the tidal reach of Shell Creek, which joins the lower Peace River just upstream of the Interstate I-75 bridge across the lower Peace River. Prairie Creek drains the larger northern portion of the basin, while Shell Creek drains the southeast. There are two water quality monitoring locations in Prairie Creek. Historic data for some water quality parameters date back to the late 1960s at the upstream USGS long-term Prairie Creek monitoring site near Fort Ogden. However, most of the consistent data are available back to only the early 1990s. The second downstream Prairie Creek monitoring location is at CR 764 and has been sampled monthly since 1991 in conjunction with the City of Punta Gorda's Hydrobiological Monitoring Program (HBMP). The USGS also collects basin water quality data from the Shell Creek Reservoir monitoring site just upstream of the dam, with selected information dating back to the late 1960s. Since 1991, data have been collected monthly at this reservoir monitoring location as part of the HBMP.

Since the 1940s, increasing areas of the basin have been converted to more intense forms of agricultural use. As in other basins, such land use shifts have resulted in corresponding changes in water quality that are attributable to agricultural discharges of mineralized ground water to surface waters. Many of these water quality parameters exhibit long-term increasing patterns and were measured at or near historically high levels during the recent 1999-2001 drought. A summary of water quality changes in this basin is outlined below.

- Available water quality data indicate comparatively large historic increases in levels of measured conductivity (specific conductance) in Prairie Creek and the Shell Creek Reservoir.

- Similar corresponding patterns of increasing chloride and silica concentrations have also occurred.

- Conversions of native upland habitats (96,457 acres) and wetlands (14,680 acres) since the 1940s accounted for 94 percent of the agricultural expansion in the basin.

3.9.3 Water Budget

The water budget was examined for the Shell Creek basin in the context of land use changes and rainfall over time and used to quantify potential impacts of these changes to the watershed (described previously). Results of the water budget analysis are summarized below.

- Shell Creek did not have a gage until 1965, when a USGS stream gaging station was constructed near the newly built Hendrickson Dam. It should be noted that the USGS gaging station was constructed on the Hendrickson Dam in 1965 and, as a consequence, "pre-development" data are not available for comparison. The data recorded at the USGS gage has not displayed significant trends in hydrologic functions during the later water budget intervals that cannot be attributed to variations in rainfall.

- The major hydrologic changes in the basin, such as dam building and the growth of agriculture, occurred before the first stream gages were installed in the basin. Without pre-development era stream flow data, the hydrologic impact of development in the basin cannot be assessed in detail.

- The Hendrickson Dam was constructed in 1965 to form the Shell Creek Reservoir. Shell Creek Reservoir is currently used as a surface water supply source for the City of Punta Gorda.

3.9.4 Land Use

The Shell Creek basin is second only to the Peace River at Bartow basin in size and includes approximately 213,537 acres (15 percent) of the Peace River watershed. Land use patterns in this basin are similar to several others. Improved pasture and agriculture, in general, comprise the largest land uses in the basin. Phosphate mining is absent and shell and sand mining are negligible (76 acres). Urban land uses make up only two percent of the basin. Increases in acres of agricultural land uses were a result of conversions of primarily native upland habitats, 75 percent (72,758 acres) of which had been converted by 1979.

In the 1940s, 9,474 acres (four percent of the basin) of the basin was developed and most was in intense agriculture (8,946 acres). There were very small areas of improved pasture (about 301 acres) and urban (227 acres) land uses. Undeveloped lands include 49,524 acres (23 percent of the basin) of wetlands and 154,296 acres (72 percent) of native upland habitats which together comprised 95 percent of the basin. Table 3.9.2 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.9.5, 3.9.6, and 3.9.7.

By 1979, improved pasture and intense agriculture accounted for 86,693 acres (41 percent) of the basin due to the conversion of more than 72,000 acres of native upland habitats to agricultural land uses. Wetland conversions to agriculture during this time period were small in comparison and totaled 7,715 acres. Urban land uses were still comparatively negligible in 1979 (326 acres).

Between 1979 and 1999, agricultural land uses expanded to include 118,615 acres (56 percent) of the Shell Creek basin and were relatively evenly distributed between improved pasture (31 percent of the basin) and intense agriculture (25 percent of the basin). Approximately 32,604 acres of native upland habitats were converted to agriculture during this time period and the 2,448 acres of native upland habitats were converted to urban lands. Urban lands in the basin increased ten fold, from 326 acres in 1979 to 3,264 in 1999, and made up two percent of the basin. Sand and shell mining in this basin increased from zero in the 1940s and in 1979, to 76 acres in 1999, all of which are subject to mandatory reclamation.

More than half of the Shell Creek basin was in agriculture by 1999, although most of the agricultural increases occurred pre-1979. Conversions of native upland habitats (96,457 acres) and wetlands (14,680 acres) since the 1940s accounted for 94 percent of the agricultural expansion in the basin.

Table 3.9.2. Land Uses 1940s – 1999: Shell Creek Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	0	0	0	0	76	<1
Urban Land Use	227	<1	326	<1	3,264	2
Improved Pasture	301	<1	33,226	16	52,331	25
Intense Agriculture	8,946	4	53,467	25	66,284	31
Subtotal	**9,474**	**4**	**87,018**	**41**	**121,955**	**57**
Undeveloped						
Wetlands	49,524	23	36,496	17	30,787	14
Native Upland Habitats	154,296	72	89,555	42	59,324	28
Subtotal	**203,820**	**95**	**126,051**	**59**	**90,111**	**42**
Water						
Streams and River Channels	216	<1	331	<1	206	<1
Lakes and Open Water	26	<1	137	<1	1,266	1
Subtotal	**243**	**<1**	**468**	**<1**	**1,472**	**1**
Total	**213,537**	**100**	**213,537**	**100**	**213,537**	**100**

Figure 3.9.5. Land Uses: Shell Creek Basin

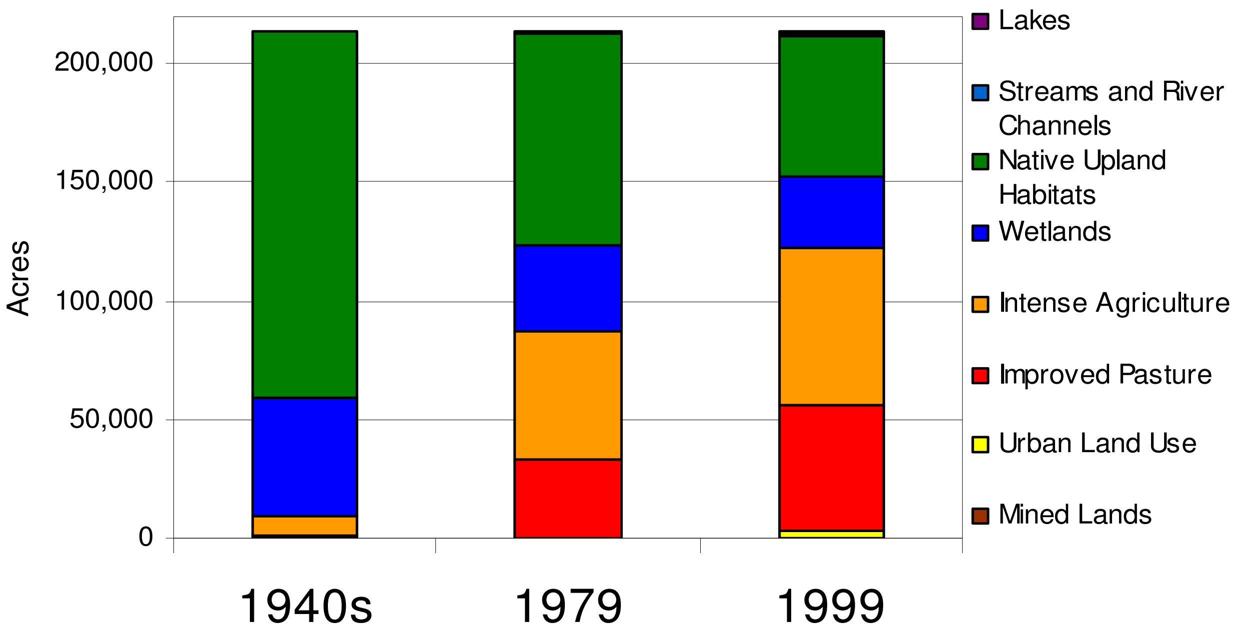


Figure 3.9.6. Changes in Undeveloped Land Use: Shell Creek Basin
(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

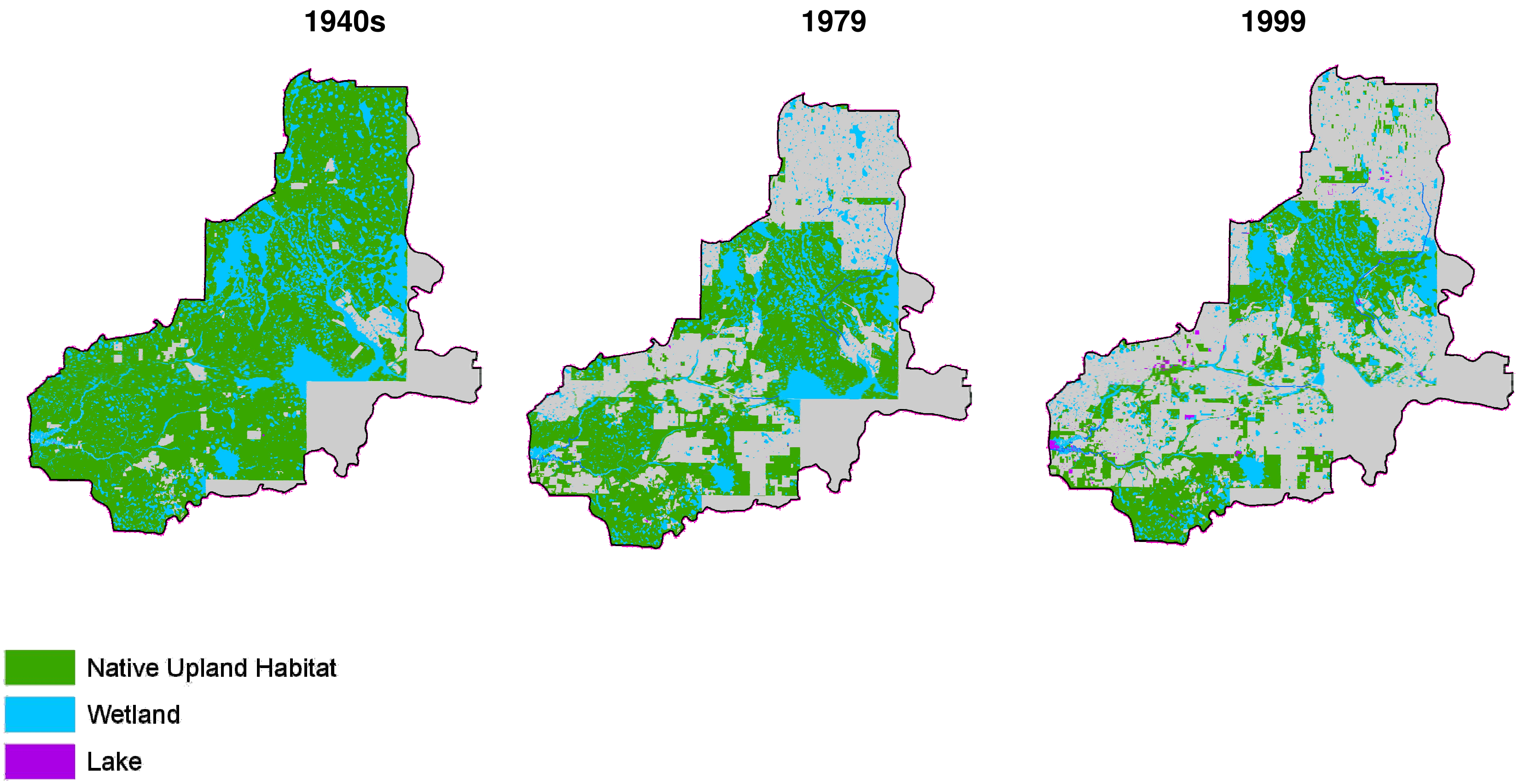
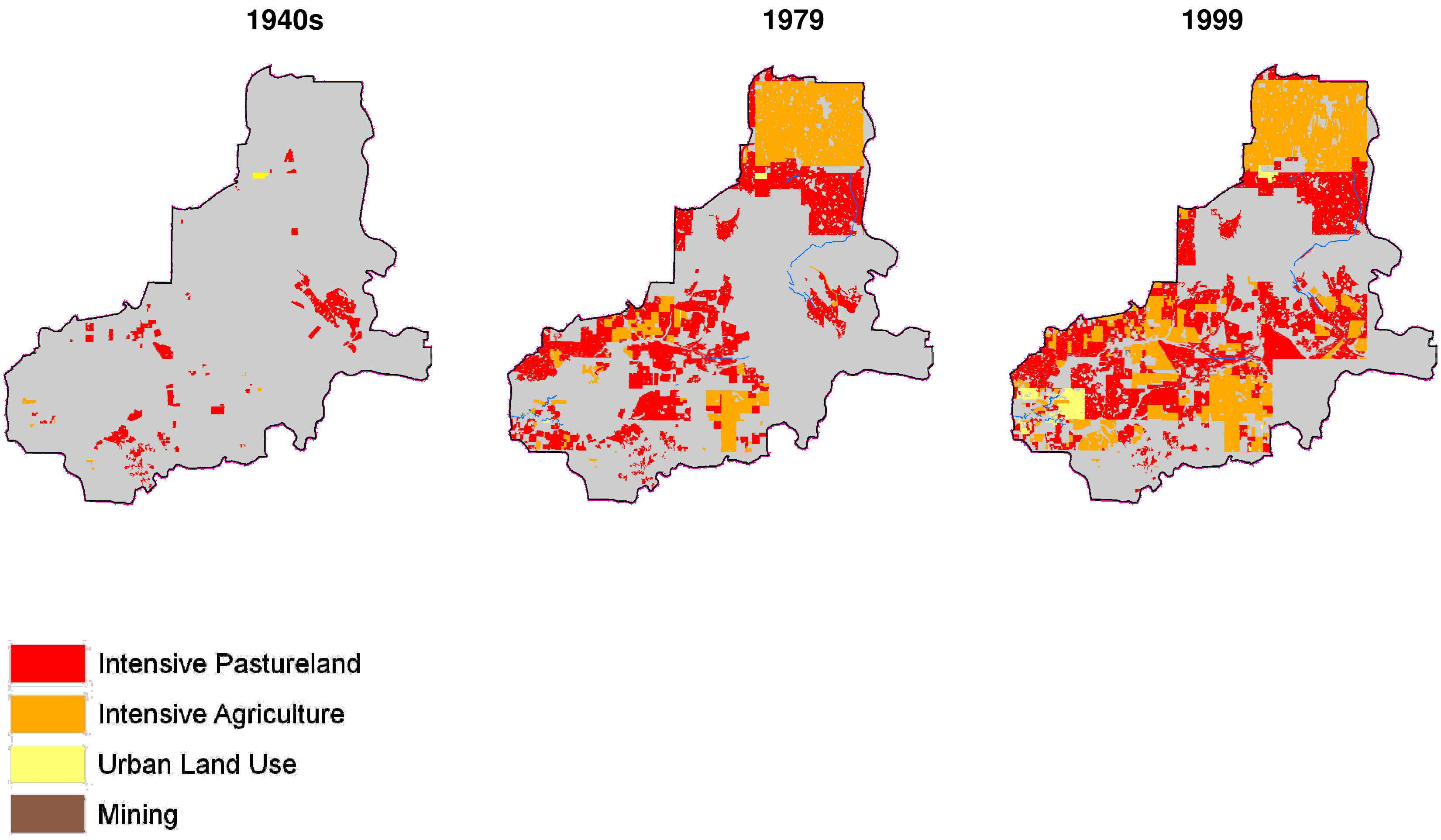


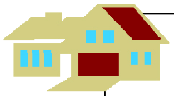
Figure 3.9.7. Changes in Developed Land Use: Shell Creek Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)



3.10 Coastal Lower Peace River

The Coastal Lower Peace River basin is approximately 154,571 acres in size and encompasses about 600 square miles. It includes parts of Charlotte, De Soto, and Sarasota counties. The basin is mapped in Figure 3.10.1 and an aerial photograph of the basin is presented in Figure 3.10.2.



The Coastal Lower Peace River basin encompasses 164,571 acres (12 percent) of the Peace River watershed. As described previously, this basin and the Peace River at Bartow basin are the only basins with a large urban land use component.

3.10.1 Hydrologic Features

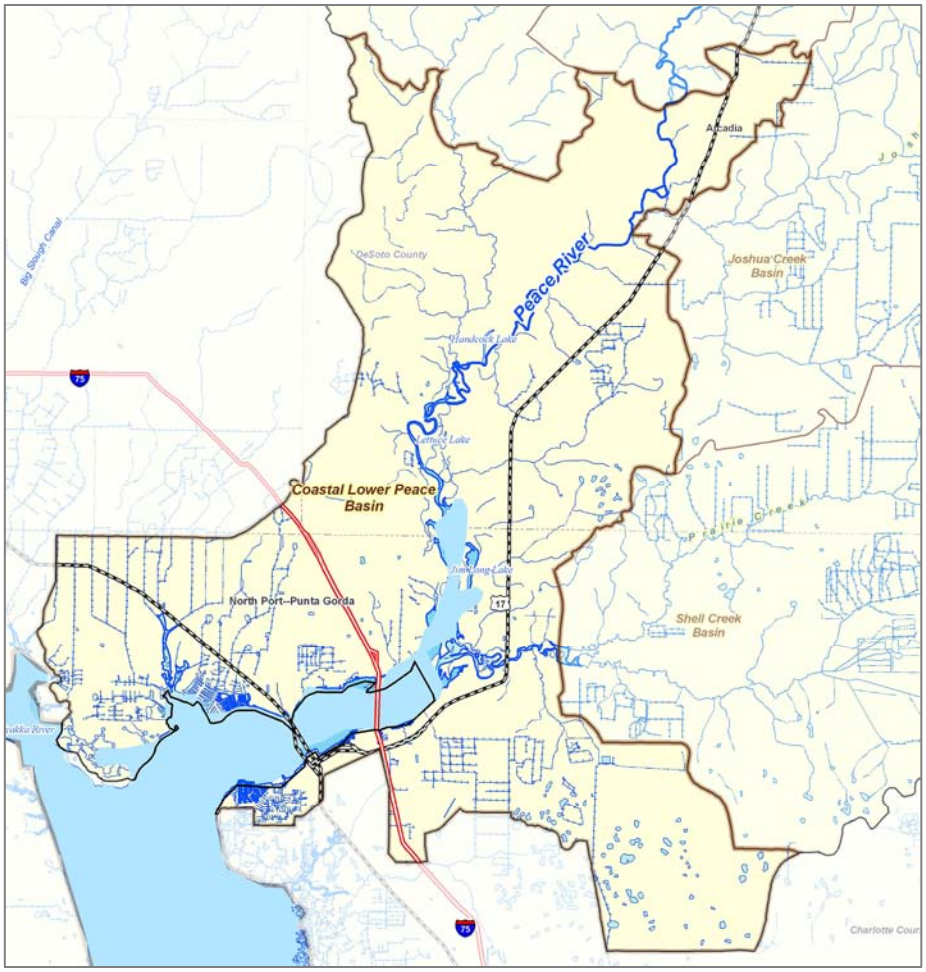
This basin is bisected by the Peace River while Horse, Joshua, Prairie, and Shell Creeks drain the eastern and north-central parts of the area. The basin is primarily an area of upward flow potential except in the southeastern part of DeSoto County. Areas of discharge from the Upper Floridan aquifer occur in the river valleys and in areas of low topographic relief. In river valleys, upward discharge is the result of decreased heads in the shallower aquifers.

This Coastal Lower Peace River basin is bisected by the Peace River and Horse, Joshua, Prairie, and Shell Creeks drain the eastern and north-central parts of the study area.

The regional ground water system underlying the basin consists of a sequence of aquifers and confining units, each containing discrete zones of varying permeabilities. The principal hydrogeologic units that underlie the basin are the surficial, intermediate, and the Upper Floridan aquifer. Aquifer heterogeneity results in commensurate variability in water quality and hydraulic properties.

The surficial aquifer is the uppermost aquifer and consists of relatively thin, unconsolidated sand, shell, and limestone and is unconfined. The thickness of the surficial aquifer ranges from 19 feet to 69 feet. Hydraulic properties are variable because of the large range of horizontal hydraulic conductivity for the lithologic units that make up the aquifer. The intermediate aquifer is a confined system, having as many as three permeable zones. It is composed of clastic sediments interbedded with carbonate rocks.

Figure 3.10.1. Location of the Lower Coastal Peace River at the Peace River Watershed



The Upper Floridan aquifer is the lowermost aquifer and consists of a thick, stratified sequence of limestone and dolomite. Use of the Upper Floridan aquifer is generally restricted because of poor water quality. Confining units separating permeable zones and aquifers in the study area consist of clays and low permeable carbonates.

3.10.2 Land Use

The Coastal Lower Peace River basin encompasses 164,571 acres (12 percent) of the Peace River watershed. As described previously, this basin and the Peace River at Bartow basin are the only basins with a large urban land use component. Like most of the watershed, the largest conversions to existing land uses occurred between the 1940s and1979 rather than post-1979.

In the 1940s, seven percent of the basin was in agriculture (11,641 acres) and included 4,756 acres of improved pasture and 6,885 acres of intense agriculture. Only two percent (3,222 acres) of the basin included urban land uses. Native upland habitats (64 percent) and wetlands (25 percent) made up the remaining 157,580 acres in the basin. Table 3.10.1 provides a summary of the land use changes and the detailed change analysis indicating specific changes from one land use to another are provided in *Appendix G*. Land use changes are presented in Figures 3.10.3, 3.10.4, and 3.10.5.

By 1979, acres of developed lands in the basin increased to over 68,000 acres and comprised 41 percent of the basin. The greatest change in the Coastal Lower Peace River basin was the conversion of 23,426 acres of native upland habitat to urban lands between the 1940s and 1979. Similarly, 21,629 acres of native upland habitats were converted to agricultural land uses during this time period. Conversions of wetlands to urban totaled 2,762 acres, while conversions of wetlands to improved pasture totaled 1,632 acres. About 45,079 acres (72 percent) of the native upland hardwoods lost between the 1940s and 1999 were converted to urban and agricultural land uses by 1979.

Over half of the Coastal Lower Peace River basin was developed by 1999 and approximately 27 percent (44,382 acres) was in urban land use. Conversions to urban land uses increased by 12,279 between 1979 and 1999 and were predominantly from native upland habitats (9,031 acres) and improved pasture (2,266 acres). Acres of agriculture increased little, from 36,349 to 39,673 acres in 1999, making up 24 percent of the land use in the basin. Shell and sand (not phosphate) mining accounted for 309 acres in the basin. Fourteen percent of the native upland habitat was converted to urban land uses and 12 percent to agriculture during this time period.

Acres of native upland habitat in the basin decreased from over 104,741 acres (64 percent) in the 1940s to about 42,132 acres (26 percent) in 1999 and represented the largest change in land use. Wetlands made up 41,197 acres (25 percent) of the basin in the 1940s and only 31,211 acres (19 percent) in 1999. These conversions were greatest before 1979.

Figure 3.10.2. Aerial Photograph of the Coastal Lower Peace River Basin

Table 3.10.1. Land Uses 1940s – 1999: Coastal Lower Peace River Basin

Land Use Designation	Time Period					
	1940s		1979		1999	
	Acres	Percent	Acres	Percent	Acres	Percent
Developed						
Mined Lands*	0	0	0	0	309	<1
Urban Land Use	3,222	2	31,793	19	44,072	27
Improved Pasture	4,756	3	25,706	16	25,263	15
Intense Agriculture	6,885	4	10,643	6	14,411	9
Subtotal	**14,864**	**9**	**68,142**	**41**	**84,055**	**51**
Undeveloped						
Wetlands	41,197	25	33,275	20	31,211	19
Native Upland Habitats	104,741	64	57,256	35	42,132	26
Subtotal	**145,938**	**89**	**90,531**	**55**	**73,342**	**45**
Water						
Streams and River Channels	3,021	2	4,578	3	4,697	3
Lakes and Open Water	58	<1	671	<1	1,807	1
Bays and Estuaries	692	<1	650	<1	671	<1
Subtotal	**3,770**	**2**	**5,899**	**4**	**7,174**	**4**
Total	**164,571**	**100**	**164,571**	**100**	**164,571**	**100**

* Includes reclaimed (totally and partially) lands

Figure 3.10.3. Land Uses: Lower Coastal Peace River Basin

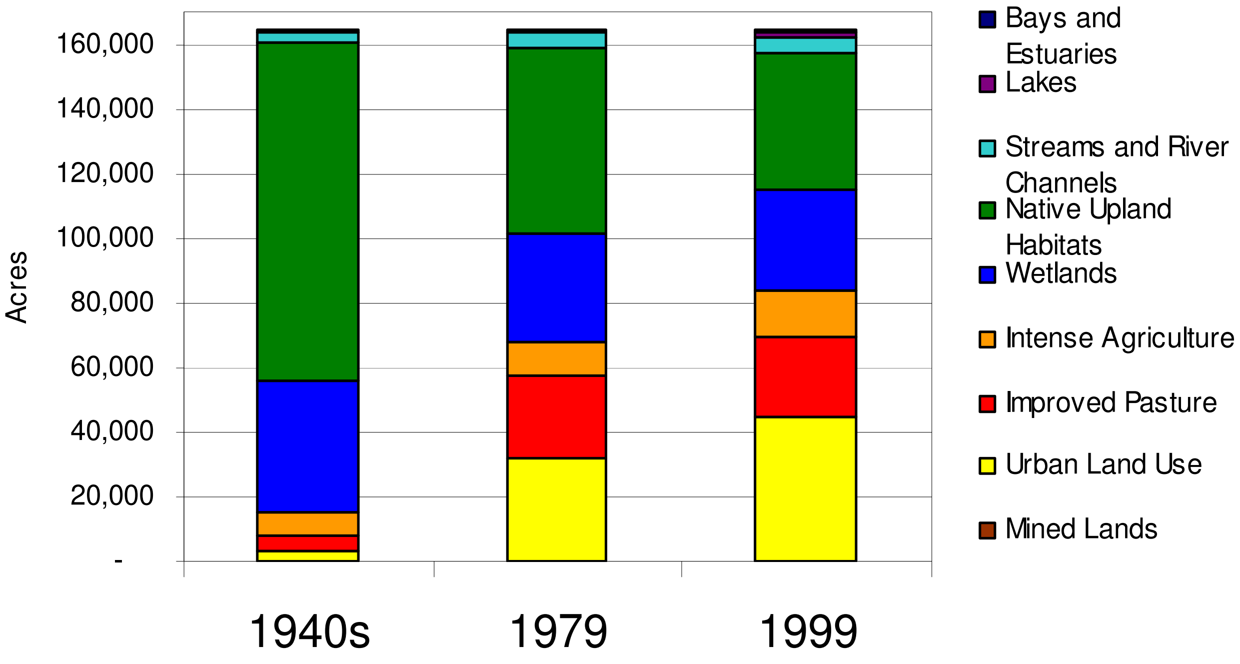


Figure 3.10.4. Changes in Undeveloped Land Use: Coastal Lower Peace River Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for “missing” data at the edge(s) of some basins)

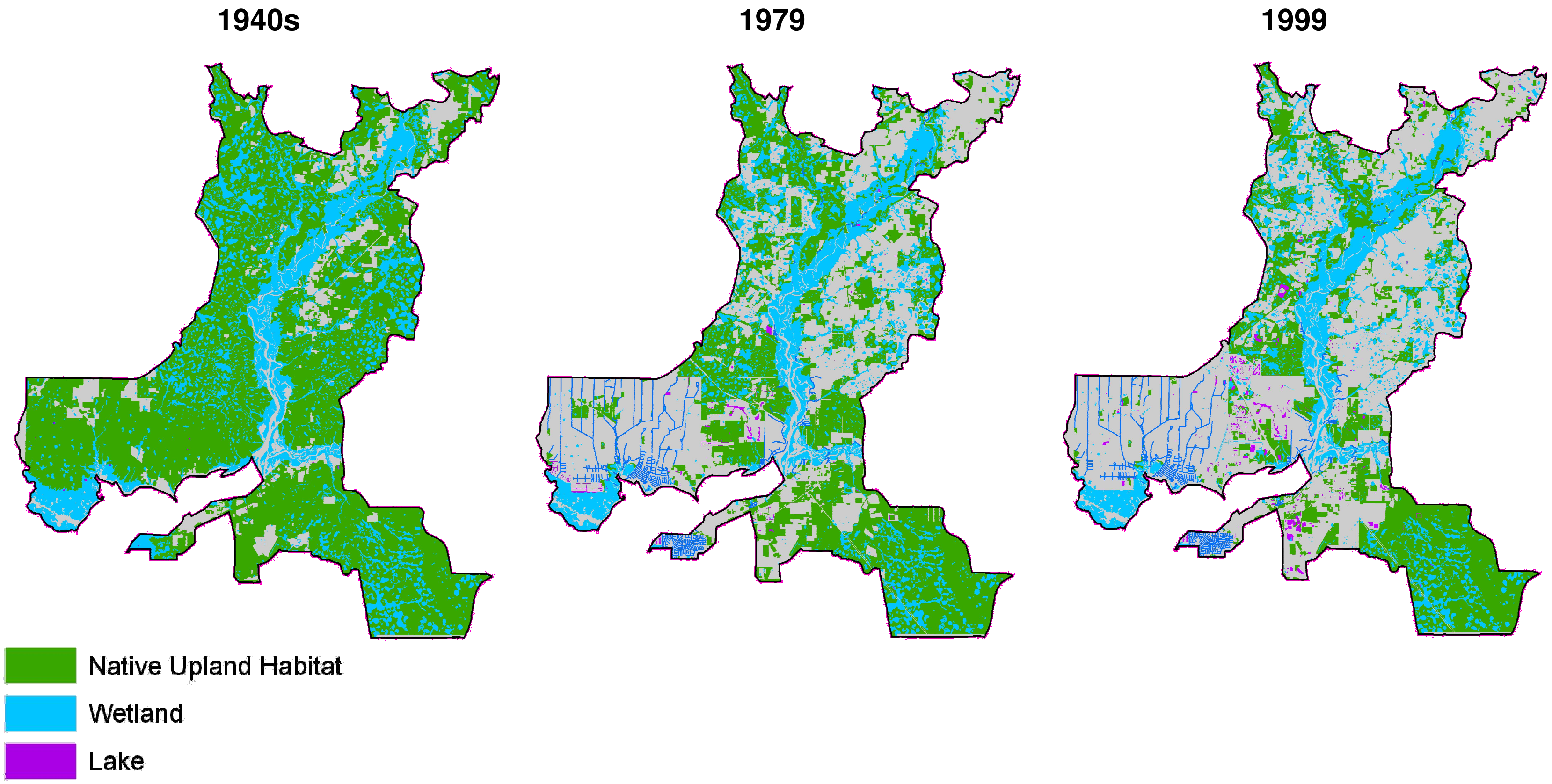
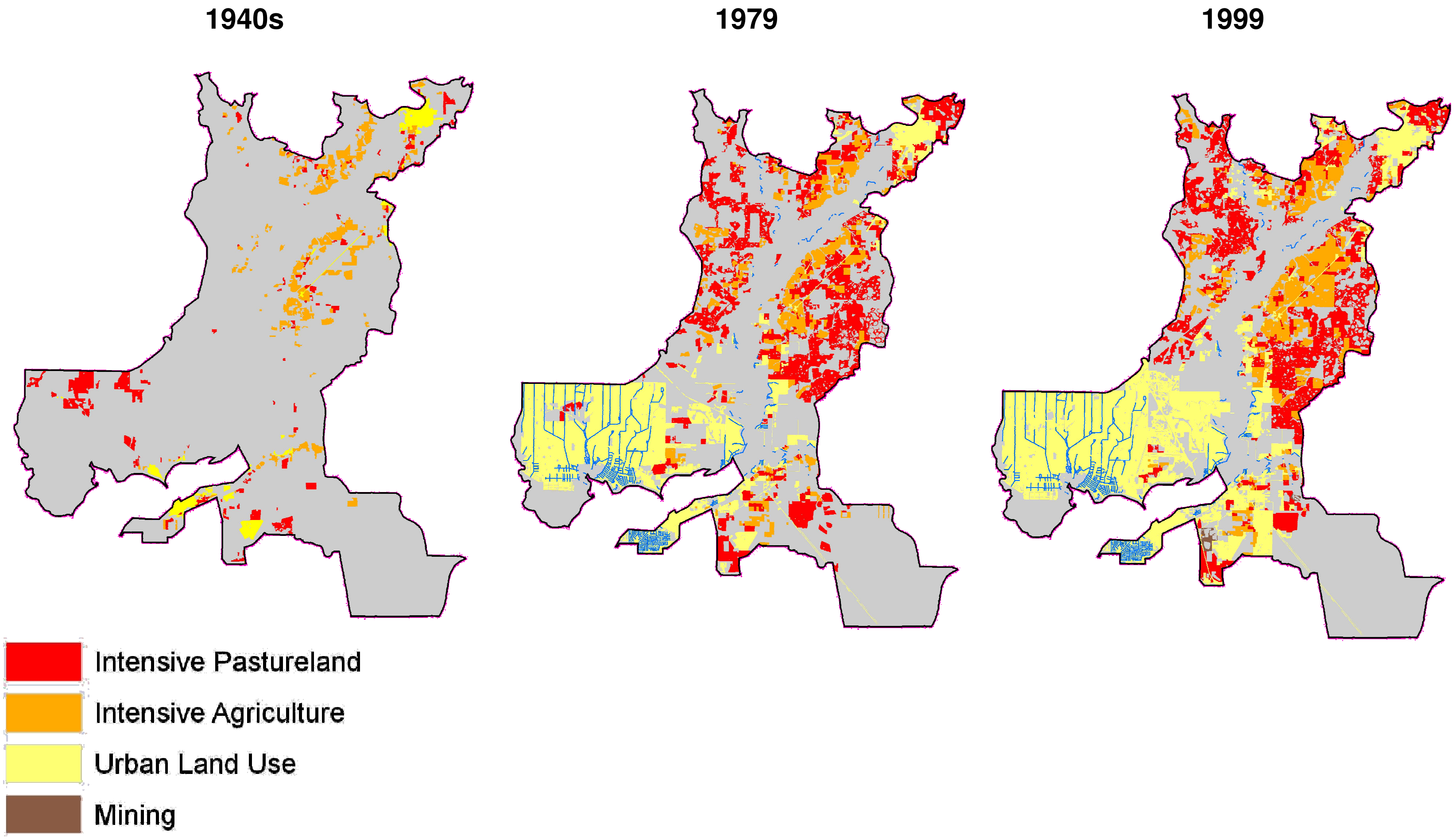


Figure 3.10.5 Changes in Developed Land Use: Coastal Lower Peace River Basin

(absence of 1940s aerial photography in some counties precluded land use comparisons between years and accounts for "missing" data at the edge(s) of some basins)



1940s

1979

1999

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4.0 Cumulative Impacts to the Peace River Watershed

This comprehensive analysis of the cumulative impacts to the Peace River watershed involves a comparison of land uses, hydrology, and water quality among individual basins in the watershed. To accomplish this, historic changes and patterns among specific stressors (agriculture, urbanization, phosphate mining, and rainfall variability) were examined in the context of hydrology, water quality, and natural systems (measured as undeveloped land uses) for the nine watershed basins. These analyses are presented in the following three sections:

- Hydrology
- Water Quality
- Natural Systems

The primary objectives were to differentiate between anthropogenic and natural causes of variability and quantify the relative effects of the anthropogenic stressors. Relative impacts of stressors on hydrology, water quality, and natural habitats are presented here and summarized in Section 4.4. Importantly, natural habitats include native upland habitats and wetlands and are quantified based on land use, as are phosphate mining, agriculture, and urbanization.

4.1 Hydrology

Analysis of impacts to hydrology in the Peace River watershed included rainfall, surface water flows, ground water, and water budget analyses. Trends in the watershed and among basins for each of these indicators are presented in the following sections.

4.1.1 Rainfall

Long-term rainfall patterns are associated with changes in stream flows in the watershed. Time series analyses and total annual rainfall were used to evaluate these impacts.

4.1.1.1 Time Series Analyses

Historical data from six rainfall monitoring stations in the Peace River watershed were analyzed to assess the potential presence of long-term rainfall patterns and evaluate identified patterns and/or seasonal changes in the context of the Atlantic Multidecadal Oscillation (AMO). Monthly and annual total rainfall values were analyzed for each of the six Peace River watershed rainfall gages using several alternative methods. Conclusions based on the results of the time series rainfall data analyses are summarized below.

- Long-term total monthly rainfall patterns were similar among all of the selected rainfall gages.

- The variability in total monthly rainfall was sufficient to obscure any small temporal changes that may have occurred, and there were no indications of any consistent larger temporal changes (or patterns) when the long-term rainfall data were analyzed on a monthly basis.

- Results of the analyses suggest that long-term total monthly rainfall at the more coastal Punta Gorda gage has been slight greater than that at the more interior Peace River watershed basin gages.

- In comparison, when the long-term rainfall data are viewed as annual totals, the data clearly showed both increased variations among the watershed gages and greater indications of both historical wetter and drier intervals. Calculated five-year moving averages, used to further reduce short-term background "noise", clearly show a history of longer wet and dry intervals over the period-of-record.

- Long-term annual rainfall averaged for the four gages at Lakeland, Bartow, Wauchula, and Arcadia indicated rainfall levels were slightly higher prior to the mid-1960s when compared with the period following the mid-1960s.

> *Rainfall levels were slightly higher prior to the mid-1960s when compared with the period following the mid-1960s.*

4.1.1.2 Wet Season and Dry Season Total Annual Rainfall

Possible long-term seasonal differences in rainfall patterns were evaluated using time series procedures similar to those applied (above) to annual rainfall. Time series plots and statistically smoothed five-year moving averages were used to evaluate potential changes in long-term patterns of total rainfall over both the four month wet season (June-September) and the eight drier months (January-May and October-December). The terms wet season and dry season were applied relative to the long-term annual average hydrograph for southwest Florida. The four month summer wet season, on average, accounts for approximately 59 percent of the 52 inches of total average annual precipitation. The typical summer wet season is characterized by rainfall patterns that are influenced by frequent, localized, convective thunderstorms and periodic, widespread, heavy rains associated with infrequent tropical cyclones. Over the remainder of the year, rainfall generally occurs as frontal systems moving down and across the area from the northwest. However, high rainfall El Niño events periodically occur during the winter/spring dry months resulting in seasonally atypical high flows throughout the watershed. Strong El Niño years are often subsequently followed by La Niña events, which are characterized by much lower than usual rainfall over extended periods (Coley and Waylen 2006). Summary results of the seasonal analyses of long-term rainfall patterns are presented below.

- Annual average wet season (June-September) rainfall in the Peace River watershed was, in general, slightly higher during the 1930s through the mid-1960s when compared with the interval from the late 1960s through the early 1990s.

- No similar long-term patterns were apparent at any of the selected monitoring stations with regard to dry season (January-May and October-December) rainfall, although periodic high annual totals were observed corresponding to El Niño events.

> *Annual average wet season rainfall in the Peace River watershed was, in general, slightly higher during the 1930s through the mid-1960s when compared with the interval from the late 1960s through the early 1990s. No similar long-term pattern was apparent at any of the selected monitoring stations with regard to dry season rainfall, although periodic high annual totals were observed corresponding to El Niño events.*

A series of graphical and statistical methods were used to assess whether patterns in surface water flow (see below) that appear consistent with the AMO theory were also apparent in Peace River watershed rainfall patterns. The primary factor affecting flow was rainfall (*Appendix H – Water Budgets*), with flows integrating rainfall across watershed, both spatially and temporally. A number of sequential relatively wet or dry years often influence subsequent monthly and annual flows over an extended period. Small temporal changes in rainfall can be more difficult to distinguish, since flow measurements from fixed stations are highly variable and do not reflect the spatial or temporal integration inherent in corresponding basin flow data.

Analyses (*Appendix D – Changes and Trends in Hydrology*) indicated that flows in the Peace River watershed were generally higher during the 1930-1960 time period, then declined through the 1960s and early 1970s, and have generally increased since the mid-1990s. Monthly rainfall data were compared between three AMO periods corresponding with the warmer wet phase prior to 1969, the cooler dry interval between 1969 and 1994, and the recent warmer wet phase since 1995. Monthly total rainfall, grouped by the three AMO periods, was analyzed to evaluate variability in annual rainfall. Comparisons of rainfall data among gages in the Peace River watershed indicate patterns consistent with the slightly higher summer rainfall described for the warmer AMO intervals. Notably, these analyses indicated that during the two warmer AMO phases, rainfall was generally higher at the beginning and end of the four month summer wet season.

4.1.2 Surface Water Flows

4.1.2.1 Overview

The five largest basins in the Peace River watershed are the Peace River at Bartow, Peace River at Zolfo Springs, Charlie Creek, Shell Creek, and Coastal Lower Peace. Each of these basins makes up between 12 and 17 percent of the watershed, and combined, they comprise 70 percent of the watershed area. The remaining four basins are Peace River at Arcadia, Payne Creek, Joshua Creek, and Horse Creek, make up between six and nine percent of the watershed. Comparisons of land use types and between the 1940s, 1979, and 1999 (see *Chapter 3*) indicate the degree to which the watershed has been previously modified. These modifications have primarily been the result of expansions of more intense agriculture, urbanization, and phosphate mining activities. These landform changes can affect both surface water runoff and infiltration rates.

Extensive areas of the Peace River at Bartow, Peace River at Zolfo Springs, and Payne Creek basins have been altered by phosphate mining activities. Mining activities have altered natural drainage patterns and, prior to improved mining operations, resulted in lowered ground water levels (Basso 2003, Lewelling and Wylie 1993, Lewelling *et al.*1998, URS 2005).

- Use of ground water by agriculture and phosphate mining operations was estimated to be 22 million gallons per day (mgd) in the early 1930s (Peek 1951). By 1960, ground water use attributable to mining activities had increased to approximately 200 mgd and accounted for 80 percent of the ground water use in Polk County (Stewart 1966). Resulting declines in water levels in the Upper Floridan aquifer reduced the potentiometeric surface enough that flows from Kissengen Spring were reduced to intermittent in the early 1950s, and the spring ceased flowing by 1960 (Basso 2003).

> *The early loss of base flows in the upper reaches of the Peace River in Polk County reflected historic ground water reductions predominantly associated with mining withdrawals.*

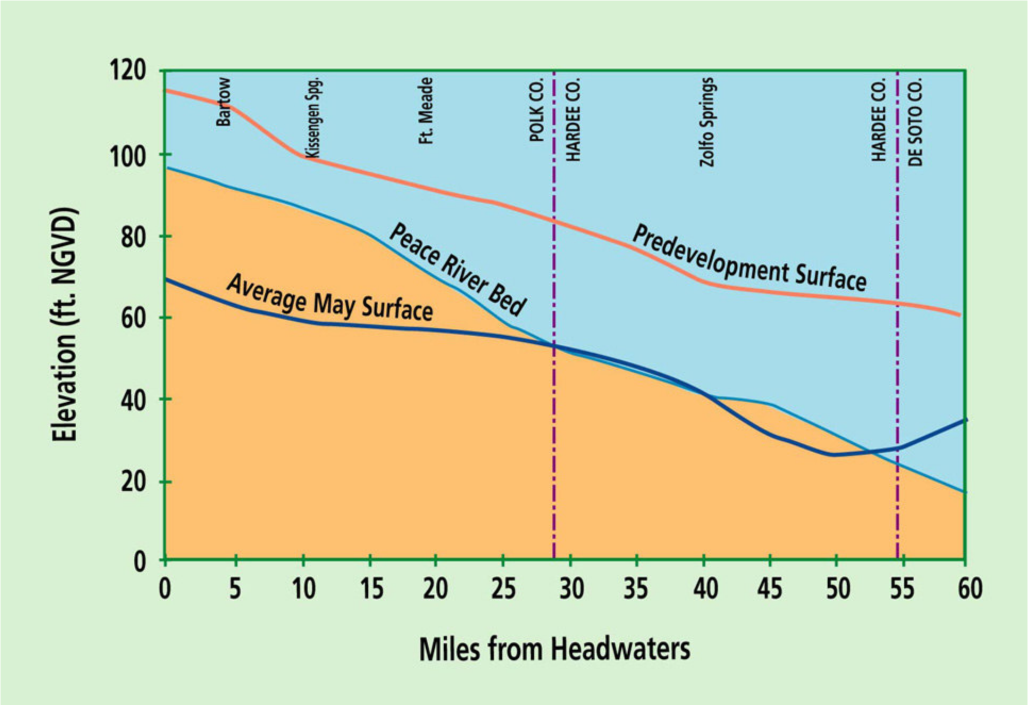
- This early loss of base flows in the upper reaches of the Peace River in Polk County reflected historic ground water level reductions predominantly associated with mining withdrawals (Hammett 1990) from the intermediate and the Upper Floridan aquifer systems.

- The cessation of spring flows in the upper watershed was subsequently compounded by loss of flows from the riverbed via sinkholes and seepage to the underlying aquifer. Estimated predevelopment and current dry season (May) potentiometeric surfaces relative to the bottom elevation of the Peace River from Polk County downstream to upper DeSoto County are presented in Figure 4.1.2.1. Historically, the potentiometeric surface was above the bottom of the river and water flowed from springs and karst geologic formations in the upper river floodplain into the river, supporting dry season base flow. Due to anthropogenic ground water withdrawals for agriculture, phosphate mining, and urban development, the potentiometeric surface of the Upper Floridan is now below the bottom elevation of the river and water often flows into these same karst formations during dry, low flow conditions.

- In some mined and reclaimed areas, surface waters that historically flowed to the river are diverted or seasonally impounded, resulting in disconnected surface water features.

- Surface flows in some areas may also be altered subsequent to phosphate mining due to increased recharge to the aquifer, as rainwater readily infiltrates the resulting disturbed soil structure, following mining of the upper confining layers associated with the phosphate matrix.

Figure 4.1.2.1. Effects of Changes in the Upper Floridan Potentiometeric Surface (SWFWMD based on USGS data)



- Phosphate mining also results in other hydrologic alterations from natural surface drainage features to a modified topography that includes clay settling areas and reclaimed water conveyances. Along the Peace River between Bartow and Bowling Green, many natural surface water drainage features have been replaced by stormwater outfalls and reclaimed stream channels following mining.

- As phosphate mining and agriculture expanded in the upper watershed, total ground water withdrawals in Polk County peaked slightly above 400 mgd in the mid-1970s (Basso 2003). The phosphate industry has significantly reduced its ground water use since then due to water conservation and greater reliance on the capture of surface water. However, other anthropogenic uses have expanded and ground water consumption in Polk County in 1999 was an estimated 274 mgd (Basso 2003).

The area of the watershed south of the Peace River at Bartow, Peace River at Zolfo Springs, and Payne Creek basins have also experienced extensive land use and hydrologic alterations since the 1940s reference period. These changes are reflected in the cumulative loss of wetland and native upland habitats as agriculture in the southern basins progressively changed from predominately unimproved pasture to improved pasture, and then to increasing areas of more intense farming such as citrus and row crops. These progressions towards more intense agricultural land uses were associated with commensurate increases in ground water use (*Appendix H – Water Budgets*).

- Supplemented base flows have been reported for portions of the Peace River. Annual ninety percent exceedance flows (flows that are exceeded 90 percent of the year) from 1951 to 1996 (Flannery and Barcelo 1998) indicate that, for Joshua Creek in particular, "…agricultural irrigation waters pumped from the Floridan aquifer supplement the surficial aquifer resulting in greater base low and runoff."

- The 2002 *Estimated Water Use Report* (SWFWMD 2002) indicates that agricultural ground water withdrawals are more than ten times that of surface water withdrawals. Consequently, most hydrologic models used for the Peace River watershed indicate that agricultural land uses increase hydrologic yields due to increased ground water use for irrigation.

- Based on hydrologic model results (*Chapter 2*), a conversion from forested uplands to commercial land use would result in the largest proportional increase in surface water runoff. However, conversions to row crops and groves from forested uplands would result in the second and third largest proportional increases in runoff, respectively.

The Peace River is also used as a regional public water supply source. The Peace River / Manasota Regional Water Supply Authority (PRMRWSA) Peace River Treatment Facility is located adjacent to a partially connected oxbow along the tidal Peace River in southwest DeSoto County. Although the facility has only been operated by the PRMRWSA since 1991, it began operations in 1980 under a SWFWMD consumptive use permit issued to General Development Utilities. The facility presently has the capacity to treat and supply up to 24 mgd, which is equivalent to withdrawals from the river of 37.2 cubic feet per second (cfs).

The existing raw (untreated) water diversion station has four pumps with a combined maximum capacity of 44 mgd (68.0 cfs). During periods of high river flow, untreated water is stored in an off-stream reservoir and excess treated water is stored in 21 aquifer storage/recovery (ASR) wells. Conversely, when water is unavailable from the Peace River due to the established minimum 130 cfs cutoff (as measured at the upstream USGS Peace River at Arcadia gage), water is pumped from the raw water reservoir to the facility for treatment and/or previously treated water can be recovered from the ASR system to meet public water supply demands in the service area. Additional expansions of this regional water supply facility are currently underway and more are planned for the future.

4.1.2.2 Long-term Changes in Watershed Flows

Period-of-record data for each of the 14 USGS watershed flow gages were evaluated for statistically significant trends over time using nonparametric Seasonal Kendall Tau tests. Trend tests were run for each of 10 different monthly flow statistical metrics, ranging from the maximum to the minimum monthly flow over the period-of-record for each stream flow gage. The results are summarized below.

- In the northern portion of the watershed, declines in flows were statistically significant at the Peace River at Bartow (since 1940) and Peace River at Zolfo Springs (since 1934) gaging stations for each of the calculated monthly percentiles. These stations are located on the main river channel in the upper reaches of the watershed and have the longest periods-of-record.

- In the southern portion of the watershed, by comparison, flows have increased over their periods-of-record (which are of shorter duration than the northern gages). Shell Creek flow data indicate statistically significant increases in the lowest flow percentiles (base flows), while there have been increasing trends in Prairie Creek at all percentiles between the monthly minimum and median values, and all but the very highest percentiles of flow at the Joshua Creek gage have increased over time.

- The increased flows measured at the Joshua Creek gage are similar to those observed outside the Peace River watershed at both the Myakka River near Sarasota and Little Manatee River near Wimauma reference basin gages. Both of these basins have historically had anthropogenically augmented flows (Appendix D – *Changes and Trends in Hydrology*).

The interpretation of such trend comparisons among basins over different time intervals can only be general, since the results of trend analyses can differ significantly depending on the time intervals tested. An alternative approach was therefore applied to identify the time periods over which the trends occurred, and subsequently provide direct comparisons among the Peace River watershed basins. A series of Seasonal Kendall Tau trend test were run for each of the USGS gaging sites using standardized five-year intervals, such that the number of intervals tested for each gage differed depending on the length of the period-of-record for a particular gage. The Peace River at Zolfo Springs gage, for example, has a long record so trend tests were run in five-year intervals starting in 1935 (for example, 1935-2004, 1940-2004, 1945-2004). Since it usually requires six to eight years of monthly data to determine statistical significant trends in highly seasonal data, the last interval used for all gages was 1995-2004. In order to facilitate the comparisons among gages, trend tests were conducted for three selected monthly flow metrics (listed below).

- The low flow 90 Percentile, which is exceeded ninety percent of the time.
- The median flow Q50 Percentile, which is greater and less that half the monthly flows.
- The high flow Q10 Percentile, which is exceeded only ten percent of the time.

The results of these trend tests are presented and summarized for each of the watershed basins in *Chapter 3*, while the following provides an overview of similarities and differences in the observed flow trends among the basins.

- In general, the high degree of both seasonal and yearly variability in flows requires a lengthy record of monthly flow values to ascertain whether changes over time are statistically significant when correcting for serial correlations. Only low flow changes in Shell Creek were large enough to be statistically significantly over the 15 year interval 1990-2004.

- Low, median, and higher flows at the three Peace River gages in the main channel (Peace River at Bartow, Peace River at Zolfo Springs, and Peace River at Arcadia) show significant declines over longer time intervals beginning in the 1930s, 1940s and 1950s. However, there have not been any statistically significant changes in the tested flow percentiles since 1970 (35 years) in the main stem of the river.

> *Low, median, and high flows at three Peace River gages show significant declines over longer time intervals beginning in the 1930s, 1940s and 1950s. However, there have not been any statistically significant changes in the tested flow percentiles since 1970 (35 years) in the main stem of the river.*

- The patterns of declining flows at the two upper Peace River gages (Bartow and Zolfo Springs) are very similar to patterns identified at the reference basin Withlacoochee River at Croom gage (Figure 4.1.2.2). The pattern of declining annual flows observed from the mid-1960s to the early 1990s at the three USGS gages in the Peace River watershed was also mirrored by a similar declining pattern in the relatively unimpacted Withlacoochee River at Croom USGS basin. The bottom figure shows similar time series plots for the three agricultural dominated watershed tributary basins with long-term flow records. Annual flows in the Charlie Creek basin, which has had the least amount of anthropogenic changes since the 1940s, declined up to the early 1990s. In comparison, flows in both the Joshua and Horse Creek basins began increasing in the early 1980s. These increases reflect expanding agricultural ground water dry season discharges, and augmented base flow in these basins.

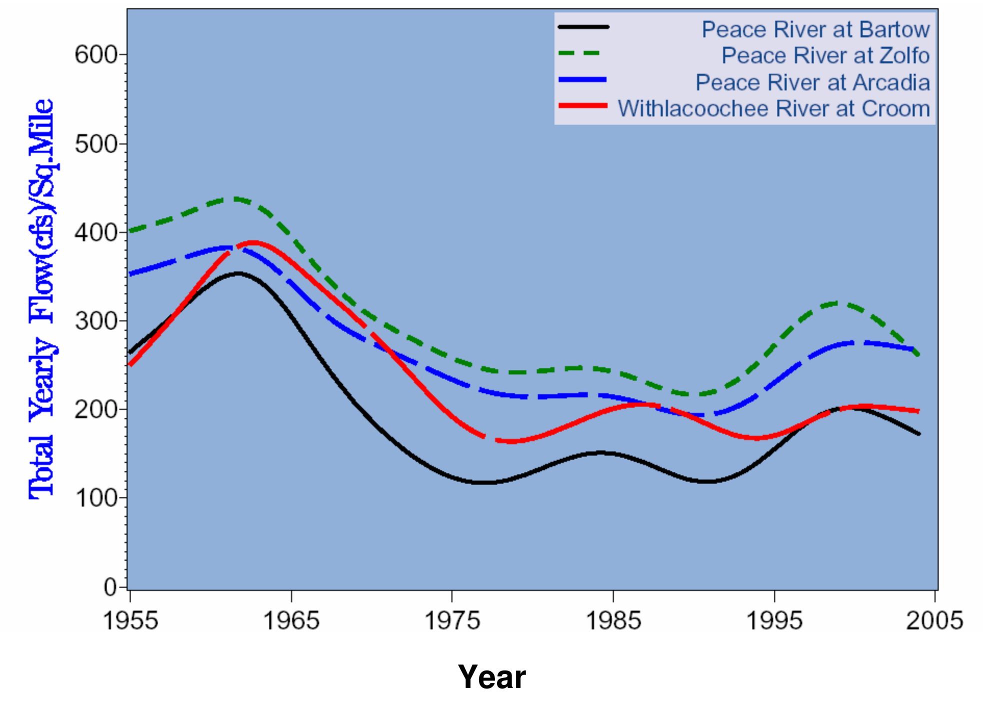
- Increased flows in Joshua Creek are conspicuous, since the increases occur over most of the gaged period-of-record for all three flow percentiles (low, median, and high).

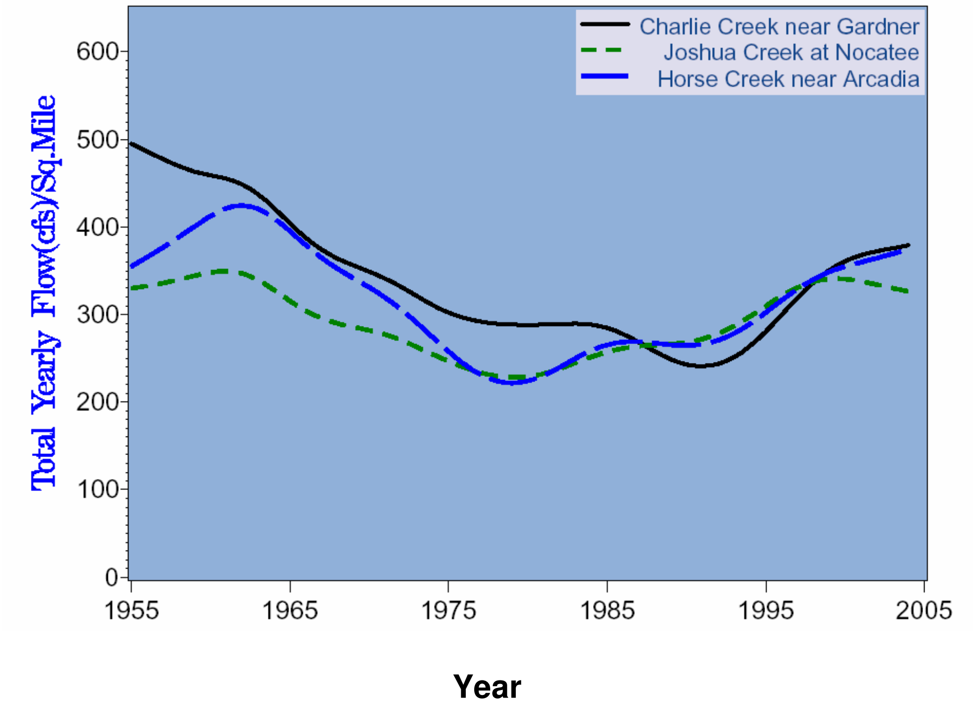
- Similar increases in Prairie Creek flows also stand out, although the gaged period-of-record is much shorter. These results indicate that increases in the Prairie Creek flows have occurred much more rapidly than in Joshua Creek since the 1980s.

- Horse Creek flows, by comparison, only show increases over the longer 1970-2004 and 1975-2004 periods, and do not show the same recent rapid increases apparent at the Prairie and Joshua Creek gages.

- Analysis results indicate that low (base) flows in Saddle Creek at Structure P-11 have also increased over time.

Figure 4.1.2.2. Comparisons of Five-Year Moving Average Total Annual Flows Standardized by Basin Area (Square Miles)



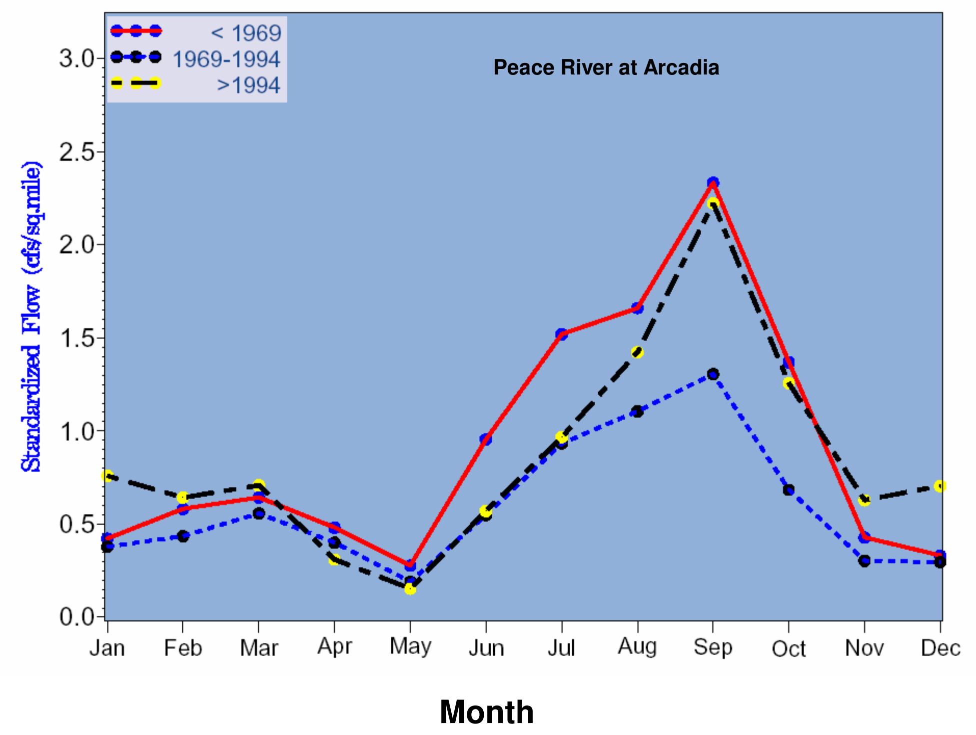


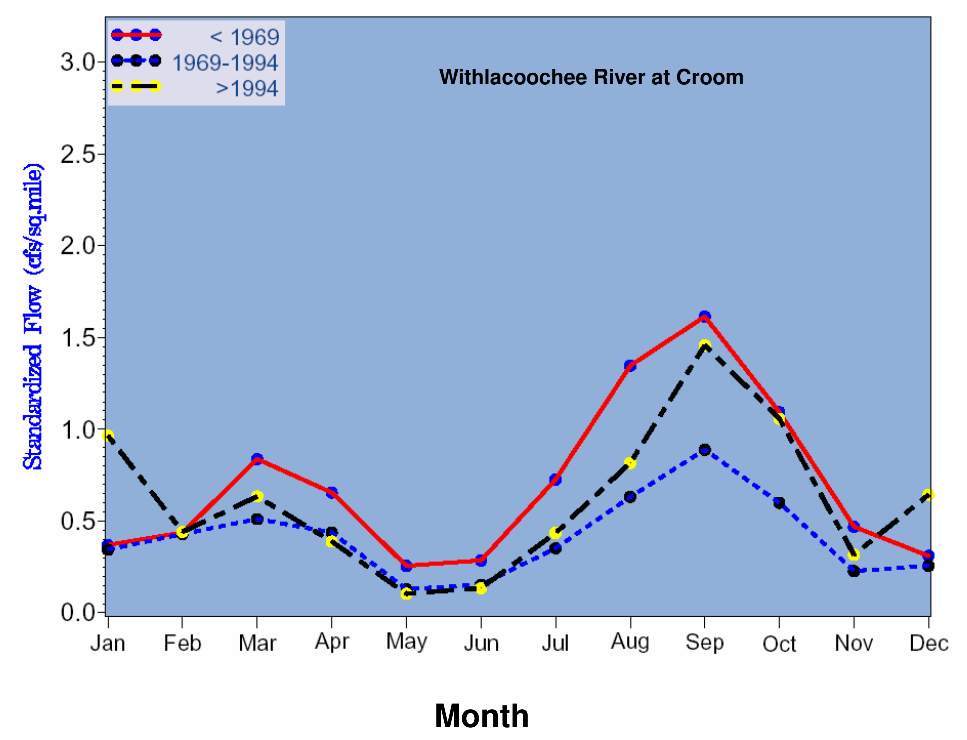
Several graphical and statistical methods of analysis were used to evaluate the influence of AMO events on patterns of higher flows that occurred during the 1930-1960 time interval, the declines in flows during the 1960s and early 1970s, and the subsequent signs of increasing flows in the mid-1990s. The three AMO periods evaluated were the warmer wet phase prior to 1969, the cooler dry interval between 1969 and 1994, and the recent warmer wet period since 1995. The differences in periods-of-record among gages made uniform comparisons among the three AMO phases impossible and limited portions of the analyses. In addition, differences in time intervals among the AMO events limited the robustness of some of the applied statistical tests.

Historical flow data for several USGS gages (Peace River at Bartow, Peace River at Zolfo Springs, Peace River at Arcadia, Charlie Creek, Joshua Creek, and Horse Creek basins) include both the warmer wet AMO phases prior to 1969 and the more recent period since 1995, as well as the cooler dry phase between 1969-1994. Summer wet season (June-September) flows were distinctly higher for the high (Q10), mean, and median (Q50) percentiles during the two warmer wet AMO periods when compared to the cooler dry 1969-1994 phase. There were no large consistent differences between the three AMO periods for the other nine months of the year. Monthly mean differences in flow (standardized by the size of the basin) among the three AMO periods are illustrated in Figure 4.1.2.3. As these figures indicate, summer wet season flows during the cooler 1969-2004 AMO period were noticeably lower than during the two warmer, preceding and following, wet AMO phases. Differences among the three AMO periods were not apparent in low (Q90) monthly summer flows.

Summer wet season flows were distinctly higher for high, mean and median flows during the two warmer AMO periods when compared to the cooler dry AMO phase.

Figure 4.1.2.3. Seasonal Differences In Mean Monthly Flow Relative To AMO Phases.





Historical changes in watershed flows have been evaluated by others (Hammett 1988 and 1990, Hickey 1998, and Basso 2002) by graphing cumulative annual flows over time (sometimes referred to as "single mass plots"). Changes in flow patterns can be evaluated based on changes in the slopes of lines graphically fitted to the cumulative annual flows over time. When "breaks" in the slopes of these fitted lines occur, the corresponding years (along the X-axis) have been interpreted as reflecting periods of natural or anthropogenic influences on annual average flows. Similarly, graphical analysis of cumulative annual totals has been used to detect natural variations in long-term rainfall patterns.

This same method has been used to evaluate the relationships between changes in rainfall and stream flows by graphing cumulative total annual gaged flows against cumulative annual measured basin rainfall (sometimes referred to as "double mass plots"). Breaks in the slopes of fitted lines can be interpreted as indicating changes in the relationships between rainfall and flow during different time intervals. In these plots, the data points represent consecutive years, which allow specific time periods to be associated with observed changes in the relationships between rainfall and flow.

Cumulative time series plots of rainfall and flow (single mass), and flow versus rainfall (double mass) were developed using data from five long-term USGS gages in the Peace River watershed and the reference Withlacoochee River at Croom basin gage. The Withlacoochee River at Croom basin was selected for comparison since it is located just north of the upper Peace River watershed, has no phosphate mining, and other development is comparatively limited. Moving downstream, the three gages along the main river channel (Peace River at Bartow, Zolfo Springs and Arcadia) progressively include increasing larger upstream watershed areas. Charlie Creek gaged flows correspond to the basin least likely to be affected by intense anthropogenic stressors, while the Joshua Creek basin has undergone extensive land use conversions to more intense agricultural practices. The resulting patterns depicted in these analyses (Appendix D – *Changes and Trends in Hydrology*) relative to changes in rainfall and flow, and their relationships are summarized below.

- Graphics of data from the three main channel USGS gages indicated similar long-term flow patterns.

- The plots of cumulative annual rainfall over time (single mass) indicate only slight variations (oscillation) in rainfall above and below the long-term fitted line, but suggest differences (or breaks) in slopes before the 1960s and again in the early 1990s.

- In comparison, cumulative time series plots of annual flows indicate distinct long-term patterns when compared to the overall regression line. These plots show marked breaks approximately in both 1960 and 1994.

- Plots of cumulative annual flow versus cumulative annual rainfall (double mass) indicate distinct changes in the relationships between rainfall and flow following two "breaks", one in the early 1960s and the other in the early 1990s.

- These breaks in the relationships between cumulative long-term river flow and rainfall generally coincide with the AMO wet and dry southwest Florida rainfall periods (Section 2.1.4.2).

- Although evident in data from all three main channel Peace River USGS stations, the breaks in cumulative flows and cumulative rainfall relationships indicated larger disparities farther upstream. These differences probably reflect differences in watershed size and the greater influence of anthropogenic impacts farther upstream.

- The breaks shown in the plots of both the cumulative flows over time, and cumulative flow versus cumulative rainfall for the Charlie Creek and Withlacoochee River at Croom basins were very similar to those observed for the Peace River gages.

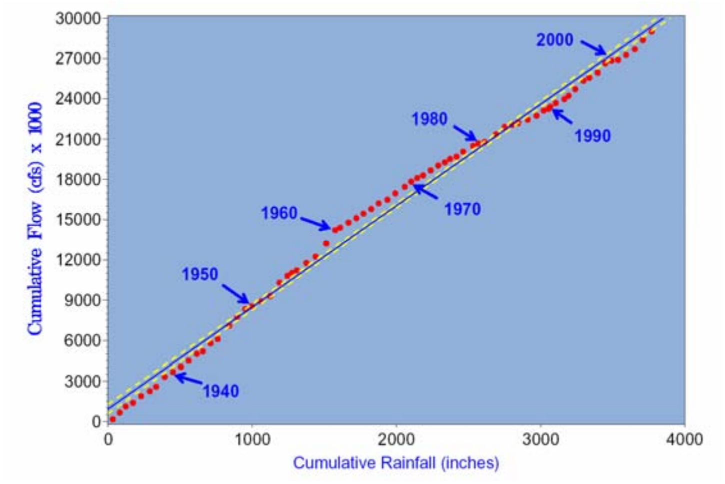
- In contrast with the other basins, the more recent break in these same plots for Joshua Creek occurred in the late 1970s to early 1980s rather than around 1994. As previously discussed, land use in the Joshua Creek watershed has shifted from generally undeveloped to more intense agriculture and base flows have increased significantly due to increasing ground water discharges.

- Most of the variation in annual total flow measured at the Peace River at Arcadia gage coincides with similar long-term changes at the reference Withlacoochee River at Croom USGS gaging station. This suggests that most of the variation in total annual flow at these gages is due to natural long-term variations in rainfall in southwest Florida (Kelly 2004). As previously described, the Withlacoochee River at Croom gage was selected for comparison because it has relatively limited anthropogenic influences.

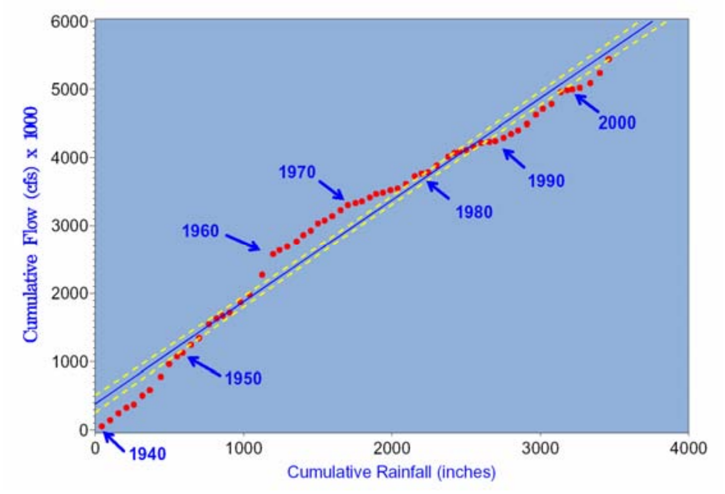
- Similarly, most of the long-term variations in total annual flow measured at the Peace River at Zolfo Springs USGS gage were analogous to variation at the Withlacoochee River at Croom (Figure 4.1.2.4).

- In contrast, comparisons of annual total cumulative flows at the Peace River at Bartow and the Withlacoochee River at Croom indicate breaks in the flow relationships around 1963 and again around 1990. The timing of these apparent “breaks” does not coincide with any apparent large scale anthropogenic changes in the Peace River at Bartow basin that could account for the change in annual total flows. However, these two changes in flow relationships do coincide roughly with the identified AMO events. The changes between the two basins may reflect differences in rainfall/flow interactions between basins with and without substantial impacted natural base flow (Figure 4.1.2.4).

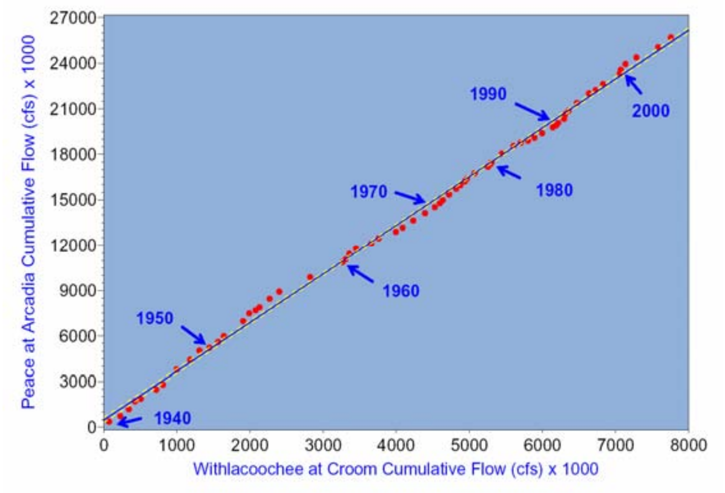
Figure 4.1.2.4. Comparisons of Rainfall Versus Flow at Bartow and Arcadia and Long-Term Flows in the Peace River and Withlacoochee Watersheds



Rainfall versus Peace River at Arcadia Flow (1932-2004)



Rainfall versus Peace River Flow at Bartow (1940-2004)



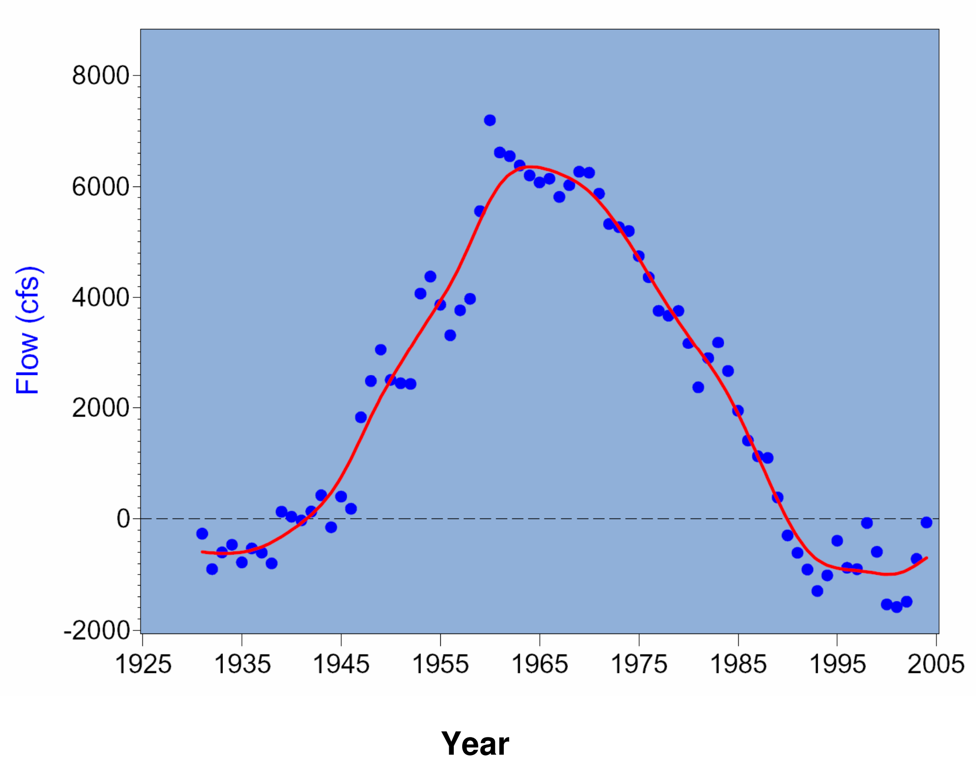
Peace River at Arcadia versus Withlacoochee at Croom flow (1940-2004)

In the upper portion of the Peace River watershed, base flows along the main river channel have declined due to historic ground water withdrawals and subsequent reductions in the potentiometric surface, in turn resulting in cessation of spring flows and reduced ground water contributions during the dry season. The base flow in Payne Creek, by comparison, is augmented, by both agricultural and National Pollutant Discharge Elimination System (NPDES) permitted ground water discharges. A number of the gaged creeks in the southern watershed basins reflect increased base flow resulting from agricultural ground water discharges.

> *Most of the variation in annual total flow at the Peace River at Arcadia gage coincides with similar long-term flow changes at the Withlacoochee River at Croom. This suggests that most of the variation in total annual flow is due to natural long-term variations in rainfall in southwest Florida.*

Long-term changes in high flows throughout the watershed correspond with AMO theory that describes natural climate cycles, or phases, that can persist over decades. Warmer phases are associated with the periods 1869-1893, 1926-1969, and to date since 1995, while cooler phases predominated during 1894-1925 and 1970-94 (Landsea *et al.* 1999). A graph of the cumulative yearly differences in annual total flows for the Peace River at Arcadia USGS gage relative to the long-term average (1932-2003) of 1084 cfs is presented in Figure 4.1.2.5 and demonstrates the long-term flow patterns in the Peace River. The graph illustrates that during above average river flows, the cumulative total flow increases, while during periods when flows are below the long-term average, the cumulative total declines. Long-term data from the Peace River at Arcadia gage indicate that from the mid-1930s to approximately 1960, total annual flows were generally above the long-term average, while between 1960 and 1994 annual flows were generally below the long-term average. Over the past decade, annual flows have fluctuated above and below the long-term average of 1,084 cfs.

Figure 4.1.2.5. Pattern of Cumulative Difference from Long-Term Average Peace River at Arcadia Flow



4.1.3 Ground Water

The Peace River watershed includes three separate physiographic regions, the boundaries of which correspond geologically with a series of paleoshorelines. The headwaters region of the Peace River is within the physiographic region of the Polk Upland province, which is characterized by numerous lakes and regionally functions as a significant aquifer recharge area. The upper Peace River watershed then transitions from an upland, internally drained lake district to a poorly drained upland region that extends south from near Bartow into central Hardee County (Lewelling *et al.* 1998, and Basso 2003). A distinctive geologic shoreline toward the southern end of Hardee County marks the end of the Polk Uplands. South from the Polk Uplands toward Charlotte Harbor, the Peace River flows through both the DeSoto Plain and the Gulf Coastal Lowlands (White 1970). The underlying geology of the Peace River watershed includes three primary aquifer systems (Barr 1996, Lewelling *et al.* 1998, Basso 2003, and URS 2006), briefly described here.

- The upper surficial aquifer system, the thickness of which extends over tens of feet, primarily includes Holocene to Pliocene age unconsolidated quartz sand, silt, and siliciclastic sediments.

- The deeper underlying Miocene age Hawthorn Group sediments form the intermediate aquifer system, which is comprised of a confining unit composed of interbedded limestone, phosphatic clays, sandy and clayey units, as well as the water bearing Arcadia formation. The thickness of the intermediate aquifer system extends over 450 feet deep in upper DeSoto

County and significantly thins toward Polk County. At the top of the watershed, water bearing units in the thin intermediate layer are nearly absent. The low hydraulic conductivity of the intermediate aquifer system restricts the movement of water between the overlying surficial aquifer system and underlying Upper Floridan aquifer system. However, the karst formations in the river bed of the upper river reach between Bartow and Fort Meade are an exception and surface waters are connected with deeper underlying layers.

- Structurally, the Upper Floridan aquifer system is comprised of Eocene/Paleocene Suwannee and Ocala limestone formations, as well as portions of the dolomite Avon Park formation. The Upper Floridan aquifer system underlying the Peace River watershed is generally comprised of a pair of permeable zones (Hickey 1982) separated by a semi-confining unit characterized by low permeable, fine-grained, chalky Ocala limestone. Water in the Upper Floridan aquifer generally becomes more mineralized as the depth of the system increases towards the southwest.

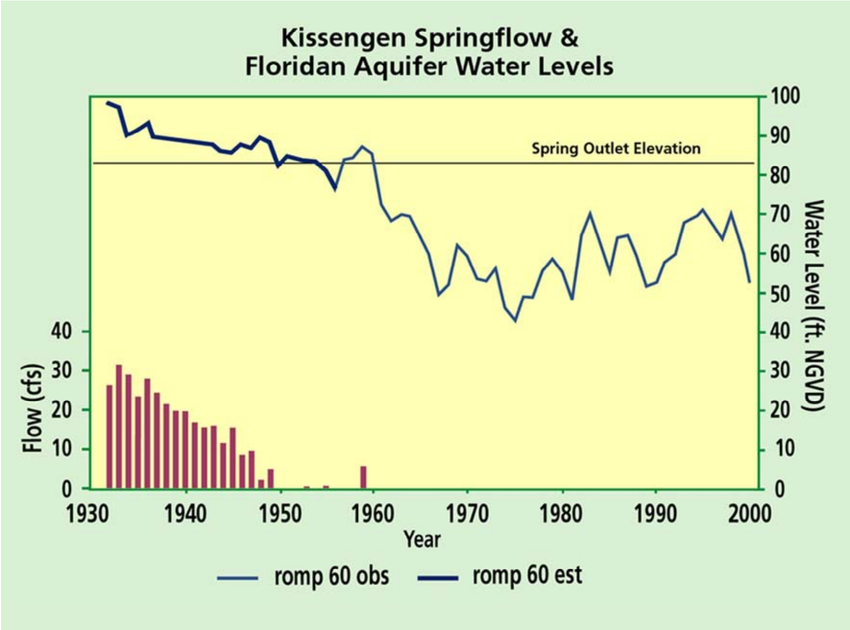
Basso (2003) provided a comprehensive overview and summary of available historical information and changes in ground water levels in the upper Peace River watershed, as well as the associated impacts of historical ground water withdrawals.

- Historical, surficial and intermediate aquifer ground water level information from Regional Observation Monitoring Program (ROMP) wells dating from the late 1970s (ROMP wells 59, 45, and 40) generally indicates that ground water levels have not progressively changed over the last 20 years.

- The availability of consistent, historical ground water level data is limited in the upper watershed. Regressions were therefore used to estimate historical Upper Floridan aquifer levels at ROMP wells 60, 59, and 45 back to the late 1940s. Predevelopment aquifer levels were an estimated 11 to 23 feet higher than the 1948 to 1960 average. Time series plots indicated a dramatic decline in Upper Floridan aquifer levels after 1960. Aquifer levels at the three ROMP sites continued to decline and reached historically low levels in the mid-1970s. However, Upper Floridan aquifer levels steadily increased by approximately 20 feet during the following several decades.

- These dramatic declines in water levels in Upper Floridan aquifer following 1960 essentially eliminated ground water discharges (base flows) to the upper Peace River from Kissengen spring and other spring formations in the upper watershed. The declines in estimated and observed historical ground water levels in the regional observation and monitoring program (ROMP) wells are presented in Figure 4.1.2.6. In this figure, Kissengen Spring flows declined, became intermittent flowing the early 1950s, and then ceased by 1960.

Figure 4.1.2.6. Historical Declines In Kissengen Spring Flows (SWFWMD, Basso 2003)



Available historical ground water level data were used to assess long-term changes in aquifer levels throughout the Peace River watershed (see *Appendix D – Changes and Trends in Hydrology*). Data sources included USGS and SWFWMD monitoring programs. The objective was to obtain historical, long-term data gathered as part of routine standardized monitoring programs with documented quality assurance protocols to avoid potential data discrepancies. Data were then divided into subsets based both on the number of observations and the length of record available from each monitoring location.

Using these criteria, 51 currently active monitoring wells with data dating back into the 1980s were selected (locations are mapped in the GIS map portfolio), and time series plots were developed for the period-of-record for each location. Estimated ground water withdrawals, by basin, and water use by County, are presented in Tables 4.1.3.1 and 4.1.3.2, respectively. General overviews of long-term ground water patterns indicated by the time series plots of ground water level presented by region (county) and aquifer are summarized below.

- **Charlotte County –** Ground water level data from the long-term monitoring sites in the southern portion of the Peace River watershed date back only to the 1970s and are limited to surficial and intermediate aquifer measurements. Values from ROMP 10 (surficial) and ROMP 11 (intermediate) wells exhibited sudden declines not apparent at the other sites.

- **DeSoto County –** Combined (intermediate and Upper Floridan) ground water level data from the Marshall Deep monitoring location indicate a long-term pattern of declining levels since the early 1960s. Smaller declines appear to date back to the 1970s and are evident from intermediate and Floridan data at ROMP 31. Aquifer levels at the other wells in the region have remained relatively stable over their periods-of-record, although influences of the 1999-2001 La Niña event are apparent at several wells.

- **Hardee County –** Intermediate and Floridan ground water levels at ROMP 30, and Floridan levels at ROMP 31, exhibit relatively large (10-25 feet) short-term variations, and general declines in water levels dating back to the beginning of monitoring at the end of the 1970s / early 1980s. Intermediate ground water level data at the Rowell Deep monitoring site date back to the 1960s and patterns indicate a long-term decline in water levels over the period-of-record.

- **Polk County –** Unlike the southern areas of the watershed, the periods-of-record for many of the monitoring wells in the upper Peace River watershed extend back to the early 1960s and even to the mid-1950s. No patterns of decline or increase are apparent in most of the monitoring wells with shorter records (ROMP wells 45, 57 and 59). However, long-term intermediate and Floridan monitoring well levels (Fort Green Springs and ROMP 60) generally indicate historic declines through the late 1960s and early 1970s followed by increases in water levels. Exceptions to these increases in water levels since the 1970s are apparent in long-term Floridan aquifer levels at both Loughman Deep and ROMP 40 locations, where levels have declined since the early 1980s. Again, the influence of the recent 1999-2001 La Niña event is apparent at many of the long-term monitoring sites in the upper watershed.

These comparisons indicate that, in recent decades, the aquifer levels have declined most significantly in the central and southern portions of the watershed. In contrast, ground water withdrawals for phosphate mining operations have been dramatically reduced since the 1970s due to conservation and capture of onsite stormwater, which has in turn led to a recovery of ground water levels in Polk County. However, much of the reduced ground water use by phosphate mining has been offset by increased ground water withdrawals for potable and agricultural purposes.

Table 4.1.3.1. Estimated Ground Water Withdrawal Volumes (mgd) in the Peace River Watershed

Basin	1941-1943	1976-1978	1989-1991	1997-1999
Peace River at River at Bartow	63	176	156	151
Peace River at River at Zolfo Springs	34	102	100	95
Peace River at River at Arcadia	7	30	37	40
Payne Creek	7	24	24	24
Charlie Creek	11	49	57	62
Horse Creek	6	27	34	37
Joshua Creek	9	27	33	36
Shell Creek	13	44	54	55
Coastal Lower Peace River	5	20	25	26

Table 4.1.3.2. Estimated Water Use by County (mgd) in the Peace River Watershed

County	Agriculture		Public and Domestic Supply	
	1998	1999	1998	1999
Charlotte	13.8	17.5	16.5	16.6
DeSoto	70.0	75.3	2.9	3.0
Hardee	60.4	63.2	2.3	2.2
Highlands	53.7	53.9	10.4	9.4
Polk	122.4	121.1	80.3	79.8
County	**Industry and Mining**		**Recreational/Aesthetic**	
	1998	**1999**	**1998**	**1999**
Charlotte	1.4	1.1	2.8	3.3
DeSoto	0.2	0.2	0.5	0.4
Hardee	0.5	4.1	0.2	0.2
Highlands	0.9	0.3	4.0	4.5
Polk	98.2	81.4	8.2	10.0

Source: SWFWMD Estimated Water Use 1998 to 2002 – Summary Report (2004)

4.1.4 Watershed Budget

The water budgets are useful for understanding the magnitude of, and relationships among, the water fluxes in the Peace River watershed and are best used in conjunction with time series data to identify and assess trends that are of interest. For example, changes in rainfall or stream flow over time that may be easily recognizable in a time series representation may be difficult to see based on water budget results alone. Inter-annual variability in a major water budget parameter, such as rainfall, is often greater than potential significant long-term changes. Therefore, when assessing cumulative hydrologic impacts, it is best to initially identify trends and then assess the impact of such trends on watershed functions using water budgets.

Water budgets can be used to quantify the relative hydrologic impacts of natural and anthropogenic changes. However, anthropogenic activities can only be identified if they are of sufficient magnitude to differentiate anthropogenic impacts from the natural variations, or "noise" in the data. Consequently, only relatively large anthropogenic effects are apparent from the water budgets developed for the Peace River watershed and these analyses may better characterize hydrologic responses among basins at the watershed level, but be inappropriate for assessing small basin- or site- specific conditions. As such, the water budget results should be interpreted with some degree of caution. The water budgets were based on simplified conceptual models of watershed functions intended to account for water fluxes at an order of magnitude scale. The water budget results are based on many parameters with a large amount of uncertainty, and anthropogenic effects were often obscured by variation in natural hydrologic functions such as rainfall and evapotranspiration.

Water budgets were prepared for eight basins in the Peace River watershed, for four representative time periods relative to available land use information: 1941-1943, 1976-1978, 1989-1991, and 1997-1999. The Lower Coastal Peace basin was excluded due to the absence of a gage in that basin. The goal of the water budget analysis was to quantify the volumetric flow rates of water in and out of each basin, and to the extent possible, assess the cumulative impacts over time.

- Rainfall was the largest component of the water budgets, and natural variation in rainfall rates was the most important factor in explaining the change in water budgets over time.

- Compared to the "early development" period of 1941-1943, rainfall declined in 1976-1979 and 1989-1991, but recovered during the 1997-1999 period.

- Corresponding to these long-term rainfall patterns, stream flow was lowest in the 1976-1979 and 1989-1991 periods, and increased again during the 1997-1999 period. When expressed per unit basin area (converted to inches per year), stream flow is the lowest in the basin above the Bartow gage, and the highest in the Payne Creek and Joshua Creek basins.

- After rainfall, evapotranspiration (ET) was the second largest component of the water budgets, with average ET being on the order of 37 inches per year.

- The impact of land use changes on ET was assessed via land use/land cover specific "crop coefficients".

- The water budget analysis indicates that the impact of land use changes on ET has been relatively small. Area-weighted crop coefficients have decreased in the upper portion of the Peace River watershed (above Zolfo Springs), but have remained stable elsewhere in the basin.

- The decline in crop coefficients and ET in the upper portion of the basin can be attributed to increased urban development. The estimated ET reduction in the watershed above Bartow from the early development period of 1941-1943 to the most recent assessment period of 1997-1999 was approximately three inches/year.

- While rainfall is the most important component of the water budget and the primary influence on mean stream flows, the subtle influence of human activities often manifests itself via the runoff and base flow components of stream flow at the basin level.

- Examples of human influences that are recognizable in the water budget analysis are briefly described below.

    - Reduced base flow in the upper Peace River has occurred as the combined result of declining potentiometric surfaces in Upper Floridan aquifer, the loss of storage due to declining lake levels in Saddle Creek and Peace Creek drainages, and increases in urbanization and associated increased runoff.

    - In contrast there have been increases in base flow in the tributary basins affected by agriculture. Stream base flow in Joshua Creek has approximately doubled since the late 1970s. Such increases can be attributed to agricultural irrigation being returned as stream flow that essentially represents a transfer from ground water to surface water. Irrigation water use is greatest during the dry winter and spring months, and thus augments natural base flow.

    - Increases in stream and base flow have also occurred in Payne Creek, which has undergone extensive phosphate mining. The exact hydrologic impacts and causal relationships from phosphate mining were difficult to assess at the scale of this water budget analysis, but stream flow data indicate that Payne Creek has higher standardized stream flows and base flow than other basins in the Peace River watershed. Ground water discharges associated with mining activities and agriculture are likely contributing factors to increases in stream flow.

- Hydrologic modeling with the EPA Stormwater Management Model (SWMM) was used to further analyze the relationship between land use change and runoff. The following three scenarios were evaluated:

    - Urban land uses having remained native uplands
    - Active phosphate mining areas having remained native uplands
    - Wetlands having not been drained and converted into improved pasture

- The SWMM runoff analysis suggested the following:

    - Urbanization has had the largest impact on runoff in the basin above Bartow and had a runoff value that was 23 percent higher than if currently urbanized areas were native uplands. Impacts in other basins (less urbanized) were much smaller.

- Without phosphate mining, runoff would be 10 percent higher in the Payne Creek basin.

- Conversion of wetlands to improved pasture has affected both dry season and wet season runoff. In the dry season, wetlands act as storage areas and the conversion to improved pasture increased runoff by up to 5 percent. During wet weather, the presence of wetlands would have increased runoff rates by about 11 percent.

4.2 Water Quality

Historically, water quality in the upper Peace River watershed has been affected by a number of anthropogenic activities. These have included point and nonpoint source discharges from phosphate mining and processing, point source municipal/industrial effluents, and nonpoint runoff from expanding urban and intense agricultural land uses. The two primary influences on water quality in the Peace River watershed have historically been attributed to: 1) nutrient inputs and the eutrophication of Lake Hancock and subsequent increased nitrogen loadings to the upper river; and 2) discharges to the river from phosphate mining and processing associated with extensive mining of large tracts of land in the upper basins (PBS&J 1999, Janicki Environmental 2003). More recently increases in ground water discharges from agricultural practices in the southern basins have resulted in increases in conductivity and associated water quality characteristics (SWFWMD 2004) and nitrogen levels (Janicki Environmental 2003) and have been associated with increased discharges of highly mineralized ground water and nonpoint source nutrient (nitrogen) loadings.

Until about the early 1990s, nutrient laden effluent from a number of industrial and municipal sources flowed directly into Lake Hancock, a hypereutrophic lake at the Peace River headwaters. It has been estimated that there are over 12,000 acre-feet of unconsolidated, deep organic muck currently covering the lake bottom. As a result, the water leaving Lake Hancock is typically characterized by: 1) very high concentrations of blue green algae, 2) high turbidity, and 3) elevated organic content that leads to high biological oxygen demand (BOD) and associated low dissolved oxygen concentrations. Champeau (1990) suggested that the degraded water quality of Lake Hancock influences both the diversity and abundance of fishes in the upper reaches of the Peace River. Champeau (1988) observed that degraded water quality is both more frequent and severe in the upstream reaches of the river toward Lake Hancock and suggested that lower flows from impacted tributaries in the middle/lower river might be responsible for the increases in fish species richness and diversity in the lower Peace River watershed. He hypothesized that the good water quality (lower nutrients, lower phytoplankton biomass, and more stable dissolved oxygen conditions) in these tributaries provides habitat for these species that is unavailable along the main stem of the Peace River.

Geologically, extensive regions of the Peace River watershed contain Miocene deposits rich in phosphate ore. During the late 1800s, large areas of the river bottom in the upper watershed were directly mined for phosphate ore, followed in the early 1900s by expanded strip mining over areas of the northern Peace River watershed. Much of the early phosphate strip mining occurred in the Hillsborough and Alafia River watersheds, and historically expanded into the upper Peace River watershed during the 1940s. Over time, phosphate mining has continued to move south as the ore reserves in the upper portion of the watershed were removed (*Appendix G* and GIS map portfolio). Degraded water quality and occasional catastrophic fish kills were associated with some phosphate mining areas following accidental discharges of materials from clay settling areas and mining operations (see *Appendix E*). However, increasingly strict environmental regulations implemented by state and federal governments in the late 1970s (see *Chapter 5 - Regulatory Effectiveness*) dramatically reduced both the occurrence and the severity of these events and significantly reduced the inputs of phosphorous rich waters directly into the upper Peace River. As a result, while dissolved inorganic phosphorus concentrations in the Peace River and upper Charlotte Harbor are naturally high relative to most other rivers and estuaries, peak levels have declined by as much as an order of magnitude since the early 1980s.

4.2.1 Time Series Comparisons of Water Quality among Basins

The following briefly describes some of the major water quality patterns apparent in the time series information summarized above in *Chapter 3* for each of the watershed basins, and presented in detail in *Appendix E – Changes and Trends in Water Quality*.

- Lake Hancock water quality has been characterized as "poor", based on the Florida Trophic State Index, since at least 1970, and water quality in the lake has been a concern as far back as the 1950s. The Florida Department of Environmental Protection (FDEP) has verified the impaired condition of the lake and levels of total nitrogen, total phosphorus, and biological oxygen demand all exceeded the State threshold screening values by considerable amounts.

- A large portion of the organic nitrogen exported from the lake is a result of nitrogen-fixation by high levels of blue-green algae concentrations.

- Instances of low dissolved oxygen concentrations are conspicuous in the upstream portions of the Peace River, and both the frequency and downstream extent of low dissolved oxygen levels increase as discharges from Lake Hancock increase. Flows from the lake via Saddle Creek are characteristically high in total suspended solids, total Kjeldahl nitrogen, total organic carbon, and chlorophyll *a*. The high chlorophyll concentrations (algae) and organic material associated with these discharges result in extreme fluctuations in dissolved oxygen levels in the upper Peace River. During periods of high rainfall, discharges from the lake increase, and the low dissolved oxygen conditions are exacerbated.

- Values for a number of other water quality parameters in the upper Peace River have improved noticeably since the 1960s and 1970s following implementation of regulatory measures and changes in phosphate mining practices that eliminated direct processing discharges and reduced other phosphate mining related discharges to surface waters. These changes resulted in decreased levels of specific conductivity, total dissolved solids, calcium, magnesium, sulfate, silica, total phosphorus, orthophosphate, fluoride, and strontium in the upper river.

- Water quality characteristics suggest that historically high ground water withdrawals and subsequent discharges, predominantly from mining activities, substantially augmented river base flows and masked the decline of natural spring discharges that followed reductions in ground water levels. Augmentation of river flow from ground water withdrawals from the 1950s to the early 1970s were so large that when they were reduced, average water color in the upper reaches of the river also increased. Increases in water color may have subsequently reduced the distribution of the submerged aquatic plant *Vallisneria americana* (tape grass) in the upper river, thereby reducing the availability of this valuable fish habitat.

- The tributary basins of the Peace River watershed all show evidence of water quality changes attributable to mineralized ground water discharges to surface waters from agricultural activities. Depending on the basin (and available data), long-term increases are apparent in conductivity, pH, total dissolved solids, calcium, magnesium, sodium, potassium, chloride, silica, and sulfate. Concentrations of many of these water quality parameters were at or near historical highs during the recent 1999-2001 drought. The basins were ranked relative to the magnitude of the changes in water quality, and are listed below from largest to smallest changes.

    - Joshua Creek
    - Shell Creek (Prairie Creek and Shell Creek)
    - Horse Creek
    - Payne Creek
    - Charlie Creek

- Water quality impacts in the watershed due to urbanization have historically included discharges from municipal waste water treatment facilities, as well as stormwater discharges. However, many of these discharges have been dramatically reduced/eliminated and water quality has improved due to National Pollutant Discharge Elimination Systems (NPDES) permitting,

- Water in the Upper Floridan aquifer generally is more mineralized moving from the northern region of the Peace River watershed toward the south and west. Consequently, relatively similar volumes of Upper Floridan ground water discharged to receiving surface waters in the southern watershed basins can have a greater effect on surface water quality characteristics when compared to discharges in the upper watershed.

- The high conductivity levels (and other water quality constituents) in these southern agricultural dominated basins directly reflects the discharge of highly mineralized ground water from the Upper Floridan aquifer into these creeks.

- Water quality in a number of the tributary watershed basins that have undergone land use changes to more intense agriculture also show recent increases in inorganic nitrite+nitrate nitrogen concentrations.

- Dissolved inorganic phosphorus concentrations in the lower Peace River/upper Charlotte Harbor estuary are extremely high when compared to other estuarine systems. However, measured phosphorus levels in the estuary have declined by as much as an order of magnitude since the early 1980s.

- Except for statistically significant long-term declines in phosphorus levels and recent significant increases in silica concentrations, the water quality of the lower Peace River and upper Charlotte Harbor has remained relatively unchanged over the past quarter century.

- There are distinct seasonal differences in a number of water quality characteristics in the lower river and estuary (including salinity, dissolved oxygen, water color, turbidity, phosphorus, nitrogen, organic carbon, and chlorophyll *a*) related to differences in flow and/or temperature.

- Phytoplankton levels in the Peace River and Charlotte Harbor during periods of low to moderate freshwater flow are limited by the availability of inorganic nitrogen. However, as flows increase, water color levels correspondingly increase and phytoplankton production in the river and upper Charlotte Harbor are increasingly limited by the ability of light to penetrate the water column.

- Dissolved oxygen concentrations in the lower Peace River/upper Charlotte Harbor estuary show clear seasonal cycles in response to higher freshwater flows during the summer wet season. The duration and magnitude of periods of low dissolved oxygen concentrations increase toward the river mouth and harbor as higher bottom salinities establish greater vertical stratification in the water column during high flows. Bottom dissolved oxygen concentrations in upper Charlotte Harbor are characterized by hypoxic (less than 2.0 mg/L) and even anoxic (less than 0.2 mg/L) conditions during extended periods of high flows during the summer wet season.

4.2.2 Water Quality Among Basins

Water quality characteristics were also compared among and between watershed basins to assess potential causes or explanations for observed differences. Two recent sequential time periods provided the opportunity to evaluate selected water quality parameters under extremely dry and wet conditions. Both surface water flows and ground water demands were strongly influenced by the three-year drought that affected the Peace River watershed from 1999-2001 (*Appendix D*). The three years that followed (2002-2004) were characterized by wetter than normal conditions, during which a number of tropical cyclonic events influenced the Peace River watershed.

Graphical analyses were developed to compare and contrast values for selected water quality characteristics among basins during these unusually dry and wet time intervals. Box-and-whisker plots were used to compare the statistical distributions of values for water quality parameters among the basins during both the dry 1999-2001 and wet 2002-2004 time intervals. Individual box plots are indicated in these figures for 12 Peace River watershed locations and two of the previously used reference basins and presented in Figures 4.2.2.1 and 4.2.2.2.

Peace River Water Quality Monitoring Locations

- Saddle Creek at Structure P-11 Near Bartow
- Peace River at Bartow
- Peace River at Fort Meade
- Peace River at Zolfo Springs
- Payne Creek near Bowling Green
- Charlie Creek near Gardner
- Peace River at Arcadia
- Joshua Creek at Nocatee
- Horse Creek near Myakka Head
- Horse Creek near Arcadia
- Prairie Creek near Fort Ogden
- Shell Creek near Punta Gorda

Reference Water Quality Monitoring Locations

- Myakka River near Sarasota (agriculturally augmented base flow)
- Withlacoochee River at Croom (relatively limited anthropogenic influences)

The top of the "box " in the box-and-whisker plots represents the upper 75th percentile of data observed over the time interval for the water quality parameter for each location, while the bottom of the box represents the lower 25th percentile. The "whisker" vertical lines beyond the box extend from the minimum to the maximum values observed during the time interval. The horizontal line across the middle of the box indicates the statistical median of all observations for the sampling location, and the red dot denotes the mean value over the three year time period.

Spatial differences and potential explanations for differences in water quality in the watershed suggest are summarized below. Differences between the extremely dry 1999-2001 and relatively wet 2002-2004 time periods are also presented.

Color – Average levels were distinctly lower in most of the basins during the drier 1999-2001 period when compared with the wetter 2002-2004 period. This reflects the high natural color levels in southwest Florida stream that occur primarily due to humic compounds associated with the runoff of decomposed vegetation and organic material from forested uplands and wetlands. Depending on the source, these humic compounds typically contain high levels of tannins, lignins, and fulvic acids. Water color levels in the Payne Creek basin stand out as characteristically low in comparison with the other basins. This difference was particularly evident during the wetter 2002-2004 interval, suggesting that even during periods of relatively high rainfall and surface flow in Payne Creek, flows do not typically include large amounts of decomposed vegetation or other organic matter. Other water quality characteristics, such as conductivity, combined with apparent historic increases in dry season base flow, suggest that Payne Creek flows are associated with agricultural ground water and/or mining and power facility NPDES discharges.

Conductivity (Specific Conductance) – Conductivity levels from 2002 to 2004 at the Joshua, Prairie, and Shell creek monitoring sites were distinctly higher than levels measured in other watershed basins. Mean, median, and maximum conductivity values and the normal range of variation (between the 25th and 75th percentiles) in these three creeks during these three recent wet years were typically more than double the levels observed in other basins. Average conductivity levels throughout the watershed, and particularly at these three creek locations, were generally higher during the preceding dry 1999-2001 period. Conductivity levels at the lower Horse Creek monitoring site near Arcadia were also conspicuously higher during the drought. Large agricultural areas in the lower portion of the Horse Creek basin and in the Joshua and Shell Creek basins have shifted in recent decades to more intensive agriculture that rely heavily on ground water for irrigation and/or freeze protection. Upper Floridan aquifer ground water generally becomes more mineralized moving southwest from the northern region of the Peace River watershed. Consequently, relatively similar volumes of Upper Floridan ground water discharged to receiving surface waters in the southern watershed basins can alter surface water quality much more dramatically when compared to ground water discharged into the more northern basins. The high conductivity levels (and other constituents described below) in the southern agricultural dominated basins reflect highly mineralized Upper Floridan ground water being discharged into the creeks.

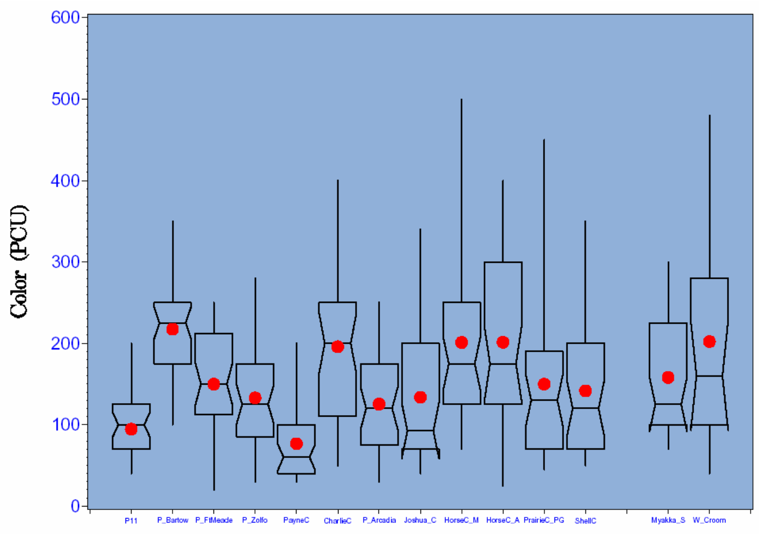
Ions and Total Dissolved Solids – There are a number dissolved positive and negative ions commonly associated with southwest Florida ground water. Data are most widely available for chloride, calcium, sodium, and sulfate ions. The graphical comparisons of these parameters, along with total dissolved solids among the watershed surface water monitoring sites again indicates the magnitude of the influences of highly mineralized ground water discharges in the southern agricultural areas, particularly in the Joshua Creek basin. Ion levels in basin surface waters were notably higher the during the 1999-2001 drought than during the ensuing 2002-2004 wetter time interval, as described earlier for conductivity.

Phosphorus and Fluoride – Total phosphorus and orthophosphate values were generally highest in the northern reaches of the main channel of the Peace River. Among the tributaries, the highest concentrations occurred in the Payne Creek basin. Similar spatial patterns were also reflected for concentrations of fluoride. These elevated concentrations of phosphorus and fluoride are directly associated with areas of historic and current phosphate mining.

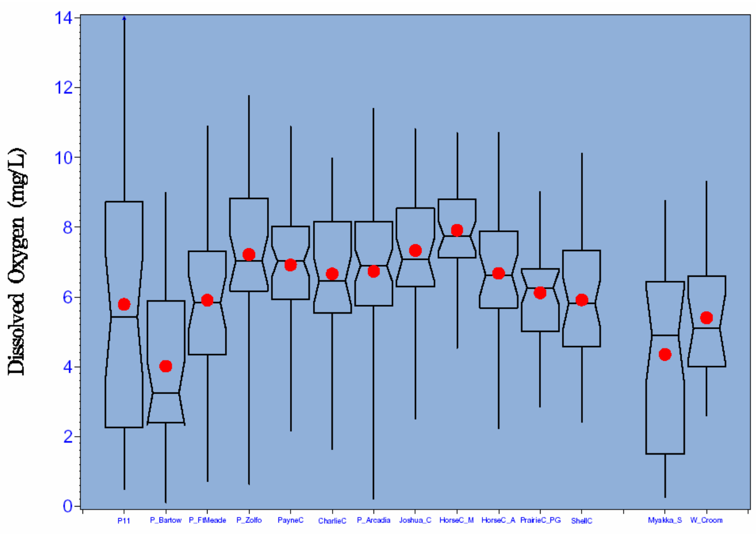
Dissolved Oxygen – Comparisons of dissolved oxygen levels among the monitoring locations during the 1999-2001 drought and wetter 2002-2004 periods indicate that dissolved oxygen levels below the Class III standard of 5.0 mg/L, and even reflecting hypoxic conditions (below 2.0 mg/L), occurred primarily in the main river channel between Lake Hancock and Arcadia. Overall, low dissolved oxygen levels are notably lower toward the northern end of the watershed and are more frequent and extend farther down the river during wetter conditions. The reason for these dissolved oxygen patterns is evident in the spatial and temporal patterns of total suspended solids (TSS), turbidity, total Kjeldahl nitrogen, total organic carbon and chlorophyll *a*. These parameters show the high levels of organic materials from Lake Hancock that are discharged into the upper Peace River via Saddle Creek. Discharged water from Lake Hancock has high concentrations of chlorophyll *a* (algae) and organic material that result in extreme fluctuations in dissolved oxygen levels observed in the upper Peace River. During wetter conditions, these dissolved oxygen patterns are accentuated by larger discharges from the lake.

Inorganic Nitrite+Nitrate Nitrogen – There are two main sources of inorganic nitrite+nitrate nitrogen in the Peace River watershed. The first is associated with the high levels of organic material from Lake Hancock, while the second more dispersed source is primarily linked with agricultural uses in the tributary basins. The water entering the upper Peace River via Saddle Creek is characterized by very low inorganic nitrite+nitrate nitrogen levels. Most of the inorganic nitrogen in Lake Hancock has been incorporated into algae, resulting in high chlorophyll *a* concentrations. As algae and other organic material are decomposed in the river, organic nitrogen is converted to inorganic nitrogen and downstream concentrations of inorganic nitrogen increase. Relatively high inorganic nitrogen concentrations are also apparent in a number of the tributary basins with more intense agricultural land uses. Interestingly, relatively high concentrations of inorganic nitrogen were observed in the Payne Creek basin during both the dry 1999-2001 and wetter 2002-2004 time periods.

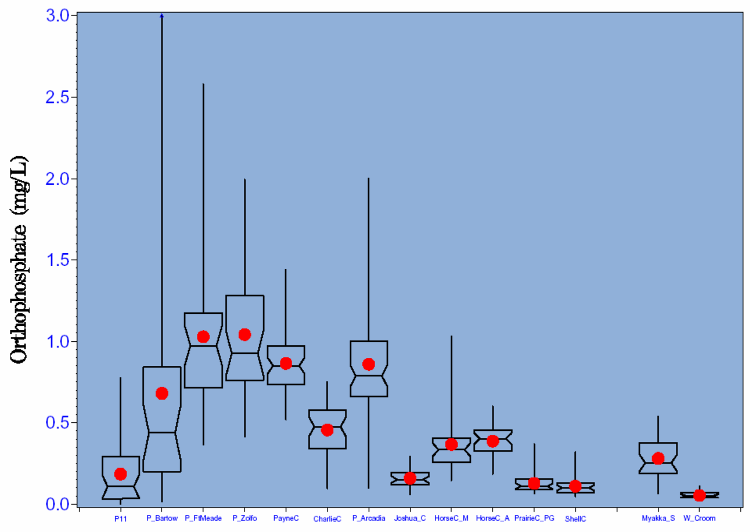
Figure 4.2.2.1. Spatial Comparisons among Basins (2002-2004) in Water Color, Dissolved Oxygen, Orthophosphate, and Inorganic Nitrite+ Nitrate Levels



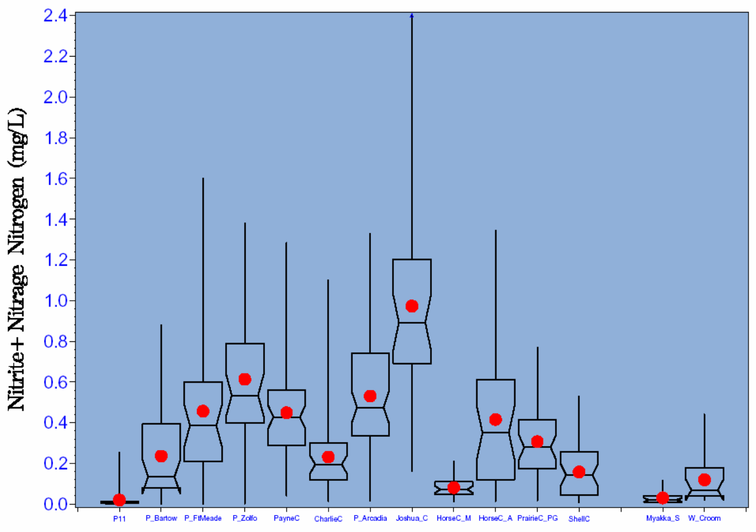
Watershed difference in water color among selected sampling sites (2002-2004)



Watershed difference in dissolved oxygen among selected sampling sites (2002-2004)

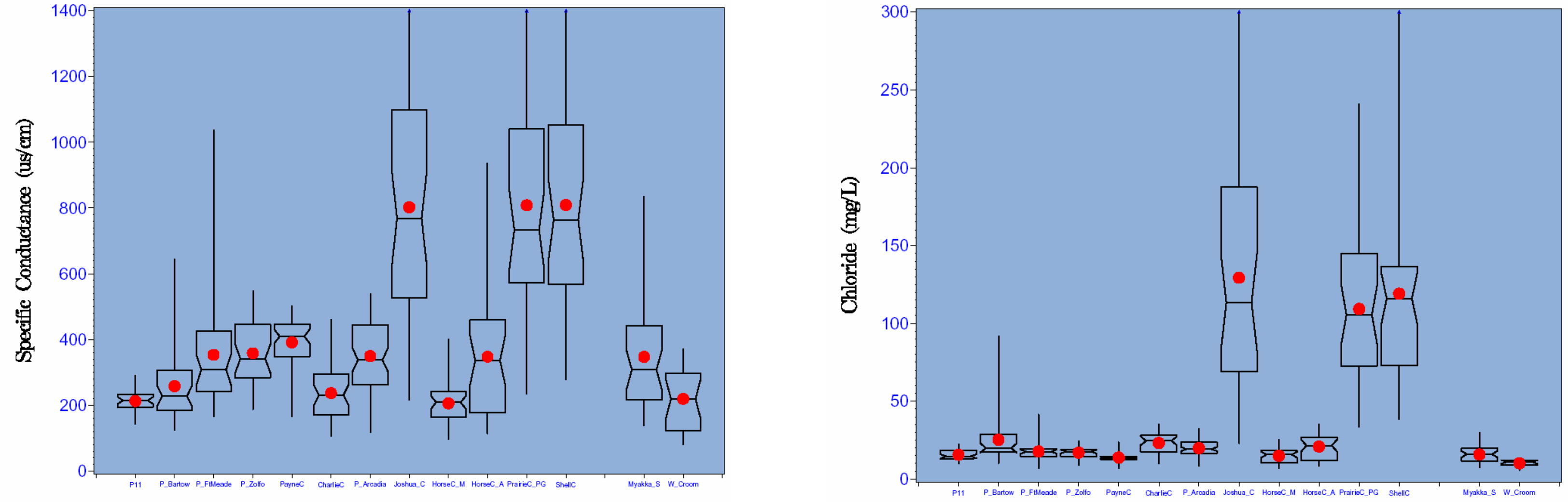


Watershed difference in orthophosphate among selected sampling sites (2002-2004)



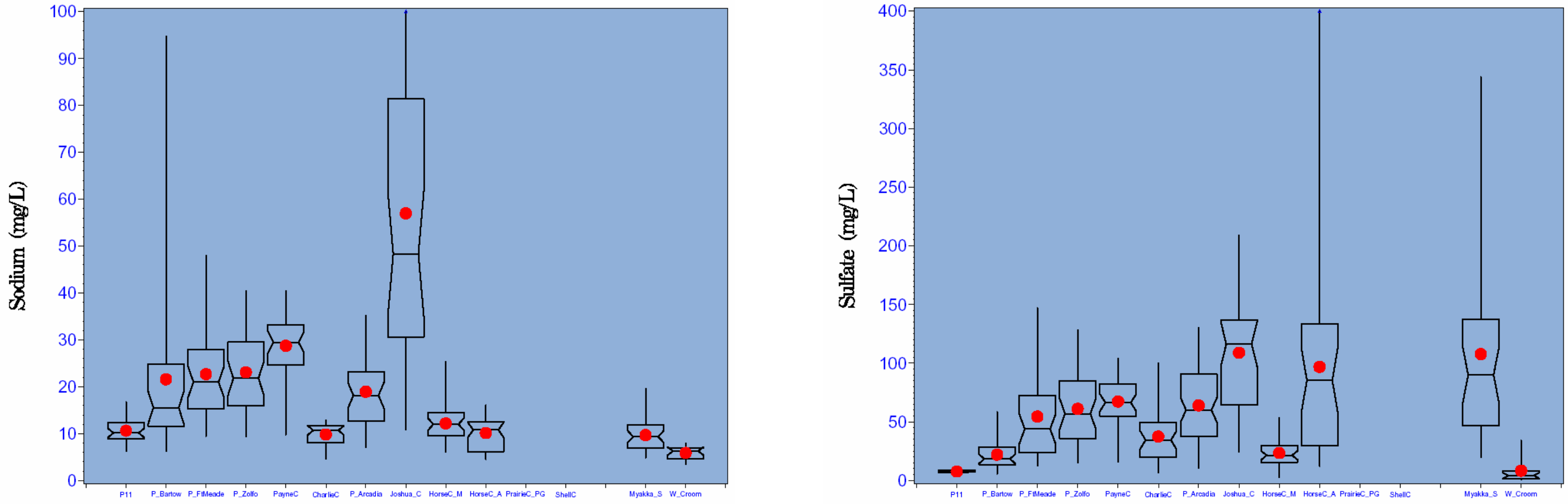
Watershed difference in nitrite+nitrate nitrogen among selected sampling sites (2002-2004)

Figure 4.2.2.2. Spatial Comparisons among Basins (2002-2004) in Conductivity, Chloride, Sodium, and Sulfate Levels



Watershed difference in specific conductance among selected sampling sites (2002-2004)

Watershed difference in chloride among selected sampling sites (2002-2004)



Watershed difference in sodium among selected sampling sites (2002-2004)

Watershed difference in sulfate among selected sampling sites (2002-2004)

4.2.3 Conductivity Impairment

Specific conductance is a measure of the capacity of water to conduct electricity and is directly linked to the amount of dissolved salts in the water. In an aqueous environment, salts will disassociate into positively and negatively charged ions that conduct electricity. The terms "specific conductance", "conductance", and "conductivity" are often used interchangeably, although specific conductance refers to conductivity normalized to a standard temperature of 25ºC and recorded in micromhos per centimeter (µmhos/cm). Modern water quality meters normalize conductivity readings to this standard temperature. Specific conductance is an indirect measure of the presence of inorganic dissolved solids such as chloride, bicarbonate, nitrate, sulfate, phosphate, sodium, magnesium, calcium and iron. The relative importance of each of these specific ions and the associated effects on conductivity can vary both spatially and temporally.

Distilled or deionized water has a specific conductance of approximately 1-5 µmhos/cm, compared with seawater (which has a high level of dissolved salts) which has a specific conductance of approximately 35,000-50,000 µmhos/cm (FDEP 2005). Consequently, changes in conductivity over time in surface water and/or ground water can indicate changes in the mineral content of that water.

Increases in conductivity are often linked to an increased influence of water from highly mineralized aquifers on otherwise low-conductivity surface waters. In the headwaters of the Myakka River, increased conductivity was linked to off-site seepage of irrigation water that originated from the more highly mineralized intermediate and Upper Floridan ground water aquifers and reflects a commensurate increase in the amount of intensively farmed agricultural land uses (PBS&J 1998).

Conductivity values have decreased over time at some locations in the upper Peace River (Saddle Creek, Peace River at Bartow, Peace River at Fort Meade, and Peace River at Zolfo Springs), while increasing at others (Payne Creek). Declining conductivity is associated with reduced mining discharges. No significant trend in conductivity has been measured over the period-of-record for the Peace River at the Arcadia gage (see *Appendix E*).

In the lower Peace River watershed, increases in conductivity over the period-of-record have been documented for Horse Creek, Joshua Creek, Shell Creek, and Prairie Creek. These particular basins have little urbanization and phosphate mining influences are minimal to absent (*Chapter 3*) and the data suggest that the influence of irrigation water associated with agricultural land uses has been increasing, similar to that documented in the upper Myakka River (PBS&J 1998).

The current water quality standard for specific conductance (Chapter 62-302.530(23)) for Class III waters is the following:

> *"Specific conductance (micromhos/cm) shall not be increased more than 50 percent above background or to 1,275, whichever is greater."*

Based on this standard, the specific conductance has been exceeded frequently at a number of locations in Joshua, Prairie, and Shell Creeks (Chapter 5). While there are only three stream segments (two in Shell Creek and one in Prairie Creek) listed by FDEP as "verified impaired," there are additional locations under consideration for listing in the Peace River watershed (*Chapter 5*).

In response to the issue of impairment, the Southwest Florida Water Management District (SWFWMD) developed the *Shell, Prairie and Joshua Creeks Watersheds Management Plan* (SWFWMD 2004). The goals of this Plan, to be fully implemented by 2014, are to reduce specific conductance levels to no more than 775 µmhos/cm at all times, reduce chloride levels to below 250 mg/l, and reduce total dissolved solids levels to below 500 mg/l. Thus, the goal of the Reasonable Assurance Plan, which makes up part of the larger Watersheds Management Plan, is to reduce conductivity to levels to below the existing State Standard "never to exceed" value of 1,275 µmhos/cm. The 775 µmhos/cm threshold value was selected as a surrogate water quality parameter to meet Class I Water Quality Standards for chloride and TDS (SWFWMD 2004).

This apparent discrepancy in conductivity threshold values between the State water quality standard and the SWFWMD Plan is an indication of concerns relative to whether or not the existing State water quality standard for conductivity is sufficiently protective. Of particular relevance to the Peace River is the language that specific conductance shall not be increased more than 50 percent above background or to 1,275, *whichever is greater* (emphasis added). In locations where specific conductance may have increased by more than 50 percent above background, but where levels are still less than 1,275 µmhos/cm, the existing water quality standard would not be exceeded.

In locations such as Horse Creek near Arcadia (Figure 4.2.3.1) and Joshua Creek at Nocatee (Figure 4.2.3.2) trends over time indicate conductance has increased more than 50 percent, but monthly values are still either entirely (Horse Creek) or mostly (Joshua Creek) below the threshold value of 1,275 µmhos/cm. In terms of the existing water quality standard, concern remains over whether conductance values that are nearly double their historic values, but are still less than 1,275 µmhos/cm, constitute a water quality issue.

Figure 4.2.3.1. Specific Conductance at Horse Creek at Arcadia (Appendix E)

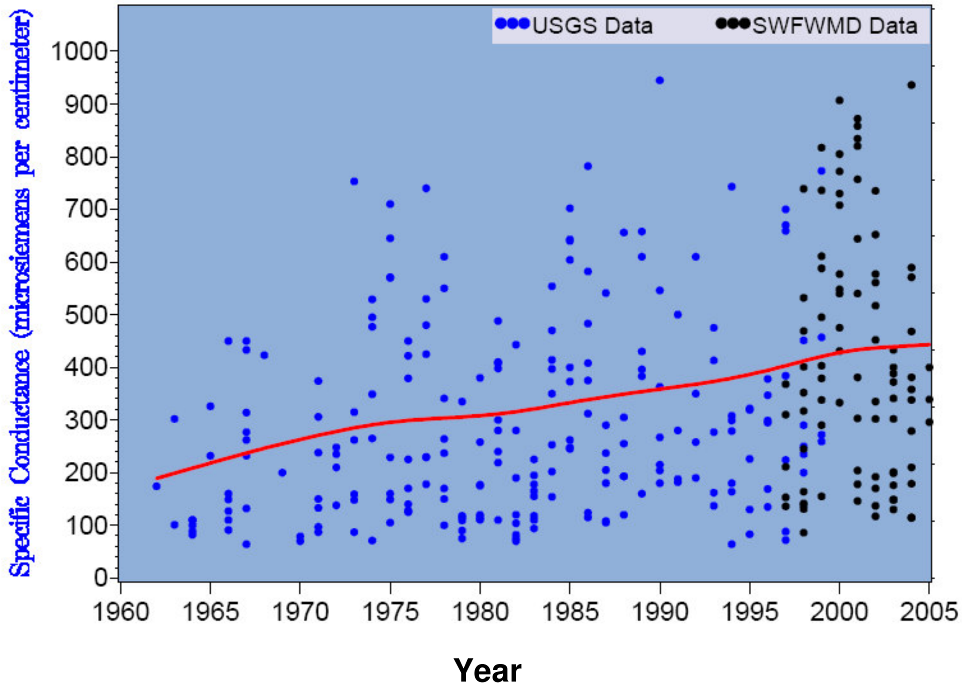
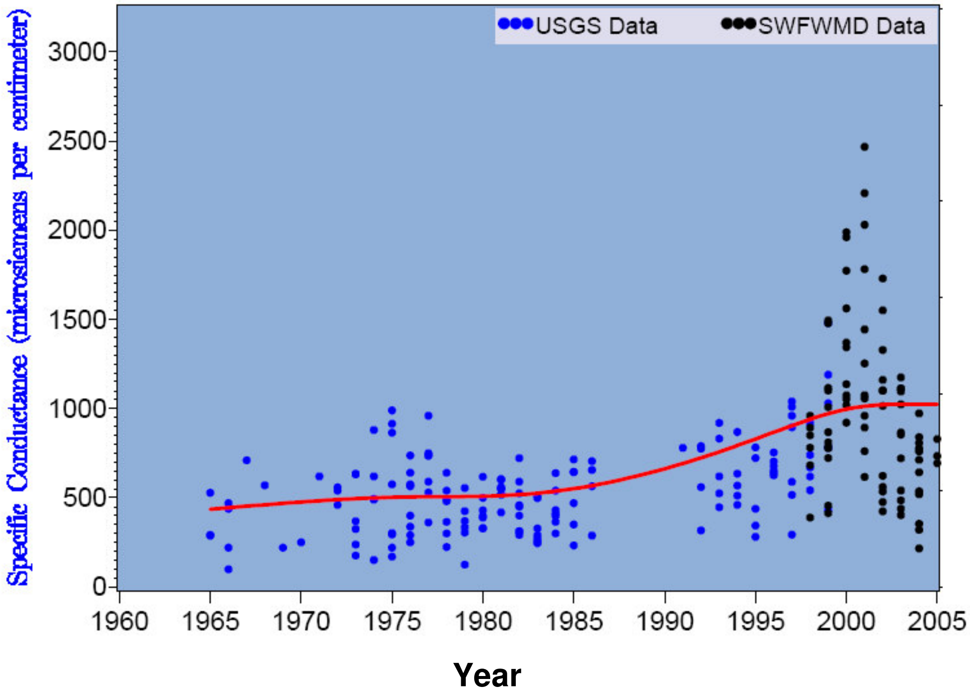
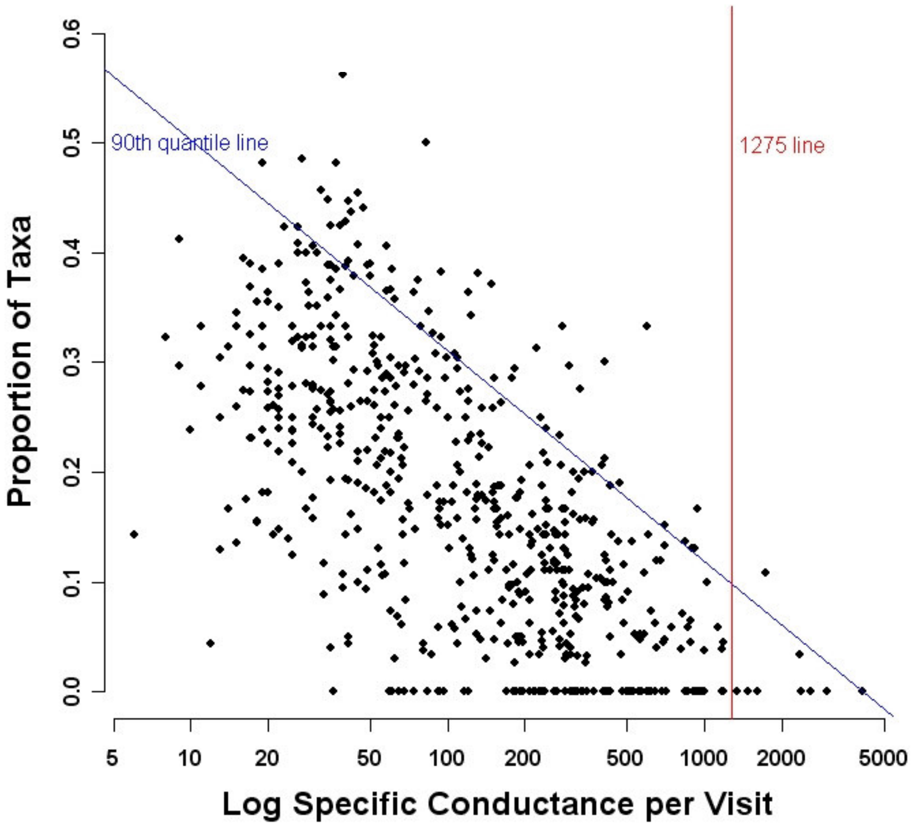


Figure 4.2.3.2. Specific Conductance at Joshua Creek at Nocatee (Appendix E)



Recently, the FDEP Triennial Review Committee requested that the FDEP Biology Section evaluate scientific evidence to evaluate the existing Surface Water Quality Standard for specific conductance and make recommendations for revising standards if necessary. The existing conductivity standard relies on numerical and narrative criteria developed using an approach most often associated with toxicity testing of pollutants for protection of aquatic life and human health (FDEP 2005). In its report to the Triennial Review Committee, FDEP (2005) used a bioassessment approach, wherein the specific conductance of various water bodies was compared to the health of indicator benthic macroinvertebrate communities. A key component to this approach was the use of "Florida Sensitive Taxa" which are defined as those species that demonstrate "…. a statistically significant decrease in abundance with increases in human disturbance in the Peninsula, Panhandle and Northeast Bioregions" (FDEP 2005). These organisms become proportionately less abundant in Florida streams as a function of increases in the specific conductance of those streams (Figure 4.2.3.3, after FDEP 2005).

Figure 4.2.3.3. Proportion of Total "Florida Sensitive Taxa" Species, as Related to the Log (base 10) of Specific Conductance



The data summarized in Figure 4.2.3.3 demonstrate that increases in specific conductance are associated with significant reductions in Florida Sensitive Taxa, and that a threshold value of 1,275 μmhos/cm does not appear to be protective of biological communities. The majority of locations represented in Figure 4.2.3.3 had no Florida Sensitive Taxa when specific conductance exceeded 1,275 µmhos/cm – only two of the sites had any Florida Sensitive Taxa, and neither one had a proportion of these taxa higher than 15 percent of the total species present. In a report to the Triennial Review Commission, FDEP (2005) included the recommendations listed below.

- This study supports revision of the specific conductance criterion. Results might be used to revise the Class I, III and IV freshwater surface water quality specific conductance criterion (62-302.530(23) F.A.C.) in the form of an equation.

- Alternative revisions to the specific conductance criterion should be considered, and the allowable changes in specific conductance explicitly calculated against effects on the distribution and abundance of Florida Sensitive Taxa. This may provide benchmarks for estimation of the community-level effects that are associated with potential changes to Water Quality Criteria.

A revision such as that described above, based on available data included in FDEP (2005), could result in a more protective standard for biological communities in the Peace River watershed, where data suggest a possible negative impact of increased mineral content of the water on fish populations (*Appendix L*).

4.2.4 Conductivity and Fish

As part of the CIS, a study was conducted (*Appendix J - Ichthyological History*) to enumerate and historically compare the fish species reported both from the freshwater and tidal areas of the Peace River watershed. This study was based on a review of museum material, as well as information available in the primary and secondary literature. Analyses of available fish species information were conducted using the presence/absence methods, sample based species accumulation estimates, and community based comparisons of similarities among basins.

At virtually all levels examined in the previous studies, from regional to first and second order streams, the existing Peace River fish showed adverse effects over time due to changes believed to be associated with four anthropogenic activities:

- Historic and current mining for phosphate in streams
- Historic and current landscape changes by agriculture and urbanization
- Historic losses of ground water flows to the river in the upper karst areas of the watershed
- Irrigation runoff from ground water with high total dissolved solids and high conductivity

Many unaltered, low order tributaries in the Peace River watershed have very low conductivity levels and acidic pH levels, which provide a barrier to some secondary freshwater and marine fishes, although some unaltered streams in karst regions may have spring sources with higher pH and conductivity levels. Except for basins with contoured overburden (native soils) (Lewelling and Wylie, 1993), none of the mined, reclaimed, or downstream "preserved" stream segments have these characteristics. The State Standard for specific conductivity appears inadequate to protect many freshwater fishes in Class III waters from adverse impacts. No recent collections (since 1972) have been made in Joshua, Shell or Prairie Creeks, therefore the effects of the high conductivity levels from irrigation water on fish community structure in these areas remains unknown. However, based on known distribution patterns of conductivity/salinity, as many as 15 species with historical presence may have since disappeared from these agriculturally impacted creek systems. Other conclusions reached from this study are presented below.

- Many freshwater fishes evolved under conditions of very low levels of total dissolved solids (low conductivity). At least 15 fish species in the Peace River appear to be limited to conductivities below the present State Standard of 1,275 µmhos/cm.

- Significant losses of fish species in Joshua, Prairie, and Shell creeks may have occurred as the result of rising conductivity levels (well above the State Standard) associated with pumping highly mineralized ground water for agricultural irrigation under SWFWMD permits.

- Payne Creek conductivity levels have increased with phosphate mining and agricultural ground water discharges and may partially explain the low numbers of fish species found there.

- Present day Horse Creek may have more species of fishes than the main stem of the Peace River and certainly more than in the recent past. Phosphate mining is still a minor, but expanding, component of the Horse Creek basin. The fish species diversity of Charlie Creek may be nearly as rich as Horse Creek, but there are no recent data to support this. The Charlie Creek basin is characterized by relatively lower intensity agriculture.

4.2.5 Point and Nonpoint Pollution Sources

Nutrient and suspended solids loadings, can be assessed by combining domestic point sources and urban stormwater runoff loadings. Coastal Environmental, Inc. (1995) estimated annual loads for the entire Peace River watershed for total nitrogen (1,800 tons/yr), total phosphorus (640 tons/yr), and total suspended solids (14,400 tons/yr). Direct loading from point sources discharges (both domestic and industrial) have been estimated to account for between two and 10 percent of the total nitrogen load exported from the watershed (Alexander *et al.* 2000 and Coastal Environmental, Inc. 1995, respectively), while nonpoint source loads associated with urban land uses have been estimated to account for between four and 17 percent of the total nitrogen load (Coastal Environmental, Inc. 1995 and Alexander *et al.* 2000, respectively).

When considering nutrient loadings, nitrogen is the nutrient of greatest concern relative to limiting algal growth in the lower Peace River/Charlotte Harbor estuarine system (Montgomery *et al.* 1991, Turner *et al.* 2006). It has been estimated that the combined loadings from point sources (both domestic and industrial) and urban stormwater runoff account for between 14 and 19 percent of the total nitrogen loads from the Peace River watershed, which is smaller impact than corresponding nitrogen loadings from agricultural land uses (Coastal Environmental, Inc. 1995, Alexander *et al.* 2000). Regionally within the watershed, however, the impacts of urban nitrogen loading are concentrated and much more important in the two highly urbanized northern (Peace River at Bartow) and southern (Coastal Lower Peace River) watershed basins.

Within the Peace River at Bartow basin, the contribution of domestic point sources accounted for an estimated four percent of the total annual nitrogen load, while 41 percent of the nonpoint source loadings of nitrogen were attributed to urban land uses (Coastal Environmental, Inc. 1995). Since the total loadings of nitrogen from nonpoint sources in the basin accounted for an estimated 57 percent of the total annual load, the anticipated combined impact of urbanization would comprise approximately 27 percent of the annual total nitrogen loading in the Peace River at Bartow basin (.04 + [0.41 x 0.57] = 0.27). Accordingly, Coastal Environmental, Inc. (1995) identified the Peace River at Bartow basin as the highest priority basin for potential implementation of current and prospective urban related nutrient load reductions necessary to protect both the Peace River and Charlotte Harbor. Using slightly different methods and newer land use information (PBS&J and W. Dexter Bender 1999), total urban nitrogen loading in the Peace River at Bartow basin accounted for up to 42 percent of the annual load (residential = 25 percent, commercial = 10 percent, industrial = 4 percent, and transportation = 3 percent).

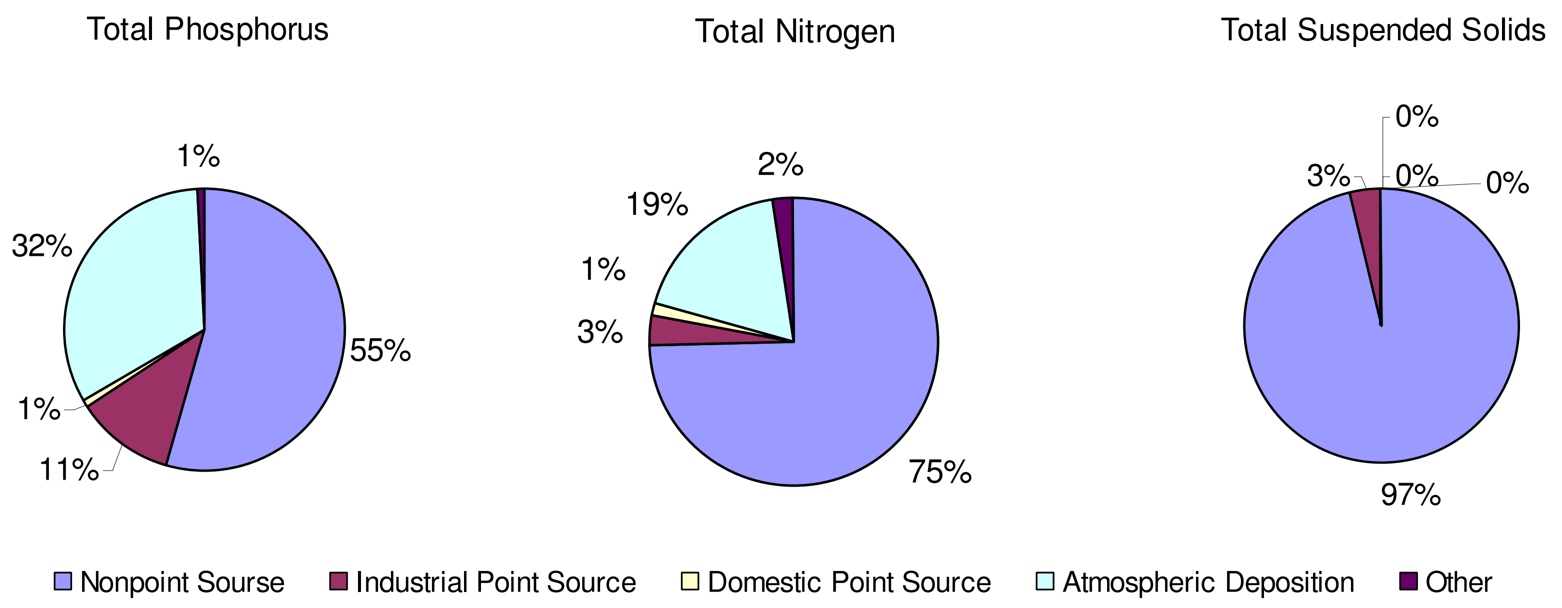
In the Coastal Lower Peace River basin, which has no flow gage, Coastal Environmental, Inc. (1995) estimated that domestic point sources accounted for up to approximately 13 percent of the total nitrogen loading, with 34 percent of the nonpoint source nitrogen loading attributable to urban land uses. Since nonpoint sources were an estimated 87 percent of total annual nitrogen loading, the estimated combined impact of urbanization was 43 percent of the nitrogen load for the lower Peace River (0.13 + [0.34 x 0.87] = 0.43). Again, using newer land use information and slightly different methods (PBS&J and W. Dexter Bender 1999), total nitrogen loading from urban land uses in the Coastal Lower Peace River basin accounted for approximately 33 percent of the annual loading (residential 26 percent, commercial 5 percent, and transportation 2 percent).

It should be pointed out that since the completion of these studies, FDEP has continued to require the reduction or elimination a number of previous direct point source discharges within the watershed (such as Myrtle Slough discharges from the City of Punta Gorda wastewater spray field), thus increasing the importance of efforts to address the more difficult issue of nonpoint source nitrogen loadings.

A pollutant loading model developed for the Peace River (Squires *et al*. 1998) estimated that industrial point source discharges accounted for 3.2, 11.4, and 3.4 percent, of the total nitrogen, total phosphorus, and total suspended solids loads, respectively, to Charlotte Harbor for the years 1992 to 1994. Nonpoint source loads (stormwater runoff) accounted for an estimated 75, 55, and 97 percent, respectively, of the total nitrogen, total phosphorus, and total suspended solids loadings into Charlotte Harbor (see Figure 4.2.5.1).

While point source discharges to the Peace River and ultimately to Charlotte Harbor (including those associated with phosphate mining activities) do not appear to significantly contribute to total loadings, point source discharges are significant in the upper Peace River. For example, Squires *et al.* (1998) estimated that industrial point source discharges accounted for approximately 24 percent (Peace River at Zolfo Springs) and 43 percent (Payne Creek) of the nitrogen load measured in the upper river. The point of discharge (river, sanitary sewer, or reuse system) could not be verified, however, for 59 percent of the industrial point source discharges to the upper Peace River and these estimates should, therefore, be viewed with caution.

Figure 4.2.5.1. Sources of Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loads to Charlotte Harbor



Industrial point source discharges have been estimated to contribute approximately three percent of the total load of nitrogen and suspended solids into Charlotte Harbor and therefore are a relatively minor source of harbor-wide loads. Nitrogen loads from industrial point sources are approximately the same as estimated loads from septic tank systems located throughout the watershed. Phosphorus loads from industrial point sources are more substantial, accounting for 11 percent of the harbor-wide load. However, the role of industrial point source loads is more substantial in the uppermost regions of the watershed, where they account for 24 and 43 percent of the nitrogen loads for the Peace River at Zolfo Springs, and for Payne Creek, respectively.

Urban land uses are also often associated with increased loadings of metals to receiving water bodies. Although elevated levels of metals were found at some marina locations in Charlotte Harbor, Schropp (1995) concluded that "…human activities have not substantially affected sediments in the open parts of Charlotte Harbor…this situation is quite different from some other Florida estuaries, such as Tampa Bay and Biscayne Bay, in which widespread metal enrichment has been observed…" Additionally, Schropp (1995) concluded that levels of hydrocarbon concentrations in Charlotte Harbor were low and "…similar to those reported from unpolluted sections of Tampa Bay…", although levels were elevated at locations near marinas and also within residential canals.

4.3 Natural Systems and Land Use

Land use patterns in the Peace River watershed have changed dramatically since the 1940s. Land use changes are described in this chapter as a means of evaluating trends among the basins at the watershed level. An overview of general changes and trends in land uses among basins, both spatially and temporally, are summarized in Table 4.3. In some cases, the patterns of land use that dominate the watershed are very different from those at the basin level. Basins in the watershed are classified into three regions:

- Upper watershed - Peace River at Bartow, Peace River at Zolfo Springs, and Payne Creek.
- Middle watershed - Peace River at Arcadia and Charlie Creek.
- Lower watershed - Horse Creek, Coastal Lower Peace River, Joshua Creek, and Shell Creek.

Developed and undeveloped land uses are listed below. Land use was quantified for the 1940s, 1979, and 1999 time periods and conversions among land uses were analyzed for three time periods: 1940s – 1979, 1970 – 1999, and 1940s - 1999. The results if these analyses are presented in the following sections.

Developed Land Uses

- Improved pasture
- Intense agriculture
- Urban lands
- Mined lands

Undeveloped Land Uses

- Native upland habitat
- Wetlands
- Streams and river channels
- Lakes*

** Lakes may occur as either developed or undeveloped land uses*

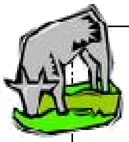
Table 4.3. Summary of Basin Characteristics and Land Use Changes in the Peace River Watershed

Basin Characteristic		Upper Peace River Watershed			Middle Peace River Watershed		Lower Peace River Watershed			
		Peace River at Bartow	**Peace River at Zolfo Springs**	**Payne Creek**	**Charlie Creek**	**Peace River at Arcadia**	**Horse Creek**	**Joshua Creek**	**Shell Creek**	**Coastal Lower Peace**
Current Predominant Land Use		Urban	Mining	Mining	Improved Pasture	Improved Pasture	Improved Pasture	Improved Pasture	Intense Agriculture	Urban
Greatest Land Use Conversion	**1940s – 1979**	Native upland habitat to pasture and urban	Native uplands to pasture and mining	Native uplands to pasture and intense agriculture	Native uplands to pasture	Native uplands to pasture	Native uplands to pasture	Native uplands to pasture	Native uplands to pasture and intense agriculture	Native uplands to urban and pasture
	1979 - 1999	Native uplands and wetlands to urban and pasture; intense agriculture to urban	Native uplands and pasture to mining	Native uplands to mining	Native uplands to pasture	Native uplands to pasture	Native uplands to pasture	Pasture to intense agriculture	Native uplands to pasture and pasture to intense agriculture	Native uplands to urban and pasture
	1940s - 1999	Native uplands to urban and pasture	Native uplands to pasture and mining	Native uplands and wetlands to mining	Native uplands to pasture and intense agriculture	Native uplands to pasture and intense agriculture	Native uplands to pasture	Native uplands to pasture	Native uplands to pasture and intense agriculture	Native uplands to urban and pasture

4.3.1 Land Use Changes: 1940s - 1999

Developed land uses in the Peace River watershed expanded from 13 percent in the 1940s to 50 percent in 1979, and grew to 64 percent of the watershed in 1999 (Table 4.3.1). Changes in developed land uses (improved pasture, intense agriculture, phosphate mining, and urban) are mapped in Figures 4.3.1.1 – 4.3.1.3. Population growth associated with the changes in urban land use are graphed in Figure 4.3.1.4, and areas of mined lands are mapped in Figure 4.3.1.5.

Commensurate with the increase in developed lands in the watershed, undeveloped lands decreased from 85 percent of the watershed in the 1940s, to 48 percent of the watershed in 1979, and decreased further to include only 33 percent of the watershed in 1999. Changes in undeveloped land uses (native upland habitats, wetlands, lakes, and other waters) and follow in Figures 4.3.1.6 – 4.3.1.8.



Developed land uses increased from 13 percent of the watershed in the 1940s to 64 percent in 1999. Undeveloped land use decreased from 85 percent of the watershed in the 1940s to 33 percent of in 1999.

Table 4.3.1. Developed and Undeveloped Land Use in the Peace River Watershed: 1940s - 1999

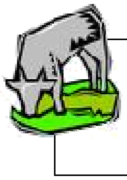
Land Use	Acres (Percent) in Land Use Class		
	1940	1979	1999
Developed			
Improved Pasture	39,640 (2.8)	356,925 (25.6)	379,346 (27.2)
Intense Agriculture	107,115 (7.7)	191,496 (13.7)	229,832 (16.5)
Mined lands	7,495 (0.5)	64,437 (4.6)	143,487 (10.3)
Urban Land Use	14,659 (1.0)	73,049 (5.2)	133,571 (9.6)
Undeveloped			
Native Upland Habitat	834,311 (59.7)	419,449 (30.0)	242,849 (17.4)
Wetlands	354,674 (25.4)	249,255 (17.8)	218,232 (15.6)
Water			
Lakes	33,779 (2.4)	35,432 (2.5)	43,027 (3.1)
Other Water	5,011 (0.4)	6,641 (0.5)	6,338 (0.5)
Total	**1,396,683 (100)**	**1,396,683 (100)**	**1,396,683 (100)**

4.3.1.1 Improved Pasture

The land use with the largest increase in the watershed was improved pasture, which expanded from 40,000 acres (three percent of the watershed) in the 1940s to 379,000 acres (27 percent) by 1999

(Table 4.3.1). Most of the increase occurred by 1979 when improved pasture accounted for 26 percent of the watershed. The increase was comprised mostly of conversions of native upland habitat and wetlands. Approximately 304,000 acres (36 percent) of native upland habitat and 48,000 acres (14 percent) of wetlands were converted to improved pasture between the 1940s and 1999.

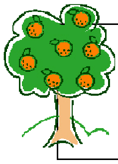
Improved pasture made up less than five percent of each of the nine basins in the 1940s (Appendix G), compared with 15 to 47 percent in 1979. Improved pasture increased mostly in basins in the middle watershed. For example, there was a 31 percent increase in improved pasture in the Peace River at Arcadia basin, 39 percent in the Charlie Creek basin, and 47 percent in the Joshua Creek basin. Acres of improved pasture increased only two percent from 25.6 percent to 27.2 percent in the watershed between 1979 and 1999. However, improved pasture increased approximately nine percent in Horse Creek and Shell Creek basins, and increased four and six percent respectively, in the Peace River at Arcadia and Charlie Creek basins. Decreases ranged from one (Coastal Lower Peace River basin) to seven (Payne Creek basin) percent in the remaining basins between 1979 and 1999.



The land use with the largest increase was improved pasture, which expanded from 40,000 acres (three percent of the watershed) in the 1940s to 379,000 acres (27 percent) by 1999.

4.3.1.2 Intense Agriculture: 1940s - 1999

Acres of intense agriculture more than doubled from the 1940s to 1999 and totaled approximately 229,832 acres in 1999 (Table 4.3.1.1). The largest conversion to intense agriculture between the 1940s and 1999 originated from the conversion of primarily native upland habitat. Approximately 147,710 acres of native upland habitat were converted to intense agriculture by 1999. Approximately 101,021 acres (68 percent) of the native upland habit was converted to intense agriculture by 1979 (Table 4.3.1.2), while 28,682 acres of native upland habitat were converted to intense agriculture between1979 and the 1990s. In comparison, approximately 49,930 acres of improved pasture accounted for the largest conversion to intense agriculture between 1979 and 1999 and (Table 4.3.1.3).



Numbers of acres of intense agriculture more than doubled from approximately 107,000 acres in the 1940s to 230,000 acres in 1999 and represented the largest overall land use conversion in the watershed.

Approximately 56 percent of intense agriculture in the watershed occurred primarily in the three basins in the upper watershed in the 1940s (Appendix G). By 1979, intense agriculture expanded within every basin in the watershed with the exception of the Peace River at Bartow basin where it did not change. The largest increases occurred in the Shell Creek basin (20 percent) and the southern portion of the upper watershed in the Payne Creek basin (nine percent). By 1999, intense agriculture increased in the middle and lower watershed by an average of eight percent in each basin. In the same time period intense agriculture decreased in the upper watershed by an average of five percent.

The largest change from intense agriculture to another land occurred due to conversions to urban lands (20,257 acres) between the 1940s and 1999, approximately 41 percent of which (8,312 acres) was converted by 1979.

Figure 4.3.1.1. Developed Land Use in the Peace River Watershed in the 1940s

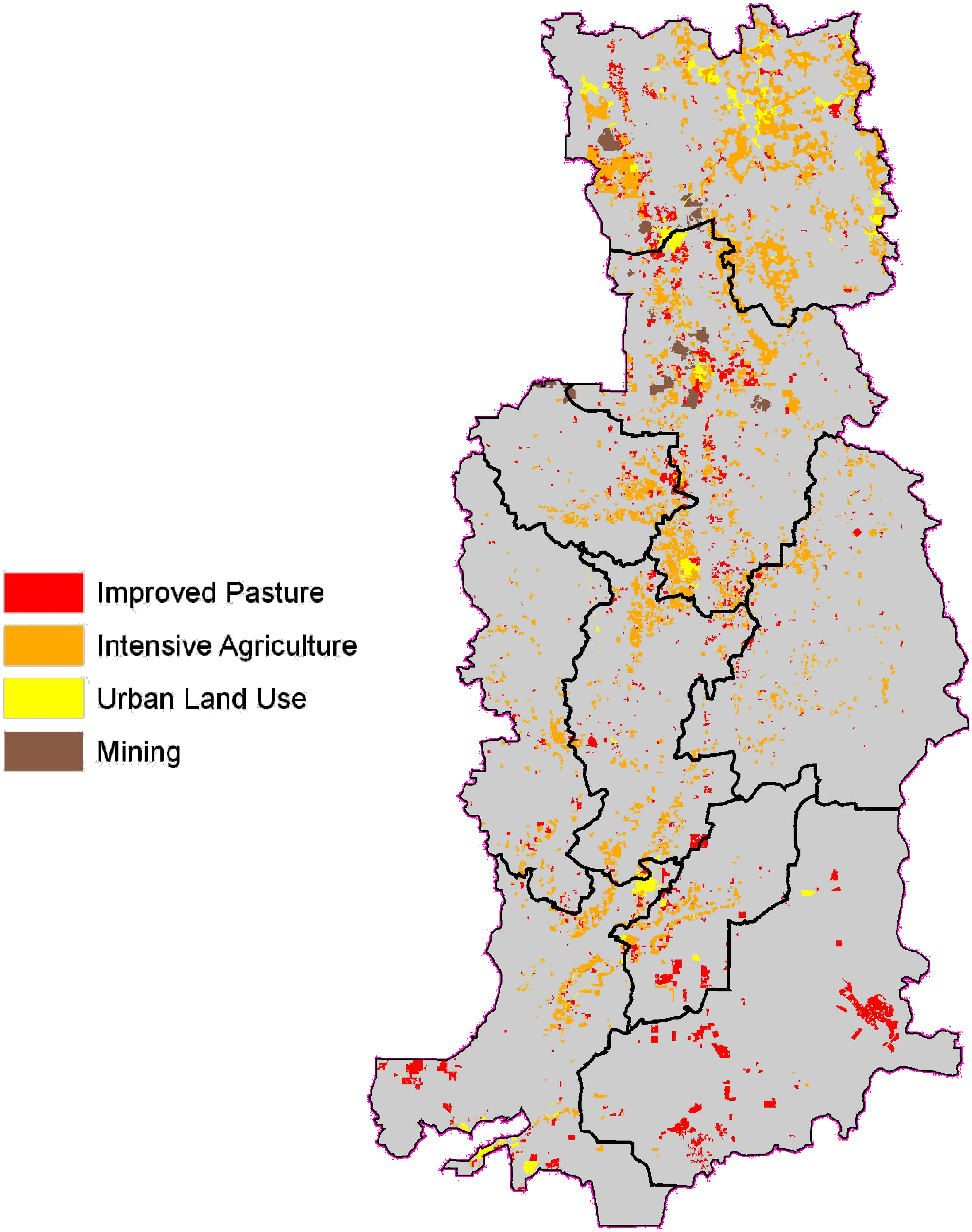


Figure 4.3.1.2. Developed Land Use in the Peace River Watershed in 1979

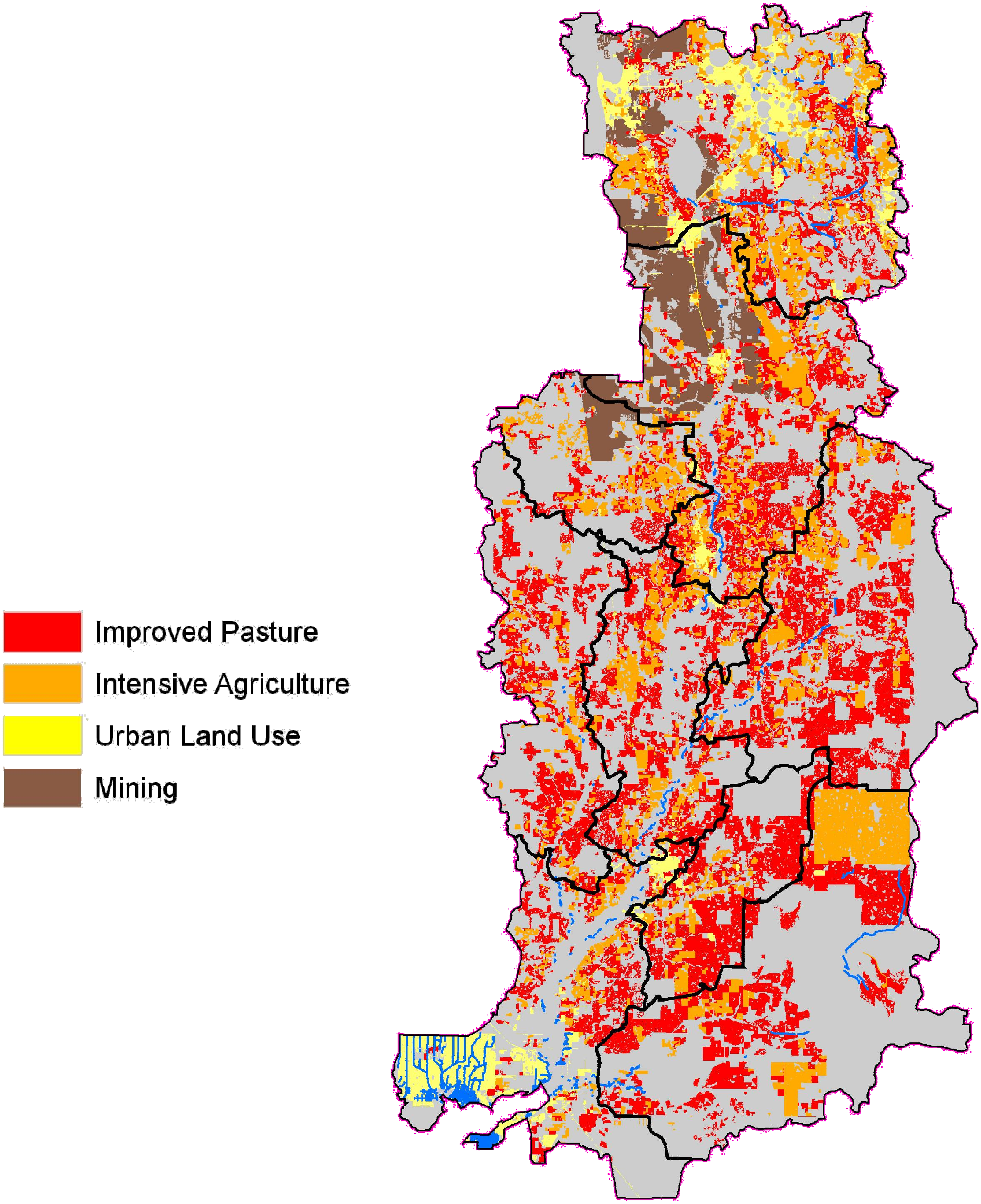


Figure 4.3.1.3. Developed Land Use in the Peace River Watershed in 1999

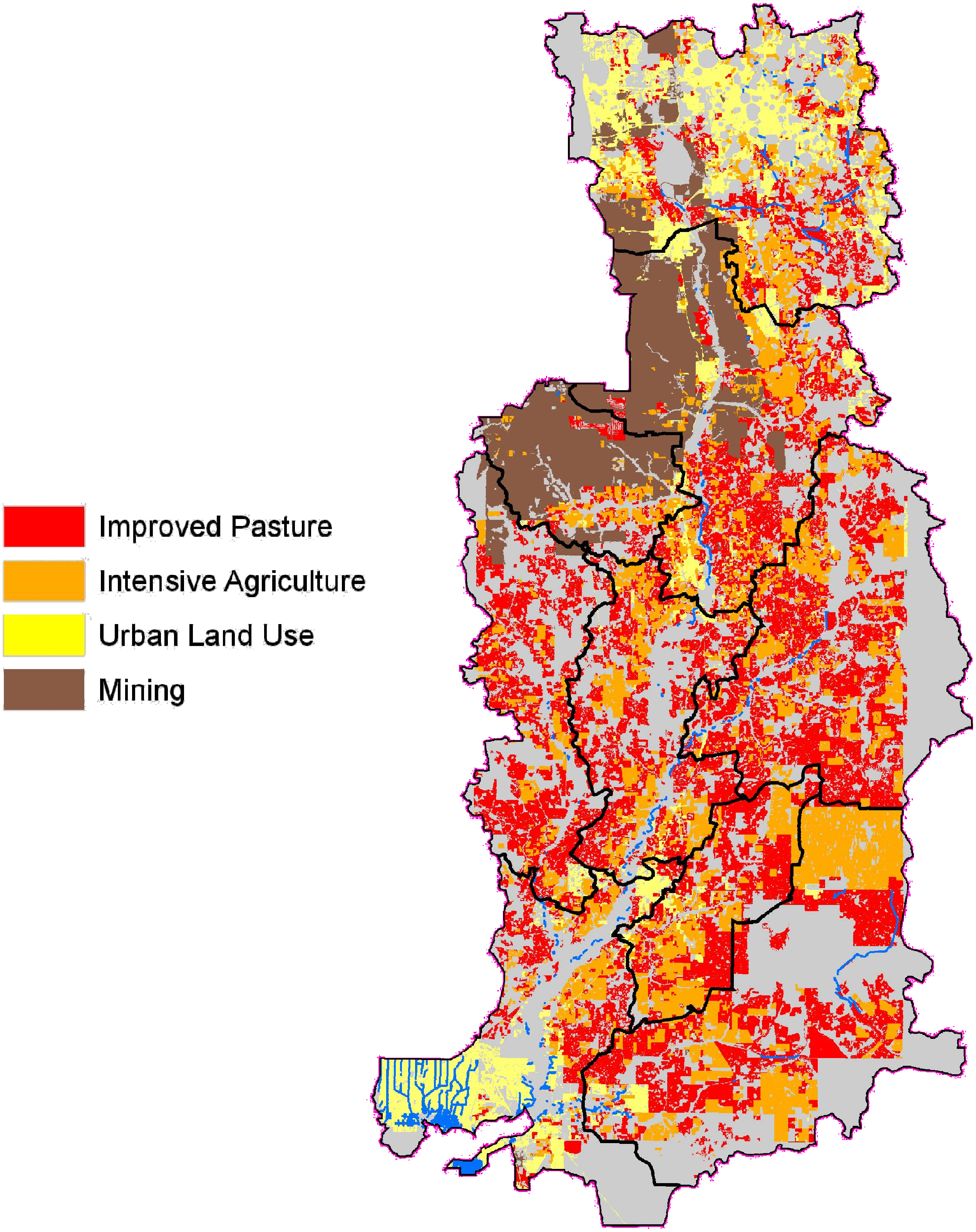


Table 4.3.1.1. Changes in Developed and Undeveloped Land Use in the Peace River Watershed: 1940s to 1999

1940s		1999 Land Use Acres									
Land Use Class	**Total Acres**	**Mined lands**	**Urban Land Use**	**Improved Pasture**	**Intense Agriculture**	**Wetlands**	**Native Upland Habitat**	**Lakes**	**Bays and Estuaries**	**Streams and River Channels**	**Total Acres**
Mined lands	7,495	5,230	109	4,725	9,075	35,265	88,351	731	0	1	143,487
Urban Land Use	14,659	621	13,963	7,539	20,257	17,661	73,108	350	63	10	133,571
Improved Pasture	39,640	910	154	14,935	10,710	48,378	304,092	145	0	23	379,346
Intense Agriculture	107,115	276	148	7,657	59,698	14,270	147,710	74	0	0	229,832
Wetlands	354,674	228	69	628	542	200,955	13,048	2,159	5	598	218,232
Native Upland Habitat	834,311	112	187	3,537	6,499	31,042	201,256	124	0	92	242,849
Lakes	33,779	117	27	545	320	5,902	5,789	30,181	0	146	43,027
Bays and Estuaries	692	0	1	0	0	44	7	0	615	3	671
Streams, River Channels	4,320	0	2	74	14	1,158	951	15	8	3,446	5,668
Total	1,396,683										1,396,683

*The change in land uses between the 1940s and 1999 can first be accounted for by reading across a row. For example, 14,659 acres of urban lands in the 1940s increased to 133,571 acres in 1999 (an increase of 118,912 acres). Urban land uses in 1999 included 621 acres of formerly mined lands, 13,963 acres of urban lands that were urban lands in the 1940s, 7,539 acres of former improved pasture, and 20,257 acres of former intense agriculture. In addition, 17,661 acres of wetlands, 73,108 acres of native upland habitat, 350 acres of lakes/open water, and 10 acres of streams and river channels were converted to urban lands between the 1940s and 1999.

*The difference between the acres of urban lands in the 1940s (14,659) and the acres of urban lands that remained as urban lands (13,963 acres) can be accounted for by reading down the urban land use column. For example, 109 acres of urban lands were converted to mined lands, 154 acres of urban lands were converted to improved pasture, 148 acres were converted to intense agriculture, 69 acres went to wetlands, 187 acres were converted to native upland habitats, 27 acres were converted to lakes and open water, and 3 acres went to bays and estuaries and streams and river channels.

**Streams and river channels are addressed as linear feet of impacts in Table 4.5.1.

Table 4.3.1.2. Changes in Developed and Undeveloped Land Use in the Peace River Watershed: 1940s to 1979

1940s		1979 Land Use Acres									
Land Use Class	**Acres**	**Mined lands**	**Urban Land Use**	**Improved Pasture**	**Intense Agriculture**	**Wetlands**	**Native Upland Habitat**	**Lakes**	**Bays and Estuaries**	**Streams and River Channels**	**Acres**
Mined lands	7,495	5,374	2	2,552	4,320	19,336	32,627	226	0	0	64,437
Urban Land Use	14,659	270	13,838	4,665	8,312	7,302	38,432	151	63	16	73,049
Improved Pasture	39,640	792	326	21,332	12,765	39,524	281,890	285	0	11	356,925
Intense Agriculture	107,115	158	149	4,761	77,320	8,045	101,021	42	0	0	191,496
Wetlands	354,674	293	41	533	701	235,035	9,918	2,432	15	288	249,255
Native Upland Habitat	834,311	486	292	5,533	3,530	41,380	368,017	156	0	54	419,449
Lakes	33,779	123	9	188	153	2,896	1,580	30,480	0	4	35,432
Bays and Estuaries	692	0	1	0	0	35	5	0	605	4	650
Streams and River Channels	4,320	0	2	76	14	1,122	820	8	8	3,942	5,991
Total	1,396,683										1,396,683

Table 4.3.1.3. Changes in Developed and Undeveloped Land Use in the Peace River Watershed: 1979 to 1999

1979		1999 Land Use Acres									
Land Use Class	**Acres**	**Mined lands**	**Urban Land Use**	**Improved Pasture**	**Intense Agriculture**	**Wetlands**	**Native Upland Habitat**	**Lakes**	**Bays and Estuaries**	**Streams and River Channels**	**Acres**
Mined lands	64,437	52,970	244	16,841	11,292	14,810	46,612	716	0	2	143,487
Urban Land Use	73,049	4,867	70,685	15,857	12,259	4,409	25,341	138	0	15	133,571
Improved Pasture	356,925	3,149	496	250,807	12,059	14,799	97,926	83	0	27	379,346
Intense Agriculture	191,496	862	198	49,930	146,665	3,459	28,682	36	0	1	229,832
Wetlands	249,255	1,413	323	5,163	388	199,742	9,417	1,258	2	525	218,232
Native Upland Habitat	419,449	192	887	16,205	8,434	8,309	208,655	92	0	74	242,849
Lakes	35,432	981	189	2,104	399	3,477	2,777	32,942	0	157	43,027
Bays and Estuaries	650	0	0	0	0	21	1	0	648	1	671
Streams, River Channels	5,991	3	27	18	0	230	38	166	0	5,187	5,668
Total	1,396,683										1,396,683

4.3.1.3 Urban Land Use: 1940s - 1999

The conversion of natural landscapes to residential communities with canals is one of the more significant aspects of urbanization, specifically in the Coastal Lower Peace River basin. Between 1950 and 1994, areas of open water in the lower Peace River increased by five percent, due mostly to development of residential canal-front communities (Florida Marine Research Institute (FMRI) 1998). As a result of this land use change, marsh cover decreased by 520 acres, a 22 percent decline, along the lower Peace River (FMRI 1998). The vast majority of this decline (370 acres, or 71 percent of the total loss) occurred between 1950 and 1970.

Importantly, areas of mangroves along the lower Peace River declined by 80 acres between 1950 and 1994, with 100 percent of this loss occurring between 1950 and 1970 (FMRI 1998). These results suggest that urban development in the lower Peace River has brought about a loss of 600 acres of marsh and mangroves, which are essential estuarine habitat for fish and wildlife, and that most of these losses to urbanization occurred during the 1950s and 1960s. These direct impacts on fisheries resources, in addition to increased nutrient loadings from domestic point sources and urban stormwater runoff, have negatively affected the health and productivity of the Peace River and Charlotte Harbor.

Urban lands increased from approximately 15,000 acres (one percent of the watershed) in the 1940s to 134,000 acres (10 percent of the watershed) in 1999 (Table 4.3.1) and increases were the largest by far in the Peace River at Bartow and Coastal Lower Peace basins. This net increase is primarily the result of the conversion of approximately 73,000 acres of native upland habitat to urban areas between the 1940s and 1999, making up the largest single conversion to urban lands (Table 4.3.1.2). The second largest conversion to urban lands was from improved pasture and intense agriculture, which combined accounted for approximately 38,000 acres of new urban lands between the 1940s and 1999.

Urban lands in the Peace River watershed increased from approximately 15,000 acres in the 1940s to 134,000 in 1999. Approximately 73,000 acres of native upland habitat were converted to urban areas between the 1940s and 1999, making up the largest single conversion to urban lands.

By 1999, urban lands increased to 13 percent of the Peace River at Bartow basin and 19 percent of the Coastal Lower Peace basin. There was an average increase in urban lands of one percent in the remaining seven basins. By 1999, urban lands increased to 26 percent of the Peace River at Bartow basin and 27 percent of the Coastal Lower Peace basin and had an average increase of three percent in the remaining seven basins.

Population Changes in the Watershed – General population data for the nine counties in the Peace River watershed includes data from outside the watershed, while only small portions of most of the counties are included in the watershed. Consequently, in order to account for this, population data for the Peace River watershed were obtained from the U.S. Census Bureau for county divisions that most closely followed the Peace River watershed boundary. The boundaries of these county divisions were not consistent for different periods. As a result, population in some of the counties that only had a small portion located within the watershed, such as Hillsborough, Manatee, Sarasota, Glades, and Highlands Counties ("Other Counties" in table and graph), showed discrepancies among the years due to changes in the size of the county divisions. However, since these counties only had small portions in the watershed, the discrepancies did not significantly affect population estimates for the Peace River watershed as a whole. Population data for cities were omitted if the cities were not located in the watershed. Data for portions of the counties within the watershed boundary are summarized in Table 4.3.1.4 and Figure 4.3.1.4.

Census data indicate that in 1930, approximately 62,000 people resided in the Peace River watershed, 70 percent of whom resided in Polk County. The population increased about nine percent from 1930 to 1940 to include an additional 7,000 people. While the populations in Hardee County and Charlotte County portions of the watershed decreased slightly, the increase in the Polk County was greater than the entire remainder of the watershed.

In 1950, the population increased to approximately 156,000 people and represented a doubling of the 1940 population both for the watershed as a whole, and in Polk County alone. Polk County included 77 percent of the total watershed population in 1950. Population increased 42 percent from 1950 to 222,000 in 1960 and 25 percent from 1960 to 277,000 in 1970. As was the case in previous years, Polk County made up the largest portion of the watershed's population, 80 percent in 1960 and 74 percent in 1970. Charlotte County's population almost tripled between 1960 and 1970, making it the second largest population in the watershed in 1970.

Population for 1980 was obtained from the Census Bureau's 1980 Census of the Population and Housing. Population of counties and county subdivisions were included if any portion of the watershed was located in them. Population of cities was omitted if the cities were not located in the watershed.

Population in the watershed increased 38 percent from 1970 to 382,000 in 1980, with Polk County making up 65 percent of the total population of the watershed. Charlotte County's population more than doubled from 1970 to 1980, making up 11 percent of the total population of the watershed and making it the second largest population center in the watershed.

The population in the Peace River watershed increased 14 percent from 1980 to about 435,000 in 1990. Polk County's population (293,000) continued to make up the largest portion of the watershed's population in 1990. Charlotte County's population increased from about 42,000 in 1980 to about 76,000 in 1990, making up 18 percent of the population in the watershed.

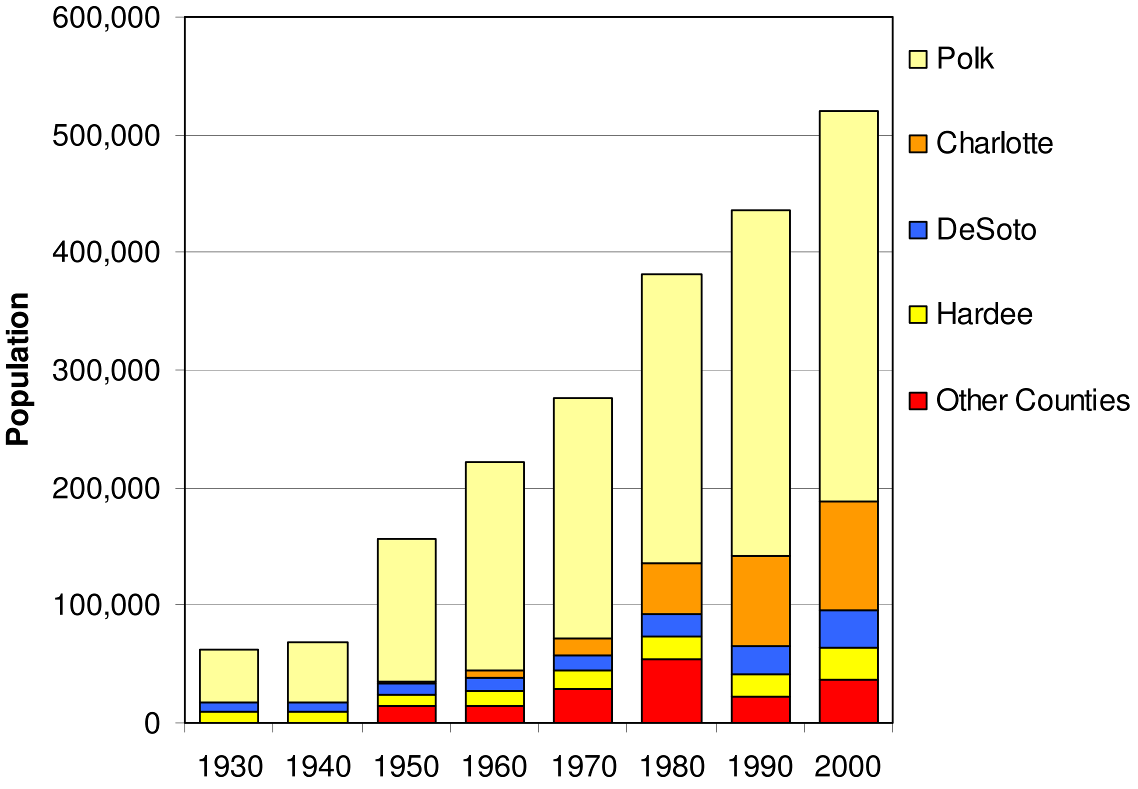
By the year 2000, the population in the watershed further increased 20 percent from 1990 to about 520,000. Polk and Charlotte Counties' population combined made up 82 percent of the total population in the watershed and 64 percent and 18 percent, respectively. Overall, the total population in the watershed increased more than 800 percent from 1930 to 2000.

Table 4.3.1.4. Population Changes in the Peace River Watershed by Portions of Counties within the Watershed Boundary

	1930	1940	1950	1960	1970	1980	1990	2000
Other Counties	0	0	14,460	14,577	29,256	54,818	22,221	36,478
Hardee	10,348	10,148	10,073	12,370	14,889	19,379	19,499	26,938
DeSoto	7,745	7,792	9,242	11,683	13,060	19,039	23,865	32,209
Charlotte	95	52	1,859	5,407	15,238	41,648	76,166	93,375
Polk	43,986	50,054	120,644	177,800	204,263	246,875	293,492	331,326
Total	62,174	68,046	156,278	221,837	276,706	381,759	435,243	520,326

* Other Counties includes Hillsborough, Manatee, Sarasota, Glades, and Highlands Counties. ** Population for 1930 – 1950 was obtained for minor civil divisions within counties located in the watershed. *** Population for 1960 – 1980 was obtained for county subdivisions within counties located in the watershed. **** Population for 1990 – 2000 was obtained for census block groups within counties located in the watershed. ***** The 1980 population for the portion of Polk County in the watershed was estimated by applying the average proportion of the population within the watershed (used in all other years) to the population of the County as a whole for each year.

Figure 4.3.1.4. Population Changes in the Peace River Watershed (1930 – 2000)



4.3.1.4 Phosphate Mined Lands

Phosphate mined lands in the Peace River watershed increased from 7,495 acres in the 1940s (Table 4.3.1.1) to 143,000 acres in 1999, due primarily to the conversion of approximately 88,000 acres of native upland habitat that was converted to mined lands during this period. Conversions from native upland habitat subsequently made up 62 percent of the mined lands in the watershed. Most of the remaining mined lands resulted from the conversion of about 35,000 acres of wetlands and 14,000 acres of intense agriculture improved pasture.

Approximately 2,265 acres of mined lands were converted to another land use between the 1940s and 1979, 792 acres (37 percent) of which were converted to improved pasture, and 621 acres (27 percent) were converted to urban lands (Table 4.3.1.2).

Phosphate mining comprised less than one percent of the watershed in the 1940s and was limited to three basins in the upper watershed (*Appendix 3.1*). In the 1940s, acres of mining included about 774 acres in the Payne Creek basin, 2,575 acres in the Peace River at Bartow basin, and 4,109 acres in the Peace River at Zolfo Springs basin.

By 1999, phosphate mining occurred in five of the nine basins: Horse Creek, Payne Creek, Peace River at Arcadia, Peace River at Bartow, and Peace River at Zolfo Springs basin (sand or shell mining accounted for the acres of mining in the Shell Creek and Coastal Lower Peace basins). The largest increase in mining was in the Payne Creek basin, in which phosphate mining expanded to include 50,238 acres (63 percent of the basin) in 1999 (Table 4.3.1.3). Mined lands were absent in the Horse Creek basin in 1979, but increased to 7,295 acres (six percent of the basin) by 1999. Approximately 183 acres of mining (as clay settling areas) appear in the Peace River at Arcadia basin in the 1999 aerial photography. These mined areas occurred where the Peace River at Arcadia, Payne Creek (to the north), and Horse Creek (to the west) basins meet, and suggest that the basin boundaries should be reevaluated in future studies.

By 1999, phosphate mining occurred in five of the nine basins, including the Peace River at Bartow, and Peace River at Zolfo Spring, Payne Creek, Peace River at Arcadia, and Horse Creek basins.

Mined lands are designated in this study as mandatory or nonmandatory reclaimed lands, as described previously in *Chapter 3*. Since 1975, reclamation on mined lands is mandatory. Mandatory reclaimed mined lands subsequently fall into categories of totally/partially reclaimed, not reclaimed, or active clay settling areas. Prior to 1975, reclamation was not mandatory, although these lands may be voluntarily reclaimed to another land use. Acres of each of these four categories are presented for the five basins in the watershed in which mining land uses occur (Table 4.3.1.5).

The acres of mined lands presented in Table 4.3.1.5 are based on a compilation of analyses of data from the industry and FDEP sources and are not necessarily consistent with the land use designations and acres presented in other land use tables in this document. For example, mandatory reclaimed mined lands and nonmandatory mined lands are in some instances identified as reclaimed lands by the industry whether or not they have been reclaimed. Aerial photography was used to distinguish between these categories.

Nearly 57,000 acres of the total 142,412 acres of mined lands in the watershed have been totally/partially reclaimed: approximately 15,000 acres are designated as mined mandatory, and the remaining 49 percent are clay settling ponds or nonmandatory lands.

The Payne Creek basin includes a total of nearly 44,000 acres of mined lands. Approximately 16,000 acres of those are identified as totally or partially reclaimed to another land use, while 3,458 acres were mined prior to 1975 and are not required to be reclaimed. Because most mining in the basin occurred subsequent to reclamation regulations, over 11,000 acres in the Payne Creek are also identified as mandatory reclamation lands and only about 3,500 acres are identified as nonmandatory reclamation. Mined lands that are designated as mandatory reclamation that have not been reclaimed, but will be at a later date, total over 11,000 acres in the Payne Creek basin. Another 14,025 acres are clay settling ponds designated as nonmandatory reclaimed mined lands.

In contrast, there are no nonmandatory mined lands in the Horse Creek Basin because mining did not reach this basin after 1975. However, of the nearly 3,500 acres of mined lands in the Horse Creek basin, only 574 acres are designated as totally/partially reclaimed. In the watershed overall, nearly 57,000 acres of the total 142,412 acres (about 40 percent) of mined lands are totally/partially reclaimed and approximately 15,000 acres (11 percent) are designated as mined mandatory. Reclamation is not required on nonmandatory mined lands (15 percent of the mined lands). Clay settling areas make up 34 percent of the mined lands and are designated separately from the other categories, that is, not all 34 percent are included in the "mandatory reclamation" category.

Figure 4.3.1.5. Areas of Phosphate Mining and Land Use in Reclaimed Mined Areas in the Peace River Watershed

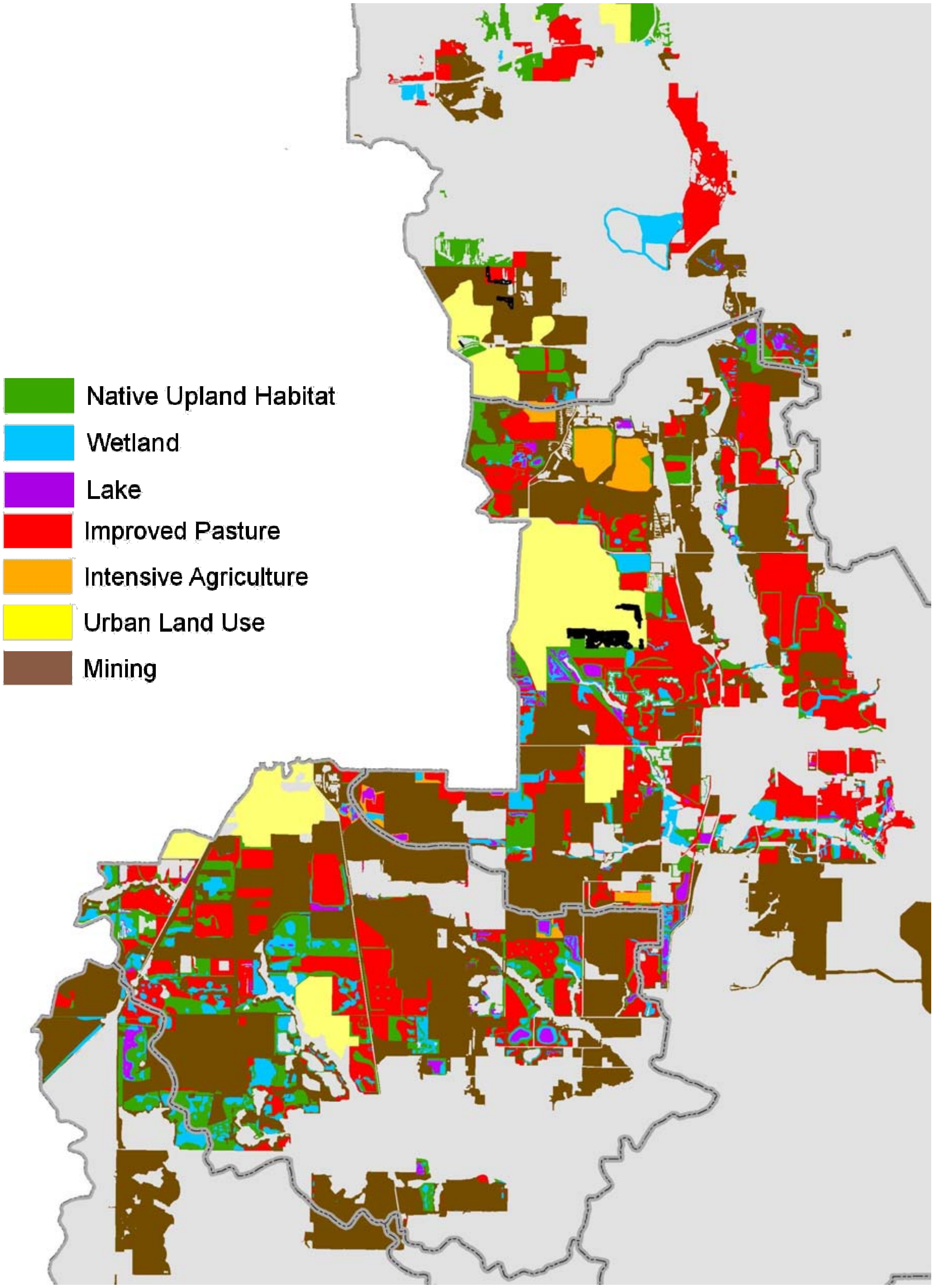


Table 4.3.1.5. Mining Changes (in Acres) in Peace River Watershed Basin

Mining Category	Horse Creek	Payne Creek	Peace River at Arcadia	Peace River at Bartow	Peace River at Zolfo Springs	Total
1999						
Totally/Partially Reclaimed	574	16,152	0	11,486	28,363	56,575
Mined Nonmandatory	0	3,458	0	8,641	9,616	21,715
Mined Mandatory	2,398	11,032	0	232	1,528	15,191
Active Clay Settling Areas	553	14,025	183	5,903	28,267	48,931
1979						
Totally/Partially Reclaimed	0	2,490	0	4,752	8,180	15,422
Mined Nonmandatory	0	4,362	0	10,957	11,952	27,270
Mined Mandatory	0	3,899	0	0	6,623	10,522
Active Clay Settling Areas	0	7,958	0	7,227	23,642	38,828
1940s						
Totally/Partially Reclaimed	0	0	0	0	0	0
Mined Nonmandatory	0	1,256	0	5,207	6,572	13,035
Mined Mandatory	0	0	0	0	0	0
Active Clay Settling Areas	0	0	0	0	387	387

4.3.1.5 Native Upland Habitat: 1940s - 1999

The largest land use change in the Peace River watershed from the 1940s to 1999 was the dramatic increase in improved pasture and the corresponding loss of native upland habitat. The Peace River watershed included 834,311 acres of native upland habitats in the 1940s, but by 1999, only 242,849 acres of the native upland habitat remained, amounting to a loss of almost 600,000 acres. Over 300,000 acres of native uplands were converted to improved pasture and intense agriculture during this time period and accounted for the largest land use conversion in the watershed.

Native upland habitat comprised an average of 63 percent of each basin in the watershed in the 1940s and was concentrated primarily in the middle and lower watershed (*Appendix G*). By 1979, native upland habitat decreased to comprise an average of 31 percent of each basin and was still concentrated in the same areas as it was in the 1940s (*Appendix G*). By 1999, native upland habitat decreased further to comprise an average of only 17 percent of each basin and remained concentrated in the middle and lower portions of the watershed.

The Peace River watershed included 834,311 acres of native upland habitats in the 1940s, but by 1999, only 242,849 acres of the native upland habitat remained, amounting to a loss of almost 600,000 acres.

The second largest conversion of native upland habitat (18 percent) was to intense agriculture between the 1940s and 1999 (Table 4.3.1.1). However, between 1979 and 1999, the second largest conversion of native upland habitat was to phosphate mined lands (Table 4.3.1.3). Approximately 47,000 acres, or 11 percent, of native upland habitat was converted to phosphate mined lands during that time period. Approximately 88,000 acres of native upland habitat was converted to phosphate mind lands from the 1940s to 1999.

4.3.1.6 Wetlands: 1940s - 1999

Losses of wetlands in the Peace River watershed between the 1940s and 1999 totaled over 136,000 acres. The greatest losses were due to conversions to improved pasture and phosphate mined lands. Approximately 40,000 acres, or 11 percent, of wetlands from the 1940s were converted to improved pasture by 1979 (Table 4.3.1.2), and another 15,000 acres, or two percent, were converted to improved pasture by 1999 (Table 4.3.1.3). Ten percent of wetlands from the 1940s were converted to phosphate mined lands by 1999.

Total acres of developed land uses in the Peace River watershed (included phosphate mining, urban, intense agriculture, and improved pasture land uses) increased from 12 percent of the watershed in the 1940s to 49 percent in 1979, and expanded to include 64 percent of the watershed in 1999 (Table 4.3.1.2). Changes in undeveloped land uses (native upland habitats, wetlands, streams and river channels, and other waters) of the watershed were commensurate and decreased from 85 percent of the watershed in the 1940s to 48 percent in 1979, and 33 percent in 1999. Expansion of agriculture throughout most of the watershed, phosphate mining in predominantly three northerly basins, and urbanization in the northern-most and southern-most basins, has resulted in large losses of wetlands and deforestation and/or loss of native upland habitats.

There was also a conspicuous increase of nearly 10,000 acres in the lakes and open water land use classes between 1940 and 1999. Approximately 6,000 acres of the 10,000 acre increase were due primarily to phosphate mining activities in Peace River at Bartow, Peace River at Zolfo Springs, and Payne Creek basins, and about 1,200 acres were due to increases in agricultural activities in the Shell Creek basin. However, the term "lakes" also includes open water, and cooling ponds for two power facilities in the watershed account for a substantial portion of the lakes.

The greatest loss of wetlands in the Peace River watershed was to improved pasture and phosphate mined lands. Approximately 40,000 acres, or 11 percent, of wetlands from the 1940s were converted to improved pasture by 1979, and another 8,000 acres, or two percent, were converted by 1999.

Approximately 105,000 acres of wetlands were lost from the 1940s to 1979 and an additional 31,000 were lost from 1979 to 1999. Between the 1940s and 1979, about 41,000 acres of wetlands were converted to native upland habitat along with 40,000 acres to improved pasture. Between 1979 and 1999, about 15,000 acres of wetlands converted to improved pasture along with 15,000 acres to phosphate mined lands. By 1999, only 57 percent of wetlands present in the 1940s remained.

Wetlands were present throughout the watershed in the 1940s and comprised an average of 25 percent of each basin (*Appendix G*). By 1979, wetlands comprised an average of only 18 percent of each basin. Each basin in the watershed experienced a loss of wetlands during this time period. The greatest wetland losses between the 1940s and 1979 were in the upper watershed. During this period, the Peace River at Bartow basin lost approximately 18 percent of its wetlands and the Peace River at Zolfo Springs basin lost approximately 10 percent of the wetlands present in the 1940s. As a result, more wetlands remained in the middle and lower areas of the watershed in 1979. By 1999, wetlands comprised only an average of 15 percent of each basin. Again, all basins in the watershed experienced a loss of wetlands during this time period. In 1999, remaining wetlands were still concentrated mostly in the middle and southern portion of the watershed.

Figure 4.3.1.6. Undeveloped Land Use in the Peace River Watershed in the 1940s

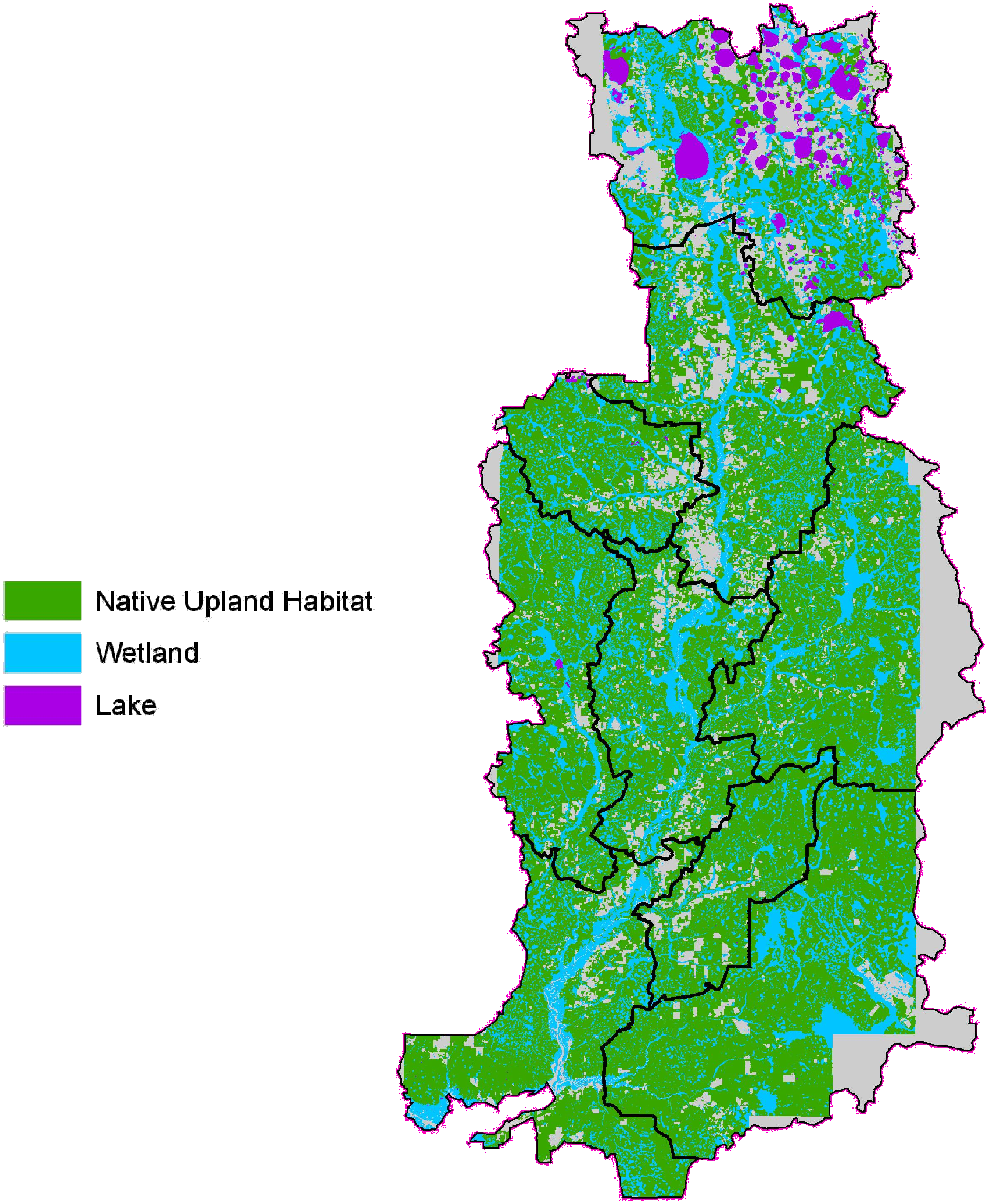


Figure 4.3.1.7. Undeveloped Land Use in the Peace River Watershed in 1979

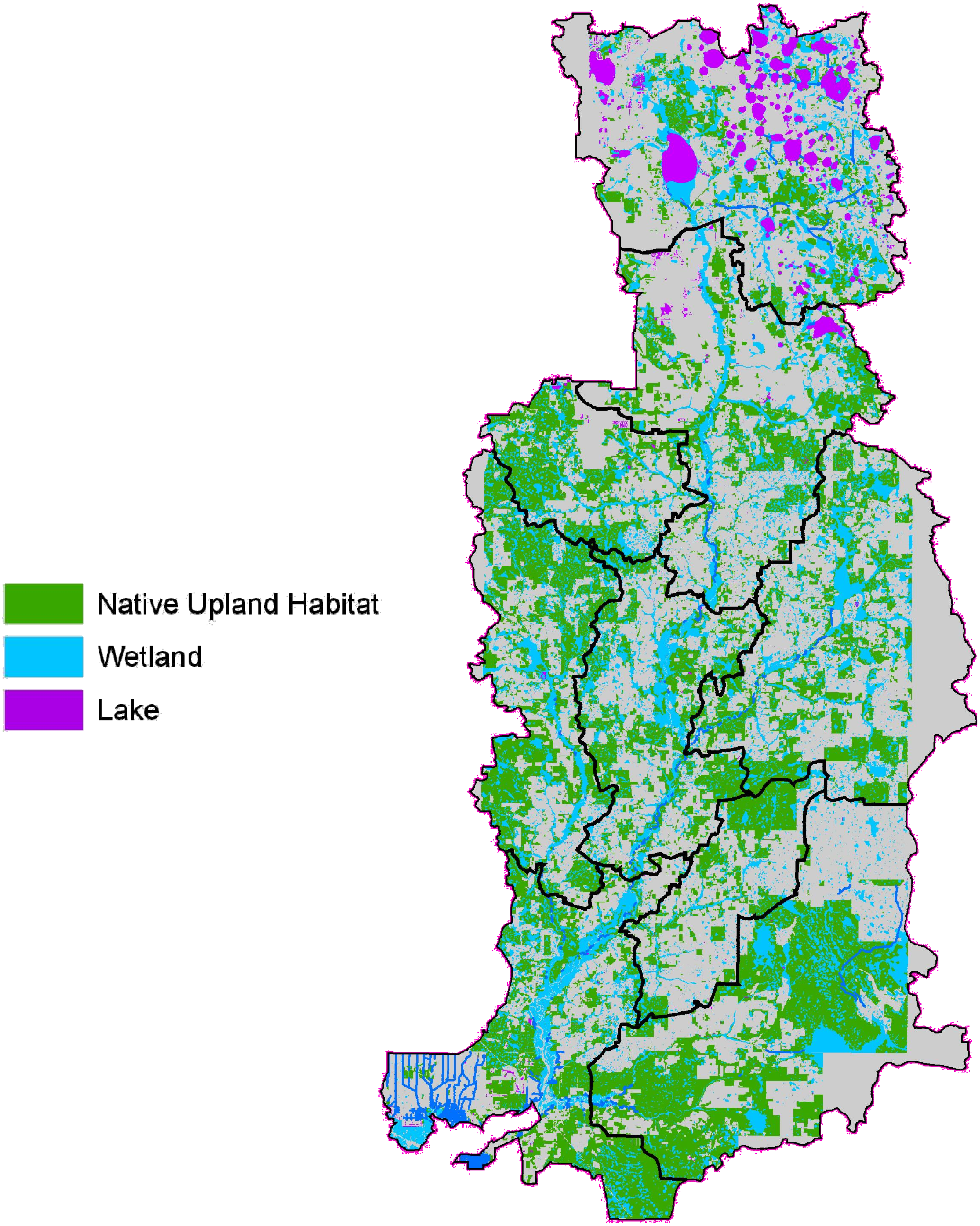
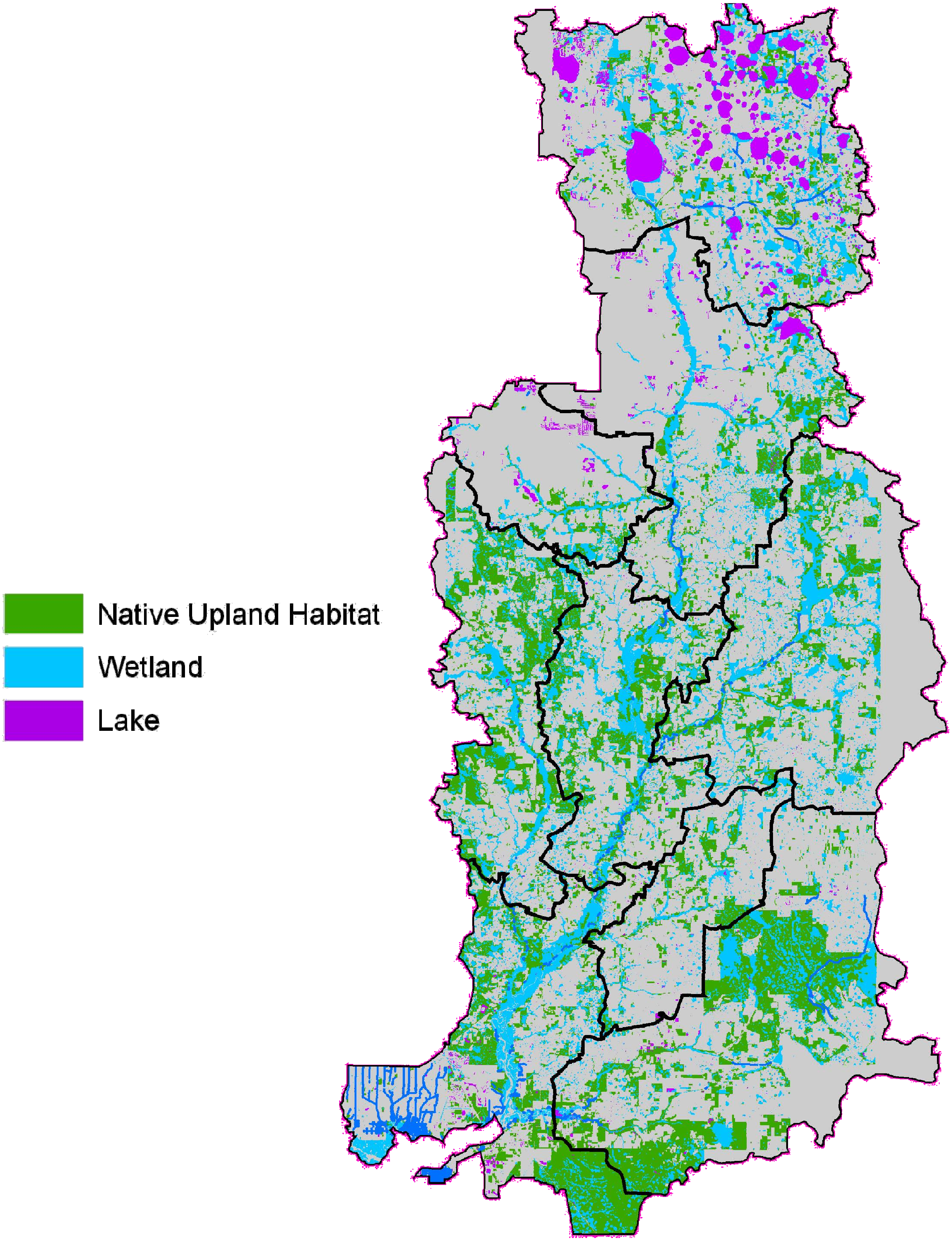


Figure 4.3.1.8. Undeveloped Land Use in the Peace River Watershed in 1999



4.3.1.7 Bays and Estuaries: 1940s - 1999

Changes in acres of land use from bays and estuaries to other land uses were most conspicuous in the Coastal Lower Peace River basin where wetlands were converted to residential communities with canals between 1979 and 1999, as described previously. However, changes in acres of bays and estuaries were not all due to actual changes in land use and were often attributable to differences in tidal exposure, pixel sizes, and other elements associated with the aerial photography.

4.3.2 Changes in Land Use: 1940s – 1979

Land use conversions in the Peace River watershed were greatest from the 1940s to 1979 (Table 4.3.1.2) when compared with the period from 1979 to 1999 and were predominantly the result of conversions from native upland habitat and wetlands to improved pasture. Developed land uses were concentrated primarily in the upper watershed in the 1940s and comprised 13 percent of the watershed. By 1979, developed land uses increased to 50 percent and occurred throughout the watershed, but remained concentrated in the upper watershed.

Undeveloped land uses made up 85 percent of the watershed in the 1940s (Table 4.3.1.1). By 1979, total undeveloped land uses had declined to 48 percent of the watershed and were more prevalent in the middle and lower watershed.

Land use conversions in the Peace River watershed were much greater from the 1940s to 1979 when compared with the period from 1979 to1999 and were predominantly the result of conversions from native upland habitat to improved pasture.

4.3.2.1 Improved Pasture: 1940s – 1979

Improved pasture expanded from 40,000 (three percent of the watershed), in the 1940s to 357,000 acres (26 percent of the watershed) in 1979 (Table 4.3.1.2) and represented the largest increase in a single land use the watershed. Approximately 282,000 acres of native upland habitat and 38,524 acres of wetlands were converted to improved pasture and accounted for nearly all of the conversions to improved pasture from the 1940s to 1979.

In the 1940s, improved pasture made up less than five percent of each basin (*Appendix G*). By 1979, acres of improved pasture had increased from less than five percent to between 15 and 17 percent in the Peace River at Bartow, Payne Creek, Shell Creek, and Coastal Lower Peace River basins. Improved pasture expanded from 24 to 39 percent in the Peace River at Zolfo Springs, Peace River at Arcadia, Horse Creek, and Charlie Creek basins.

4.3.2.2 Intense Agriculture: 1940s – 1979

Intense agriculture increased from 107,000 acres in the 1940s to 191,000 acres in 1979 (Table 4.3.1.2). Approximately 101,000 acres of native upland habitat were converted to intense agriculture during this time period. About 77,000 acres, or 40 percent, of the intense agriculture in 1979 had been classified as intense agriculture in the 1940s. While there was a net increase in intense agriculture during this time period, nearly 13,000 acres of intense agriculture were converted to improved pasture as well.

Approximately 56 percent of intense agriculture was concentrated in the upper Peace River watershed during the 1940s (*Appendix G*). By 1979, intense agriculture had expanded in every basin in the watershed with the exception of the Peace River at Bartow basin, where total acres of intense agriculture remained relatively unchanged.

4.3.2.3 Urban Lands: 1940s – 1979

Urban lands in the Peace River watershed increased from 15,000 acres (one percent of the watershed) to 73,000 acres (five percent of the watershed) between the 1940s and 1979 (Table 4.3.1.2). Approximately 38,432 acres (53 percent) of the urban lands in 1979 were the result of conversions from native upland habitat. Another 20,279 (28 percent) acres of urban lands were converted from intense agriculture (8,312 acres), wetlands (7,302 acres), and improved pasture (4,665 acres). Two hundred and seventy acres of mined lands were converted to urban lands by 1979. About 1,000 acres of urban land uses were converted to other land during this time period.

Urban lands were concentrated predominantly in the upper watershed in the 1940s and made up less than three percent of the basins where present (Appendix G). By 1979, urban lands increased to include 13 percent of the Peace River at Bartow basin and 19 percent of the Coastal Lower Peace basin, with an average increase of one percent in the remaining seven basins.

4.3.2.4 Phosphate Mined Lands: 1940s – 1979

Phosphate mining increased from less than 7,500 acres (one percent) of the Peace River watershed in the 1940s to more than 64,000 acres in 1979 (Table 4.3.1.2). Approximately 33,000 acres of native upland habitat and 19,000 acres of wetlands were converted to phosphate mined lands by 1979, and comprised the largest land use conversion to mined lands in the watershed. Conversions from intense agriculture and improved pasture combined accounted for an additional 6,872 acres of mined lands by 1979.

Approximately 33,000 acres of native upland habitat and 19,000 acres of wetlands were converted to phosphate mined lands by 1979.

Mining was concentrated in the upper watershed basins and made up less than three percent of the basins where present (Appendix G). Increases were greatest in the Peace River at Zolfo Springs basin, where phosphate mining increased to include 36,108 acres (18 percent of the basin) in 1979. The Payne Creek basin included 8,357 acres of mining and Peace River at Bartow included 19,972 acres of mining. Phosphate mining remained absent in the other five watershed basins.

4.3.2.5 Native Upland Habitat: 1940s – 1979

The greatest change in land use in the watershed was the conversion of approximately 34 percent of the native upland habitat to improved pasture from the 1940s to 1979 (Table 4.3.1.2) (this change also accounted for the largest change from the 1940s to 1999). Native upland habitat was the largest land use in the watershed in the 1940s and accounted for nearly 60 percent of the area in the watershed. By 1979, 415,000 acres of native upland habitat were converted to other land uses and native upland habitat accounted for only 30 percent of the watershed.

Native upland habitat comprised an average of 63 percent of each basin in the watershed in the 1940s and was more prevalent in the middle and lower portions of the watershed (Appendix G). By 1979, native upland habitat decreased to comprise an average of 31 percent of each basin and was still concentrated in the lower and middle watershed.

4.3.2.6 Wetlands

More than 105,000 acres of wetlands in the Peace River watershed were lost between the 1940s and 1979 (Table 4.3.1.2). Approximately 41,000 acres of wetlands were drained and subsequently converted to upland habitats, while 40,000 acres of wetlands were converted to improved pasture, and 19,000 acres to phosphate mined lands (Table 4.3.1.2). Approximately 66 percent of wetlands in the 1940s remained in the landscape in 1979.

Wetlands were present throughout the watershed during this time period and comprised an average of 25 percent of each basin (Appendix G). The largest conversion of wetlands was to native upland habitats during 1940s to 1979 time period. By 1979, each basin within the watershed had lost an average of 18 percent of wetlands from the 1940s. The greatest losses were in the upper watershed basins.

4.3.3 Changes in Land Use: 1979 - 1999

Developed land uses (urban, mining, intense agriculture, and improved pasture land uses, as described previously) increased from 50 percent of the Peace River watershed in 1979 to 64 percent of the watershed by 1999. While land use conversions occurred predominantly from the 1940s to 1979, conversions to mining and urban lands continued to increase between 1979 and 1999. Acres of developed land uses expanded in the watershed between 1979 and 1999 (Table 4.3.1.3). However, developed land uses were still concentrated primarily in the upper watershed basins.

> *While land use conversions occurred predominantly from the 1940s to 1979, conversions to mining and urban lands continued to increase between 1979 and 1999.*

Numbers of acres of undeveloped land uses decreased from 48 percent of the watershed in 1979 to 33 percent of the watershed in 1999 (Table 4.3.1.3). The greatest losses in undeveloped land uses occurred in the upper watershed.

4.3.3.1 Improved Pasture: 1979 - 1999

Improved pasture increased by more than 22,000 acres in the watershed between 1979 and 1999 (Table 4.3.1.3), due primarily to conversions from native upland habitat. Along with the large conversion of 98,000 acres of native upland habitat to improved pasture, about 15,000 acres of wetlands and 12,000 acres of intense agriculture were converted to improved pasture. In addition, approximately 50,000 acres of improved pasture were converted to intense agriculture during this time period.

Between 1979 and 1999, improved pasture expanded farther into the middle watershed basins and the Shell Creek basin, where there was an average seven percent increase in the number of acres of improved pasture (*Appendix G*).

4.3.3.2 Intense Agriculture: 1979 - 1999

Acres of intense agriculture increased by about 38,000 acres, from 191,496 acres to 229,832 acres, between the 1940s and 1999 (Table 4.3.1.3). Conversions from improved pasture accounted for about 50,000 acres of the intense agriculture in the watershed in 1999, while the second largest conversion to intense agriculture was from native upland habitat (28,682 acres). About 3,500 acres of wetlands were converted to intense agriculture by 1999 was previously wetlands.

During this time period, intense agriculture increased in the middle and lower portions of the watershed by an average of eight percent in each basin (Appendix 3.1). Decreases in intense agriculture in the upper watershed averaged about five percent in each basin.

4.3.3.3 Urban Lands: 1979 - 1999

Urban lands almost doubled in size in the watershed, increasing from about 73,000 acres in 1979 to 134,000 acres in 1999 (Table 4.3.1.3). Approximately 25,000 acres of uplands and 28,000 acres of agriculture (including both improved pasture and intense agriculture) accounted for the largest conversions to urban lands between 1979 and 1999. Conversions of nearly 5,000 acres each of mined lands and wetlands made up almost all of the remaining urban lands.

During this time period, urban lands increased to make up 26 percent of the Peace River at Bartow basin and 27 percent of the Coastal Lower Peace basin (Appendix G). Urban lands increased approximately three percent in each of the remaining seven basins.

The largest single change in land use in the Peace River watershed was the conversion of approximately 42 percent of native upland habitats to other land uses. Approximately 98,000 acres (23 percent) of the native upland habitat were converted to improved pasture.

4.3.3.4 Phosphate Mined Lands: 1979 - 1999

There were approximately 64,000 acres of phosphate mined lands in the Peace River watershed in 1979, compared with 143,000 acres in 1999 (Table 4.3.1.3). This increase of about 80,000 acres was attributable primarily to the conversion of about 47,000 acres of native upland habitat to mined lands. Another 17,000 acres of improved pasture, 15,000 acres of wetlands, and 11,000 acres of intense agriculture were converted to phosphate mining during this period (Table 4.3.1.3). Approximately 53,000 acres of mined lands in 1999 had already been mined by 1979.

By 1999, five basins, including Payne Creek, Horse Creek, Peace River at Arcadia, Peace River at Bartow, and Peace River at Zolfo Springs, had some phosphate mined lands (Appendix G) (based on land use designations, sand and shell mining occurred in Shell Creek, Lower Coastal Peace, and Charlie Creek basins). The largest increase in phosphate mined lands during this time period occurred in the Payne Creek basin. Totally/partially reclaimed mined lands increased from 15,442 acres to 56,575 acres between 1979 and 1999 (Table 4.3.1.5). Active clay settling areas increased by approximately 10,000 acres, mined nonmandatory lands decreased by nearly 5,555 acres, and mined mandatory lands increased by approximately 5,000 acres.

4.3.3.5 Native Upland Habitat: 1979 - 1999

The largest single change in a land use in the Peace River watershed from 1979 to 1999 was the loss of approximately 177,000 acres of the native upland habitats to other lands uses (Table 4.3.1.3). Approximately 98,000 acres (23 percent) of the native upland habitat present in 1979 were converted to improved pasture (Table 4.3.1.3). Over 47,000 acres of native upland habitat were converted to phosphate mined lands. By 1999, acres of native upland habitat had decreased to an average of 17 percent in each basin and remained prevalent in the lower and middle watershed, as was the case in 1979 (Appendix G).

4.3.3.6 Wetlands: 1979 - 1999

Approximately 31,023 acres, or 12 percent, of wetlands in the Peace River watershed were lost between 1979 and 1999 (Table 4.3.1.3). This loss was primarily a result of the conversion of approximately 15,000 acres of wetlands to improved pasture and 15,000 acres to phosphate mined lands. Another 8,000 acres of wetlands were drained and converted to upland habitat and not developed into another land use. Approximately 80 percent of wetlands present in 1979 were still present in 1999.

> *All nine basins in the watershed experienced a loss of wetlands during this time period and wetlands comprised an average of 15 percent of each basin in 1999. The greatest loss was in the upper watershed.*

All nine basins in the watershed experienced a loss of wetlands during this time period and wetlands comprised an average of 15 percent of each basin in 1999 (Appendix G). The greatest loss was in the upper watershed.

4.4 Strategic Habitat Conservation Areas and Biodiversity Hot Spots

Areas important to biodiversity and/or conservation in Florida have been identified by Cox *et al.* (1994) and are described here as they occur in the Peace River watershed. Existing and potential wildlife habitats in the watershed have been identified by the Florida Fish and Wildlife Conservation Commission (FWCC), based on habitat and numbers of key species, many of which are protected. Importantly, biodiversity *hot spots* and Strategic Habitat Conservation Areas (SHCAs) have been developed by Cox *et al*. (1994) to identify conservation targets considered necessary to meet conservation goals in Florida. Information regarding biodiversity hot spots and SHCAs can be used to identify land areas to be avoided as developed areas grow and expand in the watershed.

Biodiversity Hot Spots. The FFWCC biodiversity hot spots data (FFWCC 2002b) reviewed for the study area represents areas of overlap among potential habitats of 54 rare or focal species of wildlife and four important natural communities. Overlap among greater numbers of species indicates higher biodiversity (a thorough description of these hot spots is available in Cox *et al.* 1994).

Strategic Habitat Conservation Areas (SHCAs). To identify significant natural resources in the Peace River watershed, SHCAs were reviewed. SHCAs delineate habitat areas in Florida that should be conserved if key components of the biological diversity in the State are to be maintained and serve as targets for future protection, based on lands needed to meet minimum conservation goals. Using habitat and species distribution maps, public land boundaries, and literature based density estimates, Cox *et al*. (1994) developed maps of under represented species merged into a single statewide map of SHCAs to develop recommendations for minimum conservation goals.

The southwest region of Florida which includes Charlotte County and the Shell Creek basin are an important component of wildlife diversity in Florida and probably represent the most important region in Florida. In 1994, Charlotte County had 23.9 percent of its lands in conservation, compared to the state wide average of 19.6 percent for individual counties. East Charlotte and west Glades counties, along Fisheating Creek and west along S.R. 74, include a mixture of prairies, cypress swamp, pinelands, rangeland, and upland hardwood forests that make up a SHCA for Florida panther, red-cockaded woodpecker, Florida sandhill crane, short-tailed hawk, Florida grasshopper sparrow, American swallow-tailed kite, and Audubon's crested caracara.

> *Most of the important remaining natural areas (in the region) are threatened by expanding citrus operations, phosphate mining, and residential development (Cox et al. 1994).*

In contrast, north of Charlotte County, the watershed along the Peace River is part of the central Florida region, has one of the smallest percentages (5.6 percent) of conservation lands of any region in Florida. Highlands (9.4 percent), Polk (8.2 percent), DeSoto (0.1 percent), and Hardee (0.1 percent) counties all have a much smaller percentage of conservation lands than state wide averages for individual counties. In sharp contrast to these figures, this region has some of the rarest and most biologically rich lands remaining in Florida, including SHCAs for southern bald eagle, Florida scrub jay, Florida sandhill crane, Audubon's crested caracara, Florida grasshoppers sparrow, red cockaded woodpecker, wood storks, and other rare wading birds, and endemic scrub communities. Most of the important remaining natural areas are threatened by expanding citrus operations, phosphate mining, and residential development (Cox *et al.* 1994).

There are approximately 370,369 acres of areas of biodiversity hot spots in the Peace River watershed (Table 4.4.1) and they include approximately 27 percent of the watershed, while 143,011 acres of SHCAs include about 10 percent of the watershed. A review of these areas indicates that the highest levels of biodiversity (7+ focal species overlap) and SHCAs tend to be concentrated in the lower basins (Coastal Lower Peace River and Shell Creek basins) of the watershed (Figures 4.4.1 and 4.4.2). The information presented here is summarized from Cox *et al.* (1994) and much greater detail is provided in that document.

> *Approximately 23.4 percent of the Strategic Habitat Conservation Areas in the Peace River watershed, and 13.3 percent of the biodiversity hot spots, correspond to areas of improved pasture.*

Biodiversity hot spots and SHCAs coincide with 67.4 percent and 60.5, respectively, of existing undeveloped native upland habitats and wetlands, and less than three percent of lakes and other waters in the watershed. Approximately 23.4 percent of the SHCAs in the Peace River watershed, and 13.3 percent of the biodiversity hot spots, correspond to areas of improved pasture. Remaining hot spots and SHCAs correspond to areas of improved pasture, and less than five percent of the watershed includes hot spots or SHCAs that occur in areas of intense agriculture, mined lands, or urban land use. Consequently, conversions of undeveloped land uses and improved pasture to more intensely developed land uses (intense agriculture, mining, and urban) would decrease the areas available for conservation.

Table 4.4.1. Acres (and Percent) of Land Use Classes Coincident with Biodiversity Hot Spots and Strategic Habitat Conservation Areas (SHCAs)

Land Use	Acres (percent)	
	Biodiversity Hot Spots	SHCAs
Developed		
Improved Pasture	49,414 (13.3)	34,001 (23.8)
Intense Agriculture	17,547 (4.7)	11,860 (8.3)
Mined Lands	32,723 (8.8)	5,591 (3.9)
Urban Land Use	13,190 (3.6)	2,117 (1.5)
Undeveloped		
Native Upland Habitat	134,938 (36.4)	38,203 (26.7)
Wetlands	115,321 (31.1)	48,403 (33.8)
Water		
Lakes	3,312 (0.9)	854 (.6)
Other Water	3,924 (1.2)	1,982 (1.4)
Total	**370,369 (100)**	**143,011 (100)**

Figure 4.4.1. Biodiversity Hot Spots in the Peace River Watershed

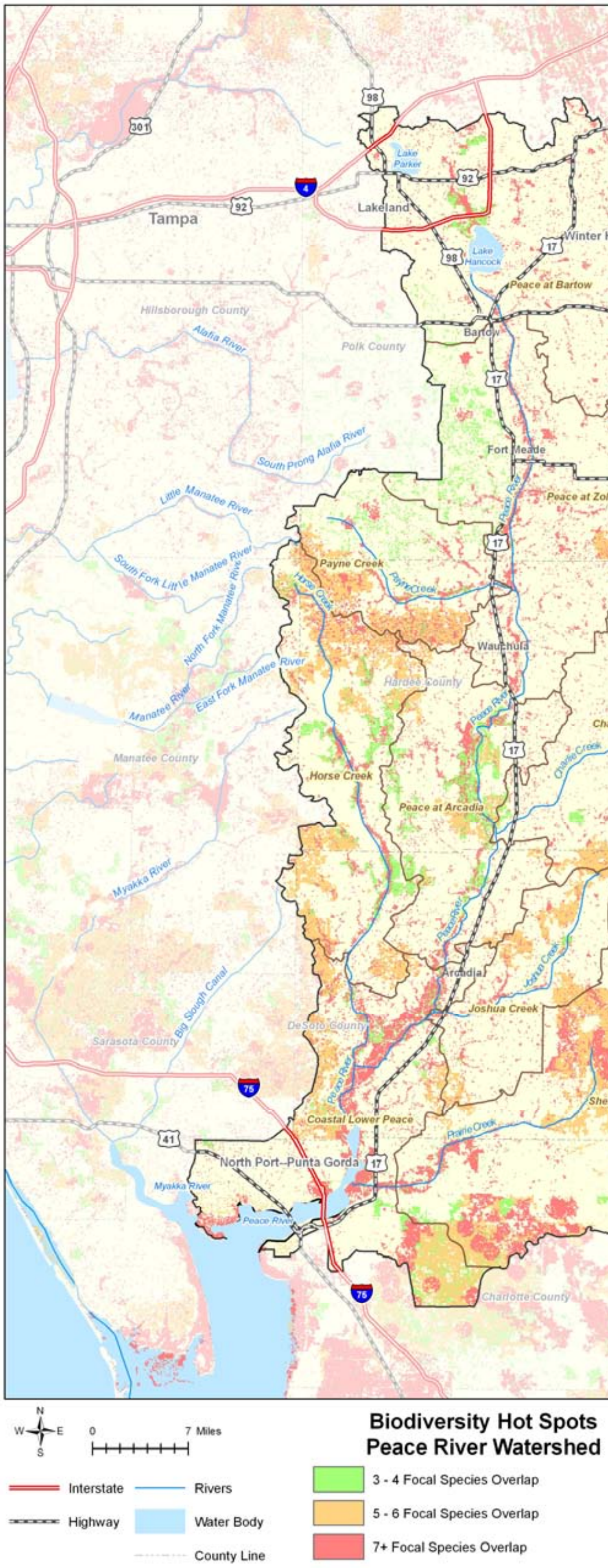
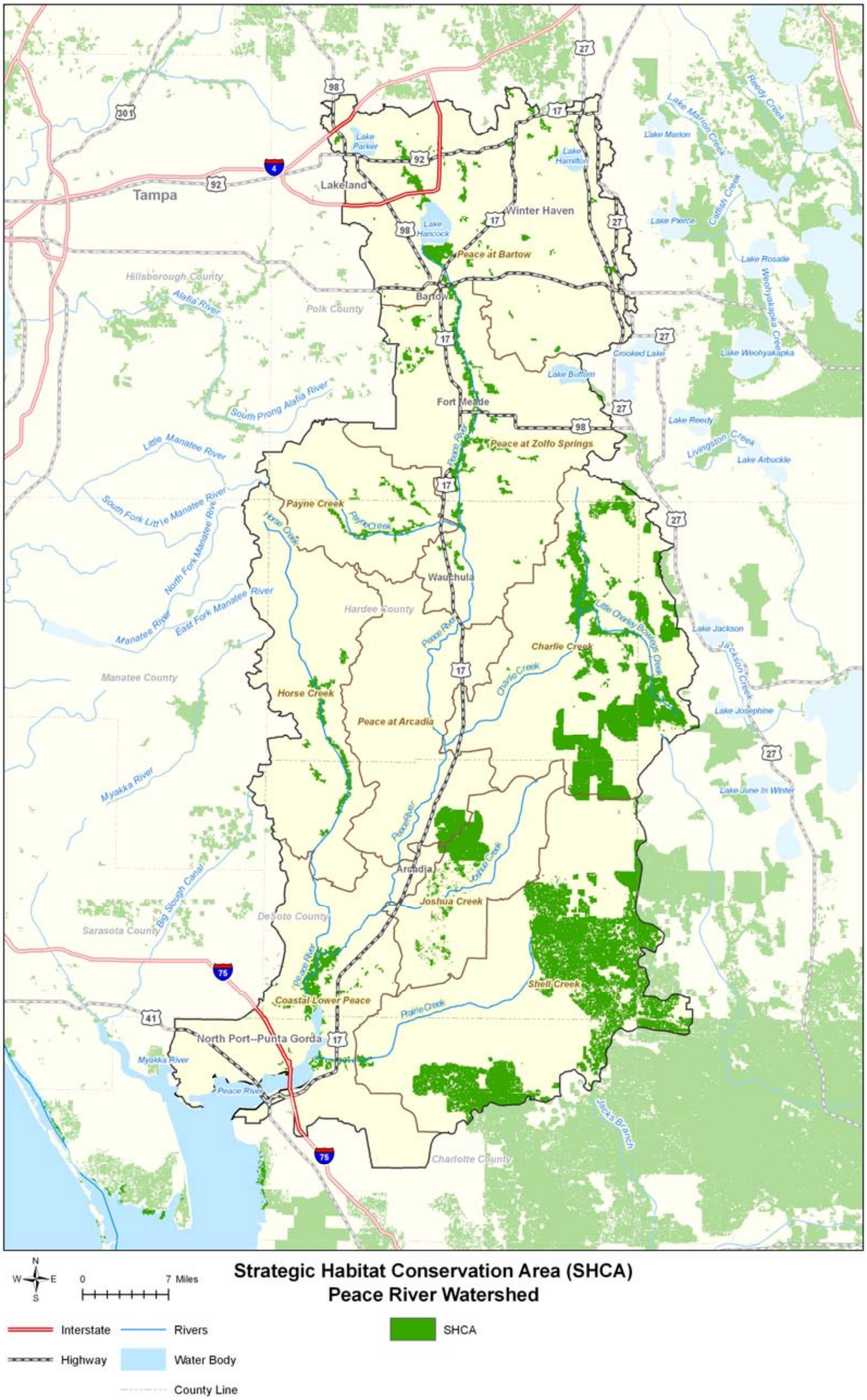


Figure 4.4.2. Strategic Habitat Conservation Areas in the Peace River Watershed



4.5 Loss of Natural Streams and River Channels

Loss of natural stream channels can alter surface water flows and runoff, surface water storage, aquifer recharge, and evapotranspiration, and can alter or eliminate fish and wildlife habitat. In the Peace River watershed, these losses are associated with phosphate mining, agriculture, and urban land use activities, which may include channelization, filling, grading, and otherwise altering natural streams. As part of this study, the loss of natural streams in the watershed was quantified and compared between the 1940s and 1999 (Table 4.5.1). Natural stream segments visible in the 1940s aerial photography but channelized or absent in the 1999 photography were identified as stream losses for this study. The loss of natural stream channels to undeveloped land uses such as lakes, upland habitat, and wetlands, also occurred and were likely the result of intermediate land use changes. Similarly, some of the observed losses of stream channels now in urban land use may have also been previously modified. Natural stream channels eliminated during phosphate mining operations may be replaced by ditching, native upland habitats, wetlands, or lakes as a result of subsequent reclamation to another land use.

Percent loss of natural stream channels between the 1940s and 1999 was greatest in the Peace River at Bartow (60.3 percent) and Payne Creek (52.1 percent) basins, each of which was more than double the loss in any other basin. Loss of natural stream channels in the remaining basins ranged from 13.4 percent (Peace River at Arcadia basin) to 23.7 percent (Joshua Creek basin), with the exception of a relatively small loss (5.4 percent) in the Charlie Creek basin.

Stream losses in the Peace River watershed between the 1940s and 1999 totaled 342.7 miles. The largest losses from developed land uses were associated with phosphate mining (101.2 miles), followed by agriculture (64.5 miles), and urban (37.5 miles) land uses.

Stream losses in the Peace River watershed between the 1940s and 1999 totaled 342.7 miles. The largest losses from developed land uses were associated with phosphate mining (101.2 miles), followed by agriculture (64.5 miles), and urban (37.5 miles) land uses. Losses of natural streams were limited primarily to the smaller first and second order streams, rather than the main river channel (third order), although a portion of the Peace River just south of Lake Hancock has been channelized extensively. Importantly, streams already channelized in the 1940s were not identified as losses and, consequently, the loss of stream segments presented here are conservative. In addition, while multiple land use changes may have occurred between the 1940s and 1999, such as conversions from agriculture to mining and then to urban, the most recent land use (1999) associated with the losses in stream segments were assigned to the stream losses and are also presented in Table 4.5.1. Natural stream and river channels in the 1940s and 1999 are mapped in Figures 4.5.1 and 4.5.2, respectively, and represent losses of stream channels between these two time periods. The channelized (ditched) streams are not included in these figures, but are included and can be differentiated from the natural streams in the hydrology portions of the GIS map portfolio).

The greatest loss of natural stream channels occurred in the Lower Coastal Peace basin (77.5 miles), followed by Payne Creek (66.9 miles), Peace River at Bartow (57.8 miles), and Peace River at Zolfo Springs (49.4 miles). Phosphate mining was the largest single 1999 land use that occurred in the place of former natural stream channels, and accounted for 105.2 miles (29.5 percent) of the absent or channelized stream segments. Phosphate mining accounted for 82 percent and 64 percent, respectively, where stream losses occurred in the Peace River at Zolfo Springs and Payne Creek basins. The largest change of natural stream channels to phosphate mining was in the Payne Creek (54.8 miles) and the Peace River at Zolfo Springs (31.6 miles) basins.

Loss of natural stream channels now in urban land uses totaled 37.5 miles and made up about 11 percent of the loss. Urban land uses in the place of former natural stream channels was greatest in the Coastal Lower Peace (24.8 miles) basin. Urban land uses replaced 24.8 miles of natural stream channels in the Lower Coastal Peace basin and 8.9 miles in the Peace River at Bartow basin, compared with a total of 3.9 miles in the remaining seven basins. Agriculture accounted for 64.5 miles, or 18.8 percent of the natural stream channels lost between the 1940s and 1999, and this replacement ranged from 4.0 acres in the Joshua Creek basin to 9.8 acres in the Peace River at Bartow basin.

Table 4.5.1. Change in Natural Stream and River Channels (linear miles) in the Peace River Watershed from the 1940s to 1999

Basin	Miles Lost				1999 Land Use in Place of Lost Stream Segment						
	1940s	1999	Change	Percent Change	Urban	Mining	Agriculture	Lakes	Upland Habitat	Wetlands	Other
Peace River at Bartow	95.9	38.1	57.8	60.3	8.9	10.3	9.8	2.7	7.1	18.7	0.3
Peace River at Zolfo Springs	290.0	240.6	49.4	17.0	0.3	31.6	7.8	2.0	1.7	5.9	0.0
Payne Creek	128.7	61.7	66.9	52.1	0.4	54.8	6.2	1.1	1.9	2.4	0.1
Charlie Creek	185.8	175.7	10.0	5.4	0.0	0.0	6.8	0.1	1.0	2.0	0.0
Peace River at Arcadia	133.6	115.7	17.9	13.4	0.1	0.0	7.2	0.3	0.1	6.8	4.4
Joshua Creek	57.9	44.2	13.7	23.7	0.7	0.0	4.0	0.1	1.4	7.6	0.0
Horse Creek	170.7	140.1	30.6	17.9	1.9	4.0	8.6	0.3	6.3	7.2	2.2
Shell Creek	93.0	74.1	18.9	20.3	0.3	0.0	7.2	5.4	3.0	2.5	0.5
Coastal Lower Peace River	397.7	320.2	77.5	19.5	24.8	0.5*	6.8	0.9	13.4	18.7	12.3
Total	**1,553.2**	**1,210.5**	**342.7**	**22.1**	**37.5**	**101.2**	**64.5**	**12.9**	**36.1**	**71.8**	**19.8**

* Sand/shell mining

Figure 4.5.1. Natural Stream and River Channels in the Peace River Watershed Circa 1940s

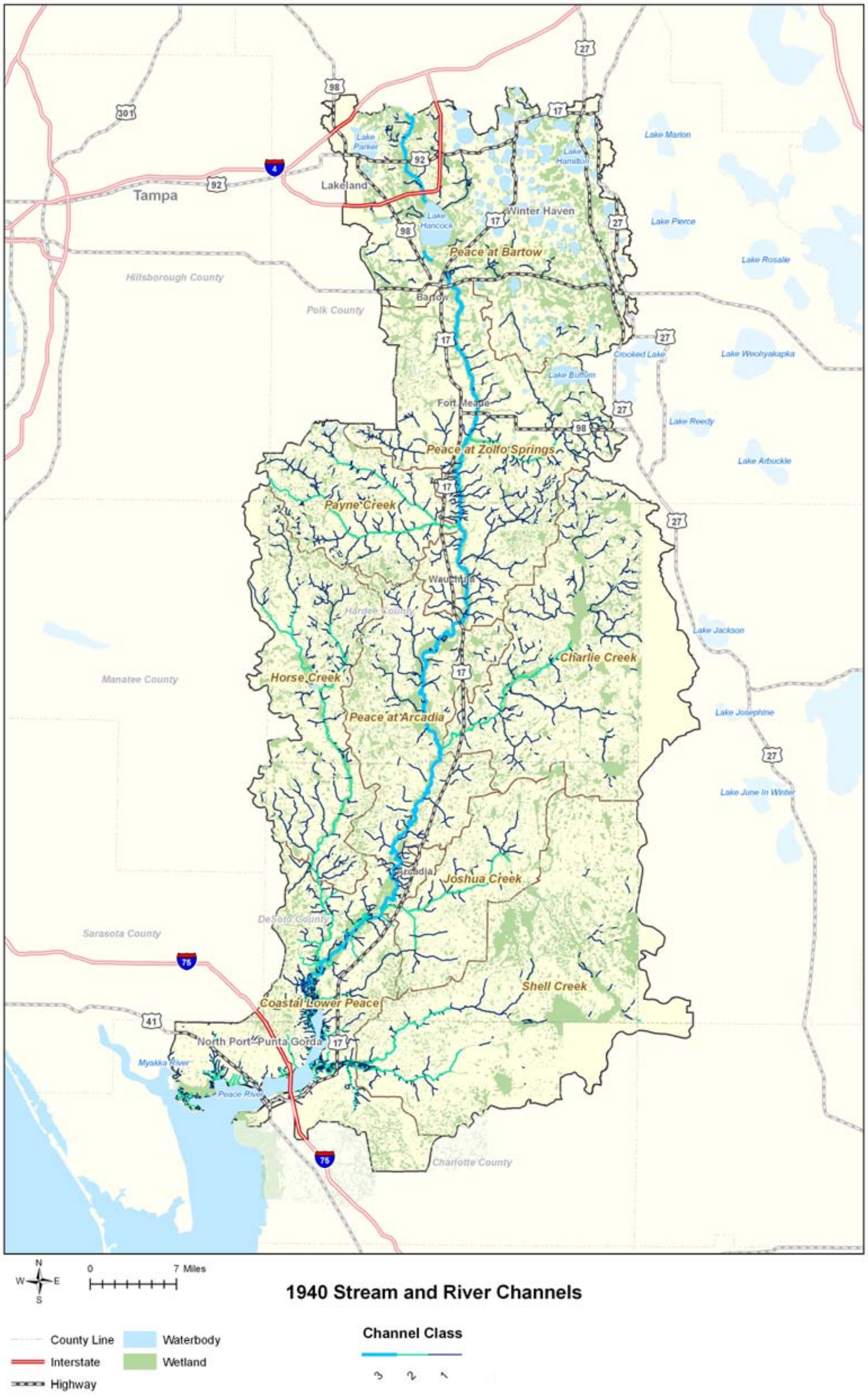
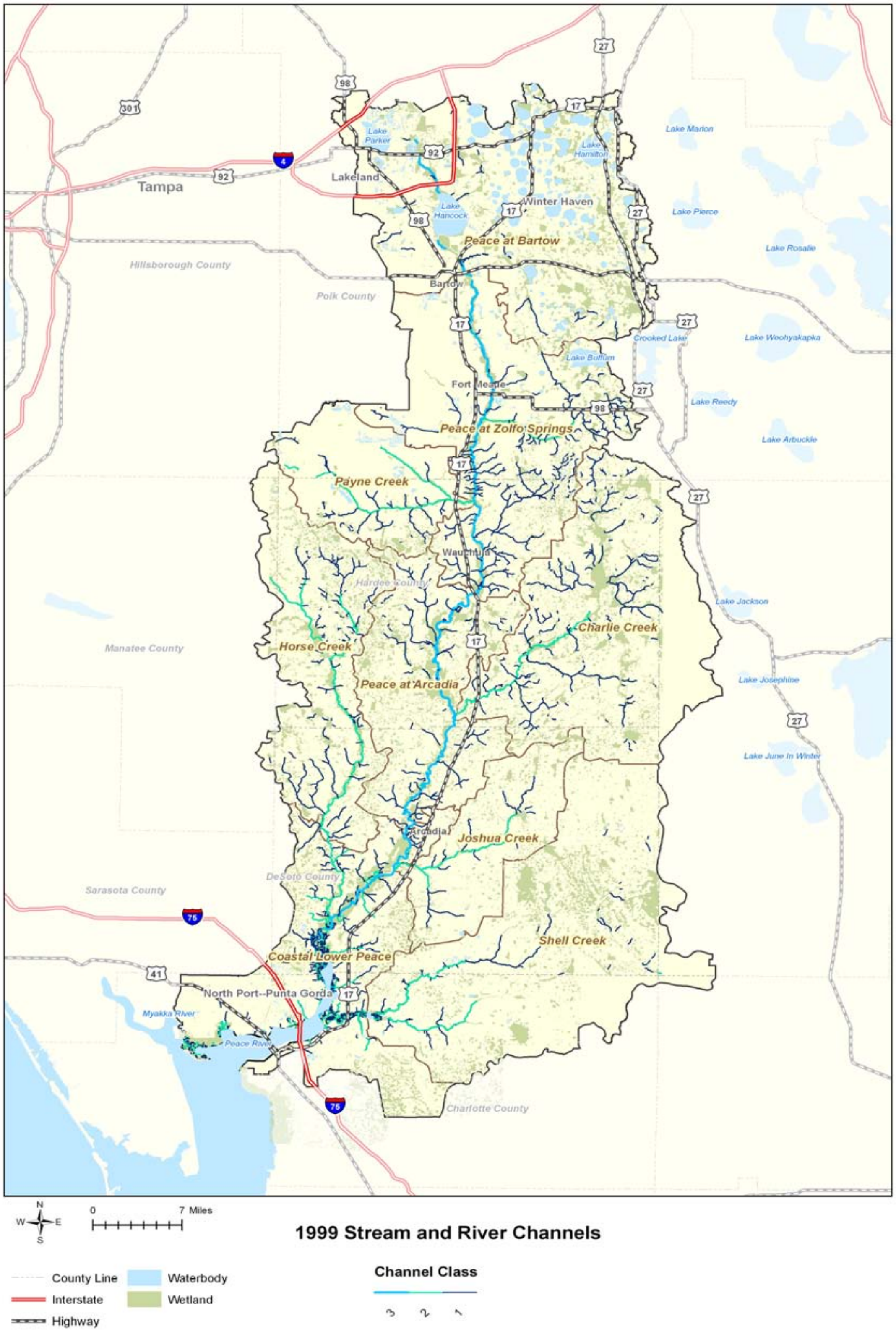


Figure 4.5.2. Natural Stream and River Channels in the Peace River Watershed in 1999



4.6 Cumulative Impacts Summary Matrix

A summary of the relative impacts of rainfall, agriculture, urbanization, and mining on the hydrology, water quality, and natural systems in the Peace River watershed is presented in Table 4.6.1. The matrix provides an overview of the relative impacts of stressors within each basin as well as the relative impacts of stressors among basins. A filled circle (vs. a partially filled or empty circle) indicates a greater influence of one stressor when compared with another (for example, agriculture more than urban) in a basin. Darker shading represents greater impacts of a stressor in a basin when compared with another (for example, greater urban impacts in the Coastal Lower Peace River basin).

4.6.1 Within-Basin Comparisons

The relative impacts of stressors in a basin are presented across rows in Table 4.6.1. For example, during the dry season in the Peace River at Bartow basin, the relative influence of agriculture on hydrology is much stronger when compared with the influence of mining and urban activities. Dry season stream flows in seven of the nine basins are influenced predominantly by agriculture when compared with urban and phosphate mining land uses and rainfall variability. The greatest influence in the Payne Creek basin is mining, and influences of agriculture and urban land uses are approximately equal in the Coastal Lower Peace River basin.

However, the relative influence of rainfall on hydrology during the wet season is strong and obscures impacts that agriculture, urban, and phosphate mining might have in most of the basins. Ground water levels are influenced by rainfall variability, as well as agriculture (largest influence), phosphate mining, and urban land uses. Rainfall strongly influences wet season stream flows in all nine basins in the Peace River watershed. Mining impacts persist in the upper portion of the watershed during wet season flows, as do urban impacts in the Peace River at Bartow and Coastal Lower Peace River basins. Agriculture impacts are relatively obscured during wet season flows except in the Joshua Creek basin.

Natural systems appear most impacted by agriculture in most of the basins. The exceptions are the Payne Creek basin, in which mining has had the greatest influence, the urban and agriculture influences in the Lower Coastal Peace, and the urban and mining influences in the in Peace River at Bartow basin. Agriculture has the largest impact on water quality all but the Peace River at Bartow, Payne Creek, and Coastal Lower Peace River basins. Urban land use activities impact water quality the most in the Peace River at Bartow and Coastal Lower Peace River basins, while acres of mining and associated impacts are greatest in the Payne Creek basin.

4.6.2 Between-Basin Comparisons

A comparison of the relative impacts of stressors between basins is presented *down columns* in Table 4.6.1. For example, impacts of agriculture on dry season stream flows are greatest in the Peace River at Bartow, Zolfo Springs, Joshua Creek, and Shell Creek basins. Impacts are less in the Horse Creek and Peace River at Arcadia basins, and even less in the Charlie Creek and Coastal Lower Peace River basins. Hydrologic impacts in the Payne Creek basin are relatively negligible. Phosphate mining impacts are greatest in the Peace River at Bartow, Zolfo Springs, and Payne Creek basins, and mining impacts on dry season stream flows are relatively negligible in the remaining six basin.

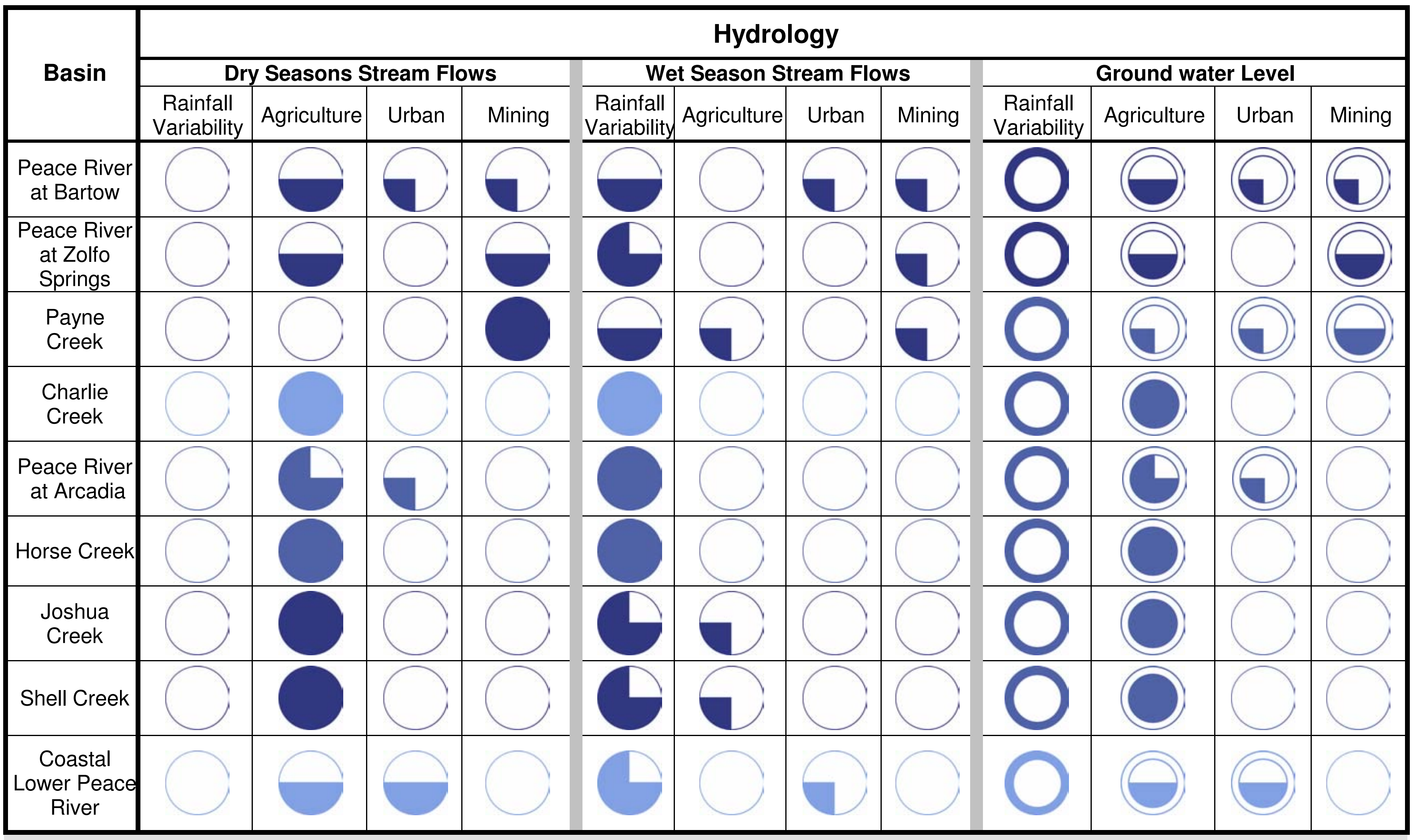
Rainfall strongly influences wet season stream flows in all nine basins in the Peace River watershed, although influences appear strongest in the upper three basins and Joshua and Shell Creek basins. Mining impacts persist in the upper portion of the watershed during wet season flows, as do urban impacts in the Peace River at Bartow and Coastal Lower Peace River basins. Agriculture impacts on stream flows are relatively obscured in most of the basins during wet season flows except in the Joshua Creek basin.

The effects of rainfall on ground water levels are strongest in the upper watershed, moderate in the middle and lower reaches, and are least in the Coastal Lower Peace River basin. Agricultural impact s on ground water persist throughout all nine basins but are greatest in the Charlie, Horse, Joshua, and Shell creeks basins.

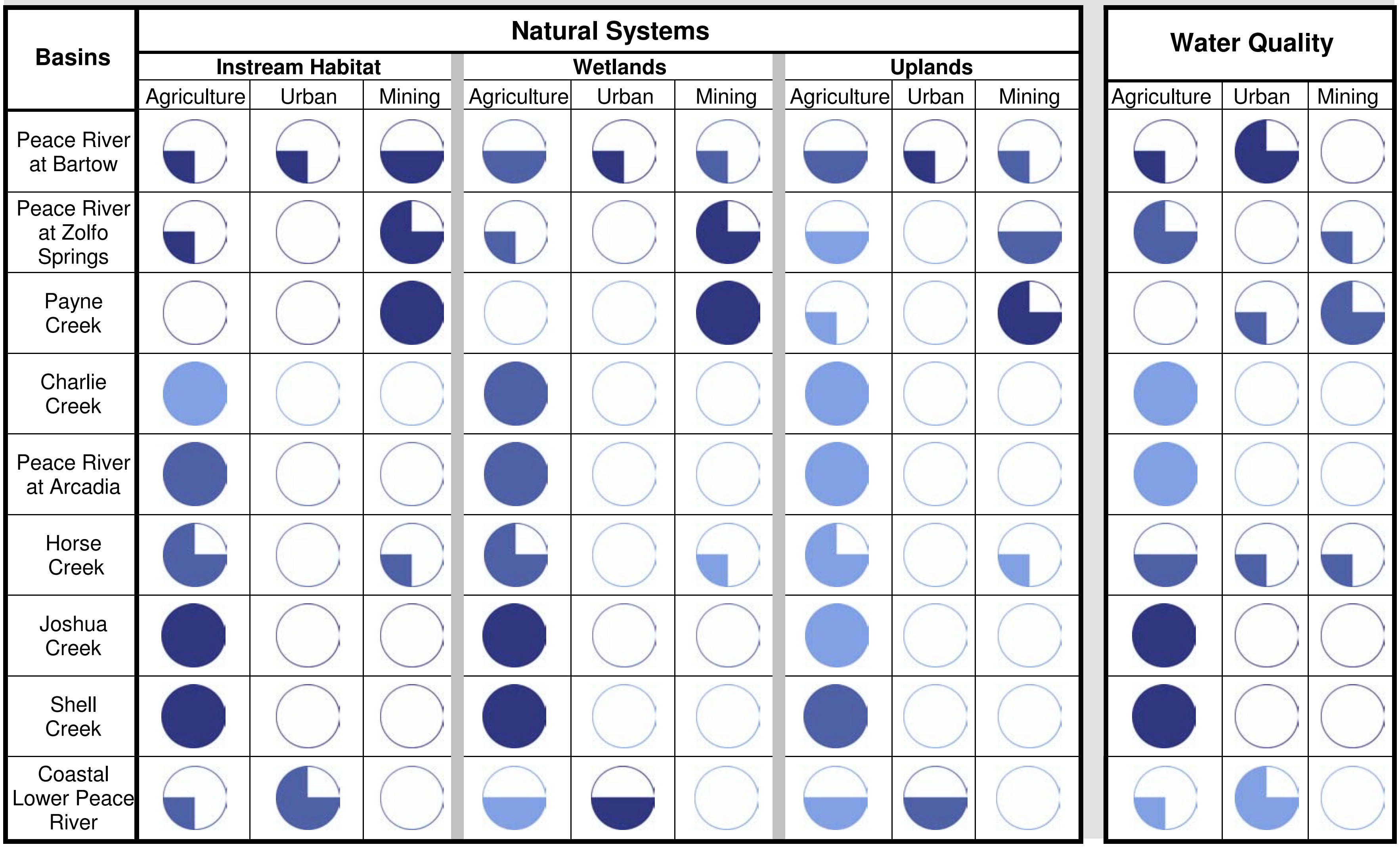
Impacts to instream habitat and wetlands due to agriculture are greatest in the Joshua Creek and Shell Creek basins, while mining impacts on these systems are greatest in the upper three basins. Urban impacts rank highest in the Coastal Lower Peace River basin, followed by the Peace River at Bartow basin, and urban impacts to these systems in other basins are negligible. Agricultural impacts to uplands (native upland habitats) are greatest in the Shell Creek and Peace River at Bartow basins, while impacts are moderate in the remaining seven basins. Urban impacts to natural systems are greatest in the upper-most (Peace River at Bartow) and lower-most (Coastal Lower Peace River) basins, and are relatively negligible in the remaining seven basins.

Impacts to water quality are greatest in the Peace River at Bartow (largely due to mining) basin and in the Joshua Creek and Shell Creek basins (primarily due to urban). Water quality impacts are relatively moderate in the Zolfo Springs and Horse Creek basins (due principally to agriculture), and in Payne Creek (primarily due to mining practices). In the Charlie Creek and Peace River at Arcadia basins, impacts are relatively small compared with the other basin and are predominantly due to agriculture. Impacts in the Coastal Lower Peace River basin are also relatively small and due mostly to urban land use practices.

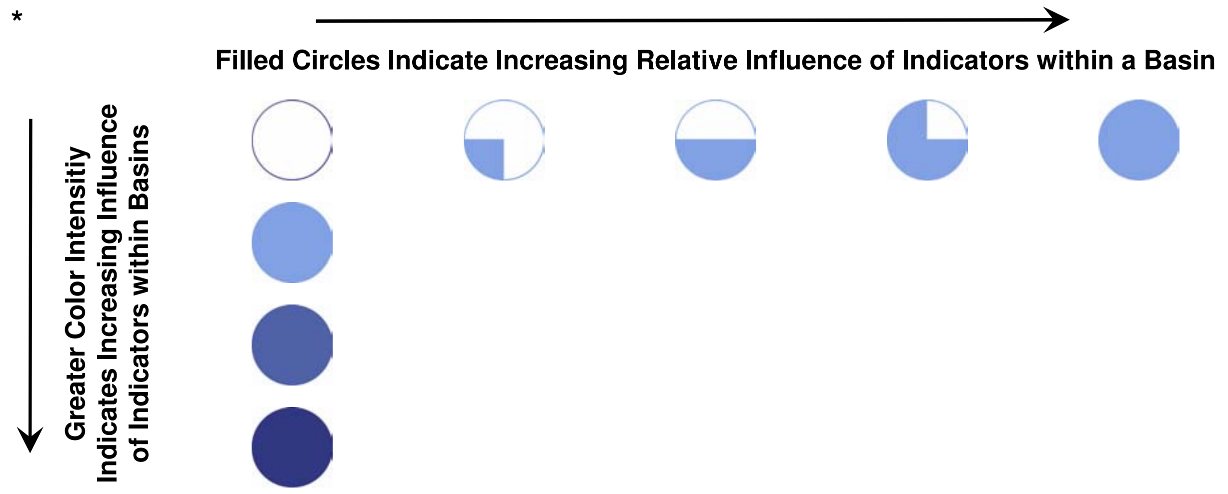
Table 4.6.1. Summary of Current Relative Influence of Stressors among Hydrology, Natural Systems, and Water Quality Indicators in the Basins of the Peace River Watershed



Basin	Hydrology											
	Dry Seasons Stream Flows				Wet Season Stream Flows				Ground water Level			
	Rainfall Variability	Agriculture	Urban	Mining	Rainfall Variability	Agriculture	Urban	Mining	Rainfall Variability	Agriculture	Urban	Mining
Peace River at Bartow	○	◑	◔	◔	◑	○	◔	◔	○	◑	◔	◔
Peace River at Zolfo Springs	○	◑	○	◑	◕	○	○	◔	○	◑	○	◑
Payne Creek	○	○	○	●	◑	◔	○	◔	○	◔	◔	◑
Charlie Creek	○	●	○	○	●	○	○	○	○	●	○	○
Peace River at Arcadia	○	◕	◔	○	●	○	○	○	○	◕	◔	○
Horse Creek	○	●	○	○	●	○	○	○	○	●	○	○
Joshua Creek	○	●	○	○	◕	◔	○	○	○	●	○	○
Shell Creek	○	●	○	○	◕	◔	○	○	○	●	○	○
Coastal Lower Peace River	○	◑	◑	○	◕	○	◔	○	○	◑	◑	○



Basins	Natural Systems									Water Quality		
	Instream Habitat			Wetlands			Uplands					
	Agriculture	Urban	Mining	Agriculture	Urban	Mining	Agriculture	Urban	Mining	Agriculture	Urban	Mining
Peace River at Bartow	◔	◔	◑	◑	◔	◔	◑	◔	◔	◔	◕	○
Peace River at Zolfo Springs	◔	○	◕	◔	○	◕	◑	○	◑	◕	○	◔
Payne Creek	○	○	●	○	○	●	◔	○	◕	○	◔	◕
Charlie Creek	●	○	○	●	○	○	●	○	○	●	○	○
Peace River at Arcadia	●	○	○	●	○	○	●	○	○	●	○	○
Horse Creek	◕	○	◔	◕	○	◔	◕	○	◔	◑	◔	◔
Joshua Creek	●	○	○	●	○	○	●	○	○	●	○	○
Shell Creek	●	○	○	●	○	○	●	○	○	●	○	○
Coastal Lower Peace River	◔	◕	○	◑	◑	○	◑	◑	○	◔	◕	○



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5.0 Overview of History and Evaluation of Regulatory Effectiveness

5.1 The Approach to Evaluating Regulatory Effectiveness

As seen in earlier sections of this report, cumulative impacts have occurred in the Peace River watershed over the decades surveyed. The greatest impacts occurred in the years prior to regulation, probably through a collective lack of understanding of deleterious practices. In the historical summary below, the early decades are characterized as starting with relatively light regulation – corresponding to lower population pressures and less intensive land and water uses – with regulatory initiatives becoming dominant in the 1970s and 1980s and continuing to grow through the present in response to population pressures and the changing political climate.

The challenge in evaluating Regulatory Effectiveness over the course of 60 years of change is, therefore, to separate the effect of regulation from everything else that has happened. Past actions cannot be judged from today's vantage point because of all the changes that have occurred. However, an examination of the chronology of legislative enactments described below and detailed in Appendix I.1 will provide much insight. The use of ground water, by example, and has been affected by progressive enactment of legislative acts and implementing rules that have affected this activity. The fact remains that ground water use predated the adoption of any regulations and was already having an impact at the time regulations were enacted. In addition, the effect of any single regulation is inserted into the continuum of ground water use over time, such that existing ground water wells probably remain unaffected for various periods following implementation, depending on a host of special circumstances. Free-flowing wells, for instance, which have been regulated since 1953, are still being found and capped today as wellheads corrode and develop leaks.

As is evident from the history of regulations below, there is a pattern of regulatory activity treading rather lightly at first and progressively becoming more prescriptive with time. Thus, again with the use of ground water by example, there have been a series of enactments, rule adoptions, and interpretations of laws and rules coming into effect through the course of time. Typically, these regulations are responses to the perception of impacts, moderated by the economic dependencies that have developed around the regulated activity, and they are not, therefore, entirely science-based measures subject to rigorous cause-effect analysis.

Regulation has not, however, been the only reaction to resource management issues. Mainly because of the ambiguity of causal relationships and the inherent complexity of managing resources on a watershed scale – both above and below ground – regulation is more and more often supplemented by resource management *policies* with the flexibility to collect scientific data and address issues that may be outside regulatory purview. Regulations and non-regulatory programs have developed side-by-side and represent a continuum of governmental response. For that reason and because the resource management plan to be adopted for the Peace River watershed is required to identify regulatory *and* non-regulatory actions, this report addresses these programmatic responses as part of Regulatory Effectiveness.

Even with the combined effect of regulation and resource management programs, we have definitely experienced, and are in all likelihood still experiencing, cumulative degradation of natural resources in the Peace River watershed. While there may be a temptation to identify scapegoat programs, agencies, or branches of government, over the course of six decades, there has been a heightening of legislative interest and action, a tightening of regulatory control, a flood of programmatic funding, and increased litigation over the application of regulation. One could argue that the sum of these activities constitutes a broad public response to some of the cumulative impacts documented in this study. The questions remain: Is this response strong enough and effectively targeted to arrest the documented decline in the watershed? Are there some types of cumulative impacts that are only now being recognized and need action?

Even with the combined effect of regulation and resource management programs, we have definitely experienced, and are in all likelihood still experiencing, cumulative degradation of natural resources in the Peace River watershed.

The efficacy of existing regulations has already been tested by legal challenges. Just within the past decade, for instance, there has been significant litigation over proposed rules and activities within the Peace River watershed (challenges to the Southern Water Use Caution Area (SWUCA) 1992 rule, the Peace River/Manasota Regional Water Supply Authority's (PRMRWSA) water use permit, and phosphate mining permits). These have not been one-sided affairs with regulated interests merely litigating for relief. Neither have they been about activities and rules with narrow applications. The SWUCA rule challenges from both private interests and local governments dealt with the fundamental efficacy of the science underlying the proposed rule, as well as the prescriptions for remedy. This rule, which was adopted after hundreds of hours of broad public and elected official participation, was not hastily conceived or ineptly drawn. The administrative law judge required 16 months to review the evidence and law, and the final order was mostly affirmed by the courts. SWUCA signifies that as regulatory programs have become more complicated in response to continued pressure on the resources, they have become more difficult to enact, even within the broad statutory frameworks enjoyed in Florida.

Once regulatory programs are in place, their implementation may be challenged whenever an agency takes a final agency action. This framework, provided under Chapter 120, Florida Statutes (FS), provides a continuum of opportunities to review and interpret statutory and rule language as it applies to specific permits. In the case of phosphate mining permits in the Peace River watershed, two public agencies initiated challenges to proposed permits, arguing in essence that the issuance of the permit would result in cumulative adverse impacts. The outcomes of these challenges have varied with the specifics of each case, but more than $12 million public dollars have been spent on these challenges. Under this kind of repetitive review then, it is hard to imagine that either the regulatory agency or the permit applicant will stray from the boundaries prescribed in law.

So, in two cases, one where the regulatory agency explored the limits of its authority and another where public agencies challenged the interpretation of regulatory authority exercised by an executive agency, the outcomes have hinged on the legislative grant of regulatory authority.

There are many regulations affecting the state and nation other than those cited above, which almost uniquely impact the Peace River watershed. As with the SWUCA rules, interested parties from all sides have challenged rules at both federal and state levels. For example, the current implementation of Total Maximum Daily Loads (TMDLs) for impaired waters is the result of federal lawsuits initiated by environmental groups against various states and the U.S. Environmental Protection Agency (USEPA). Florida's Impaired Water Rule has been reviewed under challenge, as has its Environmental Resources Permit Rule. Both regulated interests and environmental advocacy groups usually participate in rule development and challenges, making it not unreasonable to assume that, over the long run, the full measure of granted regulatory authority (as determined by courts) is exercised. In the face of cumulative impacts documented in this report, are there gaps in regulatory authority that need to be plugged? Have the gains from regulatory authority *per se* already been maximized, and, therefore, is there a need for other tools to address the on-going cumulative impacts?

The following section sketches the development of state regulations affecting the Peace River over the past four decades. The body of regulations affecting the Peace River is somewhat like an old building. It started out smaller than what exists today. Rooms have been added on. Other parts have been removed, and either replaced or discarded. Repairs have been made where needed, and adjustments have been constant. Fresh paint has been applied, often without removing the old. Floorboards have been replaced, often not with the same material. The result is like a four-dimensional maze, as the three dimensions of space transform over time. Nevertheless, the architects left traces and we have attempted to build an understanding of the essential character of this body of regulation as it evolved over time.

5.2 The History of Regulation Affecting The Peace River Watershed

No unified history has been written of environmental regulation in the State of Florida – much less for the Peace River watershed. This report will not attempt to fill that void, but in an effort to understand the effectiveness of regulations that were in place during the period of study, there needs to be an understanding of how the body of regulations grew, what problems they intended to address, how they may have been limited in scope and intent, how well they were implemented, and how this implementation may have changed over time with changing public perceptions and adaptation by those who were regulated.

What exactly are regulations? In this context, regulations are the exercise of the powers of the State of Florida authorized by statute and implemented by agencies with jurisdiction. These powers are the exercise of legitimate restraint on the rights of individuals when the exercise of those rights conflict with the health, safety, and general welfare of the public. Hence, they are often limited by what can be legitimated by the knowledge of dangers or problems to be addressed.

Because of their need for a legitimate foundation in health, safety, and welfare, environmental regulations are often reactive rather than proactive in the sense that they address issues that have already become evident. From a political standpoint, the impetus to regulate is often born of a crisis – perceived or real. The problem to be addressed by the regulation has become a political issue that demands political action. There may be a public consensus about the cause of the action, but that consensus may or may not be supported by scientific analysis at the time the regulations are proposed. Nevertheless, effective environmental regulation requires adequate knowledge of causal relationships, which can be quite elusive in the natural world. In order to proscribe or limit an activity, for instance, a rational nexus must be established between that activity and some harm that could occur.

Because of their need for a legitimate foundation in health, safety, and welfare, environmental regulations are often reactive rather than proactive in the sense that they address issues that have already become evident.

Environmental problems are often perceived much earlier than a full understanding of causal relationships. Regulations, consequently, tend to become progressively more restrictive as cause-effect relationships are more firmly established. This sometimes leads to the perception that agencies exceed their legislative authorization, and regulated interests seek relief in court. On the other hand, many public interest groups are impatient with the pace with which implementing regulations are developed and seek court mandated action.

5.2.1 Early Regulation

The first environmental regulation directly affecting the Peace River watershed may have been Senate Bill No. 57 of the 1953 Florida Legislature to protect and control the artesian waters of the state. The act simply required landowners with free-flowing artesian wells to valve these wells and adjust the flow as appropriate for the "beneficial uses." The main intent of the act seems to have been to minimize the waste of artesian water. Violation of the act was a misdemeanor; state geologists and county sheriffs were authorized to have access to all wells in the state (with consent of the owner), and after notice to the owner, install valves or caps at the expense of the owner, if necessary. Liens were authorized to recover the cost.

Following legislation in the 1940s that established the Central and Southern Florida Flood Control District and congressional authorization of the U.S. Army Corps of Engineers (USACOE) to construct the South Florida Flood Control Project, the Florida Water Resources

Study Commission was established in 1955 to determine the need for a comprehensive approach to water law. The Commission reported to the Florida Legislature, which enacted the Water Resources Act of 1957. The Commission recommended

- Ensuring that there was legal authority to capture, store, and use water in excess of reasonable uses.
- Authorizing diversions of such water beyond riparian or overlying land.
- Restricting the withdrawals of water that would exceed the natural replenishment of such waters or cause saltwater intrusion or other harm (Wade and Tucker 1996).

Even in this earliest commissioned study of water policy options, there was recognition of the need to capture, store, and use water to even out rainfall and flow patterns. There was also concern that water rights not accrue solely to the riparian or overlying land owner and that water use be sustainable.

The "1957 Act" created a Department of Water Resources within the State Board of Conservation with powers to manage water resources. The Board was given authority to adopt rules to protect water supplies from saltwater intrusion and pollution, to allow the diversions of "excess" water beyond riparian or overlying land, and to create regulatory districts to issue permits for capturing excess water. While the Board had rule-making authority to regulate certain aspects of water use, it is not apparent that any water use permits were issued under this authority (Wade and Tucker 1996).

The Water Resources Act established rather tentative measures towards managing the state's water resources. The stated purpose of the Act was to implement the "declared water policy" of the state and to prevent waste and unreasonable uses of the water resources, but to do so while respecting landowners' rights and not restricting "existing water rights" without due process of law and payment of just compensation. The Act specifically *exempted* diversions from springs for recreational uses or tourist attractions, individual users for domestic purposes or "ordinary livestock consumption," and the "control of water-borne wastes from municipalities or industries."

The Act empowered the State Board of Conservation to "authorize the capture, storage and use of water" of watercourses and lakes only in excess of "average minimum flow" and "average minimum level," respectively, based on the lowest 5 years of the preceding 20 consecutive years. Thus, the Legislature authorized the use of any water in excess of the 1-in-4 year observed low levels. The Act authorized use of ground water down to a level halfway between the average elevation observed in the previous 20 years and mean sea level.

In both cases of setting standards for the use of water, the Legislature saw that water resources were not yet limited, but that standards were needed to prevent overuse in the future. The standards set in the Act allowed cumulative impacts to occur down to the average minimum flows and levels.

> *…the Legislature saw that water resources were not yet limited, but that standards were needed to prevent overuse in the future.*

While the above powers and duties were established in some detail, the Board's ability to adopt rules and regulations was certainly more limited. While ostensibly authorized to "formulate, adopt, amend, and repeal rules and regulations, and to issue orders," it could only do so when the need for such action was "shown by a preponderance of the evidence" presented at a public hearing.

Following the floods of 1959 and 1960, the 1961 Legislature created a "Chapter 378 District" for Southwest Florida, calling it the Southwest Florida Water Management District (SWFWMD). Flood control districts under Chapter 378, FS, were created "to cooperate with the United States in a manner provided by Congress for flood control, reclamation, conservation and allied purposes . . . ." They were authorized to create "Works of the District" and "to determine, establish and control the level of waters to be maintained in all canals, lakes, rivers, channels, reservoirs, streams or other bodies of water owned and maintained by the district . . . ." The districts were governed by a five-member governing board appointed by the Governor and confirmed by the Senate, which had the power to levy property taxes based on benefits the property received "within the district not exceeding three-tenths mill . . . ." The primary purpose of SWFWMD and the use of funds were to "clean out, straighten, enlarge or change the course of any waterways, natural or artificial . . ." to achieve flood control. While SWFWMD was vested with regulatory authority, the meaning of such authority under the purposes of the chapter seems to be limited to those things related to the use or connection to "works of the district," those improvements owned and maintained by SWFWMD. By Resolution No. 63, dated October 9, 1963, "the Peace River, its natural floodway and tributaries, connecting channels, canals, and the lakes which are regulated by the District control structures, including their connecting channels and canals" were declared to be "The Works of the District" and subject to regulation. At this time, however, SWFWMD was solely focused on surface water (flood control) and probably contributed to the cumulative impacts to surface water storage that we observe today in retrospect.

The Florida Air and Water Pollution Control Act of 1967, Chapter 67-436, Laws of Florida (LOF), created the Florida Air and Water Pollution Control Commission (comprised of the Governor, Secretary of State, Attorney General, Commissioner of Agriculture, and two citizens appointed by the Governor and confirmed by the Senate) and the Air and Water Pollution Control Department to take over the all other state agency functions related to pollution and the environment. This Department was empowered to exercise control and supervision over underground waters, lakes, rivers, streams, canals, ditches, and coastal waters within the State's jurisdiction insofar as their pollution may affect the public health or impair the interest of the public persons lawfully using them. While the Commission had power to compel the attendance of witnesses and the production of evidence, its rule-making authority was limited in a fashion similar to that of the State Board of Conservation. Its decision to adopt, modify, or repeal rules could *only* be made by a majority of the entire commission based on the preponderance of competent substantial evidence presented at a public hearing.

While somewhat related, the terms "competent and substantial evidence" and "preponderance of the evidence" are conceptually different. "Competent and substantial" addresses the quality of evidence and is generally defined as evidence that a reasonable mind might accept as adequate to support a conclusion. "Preponderance of the evidence" is defined as the greater weight of the evidence – not the greater amount of evidence, but the more convincing or more "competent and substantial" evidence.

In 1968, the public adopted Article X, Section 11 of the Florida Constitution, placing sovereign submerged lands in trust for all the people and requiring the sale of such lands be authorized by law and only when in the public interest. Most public trust issues in Florida have revolved around questions about the validity of legislative grants of sovereign lands and the boundaries of sovereign lands. Legal scholars question how much further the public trust doctrine can be applied in the realm of water resource planning and regulation, especially to waters overlying sovereignty lands. Wade and Tucker (1996) opine:

> What is not clear . . . is whether the administrative structure of water resource planning, regulation and permitting established by the Water Resources Act [of 1972] represents the sole mechanism for protection of public trust values in water, or whether state management decisions which are considered by an interested party not to adequately protect the public trust values could be appealed to courts of law based on this doctrine. There is also a question of whether those provisions of the [Water Resources] Act [of 1972] which are interpreted as protecting public trust values actually meet the standard of protection required under the public trust doctrine. With regard to water allocation decisions implemented through consumptive use permitting, the specific issues would be whether the "reasonable-beneficial" use test and the public interest test provided sufficient protection of public trust values, and *whether minimum flows and levels should take a clearer role and higher priority in water allocation decisions*. (emphasis added)

In 1968, the public adopted Article X, Section 11 of the Florida Constitution, placing sovereign submerged lands in trust for all the people…

Resolution of public trust doctrine concerns is beyond the scope of this study. We simply identify this issue in the historical review of regulations because over-allocation of resources is documented contrary to the intent of statutory provisions and may have caused or been a factor in cumulative impacts to waters overlying sovereignty lands.

Finally, as the decade came to a close, the Legislature passed the Governmental Reorganization Act of 1969 transferring the State Board of Conservation to the newly created Department of Natural Resources (DNR) and replacing the Air and Water Pollution Control Commission with the Department of Air and Water Pollution Control (which by 1972 was renamed again the Department of Pollution Control).

5.2.2 The 1970s – Watershed Years for Water Regulation

In 1970, the Federal Water Pollution Control Act (FWPCA), precursor to the Clean Water Act (CWA), was enacted, which regulated discharges of pollutants to navigable waters. In 1972, the FWPCA was substantially amended to include the Section 404 program, implemented by the USACOE.

The landmark Federal Water Pollution Control Act extended the dredge and fill permitting authority of the USACOE beyond coastal waters into the freshwater rivers, streams, and lakes and adjacent wetlands as "waters of the United States" would be interpreted. This Act also authorized the National Pollution Discharge Elimination System (NPDES), which regulates the discharge of pollutants into waters.

Florida tracked the nation enacting broad environmental regulation in 1972. The Environmental Land and Water Management Act of 1972 created the state planning agency, authorized Development of Regional Impact (DRI) reviews, and created Areas of Critical State Concern for specific areas where growth pressures where deemed beyond the control of local governments.

The landmark Water Resources Act, passed by the Florida Legislature in 1972, was based on legal research recommendations embodied in *A Model Water Code* (Maloney *et al*. 1972). The *Code* featured:

- Establishing water management districts along watershed boundaries, with Governing Boards appointed by the Governor.
- Establishing a five-member State Water Resources Board with the power to review and rescind any regulation of a water management district (not adopted).
- Extensive planning requirements.
- A permit system for water withdrawals based on "reasonable-beneficial use," combining aspects of both eastern and western water law.
- A system for allocation of limited resources based upon "competing applications".
- A permit system for surface water management and well construction.
- Water quality standards.
- Permits for pollution discharges.
- A program for studying and licensing weather modification.

The Water Resources Act adopted much, but not all, of the structure outlined in *A Model Water Code*. This Act took effect in 1973, along with amendments made during the 1973 Legislature, and created much of the framework used today in the regulation of water resources, including:

- Designation of water management districts and basin boards.
- Requirement to establish minimum flows and levels.

- Restrictions on artificial recharge.
- Declarations of water shortage.
- Requirement to obtain permits for any withdrawal, diversion, impoundment, or consumptive use (except domestic wells).
- Criteria for permitting the consumptive use of water and alteration to surface waters.
- Exemptions.

The Water Resources Act created a two-tiered management structure headed by the Department of Natural Resources (DNR) with supervisory authority over the districts. That authority vests today with the Florida Department of Environmental Protection (FDEP). The Act required the adoption of a state water policy by rule, which was first adopted in 1981 and has subsequently been amended several times.

The Act gave broad powers to the water management districts to "adopt, promulgate and enforce such regulations as may be reasonably necessary to effectuate the powers, duties and functions of the Act." It required the districts to establish minimum flows and levels, provided them with powers to build works and regulate as necessary to protect water resources, and even provided that the districts could take preemptive action when they had "reason to believe that a violation … is about to occur. . . ." (Section 373.119(1), FS, 1973).

The Water Resources Act also exempted certain types of activity from some types of regulation. The broadest and most exercised exemption for the Peace River watershed provided in the Act was for agriculture:

> Nothing herein, or in any rule, regulation or order adopted pursuant thereto, shall be construed to affect the right of any person engaged in the occupation of agriculture, floriculture or horticulture to alter the topography of any tract of land for purposes consistent with the practice of such occupation; provided, however, that such alteration shall not be for the sole or predominant purpose of impounding or obstructing surface waters.

This exemption continues in the statute today – with the addition of silviculture – and may be a causal factor allowing the cumulative conversion of wetlands to agricultural uses in the Peace River watershed.

The Water Resources Act was amended again in 1974 to define the role of water management districts to assist counties and municipalities in establishing water production and transmission facilities to provide water for local distribution by these entities. In addition, the Legislature authorized the creation of water supply authorities with broad government powers to develop, store, and supply (but not distribute to the retail customer) water to its member governments.

SWFWMD adopted rules in 1974 for planning, constructing, and operating necessary water management works in the Peace River watershed. Rules were adopted to protect the Works of the District, namely certain canals, water control structures, rights-of-way, lakes, and streams owned, maintained, or accepted for responsibility by SWFWMD. These would include the Peace River, its natural floodway and tributaries, connecting channels, canals, and the lakes that are regulated by SWFWMD control structures. These rules established permit criteria for uses, requiring that proposed uses:

- Be reasonable and beneficial.
- Not be inconsistent with public interest.
- Not place fill in the water course.
- Not cause significant adverse effects to lands not owned, leased, or controlled by the applicant.
- Not cause an increase or decrease in the rate of flow of a stream or other watercourse by 5 percent or more.

SWFWMD also adopted rules to regulate the withdrawal of water from specified rivers, including the Peace River. Except for withdrawals by individuals for domestic consumption, the rules required permits and established the following criteria for permitted withdrawals:

- Must be reasonable and beneficial.
- Must be consistent with public interest.
- Not cause the rate of flow of a stream or other watercourse or the level of surface water to be lowered below the minimum rate of flow or level established.

In 1974, SWFWMD also adopted rules to regulate water wells, to establish registration for drillers, contractors, and engineering testing laboratories related to water wells, and to declare water use caution areas when it finds the use of ground water or surface water requires coordination and limited regulation for protection of the public interest and the water resources of the state.

In 1974, SWFWMD also adopted rules to regulate water wells, to establish registration for drillers, contractors, and engineering testing laboratories related to water wells, and to declare water use caution areas when it finds the use of ground water or surface water requires coordination and limited regulation for protection of the public interest and the water resources of the state.

Finally, SWFWMD adopted rules to regulate the management and storage of surface waters. These rules established that permits were required to construct, alter, abandon, or remove any dam, impoundment, reservoir, or appurtenant work or works that meet specified criteria such as impounding water on an area exceeding 40 acres, restricting or altering the rate of flow of a stream/watercourse that drains a watershed having an area exceeding 5 square miles. The rules established broad exemptions such that nothing shall be construed to affect the right of any natural person to capture, discharge, and use water for the purposes permitted by law, to engage in the occupation of agriculture and floriculture, provided there is not a substantial altering of surface drainage. The rule also established the content of permit applications, SWFWMD's right to inspection, and the use of head gates, valves, and measuring devices.

In 1968, the public adopted Article X, Section 11 of the Florida Constitution, placing sovereign submerged lands in trust for all the people…

The Environmental Reorganization Act of 1975 (Chapter 75-22, LOF) created the state agency regulatory structure that would persist until the mid-1990s. Both the Department of Environmental Regulation (DER) and Environmental Regulation Commission (ERC) were created. DER became the primary regulatory agency and received most of the regulatory and supervisory authority from Department of Natural Resources. The ERC became the exclusive standard-setting authority of DER, except as expressly provided by statute. The Secretary of the DER was given broad powers to execute the department’s statutory mandates, including the ability to delegate powers, duties, and functions to water management districts when the Secretary determines such districts have the financial and technical capability to carry out the delegation.

The Environmental Reorganization Act also provided that the Governor and Cabinet, sitting as the Land and Water Adjudicatory Committee, have the exclusive power to review, “and may rescind or modify, any rule or order of a water management district . . . .” Such a review could be initiated at any time by the Governor and Cabinet, the Secretary of the DER, the ERC, or by an interested aggrieved party.

Congress passed the Clean Water Act in 1977, amending and strengthening the Federal Water Pollution Control Act. The Clean Water Act required states to establish water quality standards for all waters within their jurisdiction and for each state to determine the TMDLs for waters not meeting water quality standards. The USACOE was given authority to regulate the discharge of dredge and fill material. The USEPA was granted jurisdiction over public water systems and underground injection, and oversight authority over USACOE’s administration of the federal dredge and fill programs.

In 1978, SWFWMD adopted rules to establish minimum flows and levels at specific locations throughout the district, including the Peace River watershed. These rules established management levels for lakes and other impoundments, cyclic variations for minimum water level, minimum flood levels, and operating levels for lakes and other impoundments with structures. They did not establish minimum flows for the Peace River or its tributaries, and these rules specifically exempted the General Development Utilities Reservoir, which had been permitted in 1975 and was under construction. The rules exempted a number of stream impoundments for water supply, but made no mention of the Shell Creek Reservoir. The inattention to minimum flows would surface two decades later with legislative mandates to schedule the establishment of minimum flows for streams.

5.2.3 Land Use Regulation

The Florida Environmental Land and Water Management Act of 1972 established a process of regulating Developments of Regional Impact (DRI). This Act established a series of regulated activities when these activities exceeded threshold levels, which may vary depending on the local population. The statute (Chapter 380, FS) has been modified numerous times since enactment and the following discussion tracks current requirements. The statute identifies 11 types of development that could trigger a DRI review: airports; attractions and recreational facilities; industrial plants, industrial parks, and distribution, warehousing or wholesaling facilities; office development; port facilities; retail and service development; hotel or motel development; recreational vehicle development; multiuse development; residential development; and schools. Since then, the Administration Commission adopted additional types of development, which have the potential for a DRI review. These include electrical generating facilities and transmission lines, hospitals, mining, and petroleum storage tanks.

The DRI review results in a development order issued by a local government, approving with or without conditions or denying the proposed development. The local government considers regional recommendations and evaluates the proposed development's consistency with its comprehensive plan. Regional planning councils have review and recommendation authority to the local government and the Department of Community Affairs (DCA). While the DCA does not issue development orders, it may appeal them to the Florida Land and Water Adjudicatory Commission, which are the Governor and Cabinet. While regional planning councils have had no standing to appeal since 1993, they convene a review by regional entities and make recommendations to the local government and the DCA, including the recommendation to appeal.

Regional planning councils comprise elected officials from each local government within their jurisdiction and gubernatorial appointees and operate with professional staff. The concept is to keep land use decisions with the local government, while having the broader public interest attended to by regional representatives and the state's interests protected by the DCA.

5.2.4 Ground Water, Stormwater, and Wetland Regulations

The early 1980s were a fertile period for new policy and regulation of surface waters. Surface water quality, especially stormwater discharge from development and the loss of isolated wetlands, became issues of concern. The Environmental Regulation Commission adopted stormwater treatment rules in 1982, requiring the detention or other forms of treatment for the first flush of stormwater runoff from impervious surfaces associated with new development. The Water Quality Assurance Act of 1983 authorized DER to delegate stormwater treatment regulation to the water management districts "financially and technically capable of implementing the delegation," by October 1, 1984. The Warren S. Henderson Wetlands Protection Act of 1984 expanded DER's dredge and fill jurisdiction somewhat, but mainly added criteria for the agency to consider in permit review. These criteria included the effects of a project on fish and wildlife, recreational values, and whether the project would affect the public health, safety, and welfare and the property of others. These criteria did not include a consideration of cumulative impacts *per se*, yet DER was authorized to consider the impacts of existing projects or those under construction, along with those under review, approved, or vested through the Development of Regional Impact law. These are the first hint of consideration of cumulative impacts in dredge and fill permitting.

The Henderson Act addressed mitigation for the first time in law. It provided that when an applicant was unable to meet the permitting criteria, the agency should consider "measures proposed by or acceptable to the applicant to mitigate the adverse effects which may be caused by the project." When water quality standards were not achievable because of existing ambient conditions, the agency was allowed to consider "mitigation measures proposed by or acceptable to the applicant that cause a net improvement of the water quality in the receiving body of water for those parameters which do not meet standards." These two forms of mitigation provided significant relief for both the agency and the applicants by acknowledging that wetland functions could be replaced and that ambient conditions of water could be improved through the permitting process. The Henderson Act also acknowledged that phosphate reclamation and restoration could be considered mitigation to the extent that they restored or improved the water quality and the type, nature, and function of biological systems present at the site prior to phosphate mining activities.

> *The Henderson Act addressed mitigation for the first time in law. It provided that when an applicant was unable to meet the permitting criteria, the agency should consider "measures proposed by or acceptable to the applicant to mitigate the adverse effects which may be caused by the project."*

To comply with new provisions of the Water Quality Assurance Act of 1983 and Warren S. Henderson Wetlands Protection Act of 1984, SWFWMD revamped its Management and Storage of Surface Water (MSSW) in 1984. Certain projects that had relied on earlier government decisions were grandfathered under these Acts.

In 1986, the Legislature adopted Section 373.414, FS, requiring water management districts that had been delegated stormwater permitting to adopt rules establishing specific permitting criteria for those isolated wetlands not within the jurisdiction of DER for the purposes of dredging and filling. These rules effectively brought isolated wetlands under permitting review through the MSSW permitting required of anyone making substantive changes to the flow of surface waters. Phosphate mining, however, remained exempt from this requirement. Before these rules were adopted, SWFWMD had exempted phosphate mining from MSSW permitting under the premise that the industry was already regulated by DNR for the reclamation of mined lands and the Henderson Act had acknowledged the use of reclaimed wetlands as mitigation.

Concern about both ground water contamination and limitations to the use of ground water increased in the early 1980s. While DER was being charged with protecting ground water from contamination, in 1982, the water management districts were charged with developing ground water basin availability inventories. During the 1980s, there were a series of legislative amendments and rule adoptions designed to protect underground geologic units from the emerging injection technology (both deep well injection and aquifer storage and recovery programs), to assist local governments in water supply planning, to emphasize the benefits of water conservation, to authorize water management districts to adopt rules establishing a general permit system for water use, and to adopt and modify a water shortage plan within the SWFWMD.

In mandating the development of ground water basin resource availability inventories, Section 373.0395, FS (1982 Supplement to Florida Statutes 1981), stated the legislative intent "that future growth and development planning reflect the limitations of the available ground water or other available water supplies." Inventories were mandated to identify ground water basins with their associated recharge areas and:

- Identify areas that would be "prone to contamination or overdraft resulting from current or projected development".
- Establish "criteria to establish minimum seasonal surface and ground water levels".
- Locate areas suitable for future water resource development, including wastewater reuse.
- Estimate "potential quantities of water available for consumptive uses".
- Be submitted to each affected municipality, county, and regional planning agency for consideration in future local government comprehensive planning.

In mandating the development of ground water basin resource availability inventories, Section 373.0395, FS (1982 Supplement to Florida Statutes 1981), stated the legislative intent "that future growth and development planning reflect the limitations of the available ground water or other available water supplies."

The last major legislative initiative in the environmental arena for an active decade of new rules and regulations was the Stormwater Management Act of 1989, which gave DER the authority to establish a state water policy with goals, objectives, and guidance for the development and review of programs, rules, and plans relating to water resources. After a decade of relying on the water management districts to administer the regulatory programs related to surface water systems, the Legislature reaffirmed its reliance on the executive agency for overall policy guidance.

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5.2.5 Consolidation and Streamlining

After nearly two decades of laying a foundation for the Florida environmental regulatory environment, both in response to federal initiatives and in response to the demands of a state undergoing rapid change, the general direction of the 1990s was to streamline, consolidate, and fill in the gaps. To make regulation work, there needed to be reasonably predictable outcomes and processes.

The Florida Environmental Reorganization Act (FERA) of 1993 (Chapter 93-218, LOF) provided the necessary statutory changes to enable Florida to assume delegation from the federal government of the NPDES permit program and to consolidate wetland resource, mangrove alteration, and surface water management permits into a single state regulatory approval: the Environmental Resource Permit (ERP). Besides merging the Department of Natural Resources (DNR) with the Department of Environmental Regulation (DER) to form the Florida Department of Environmental Protection (FDEP), FERA created the current statutory framework for a more unified and less duplicative division of regulatory responsibilities between the FDEP and the various water management districts (except for the Northwest Florida Water Management District). Of particular importance to the Peace River watershed, FERA established the framework under which permitting would be required for phosphate mining activities that had previously been exempted by SWFWMD for management and storage of surface waters. Even though regulation of land reclamation after phosphate mining had required acre-for-acre and type-for-type replacement of all wetlands, FERA brought the *permitting* review of isolated wetland impacts to phosphate mining.

One area of particular concern was compensatory mitigation for wetland impacts. FERA directed the water management districts and FDEP to participate in and encourage the establishment of public and private regional mitigation areas and mitigation banks. It also directed the adoption of rules governing the creation and use of mitigation banks to offset adverse impacts caused by activities regulated under Part IV of Chapter 373, FS. As a result of this legislation, two wetland mitigation banks were implemented in the Peace River watershed: one in the Horse Creek basin and another along the main channel of the Peace River near Wauchula. Together these mitigation banks have preserved approximately 900 acres of wetlands and upland buffers through perpetual conservation easements, along with enhancing and restoring wetlands within the mitigation bank preserves. The maintenance and management of these mitigation banks are funded in perpetuity through long-term management trust funds set aside from the sale of wetland mitigation credits, as required in Part IV of Chapter 373, FS. Approximately 349 wetland mitigation credits may be earned in these two mitigation banks upon meeting success criteria, and these credits can then be used to offset an appropriate amount of wetland loss, depending on the quality of the wetlands being impacted. Impacts offset by wetland mitigation credits are predominantly from infrastructure projects associated with urban development: roads, airports, landfills, electrical transmission lines, and commercial development.

In 1996, the Legislature amended Section 373.042, FS, to require SWFWMD to submit a priority list and schedule to establish minimum flow levels for surface watercourses, aquifers, and surface water. The following year the Legislature adopted Section 373.0421, FS, to provide legislative intent and list criteria and exemptions for establishing and implementing minimum flows and levels.

5.3 Programmatic Responses

Throughout the 1990s, SWFWMD wrestled with the complex issues associated with over-allocation of the Upper Floridan Aquifer System (UFAS) within SWUCA. These efforts resulted in the SWUCA Recovery Strategy and are covered in more detail in section 5.3.1 below.

5.3.1 Southern Water Use Caution Area (SWUCA)

Over-allocation of ground water use could arguably be the most significant cumulative impact in the Peace River watershed. Ground water withdrawals in the upper Peace River watershed caused the cessation of flows from Kissengen Springs (circa 1950) and other smaller springs, converting the upper Peace River from a gaining stream (spring fed) in the 1940s to a losing stream (contributing to ground water through sinkholes in the river bed) today. As a result, the upper Peace River does not now meet its established minimum flows and is subject to a recovery strategy to meet minimum flows again by 2025.

> *…the upper Peace River does not now meet its established minimum flows and is subject to a recovery strategy to meet minimum flows again by 2025.*

SWFWMD's experiences during the past 14 years dealing with SWUCA issues have, perhaps, stimulated some of the most innovative approaches for resolving the over-allocation of a natural resource anywhere in the nation. Building on a regulatory foundation, SWFWMD has pioneered a program of market-driven incentives, public financing, conservation, and education to achieve reasonably attainable goals within a timeframe consistent with the investment expectations of water users and trends in economic development.

SWUCA is important to an understanding of the effectiveness of regulatory and non-regulatory responses to a cumulative impact over an area almost twice that of the Peace River watershed. The story involves all the elements of regulation: science-based cause/effect assessment; public involvement; rule development; legal challenge; legislative initiative; and consideration of socio-economic consequences. Going beyond reliance on regulation, however, SWUCA elucidates the interaction between law and economic reality and the role of non-regulatory approaches to solving complex, long-term problems.

SWUCA elucidates the interaction between law and economic reality and the role of non-regulatory approaches to solving complex, long-term problems.

5.3.1.1 History Leading to SWUCA

In 1982, the Florida Legislature amended Chapter 373, FS, to add Section 373.0395. This amendment required each water management district to develop ground water resource availability inventories to identify prime recharge areas, criteria for establishing minimum levels, areas suitable for development of future ground water supplies, and the potential quantities of water available for consumptive uses. The information was to be shared with local governments and regional planning agencies to develop their future growth plans to "reflect the limitations of the available ground water or other available water supplies."

Although this section was subsequently repealed in 2005 by Chapter 2005-36, LOF, which revamped a number of reporting requirements for water management districts, these inventories served their purpose in the 1980s by helping SWFWMD identify areas where pumping was excessive or projected to become excessive. Following discussion of staff findings, the SWFWMD Governing Board directed staff to conduct comprehensive hydrogeologic evaluations, referred to as Water Resource Assessment Projects (WRAPs) in the areas of greatest concern. Four WRAP areas were initially identified: Eastern Tampa Bay, Northern Tampa Bay, Highlands Ridge, and the Peace River Valley.

The WRAP for the Peace River watershed was started in the late 1980s. It was developed concurrently with the Eastern Tampa Bay WRAP and the Highlands WRAP, and the information developed from these studies prompted SWFWMD to focus its efforts on a strategy for the entire Southern Basin.

Lake levels in the Highlands Ridge have been declining since the late 1950s. In fact, an initial study of lake level declines along the Highlands Ridge predates the 1982 mandate. This study (the Ridge I Report) and the subsequent Ridge II Report completed in 1989, documented declines in lake levels that were greater than would be expected as a result of local pumping alone. Hydrographs from the 1960s show a downward trend in annual peak water levels and an increase in seasonal water level fluctuations over a period when rainfall was below historical averages and ground water withdrawals for agriculture, phosphate mining, and public supply were increasing. Changes in surface drainage may have also affected lake hydrology as the ridge communities experienced increased development. While these causal factors may be offsetting to some extent, there is information indicating that a greater induced recharge from the surficial aquifer to the Upper Floridan Aquifer System (UFAS), resulting from a reduced potentiometric surface caused by pumping throughout the Southern Basin, is a dominant causal factor for reduced lake levels.

In Eastern Tampa Bay, the primary concern was deterioration of water quality, especially along the coast. SWFWMD undertook extensive studies of water quality and quantity in regional wells and determined that there had been significant reductions of the potentiometric surface levels in the Southern Basin since predevelopment. These changes were found to be the direct result of ground water pumping within the entire Southern Basin. The Eastern Tampa Bay WRAP concluded that the UFAS in the Southern Basin was a highly transmissive and well-confined aquifer that created an interconnected system, such that ground water levels at any location in the Southern Basin were found to be a function of the *cumulative* ground water withdrawals throughout the basin.

Thus, development of a separate Peace River watershed WRAP was overtaken by the conclusions of the other WRAPs to the east and the west. The insights from these studies led the SWFWMD Governing Board to establish the Southern Water Use Caution Area (SWUCA) in 1992 to address the UFAS in the entire Southern Basin. The boundaries of the SWUCA follow a rough approximation of persistent flow lines within the UFAS, and cover the Peace River watershed, along with surrounding surface drainages. Covering 5,100 square miles, the SWUCA is more than twice the area of the Peace River watershed.

5.3.1.2 SWUCA Management Plan

Upon declaration of the SWUCA, the SWFWMD Governing Board directed staff to form a SWUCA Work Group and develop a management plan for water use permitting in the area. The Work Group included members from stakeholder groups including agricultural, phosphate mining, industrial, public water supply, environmental, and other citizen groups, and had no formal decision-making authority. SWFWMD also utilized a SWUCA Advisory Group of Experts to assist in the development and review of technical information used to formulate water management policy for the SWUCA. Following the conclusion of the Work Group meetings, SWFWMD published a draft SWUCA Management Plan in September 1993 and held a series of public hearings on that draft. A revised SWUCA Management Plan was prepared and released in April 1994, and the Governing Board directed staff to begin development of administrative rules to implement the SWUCA Management Plan.

At this point the scientists drafting the SWUCA Management Plan and the Eastern Tampa Bay WRAP anticipated that by limiting actual withdrawals from the confined aquifers within the Eastern Tampa Bay area and the SWUCA to 150 mgd and 550 mgd, respectively, SWFWMD could maintain the 1991 potentiometric surface levels. They estimated that maintaining 1991 potentiometric surface levels would stabilize the saltwater interface and lake levels over a 50-year planning horizon. SWFWMD, however, published new information in October 1994 from an effort started in 1993. Dubbed the Supplemental Investigations Report, the new information was based on refined and improved modeling techniques. The Supplemental Investigations Report confirmed SWFWMD's conclusions regarding the relationship between withdrawals from the Southern Basin and the landward movement of the saltwater interface and the need to cap withdrawals and redistribute pumping. At the same time, it also concluded that the saltwater interface would continue to move landward under the "safe yield' scenarios.

SWFWMD first proposed area-specific rules to regulate water use in the SWUCA in late 1994 with clarifications in 1995. The proposed rules included provisions that would establish a minimum aquifer level for the UFAS in the SWUCA along with a number of specific permitting requirements. Under the proposed rule, no new withdrawals would have been considered by SWFWMD until the minimum aquifer level established for each of three areas specified in the rule was achieved and sustained for a period of five years. The proposed rule also provided that while this limitation on new permitting was in effect, applications for renewals of existing permits within the SWUCA would not be denied for the sole reason that the minimum aquifer level had not been met.

SWFWMD believed that withdrawals in the SWUCA could be redistributed in a manner that would increase the "safe yield" and/or minimize impacts to resources, but it was concerned that if such redistribution were imposed instantaneously on existing permit holders, there would be significant economic disruption. The proposed rule, therefore, contained reallocation provisions to minimize the impact on existing users, while providing a mechanism to redistribute withdrawals away from the impacted areas. Under the proposed rule, applicants for a new quantity would have to negotiate a transfer of withdrawal authorization for all or part of the water quantities held by an existing permit holder, or develop and use alternative water sources. "Alternative sources" at this time generally meant a source other than ground water or ground water of too low quality for agriculture.

Other provisions of the proposed rules dealt with water efficiency requirements, the recalculation of the water "cushion" granted to agricultural permittees for emergencies, such as cold weather, and the use of a system of irrigation "credits" that would accrue when actual metered water used was less than the permitted amounts. Holders of credits would be able to use extra water in drought years or for other emergencies.

5.3.1.3 Administrative Law Judge Ruling

Numerous litigants challenged the proposed SWUCA rule and the cases were consolidated for hearing in February 1995. The hearing commenced in phases in February 1995 and was completed in November 1995. The Administrative Law Judge (ALJ) issued a 652-page final order in March 1997, which is provided in Appendix I.2. The following summarizes the effect of the ALJ's final order on SWFWMD's SWUCA Management Plan.

The ALJ generally upheld the process and science underlying the rule development. He acknowledged that rules were developed as "the result of an extensive effort by the District after a number of workshops, much debate, and study over the course of several years." He found "the District decided to accept a certain degree of harm to the water resources," and that "many of the issues raised regarding the proposed minimum level for the SWUCA involve difficult policy choices." The proposed methodology for calculating the minimum level was determined to be "reasonable and scientifically sound" and was based on a thorough scientific analysis using best available data.

The ALJ upheld the use of the 1991 potentiometric surface as the established minimum level, even though this level would allow saltwater intrusion to continue for decades into the future. Against arguments to the contrary, the ALJ ruled that SWFWMD did not have to roll back existing permits, that it could take into account the socio-economic consequences of its options, and that it could condition permits to implement a gradual approach to remediation of a problem that had been developing since before SWFWMD had regulatory authority. The ALJ acknowledged that saltwater intrusion is “a slow-moving process and absent drastic cuts or a halt in pumping it will take several hundred years for the UFAS to reach equilibrium.” Further, the equilibrium that would eventually be maintained would be considerably inland of the current position of the saltwater interface, and SWFWMD was empowered to allow that movement with knowledge that it would cause additional well failures and deterioration of water quality along the coast.

> *…the ALJ ruled that SWFWMD did not have to roll back existing permits, that it could take into account the socio-economic consequences of its options, and that it could condition permits to implement a gradual approach to remediation of a problem that had been developing since before SWFWMD had regulatory authority.*

The ALJ found that SWFWMD was reasonable in its proposal not to allow new quantities to be withdrawn throughout the SWUCA while sub-areas like the Most Impacted Areas (MIA) remained below the minimum level. Even though the measured impacts of an individual withdrawal were deemed to be greater in the vicinity of the point of withdrawal, the ALJ upheld the interrelationship between withdrawals within the entire Southern Basin, and, therefore, supported SWFWMD’s proposal to limit distant withdrawals as long as sub-areas were below the minimum level.

By far the greatest impact of the ALJ’s ruling was on the SWFWMD’s proposal to allow existing legal users to renew their permitted quantities from the UFAS, while denying applicants for new quantities until the resource had recovered. He found that the “favored treatment of renewal permits contravenes Chapter 373 and is invalid.”

Relying heavily on the *Model Water Code* and its accompanying commentary to ascertain the meaning and intent behind Chapter 373, FS, the ALJ ruled that the law clearly provides a mechanism to choose among applicants when granting water use permits from a fully allocated resource. That mechanism is to consider competing applications, per 373.233, FS, which provides both the responsibility and authority to choose among competing users for water supplies and to allocate water to the use(s) which “best serves the public interest.”

A corollary proposal to the favored treatment of renewal permits was the favored treatment of reallocation permits by which SWFWMD could allow the transfer of existing permitted quantities to different uses and locations. The ALJ ruled that the reallocation of water use permits also exceeded legislative authority. SWFWMD had proposed that a “restructuring of the current mix of uses would occur through the private market via application of the proposed reallocation provisions. . . .” Attempting to avoid the issuance of permits for new quantities, while not necessarily precluding new uses, SWFWMD had proposed that potential new users in the SWUCA could obtain access to the UFAS through the reallocation provisions of its proposed rule.

The proposed reallocation provisions were intended to:

- Facilitate redistribution of water use within the SWUCA from the most impacted area along the coast to the interior regions.
- Provide a mechanism for economic growth within the inland communities.
- Provide a mechanism for reducing total permitted quantities and increasing efficiency of use by existing permit holders.

The ALJ found that "capping the issuance of new permits while allowing the current permit-holders to transfer a part or all of their permitted quantity through negotiation and sale effectively creates a valuable private right in a commodity that has been defined by law as a public resource." While SWFWMD claimed that it retained the ultimate authority under the reallocation proposals to deny any permit not in the public interest, and that the proposed program was thereby not a "prior appropriation" system, the ALJ ruled, "the District cannot ignore the existing statutory mechanisms while creating new rights that are inconsistent with the current law."

Finally, of particular interest to this study, the ALJ addressed a challenge concerning cumulative impacts in the issuance of water use permits. In 1989, SWFWMD had adopted revisions to its water use permitting rules that, among other things, provided a mechanism to consider cumulative impacts in permitting decisions. Prior permitting rules were essentially non-cumulative in that SWFWMD only evaluated the impacts of the proposed use. The 1989 rule revisions were also the first time SWFWMD attempted to take into account the on-site environmental impacts of its water use permitting decisions. With adoption of the 1989 rules, SWFWMD applied 14 interpretive criteria that an applicant must meet on both an "individual and cumulative basis." While a litigant alleged SWFWMD, by requiring applicants to meet the permitting test of an individual and cumulative basis, had unlawfully enlarged Sections 373.223 and 373.226, FS, the ALJ sided with SWFWMD by holding that:

> For any regulatory scheme to be effective there has to be an ability to take cumulative impacts into account. Section 373.223 provides that water use should be regulated in the public interest. It is clearly within the public interest to protect environmental resources, and these resources will not be protected in the absence of consideration of cumulative impact. See, Art. II, Section 7, Fla. Const. (1968).

A number of other parties appealed the ruling to the Second District Court of Appeal. In September 2000, the Court ruled on the challenges presented to the original SWUCA rules. The Court found in favor of SWFWMD on all 13 points of appeal.

> *For any regulatory scheme to be effective there has to be an ability to take cumulative impacts into account.*

5.3.1.4 SWUCA II – The Southern Water Use Caution Area Recovery Strategy

During the appeal process, SWFWMD initiated a review of SWUCA resource concerns and strategies. The economics of agriculture were changing and so was the demand for water from that sector. Permitted ground water quantities and actual use within the SWUCA had stabilized more quickly than originally anticipated. As a result, ground water levels were in better condition than had been previously been predicted. The Legislature had adopted new provisions in 1997 that gave all water management districts new water supply policy directives, water resource and supply planning and development responsibilities, and guidance for "recovery and prevention strategies" associated with minimum flows and levels.

As part of developing a recovery strategy, a new SWUCA Work Group was formed to review resource management approaches. Work Group deliberations and public meetings started in October 1998 and continued through September 2005. Based on extensive input from the SWUCA Work Group, SWFWMD advisory committees, and the general public, a draft document was published in November 2003 and subsequently revised in November 2004 and December 2005. SWFWMD adopted a recovery strategy in March 2006 and completed rule adoption to implement the regulatory components of that strategy in June 2006. The discussion below looks at the recovery strategy with particular emphasis on its regulatory aspects related to resource allocation and cumulative impacts.

SWFWMD's recovery strategy goals are to:

- Restore minimum levels to priority lakes in the Lake Wales Ridge by 2025.
- Restore minimum flows to the upper Peace River by 2025.
- Reduce the rate of saltwater intrusion in coastal Hillsborough, Manatee, and Sarasota Counties by achieving the proposed minimum aquifer levels for saltwater intrusion by 2025; once achieved, future efforts should seek further reductions in the rate of saltwater intrusion and the ultimate stabilization of the saltwater-freshwater interface.
- Ensure that there are sufficient water supplies for all existing and projected reasonable-beneficial uses.

SWFWMD's Governing Board has adopted the following "guiding principles" for the recovery strategy:

- Contribute significantly to resource management and recovery.
- Protect investments of existing water use permit holders.
- Allow for economic expansion and new economic activities.

- Ensure that the strategy is based on the best available science, and that the science be extensively peer reviewed.
- Attempt to minimize the need for rule revisions.
- Provide financial and regulatory incentives to maximize the benefits of public and private partnerships.
- Ensure the recovery strategy is expeditiously implemented in a timeframe that is practical.
- Seek consistency with recovery strategies developed elsewhere in the state.

Taken as a whole, the goals and guiding principles cited above constitute SWFWMD's over-arching policy regarding the resolution of the cumulative impacts of over-allocation of the UFAS resource.

5.3.1.5 Regulatory Component

SWFWMD made several fundamental changes in the approach taken to the SWUCA II rules as a result of the findings in the SWUCA I litigation. (SWUCA I refers to the set of rules adopted in late 1994 and 1995 that were the subject of the March 1997 ALJ Final Order; SWUCA II refers generally to rules adopted subsequently.) The SWUCA II rules allow for continued allocation of existing permitted quantities, but continue to accommodate competing applications. When an existing permitted user applies for renewal of a permit with no proposed increased in permitted quantities, the application will be reviewed for compliance with all rule criteria, including those in the Basis of Review; however "the existing impacts to permitted quantities on an MFL water body will not be a basis for permit denial because the SWUCA Recovery Strategy taken as a whole is intended to achieve recovery to the established minimum flows and levels as soon as practicable" (Section 4.3.B.1. SWFWMD Basis of Review). Should two or more applications meet these criteria for an existing allocated quantity, the applications would be treated as competing for those quantities under Section 373.233, FS, and Rule 40D-2.311, FAC.

In the 1995 litigation over the SWUCA I rules, the ALJ found that with the lack of adopted procedure for processing competing applications, "potential applicants have no way of knowing how it will be applied, when and for what quantities they can compete or the procedures that will be followed." In light of the above finding, perhaps, SWFWMD floated a "trial balloon" draft of competing applications rule language in early 2004. In this draft rule, SWFWMD attempted to define more specifically what would "best serve the public interest." They proposed four criteria:

1. First preference would be to a renewal application.

2. Second preference would be to the application that demonstrated the greatest potential to improve the water resource.

3. The next level of preference would be to an application from a small business, small city or small county.

4. Finally, if all else were equal, the application that demonstrates the least impact to the Minimum Flow or Level of a water body would be favored.

The FDEP, on the other hand, expressed several concerns with this approach to competing applications. The most significant concern related to the automatic preference to renewal applications over all other permit applications. As proposed by SWFWMD, FDEP felt the SWFWMD Governing Board would have no flexibility to take into consideration other potentially significant public interest factors when making water allocation decisions. Further, they thought this approach contrary to the statute that provides a preference for a renewal application over a new use *only* when the applications equally serve the public interest. That is, preference for a renewal application is the tie-breaker and cannot also be part of the original competition for public interest. To quote FDEP, ". . . an application's renewal status should not be an automatic determining factor outweighing all other public interest factors in every case. The proposed rule clearly established more of a preference for existing permit holders under Florida water law" (Janet Llewelyn, letter to SWFWMD, July 2004).

FDEP suggested substitute language to better define the meaning of "best serve the public interest" in the competition between applications:

> Where one or more applicants apply for New Quantities [*sic*] of water and the applications meet all rule criteria for issuance, except that the withdrawal impacts are projected to impact the Minimum Flow or Level of the same water body, the applicants may compete for the requested quantities.
>
> The Governing Board shall allocate the quantity to the application or applications that best serve the public interest. In determining the public interest, the Governing Board shall consider, but not be limited to, the following criteria:
>
> 1. The expenses incurred for the development and maintenance of an existing permitted water supply system and the investment in infrastructure and facilities dependent on the use of the permitted quantities.
>
> 2. The level of impact of the water use on the MFL, or the degree of contribution to the recovery of the minimum flow or level.
>
> 3. The feasibility of development of an alternative water supply source which does not impact the MFL to meet the requested quantity.
>
> 4. The degree of environmental benefit, in addition to contribution to the recovery of the MFL. (Janet Llewellyn, letter to SWFWMD, July 2004; Janet Llewellyn, June 2006 by personal communication confirmed that the term "New Quantities" was in error and the proposed criteria were for all applications, including renewal applications.)

While FDEP's criteria suggest that previously invested costs associated with renewal permits would carry weight, the list is not sequential in preference and, as written, not inclusive of all factors that could be considered.

For reasons not entirely clear in the written record, neither FDEP nor SWFWMD has attempted to further refine how competing applications should be handled. Therefore, while competing applications are applicable under the SWUCA II rules, no further clarification of the statutory language is provided.

Within the Peace River watershed, SWFWMD plans to implement the SWUCA recovery plan through a combination of water resource development projects designed to achieve minimum flows and levels in the upper Peace River and eight priority lakes by 2025. In addition, SWFWMD plans to adopt a re-designed regulatory approach. Under the new water use regulations, SWFWMD will use standard permitting procedures for permit renewals that request no increase in quantity as well as new quantities of water from Alternative Sources (generally not ground water except brackish ground water treated for public use). SWFWMD will continue its scrutiny of reasonable-beneficial requirements, especially for unused quantities, and its promotion of conservation. In addition, SWFWMD's new rules regulate *new quantity* applications from both ground water withdrawals that could affect the upper Peace River minimum flow and the levels of eight priority lakes and direct withdrawals from surface features. SWFWMD will also implement a monitoring program for ground water levels throughout the SWUCA region. New quantities of water will not be permitted if the levels in monitoring wells are below the median levels experienced in the 1990s, or if new direct withdrawals are determined to be detrimental to maintenance of minimum flows or levels, *unless* the applicant implements a Net Benefit option or enters the competing application process.

> *SWFWMD's new rules regulate new quantity applications from both ground water withdrawals that could affect the upper Peace River minimum flow and the levels of eight priority lakes and direct withdrawals from surface features.*

A Net Benefit is only required when a proposed withdrawal of new quantities impacts a minimum flow or level of a waterbody and the actual flow or level is below the minimum or is expected to fall below the minimum as a result of the proposed water use. Because the Net Benefit effort is not required of existing users seeking a permit renewal, or of new water obtained through alternative source development, SWFWMD anticipates that Net Benefits will be required in only a minority of cases. In the Peace River watershed, the special SWUCA permitting criteria are the ground water level comparative analyses for the upper Peace River and the eight priority MFL lakes.

A Cumulative Impact Analysis is a key element of the adopted SWUCA Recovery Strategy. As adopted, the Cumulative Impact Analysis will not be used in each individual permit evaluation, but to assess the condition of the ground water resource in the SWUCA as part of the continual monitoring by the Governing Board of the progress of recovery to the established minimum flows and levels. SWFWMD will implement a monitoring program for ground water levels.

The SWUCA Recovery Strategy describes three Net Benefit Options. The recurring theme through all is the use of innovative solutions to offset the impact the proposed permit would have to the resource. They include:

- **Ground water Replacement Credit**

  The applicant can provide other water use permit holders with alternative supplies, such as reclaimed water, to offset their use of the limited resource and, thus, obtain credits to offset the applicant proposed use of the limited resource. Ground water Replacement Credit is 50 percent of the offset amount and is available to the supplier of the alternative supplies, the receiver, a designated third party, or some combination of the above. The receiver of alternative supplies may also obtain a stand-by permit for the non-alternative quantities offset in the event they are not sufficient or become unavailable for any reason.

- **Mitigation Plus Recovery**

  The applicant can take measures that mitigate or offset the impacts proposed, such as retirement of one use to allow the permit for another. The example provided in the SWUCA Recovery Strategy is for local government to retire an existing agricultural permit where the existing used quantities impact the MFL, so the land can be converted to residential and commercial use with less water needs. Under the new rules, retiring actively-used quantities or transferring an existing actively-used permit can be applied to situations where standard rule criteria are limiting withdrawals, or if there is an impact to an MFL water body requiring a Net Benefit.

- **Use of Quantities Created by SWFWMD Water Resources Development Projects**

  An applicant who has participated in a SWFWMD water resource development project may propose using quantities created by that project to offset proposed impacts. There is no indication in the rule of a minimum required participation or a necessary relationship between the amount of participation in the project and the amount of offset earned.

A Net Benefit is not required of existing users seeking a permit renewal, or anyone seeking a permit for new water obtained through alternative source development, and, therefore, SWFWMD anticipates they will be required in only a minority of cases. A Net Benefit must offset the predicted impact to the proposed withdrawal and also provide an additional positive effect on the water body equal to, or exceeding, 10 percent of the predicted impact.

The March 2006 SWUCA Recovery Strategy document provides examples of how the new rules would work for the preservation, transfer, and protection of permitted quantities. Focusing on the transition of land uses from agricultural to suburban and commercial, the document suggests how landowners can work with local governments or developers to effect a change of use and to prevent interlopers from competing for the retired quantities:

> In the local government's application for a water use permit that includes service to the land involved, the local government would offer retirement of the previous permitted and used quantities as mitigation plus recovery. In those areas where the local government has concern that others may try to avail themselves of a Net Benefit associated with these permitted and historically-used quantities, the local government could work with the existing agricultural permittee to apply to become co-permittee to have greater control on those permits.

There are suggested approaches on how to retire permitted quantities for the purpose of obtaining permits for new quantities of water for a new use:

> One of two approaches may be used to retire permitted quantities. The first approach is that the entity that is mitigating in the form of retiring permitted quantities transfers the permit into its name, and demonstrates ownership or control of the related property. Then as part of the application for new quantities, the entity submits a request to retire the permit along with model results showing the offset.
>
> Another possible way to retire the permit is for the local government to have an agreement with the current permit holder to notify the District to cancel its permit simultaneously with the application for the new permit (that would include model results showing the offset). In either case, the permit will be retired coincident with the issuance of a permit that contains an increase in quantities that is based on the retirement.

Another innovative aspect of the recovery strategy is allowance of "self-relocation." Existing permittees may move their permitted quantity to another property as long as there is no change in use, type, or ownership, they do not increase the quantities, and the relocation does not increase impacts to MFL water bodies. None of the rule provisions for new uses will apply. All reasonable-beneficial quantities, including those that are unused along with any water conserving credits accrued, can be transferred after permits are reviewed for all other rule criteria, including a review of any possible impacts to the MFL water bodies.

Taken together, the net benefit and self-relocation rules create a powerful market force to accomplish the SWFWMD's resource conservation and recovery objectives. Because the transferability of water rights within the regulatory structure enhances the value to property owners holding water use permits, it provides a market-driven means to induce the transfer of permitted quantities in ways that would reduce withdrawals in critical areas. Within the framework of a continually expanding water demand, market mechanisms provide a way to smooth the transition from less expensive to more expensive water, as resources are developed. It is unclear how the market mechanisms protect high demand users (agriculture and electrical generation) with limited ability to ride the increasing cost curve. Finally, there seems to be no guarantee that an applicant for new quantities of water relying on alternative water supplies or Net Benefit Options would prevail against a competing application.

Within the framework of a continually expanding water demand, market mechanisms provide a way to smooth the transition from less expensive to more expensive water, as resources are developed..

5.3.2 Nonmandatory Phosphate Reclamation

Phosphate mining has occurred in central Florida since the late 19th century. Prior to 1975, mine operators were under no obligation to reclaim lands disturbed by the severance of phosphate. In 1971, Florida passed legislation that initiated the taxation of solid minerals severed from the earth (Chapter 211, FS). The intent of this law was to encourage voluntary reclamation of mined lands by providing up to one-half of the tax for refunds of reclamation expenses. Reclamation was voluntary and reclamation standards were not established.

In 1975, Chapter 211, FS, was amended to mandate the reclamation of land mined after July 1, 1975, and refunds were available for both “old lands” (disturbed prior to July 1, 1975) and “new lands” (disturbed after July 1, 1975).

In 1977, the statute was amended again to disallow the refunding of expenses for any mandatory reclamation and restrict the use of funds only to those lands disturbed prior to July 1, 1975. In addition, the 1977 amendment created the Phosphate Land Reclamation Study Commission, which was directed to inventory lands disturbed by the severance of phosphate prior to July 1, 1975, and to recommend legislation designed to promote the reclamation of this land.

In 1978, the Florida Legislature incorporated the recommendations of the commission into Chapter 378, FS, which, among other things, created the Nonmandatory Land Reclamation Program and authorized the preparation of the Master Reclamation Plan (MRP) by DNR. It was the intent of the Legislature to provide an economic incentive to encourage the reclamation of the maximum acreage of eligible lands in the most timely manner, or the donation or purchase of nonmandatory lands. The 1978 legislation directed DNR to conduct on-site evaluations of all lands disturbed before July 1, 1975, to determine which lands needed reclamation based on the following criteria:

1. Does water leaving the site meet applicable water standards? Were health and safety hazards present? Was the soil stable or revegetated or, were any resources remaining and were they being conserved?

2. Would the environmental or economic utility or aesthetic value of the land naturally return within a reasonable time, and would reclamation substantially promote the environmental or economic utility or aesthetic value?

3. Was the reclamation of the land in the public interest because the reclamation, when combined with other reclamation under the MRP, would provide substantial regional benefit?

In addition, the Nonmandatory Land Reclamation Trust Fund (NMLRTF) was created to provide refunds for reclamation cost for lands identified in the MRP. In August 1979, DNR authorized Zellars-Williams (ZW) to evaluate the pre-July 1, 1975 mined lands pursuant to the statutory direction above. Completed in August 1980, the ZW study evaluated 748 sites covering 149,129 acres inventoried by the Commission. In the first phase, it was obvious that some sites did not meet the criteria to merit reclamation and 222 sites covering 31,196 acres were excluded from further consideration. Sites excluded were those:

- Reclaimed under the voluntarily program established in 1971.
- Voluntarily reclaimed by the owner without any refund of expenses.
- That had been converted to other phosphate industry activities such as chemical plants, phosphogypsum stacks or beneficiation plants.
- Scheduled to be re-mined or re-disturbed.
- Converted to economic uses such as residential, industrial or agricultural uses.
- Whose owner did not grant permission to conduct an on-site evaluation.

The ZW evaluation, after further study, concluded that an additional 179 sites covering 31,075 acres were also not eligible for the reclamation for the same reasons as above.

The remaining 347 sites covering 86,658 acres were determined to be eligible for reclamation under the Nonmandatory Land Reclamation Program (NMLRP). The results of the ZW Study completed in 1980 for the entire pre-1975 inventory and those within the Peace River watershed are presented in Appendix I.3.

5.3.2.1 Nonmandatory Land Reclamation Program (NMLRP) 1980 through 2005

It is important to note that the NMLRP does not dictate land use. The goal was to create a land form that met water quality, safety, soil stability, and revegetation standards. Minimum standards were established for reimbursement purposes and although economic gain may result from the reclamation project, it was not the intent to reimburse landowners for specific land uses, such as residential projects, but to reimburse only for reclamation to minimum standards. The rules do allow minimum standards to be exceeded or waived if the land use for all or a significant portion of the program is designated as a wildlife habitat. In those instances, the landowner can be reimbursed for work in excess of minimum standards. In cases where minimum standards are exceeded for other reasons, such as to enhance economic potential, the landowner is not reimbursed for work in excess of minimum standards.

As of this year, 157 reclamation programs have been completed and released. Participants include both non-mining company landowners (state and county, private individuals, and companies not in the business of mining phosphate) and company landowners (phosphate mine operators). Examples of reclaimed land uses of completed programs providing economic improvements include: citrus groves, improved pasture, residential housing, and business developments. Examples of reclaimed land uses providing ecological improvements include:

water treatment facilities, city and state parks, and wildlife habitat for hunting and fishing. Many land uses provide for both economic and environmental benefits such as industrial buffer zones and agricultural and residential areas that also provide for the conservation of wildlife areas. There are 24 reclamation programs currently under contract. The table presented in Appendix I.4 summarizes the participation in the Nonmandatory Land Reclamation Program to date.

In 2003, the Legislature amended Section 378.031, FS (Legislative Intent), to add "especially those lands for which reclamation activities will result in significant improvements to surface water bodies of regional importance in those areas of the state where phosphate mining has been permitted." Also in 2003, the Legislature established January 1, 2005, as the last day FDEP could accept applications for nonmandatory land reclamation applications.

Applications for approximately 10,056 acres were received prior to the deadline of January 1, 2005. A total of 1,007 acres were approved for funding in fiscal year (FY) 2005-2006 and 798 acres were approved for funding in FY 2006-2007. Approximately 8,200 acres included in applications received by the deadline remain unfunded. Each of the applications received by January 1, 2005 had potential to improve surface water bodies where phosphate mining had been allowed.

Approximately 8,200 acres included in applications received by the deadline remain unfunded.

The intended land use for current funded reclamation programs and current unfunded applications includes: agricultural lands with little potential for higher land use, agricultural lands with long-term potential for higher land use, and industrial water cropping. Many current funded programs include wildlife enhancements and conservation easements to the state and the potential exists for the same enhancements and easements on the unfunded programs.

5.3.2.2 NMLRTF and the Severance Tax

When the program was implemented, there were statutory limitations on the amount of funding. The long-term goal was to accumulate enough money in the NMLRTF so that by the year 2000 there would be a sufficient unencumbered balance to fund the remaining unfunded programs and eliminate the need to distribute a portion of the severance tax to the NMLRTF. To accomplish this goal, reclamation obligations were limited to 10 percent of the unencumbered fund balance until 1992, then 20 percent until 1995. This goal was achieved. By the end of FY 2000-2001, the total fund balance was $167 million and the unencumbered balance was sufficient to reclaim a substantial number of remaining eligible parcels. This same year, distributions of severance tax to this trust fund ended.

In 1996, the Legislature recognized the risk that an operator would default on their reclamation obligations. That year, the Legislature required that $30 million of the unencumbered trust fund balance be reserved for this potential. In 2000, this was increased to $50 million and the reserve included risks associated with phosphogypsum stack systems. This reserve was ultimately eliminated when FDEP was required to fund the maintenance and closure costs for two stack systems.

In February 2001, the Mulberry Corporation, which owned and operated two phosphate fertilizer processing plants Piney Point Phosphates, Inc. [Piney Point], and Mulberry Phosphate, Inc. [Mulberry]), notified FDEP that they no longer had the resources to maintain the facilities, manage process water, and ultimately close the sites as necessary to abate the imminent hazard from the potential spills of acidic process water, potential impacts to ground water, and similar environmental risks posed when an abandoned site is not being properly managed and closed. The Mulberry Corporation subsequently filed a petition for protection from creditors in the U.S. Bankruptcy Court in Tampa, Florida (Chapter 11, subsequently converted to Chapter 7 in October 2001).

Since February 2001, FDEP has spent over $130 million for construction work, site maintenance, and operation in order to safely reduce process water inventories and perform the construction tasks necessary to close the two facilities in accordance with Section 403.4154, FS. The majority of funding has come from the Nonmandatory Reclamation Trust Fund.

Legislative changes allowed the use of the NMLRTF for the purpose of maintaining and closing these stacks and, ultimately, the reserves were eliminated. As of FY 2004-2005, the total fund balance had been reduced to $52 million with only $8 million unobligated.

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The trust fund began receiving distributions from the severance tax again in 2003-2004, and currently receives 10.4 percent of the tax collected, after the first $10 million is transferred to the Conservation and Recreational Lands Fund. Appendix I.4 provides the Phosphate Industry Severance Tax Table presenting the tax rate, amounts collected, and the distribution percentages and amounts since the tax began in 1971. Also presented in Appendix I.5 is the NMLRTF Comparison of Fund Balance Chart through FY 2004-2005.

5.3.3 Minimum Flows and Levels (MFLs)

Florida's 1972 Water Resource Act requires establishing minimum flows and levels (MFLs) to ensure that withdrawals do not result in significant harm to the water resources and ecology of the area. MFLs provide a tool to assist in sound water management decisions that prevent significant adverse impacts to the water resources or ecology of the area.

Since the early 1970s, SWFWMD has been engaged in an effort to develop MFLs for water bodies. Beginning with the 1996 legislative changes to the MFL statute, SWFWMD has enhanced its program for development of MFLs. There are numerous SWFWMD initiatives associated with setting MFLs. These include:

- Developing district-wide lake and stream classification systems and databases.
- Identifying priority water bodies for setting MFLs.
- Performing applied research to support the development of MFLs.
- Setting minimum levels for priority wetlands, lakes, and aquifers, and minimum flows for priority springs, streams, and rivers.
- Monitoring waters levels, hydrology, soils, and biological communities to verify that established MFLs are at appropriate levels.

SWFWMD implements established MFLs primarily through its Water Supply Planning, Water Use Permitting, and Environmental Resource Permitting programs, as well as funding of water resources and water supply development projects that are part of a recovery or prevention strategy.

The adopted minimum flows for the upper Peace River are focused on returning perennial conditions to the upper Peace River. Specifically, they are based on maintaining the higher of the water elevations needed for fish passage (0.6 feet or 7.2 inches) or the lowest wetted perimeter inflection point (as much stream bed coverage as possible for the least amount of flow). This approach yielded minimum low flows of 17 cfs (10.2 mgd), 27 cfs (16.2 mgd), and 45 cfs (27 mgd) at the Bartow, Ft. Meade, and Zolfo Springs U.S. Geological Survey (USGS) stream gages, respectively. These flows are required to be exceeded at least 95 percent of the time on an annual basis, which is nearly 350 days per year.

In 2005, SWFWMD established a minimum low flow rate for the middle Peace River of 67 cfs as measured at Arcadia. A minimum high flow was established at 1,362 cfs. No recovery plan is needed because the minimum flows are currently maintained.

SWFWMD recognizes that multiple minimum flows are necessary to maintain the flow regime and health of aquatic ecosystems in the upper Peace River, as well. At this time, however, only minimum low flows are being established. Mid- and high-minimum flows will be established once the controlling factors that affect the mid and high flows are better understood.

Wetted perimeter inflection points and fish passage depths were evaluated jointly to establish minimum flows for the low end of the flow regime of the upper Peace River. There was no assumption 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 the higher flow of the two was used as a conservative means for establishing the minimum flow.

For rule development purposes, flows were established at the Bartow, Ft. Meade, and Zolfo Springs USGS gage sites. These sites are also where the river flows will be monitored. However, a goal of the upper Peace River recovery strategy is to not only to achieve these minimum low flows at these individual sites, but to achieve similar flow conditions throughout the upper Peace River to attain the resource benefits of these flows (wetted perimeter, fish passage).

The upper Peace River minimum flows will be in compliance when the actual river flows are at or above the established minimum flows for three consecutive years. Once the minimum low flow has been achieved and is followed by two years where the minimum low flow is not met within a rolling ten-year period (commencing with the three consecutive years of achievement), then the actual flow shall be considered below the minimum low flow. SWFWMD will determine whether actual flows are meeting the established minimum flows at each of the established minimums (Bartow, Ft. Meade, and Zolfo Springs).

From 1976 to 2000, the annual 95 percent exceedance flow met or exceeded the proposed minimum flow in 7 out of 25 years at the Bartow USGS gage. From 1976 to 2000, the annual 95 percent exceedance flow met or exceeded the proposed minimum flow in 1 out of 25 years at the Ft. Meade USGS gage. From 1976 to 2000, the annual 95 percent exceedance flow met or exceeded the minimum flow in 22 out of 25 years at the Zolfo Springs USGS gage.

Currently, the upper Peace River from Bartow to Zolfo Springs is not achieving the proposed minimum flows and SWFWMD has prepared a recovery strategy. The major element of the recovery strategy for the upper Peace River is the implementation of a series of water resource development projects that restore minimum flows.

The Lake Hancock projects are a critical part of SWFWMD's recovery strategy for meeting the minimum flows in the upper Peace River, improving water quality in the Peace River, and protecting Charlotte Harbor, an estuary of national significance.

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Lake Hancock is a 4,500-acre lake in the headwaters of the Peace River watershed, which extends 120 miles downriver to Charlotte Harbor. As part of a the SWUCA Recovery Strategy, the Lake Hancock projects are two of several planned initiatives that are critical in SWFWMD's objectives of restoring storage, flows, aquifer recharge, water quality, and ecosystems in the upper Peace River watershed.

The Lake Hancock projects include the Lake Hancock Lake Level Modification Project and the Lake Hancock Outfall Treatment Project. The goal of the Lake Level Modification Project is to store water by raising the control elevation of the existing outflow structure on Lake Hancock and to slowly release the water during the dry season to help meet the minimum flow requirements in the upper Peace River between Bartow and Zolfo Springs. The goal of the Outfall Treatment Project is to improve the quality of water discharging from Lake Hancock to improve water quality throughout the entire Peace River and protect Charlotte Harbor.

The Lake Hancock Projects are estimated to only provide about half the flow needed to meet upper Peace River minimum flows. SWFWMD will develop other projects to enhance flows to meet its target recovery date in 2025.

5.3.4 Agricultural Ground and Surface Water Management Program (AGSWM)

AGSWM was developed by SWFWMD staff and members of the agriculture community. AGSWM is an alternative regulatory process for agricultural operations that uses field visits, site specific conservation management planning, and technical provisions to foster agricultural production and environmental resource protection. SWFWMD staff encourages farmers who are planning activities that are subject to Environmental Resource Permitting (ERP) or Water Use Permitting (WUP) regulation to use the AGSWM pre-application review process, which can help facilitate exemption determination or permitting review. “Ag-Team” staff has been established in local service offices to provide full service water management regulation for agriculture. This initiative has been underway since 1991.

SWFWMD's four principal service offices have assigned and trained Ag-Team staff who specialize in Water Use, Surface Water, and Environmental regulation for agriculture. The Technical Services Department (TSD) has an Ag-Team "Facilitator" who works with local Ag-Team staff to provide technical oversight and direction, and to foster cooperation on a regional or state basis. Also, TSD has an irrigation engineer who works on agricultural water management research and other special projects to assist the regulated public. Since 1991, SWFWMD has provided about $200,000 per year for the USDA Natural Resources Conservation Service (NRCS) to support technical assistance that helps farmers and SWFWMD staff to implement site-specific ecosystem-based conservation management planning. Agricultural projects that qualify for an ERP/AGSWM exemption letter must be planned and implemented according to prescribed conservation management planning practices.

The AGSWM process, using local Ag-Teams, encourages a "customer service" based approach to ERP and WUP regulation. This can result in better understanding and faster processing of applications, which in turn, helps growers reduce production delays and helps the SWFWMD avoid compliance and enforcement procedures.

5.3.5 Integrated Habitat Network/Coordinated Development Area: Lease Nos. 3963, 3995, and 4236

The FDEP's Bureau of Mine Reclamation (BMR) currently leases and manages approximately 5,600 acres of State-owned land along the Peace and Alafia Rivers and is the designated managing agent for over 22,000 acres of Perpetual Conservation Easements in the phosphate mining district and the Green Swamp. The BMR became active in land management in the late 1980s through the statutory change of the Florida Department of Natural Resources Division of Resource Management. One of the powers and duties of the division, as set forth in Section 370.02(3)(g), FS, was that ". . . the division shall also perform functions including, but not limited to, preservation, management, and protection of lands held by the State other than parks and recreational and wilderness areas. . ." (FDEP, BMR, 2006).

In 1987, the Coastal Petroleum Litigation Settlement Agreement (Coastal Settlement) set up a matrix whereby the five phosphate mining companies were to transfer approximately 6,250 acres, in various sized tracts in the floodplains along the Peace and Alafia Rivers, to the State of Florida for alterations made by the companies in the State-owned natural channels of these rivers. The phosphate mining companies, including Agrico Chemical Company, American Cyanamid Company, Estech, Inc., International Minerals and Chemical Corporation, and Mobile Mining and Mineral Company, were to conduct these transfers over a period of 12 years.

In 1992, the Homeland portion of the Coastal Settlement property was formally leased to FDEP to establish and operate a field office and aquatic weed control research center through Lease No. 3963. In 1993, approximately 930 acres of the State-owned portion of the Coastal Settlement lands bordering the Peace River and Bowlegs Creek were leased to the Division of Resource Management through Lease No. 3995 and the BMR became the management entity. This lease has been amended five times to include additional parcels along the Peace River, Alafia River, and Little Payne Creek. A third lease, No. 4236 issued in 1999, covered over 100 parcels (composed of approximately 1,400 acres of the total 6,600 acres of the Cytec-Brewster Phosphates, Inc.) that were donated to the State to be included in the Alafia River State Recreation Area. The BMR currently manages 1,400 of these acres until phosphate mining-related activities are completed and the area reverts to management by FDEP's Division of Recreation and Parks.

The BMR outlined its concept for the Integrated Habitat Network (IHN) plan in 1992 in its publication *A Regional Conceptual Reclamation Plan for the Southern Phosphate District of Florida* (Cates 1992). According to the plan, the largely undisturbed lands in the riverine floodplains that were transferred to the State pursuant to the Coastal Settlement were to become the "core" lands of the IHN and the adjacent reclaimed "buffer" lands, or Coordinated Development Area (CDA) were to complement and enhance the habitat value of the core lands. If managed properly, these areas would benefit the water quality and quantity in the area, improve wildlife habitat, and serve as connections between the phosphate mining region's rivers and significant environmental features outside the phosphate mining region. The BMR envisioned that the plan would become a guide for the reclamation of mined phosphate lands throughout the southern phosphate district.

> *The BMR outlined its concept for the Integrated Habitat Network (IHN) plan in 1992 in its publication* A Regional Conceptual Reclamation Plan for the Southern Phosphate District of Florida (Cates 1992).

By July 2001, a draft *Management Plan for the Integrated Habitat Network: Lease Nos. 3963 and 3995* was distributed to an Advisory Committee, a group encompassing a broad range of occupations, interests, and experience whose input was used to develop and improve the management plan. In August 2001, an advisory committee/public hearing was held and comments were used to finalize the management plan. By November 2001, the draft IHN management plan was submitted to the Division of State Lands and then presented to the meeting of the Acquisition and Restoration Council in February 2002, revised, and resubmitted in April 2002. Periodic updates of land management activities have been posted on FDEP's website and the first revision, entitled *Management Plan for the Integrated Habitat Network/Coordinated Development Area: Lease Nos. 3963, 3995, and 4236*, (Management Plan), was completed in March 2006.

The properties comprising the IHN, presented in Appendix I.6, are located in the southern phosphate district in west central Florida. These properties are either (1) lands acquired by the State and leased to appropriate managing agencies or (2) those owned and managed by public or private entities. State-owned lands have been acquired through settlement, donation, conservation easement or agreement, purchase, or regulatory action. Lack of detailed information on individual parcels required initial BMR management activities to include identification of property boundaries, creation or enhancement of access sites, security and protection of the lands, and the identification of existing resources.

The parcels leased to the BMR are an "aggregation of disjunct properties" that have diverse habitats and wildlife, different lease and agreement requirements, and require assorted monitoring and management needs. They include primarily undisturbed lands within the floodplains of the Peace and Alafia River systems and the adjacent buffer lands. According to the Management Plan for the IHN, there are several significant federal, state, or local land and water resources located within the IHN that provide wildlife habitat, improved water quality, and connections between various river systems.

These include:

- Tenoroc Fish Management Area.
- Alderman Ford Park.
- Alafia River State Recreation Area.
- Payne Creek State Historic Site .
- Polk County Saddle Creek and IMC-Peace River Parks.
- SWFWMD's Medard Park.

Other nearby existing or proposed public lands with significant land and water resources include: portions of the Green Swamp Area of Critical State Concern; Myakka River State Park; Lake Wales Ridge Ecosystem; Avon Park Bombing Range; Brighthour Watershed; Babcock-Webb Wildlife Management Area; Catfish Creek State Preserve; and Disney Wilderness Preserve. The Statewide Greenways System is also expected to connect the significant land and water resources on or near IHN lands. Further connections to IHN lands could be achieved through State acquisition of nearby private or commercial parcels, as well as the Polk County and Hillsborough County Land Acquisition Programs. The BMR is also working through the Nonmandatory Reclamation and Acquisition Programs toward the restoration of tributaries of the Peace River and their basins that are critical to improved flow to the River.

> *The BMR is also working through the Nonmandatory Reclamation and Acquisition Programs toward the restoration of tributaries of the Peace River and their basins that are critical to improved flow to the River.*

Part of BMR's goal for the IHN/CDA is to have a holistically planned and functioning landscape and various projects for restoration of disturbed ecological and hydrological functions in the heavily mined Saddle Creek and the upper Peace River watersheds.

Phosphate mining began in central Florida in the late 1800s and several of the parcels in the IHN have been impacted at one time or another by phosphate mining or mining-related activities. Mining debris is still present on some of these properties and presents safety concerns for the public and impediments to beneficial wildlife habitat.

As explained in the Management Plan and as introduced in the July 1992 *A Regional Conceptual Reclamation Plan for the Southern Phosphate District of Florida* (Cates 1992) and the 1993 draft *Guidelines for the Reclamation, Management, and Disposition of Lands within the Southern Phosphate District of Florida* (Cates and Zippay 1993), the overall goal for the phosphate district incorporates:

- Environmental, economic, and some political impacts.
- Drainage and hydrologic restoration, future land use, and critical habitat replacement for lands impacted by phosphate mining.
- Wildlife corridor connections to outlying preserved lands, protection of regional water resources, and protection of non-intensive land uses.

The BMR is committed to providing basic management and protection of corridors and buffers within the IHN and southern phosphate mining region as well as the development of a research/education center to address the use of reclaimed lands for semi-intensive and intensive agriculture, increasing public awareness and understanding of the benefits and goals of the IHN/CDA, and the inclusion of this concept by other agencies into land use review policies and procedures.

The BMR works with landowners to develop easement agreements and management plans as well as in the supervision of landowner activities committed to habitat management on IHN lands. The voluntary cooperation of the public and private owners whose lands are considered a significant part of the IHN is essential to attaining the goals of this plan. Currently disjointed tracts within the IHN could be connected and enhanced by the State's acquisition of nearby parcels owned by various private or corporate landowners. The BMR is also working with adjacent property owners to ensure that lands within the IHN are protected and preserved for maximum public benefit.

While the main focus of the Management Plan for the IHN is to maintain lands for wildlife habitat, water quality and quantity, and riparian connections, there is also interest in providing limited areas for public use. The FDEP is aware of the need to facilitate public access to State-owned lands in portions of the IHN, provided that this increased use does not compromise the original conservation intent of the IHN property. As the need for more human-intensive uses of these lands increases, the BMR will work with land management agencies to ensure compatibility of use and may relinquish management of portions of the IHN on a site-specific basis.

5.4 Regulated Activities

There are many ways to categorize regulated activities, but for the purposes of this study and its specific mandate, four categories best portray the effectiveness of regulation in addressing cumulative impacts. These categories are:

- Agricultural Drainage and Water Use.
- Phosphate Mining and Mandatory Reclamation.
- Urbanization and Industrialization.
- Public Water Supply.

The following sections provide more detailed background about the regulatory framework for each of these categories in the Peace River watershed.

5.4.1 Agricultural Drainage and Water Use

Seven independent special districts, formed pursuant to Chapter 298, FS, for water control purposes, are located within the Peace River watershed. These districts were created to drain agricultural land to increase usable acreage. The two oldest districts, Peace Creek and Haines City Drainage Districts, were formed in the 1920s with the balance (Bermont, Central Charlotte, and East Charlotte Drainage Districts and Joshua and West Lakeland Water Control Districts) formed in the 1960s and 1970s. These Chapter 298, FS, districts allowed contiguous landowners to develop a "plan of reclamation" to construct drainage improvements, have the plan certified by the Circuit Court, and levy assessments on the benefited property to pay for the improvements, operation, and maintenance. Voting rights in these districts were allocated by acreage. The Chapter 298, FS, districts that persist today usually serve flood control needs. Many are reorganized as special dependent districts or subsumed in local governments, and none is organized by land ownership. Legislative changes in 1997 moved oversight for all of the state's water control districts from FDEP to the water management districts. This legislation also required that each of the water control districts develop water control plans, for review by the water management districts, detailing their current and proposed activities.

Agriculture has enjoyed a unique status since enactment of the Florida Water Resources Act in 1972. The Act provides an exemption for various forms of agriculture from the requirement to obtain a permit to alter topography for purposes consistent with the practice of particular forms of agriculture, provided that the sole or predominant purpose is not to impound or obstruct surface waters. However, even though many forms of agriculture are totally dependent on irrigation water from ground water sources, agriculture enjoys no exemption from water use permitting.

Agriculture has enjoyed a unique status since enactment of the Florida Water Resources Act in 1972. The Act provides an exemption for various forms of agriculture from the requirement to obtain a permit to alter topography for purposes consistent with the practice of particular forms of agriculture, provided that the sole or predominant purpose is not to impound or obstruct surface waters.

Of all the categories of water demand within the Peace River watershed, agriculture is by far the greatest. In its 2000 Regional Water Supply Plan, SWFWMD forecasted 2005 irrigation demand projections by county. Taking Polk, Hardee, DeSoto, and Charlotte Counties as representative of the Peace River watershed, SWFWMD's total predicted demand for irrigation was 309 mgd, whereas the same Counties' projected demand for industrial/commercial, phosphate mining/dewatering,, and power generation in 2005 was only 134.2 mgd. The projected demand for public water supply and domestic self-supply was only 108.3 mgd.

5.4.1.1 Agriculture Regulatory History

Because of the strong and long-standing legislative exemption, agricultural activities -- other than water use -- have been generally exempt from regulation. Even though today's rules may still exempt "normal" farming, the definition of what is "normal" has been refined with the adoption and implementation of Best Management Practices (BMPs). Exempt farming practices, as defined today, are those that cause little, if any, hydrological degradation to wetlands.

This has not always been the case. Prior to 1972, there was no significant regulation of water quality in Florida, and not until 1984 were wetland regulations enacted to curb the conversion of wetlands to uplands. Prior to 1984, wetlands were regularly ditched and drained to improve grazing or farming opportunities in both wetlands and adjacent uplands. Networks of generally shallow ditches were excavated to interconnect wetlands and provide drainage into sloughs or creeks, which were often ditched as well to improve conveyance of flood waters. At a minimum, the ditching reduced the wetland hydroperiod, shortening the amount time that the wetland levels remain at the seasonal high stage. This drainage improved grazing opportunities in the wetlands and helped keep adjacent upland pastures dry for a longer part of the year. In some cases, however, canals were excavated that completely converted wetlands to uplands.

Because agriculture in Florida operates under a legislative exemption that has been interpreted by policies and programs, the history of agricultural regulation is more difficult to track than other regulated operations such as development or mining. There has been a gradual transition between historical practices that resulted in significant water resource impacts and today's practices that greatly restrict wetland draining and filling. The intent of the following sections is to track regulatory changes that have affected agriculture's ability to alter wetlands.

5.4.1.2 Federal Regulatory History

In 1970, the Federal Water Pollution Control Act (FWPCA), precursor to the Clean Water Act (CWA), was enacted to regulate discharges of pollutants to navigable waters. While technically Florida agriculture was subject to these regulations, it is doubtful that these regulations had any substantial effect on agricultural discharges or drainage. In 1972, the FWPCA was substantially amended to include the Section 404 program, implemented by the USACOE. By 1975, wetlands were included in CWA jurisdiction, which greatly expanded wetland regulation in the U.S. More intense agricultural operations such as row crops or citrus that sometimes involve wetland filling were somewhat affected by this change, but regulation was still limited to navigable waters and primary tributaries that were rarely used for agriculture.

The Food Security Act of 1985 initiated the "Swampbuster" program, which suspended federal subsidies for farmers who converted wetlands for agriculture. Few, if any, crops grown in the Peace River watershed enjoy direct federal subsidies, and it is unlikely that the program was effective at reducing wetland impacts in the Peace River watershed.

On March 12, 1986, the USACOE began regulating isolated wetlands. This change likely affected more intense agricultural operations that sometimes involved wetland filling, but Section 404 authority is primarily over the discharge of pollutants (filling) into aquatic resources (wetlands) and not the drainage of wetlands *per se.* By 1986, however, the effectiveness of State wetland regulations had surpassed that of federal regulations for wetland protection.

5.4.1.3 State Regulatory History

The 1972 Florida Water Resources Act was the landmark legislation that changed regulation of water resources in Florida by establishing the regulatory framework that continues today. However, the Act specifically exempted agriculture in Section 373.119(1), FS (1973), from regulation of the alteration of topography. The exemption language has been changed little since then, and only to broaden the exemption to apply to other forms of agriculture such as silviculture. The current exemption provided in Section 373.406, (2) and (3), FS, follows:

> (2) Nothing herein, or in any rule, regulation, or order adopted pursuant hereto, shall be construed to affect the right of any person engaged in the occupation of

> agriculture, silviculture, floriculture, or horticulture to alter the topography of any tract of land for purposes consistent with the practice of such occupation. However, such alteration may not be for the sole or predominant purpose of impounding or obstructing surface waters.
>
> (3) Nothing herein, or in any rule, regulation, or order adopted pursuant hereto, shall be construed to be applicable to construction, operation, or maintenance of any agricultural closed system. However, part II of this chapter shall be applicable as to the taking and discharging of water for filling, replenishing, and maintaining the water level in any such agricultural closed system. This subsection shall not be construed to eliminate the necessity to meet generally accepted engineering practices for construction, operation, and maintenance of dams, dikes, or levees.

Even with these legislative exemptions in place, over the years a number of policies, programs, and interpretations have taken effect that were intended to increasingly restrict the ability of agricultural operations to drain wetlands. These policies and interpretations have generally been concurrent with the adoption of regulations to control activities other than agriculture. In this way, regulation of agricultural practices has become increasingly compatible with current regulations of other activities, while not losing the legislative exemptions.

With the adoption of the Warren S. Henderson Wetlands Protection Act of 1984, state regulation over wetlands was expanded, triggering a revision of the Management and Storage of Surface Water (MSSW) rules by SWFWMD. MSSW rules were revised again in 1987 to include the regulation of isolated wetlands.

Although the agricultural exemption found in Chapter 373, FS, has changed little since inception, the interpretation of what is exempted in SWFWMD rules has been tightened over the years in response to changes in statewide wetland regulations and programs. By 1986, the current exemption criteria were adopted to prevent large-scale wetland ditching and filling from agricultural activities.

The statutory exemption is currently implemented in SWFWMD rules (Chapter 40D-4.051, Florida Administrative Code [FAC]) as follows:

(1) The activities specified in Section 373.406, FS;
(2) The construction, alteration, or operation of a surface water management system for agricultural or silviculture activities which satisfies the following requirements:
    (a) The total land area does not equal or exceed 10 acres;
    (b) The area of impervious surface will not equal or exceed 2 acres;
    (c) The activities will not be conducted in wetlands;
    (d) The activities will not be conducted in existing lakes, streams, or other watercourses;
    (e) The surface water management system will not utilize drainage pumps or operable discharge structures;

(f) The activities will not utilize storm drainage facilities larger than one 24-inch diameter pipe, or its hydraulic equivalent;
(g) Discharges from the site will meet applicable state water quality standards, as set forth in Chapter 62-302 and Rule 62-4.242, FAC;
(h) The activities are part of a conservation plan prepared or approved by a local Soil and Water Conservation District Board organized pursuant to Chapter 582, FS, (S.C.S.). If the S.C.S. conservation plan is not implemented according to its terms, the exemption created in this subsection does not apply;
(i) The activities can otherwise reasonably be expected not to have significant adverse water resource impacts; and
(j) The surface water management system can be effectively maintained.

(3) All normal and necessary farming and forestry operations as are customary for the area, which can be conducted without the construction or alteration or a surface water management system. In order to qualify for this exemption, such operations and facilities shall not impede or divert the flow of surface waters entering or leaving the operation or intrude into or otherwise substantially and adversely impact significant wetlands.

5.4.1.4 Current Regulatory Programs

In response to the MSSW rule revisions, SWFWMD started the Agricultural Ground and Surface Water Management (AGSWM) program in 1991 to provide an exemption letter for agricultural activities. In addition, the program responded to the recognized need to streamline the exemption process for standard farming operations, as well as to simplify the regulatory requirements of farming operations that required permits. The program relies on a cooperative effort by SWFWMD and the NRCS to assist the agriculture community.

The AGSWM program standardizes the informational requirements for exemptions and permit applications and provides technical standards as well as technical assistance in meeting the exemption criteria for temporary, ordinary, and permanent agricultural operations.

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Operations that do not meet the exemption criteria are required to be permitted pursuant to the same ERP rules that apply to other sectors of the regulated public. Producers who want an AGSWM exemption letter must utilize Resource Management System (RMS) planning, implement site-specific BMPs, and comply with the technical standards for the appropriate exemption category. SWFWMD processes approximately 100 AGSWM exemption letters each year. Because of the on-site review and Ag-Team, AGSWM benefits include:

- Improved understanding by the farmer of potential ERP and Water Use Permit (WUP) regulation needs.
- Improved decisions and turnaround times by SWFWMD at reduced cost to the farmer.
- Improved RMS planning assistance to farmers in understanding the BMPs and their uses.
- Reduced enforcement action and related production delays and expenses.
- Reduced construction costs by using more passive stormwater management in place of ponds.
- Lowered maintenance costs.
- Eliminated processing fees associated with permits.

Perhaps most importantly, the AGSWM program thoroughly defines the exemption criteria and sets standards. By example, the AGSWM program:

- Requires 50-foot buffers on wetlands.
- Limits drainage to one 18-inch diameter pipe.
- Limits furrow depth to 6 inches.
- Prohibits filling or flow restriction in the 100-year floodplain.
- Allows grazing in wetlands as USDA-NRCS stocking rates.
- Requires a conservation farming plan.
- Requires implementation of Improved Management Practices (IMPs) that address erosion control, wetland protection, drainage management, and nutrient/pesticide management for each agricultural activity.

5.4.2 Phosphate Mining and Mandatory Reclamation

5.4.2.1 Mandatory Phosphate Reclamation

While phosphate has been mined in central Florida since the late 1800s, mine operators were under no obligation to reclaim lands disturbed by the severance of phosphate until 1975. Then, Florida passed amendments to Chapter 211, FS, requiring reclamation on lands mined after July 1, 1975. Eleven years later in 1986, Part III of Chapter 378, FS, created a program to regulate the reclamation of phosphate lands mined after July 1, 1975.

The legislative intent of the Phosphate Land Reclamation Act (Chapter 86-294, LOF) was stated in part as follows:

- That "it is essential to require reclamation to mitigate the effects of resource extraction on the environment."
- That there be "the subsequent beneficial use of the disturbed and reclaimed land."
- That the Department of Natural Resources (DNR) "should enter into memoranda of understanding to eliminate duplication and to maximize the effectiveness of the regulatory process . . . ."

The Phosphate Land Reclamation Act further limits its application solely to reclamation, not to mining operations.

Chapter 86-294, LOF, provided both the first statutory criteria for restoration and limits to industry responsibility. Restoration, for instance, was required to "return the type, nature, and function of the ecosystem to the condition in existence prior to mining." The law also said, ". . . the department shall recognize technological limitations and economic considerations." The agency was charged to adopt statewide criteria and standards for reclamation in which "criteria and standards shall govern performance and not the methodology to be used . . . or the manner in which mining and associated activities are conducted."

While fairly rigorous financial responsibility instruments are listed in the Phosphate Land Reclamation Act, they need not be implemented as long as operators are in schedule compliance. Schedule compliance is tied to the definition of "acres mined", which means acres on which phosphate operations have resulted in the extraction of phosphate rock. Once the mine site is disturbed, however, there is no practical way for anyone to independently verify the extent of "acres mined." The Act recognized this and required that the rate of mining be "determined solely by the operator and not the state."

The Phosphate Land Reclamation Act also provided several means to obtain variances, which could be granted by the Governor and Cabinet. Grounds for variances included the following:

- No practical means known or available to comply with the provisions.
- Compliance would require measures that must be spread over a considerable period of time.
- Relief or prevention of hardship, including economic hardship.
- Accommodating specific phosphate mining, processing, or chemical plant uses that otherwise would be inconsistent with the requirements .
- Providing an experimental technique that would advance the knowledge of reclamation and restoration methods.

The Act has been amended through the years since its enactment and today provides grounds for a variance from Part IV of Chapter 373, FS – Environmental Resource Permitting.

The legislative intent was for division of responsibility between SWFWMD and DNR. SWFWMD and DNR executed a memorandum of understanding on November 17, 1986, that declared "the DNR regulated phosphate mining and reclamation under Chapters 211 and 378, FS" and that "the SWFWMD, pursuant to Chapter 373, FS, regulates the management and storage of surface waters, including phosphate lands regulated by DNR." The agreement provided a procedure by which DNR would consult with SWFWMD and review the hydrologic analysis of each mine area upon an operator's submittal of a conceptual reclamation plan, and then would review annual reclamation applications for consistency with the conceptual plan review and "address water quantity issues only."

DNR did not regulate phosphate mining, however, but only reclamation of mined lands, pursuant to Section 378.204, FS, which states, "This part shall not be construed as giving the department permitting authority over mining operations." SWFWMD, on the other hand, had legislative *authority* to regulate the management and storage of surface waters (MSSW) for phosphate lands. However, effective October 1, 1986, SWFWMD exempted phosphate mining from review under 40D-4.051, FAC, provided certain conditions were met, including compliance with DNR's land reclamation standards. The net effect of these actions, which seem to reflect legislative intent, was that no state agency regulated phosphate mining or mining operations, but both DNR and SWFWMD participated in review and approval of mine reclamation.

DNR did not regulate phosphate mining, however, but only reclamation of mined lands, pursuant to Section 378.204, FS, which states, "This part shall not be construed as giving the department permitting authority over mining operations."

Chapter 62C-16, FAC, which was established in 1987, governs the mandatory reclamation process. Not less than six months before the start of phosphate mining (or within seven days of submittal of an Application of Development Approval), the mine operator must submit a conceptual reclamation plan to the FDEP Bureau of Mine Reclamation. Upon approval of the conceptual plan, the operator is authorized to implement the reclamation as phosphate mining proceeds, filing annual mining and reclamation reports with the Bureau of Mine Reclamation. Various levels of deviation from the conceptual plan are allowed by the rule, from minor field changes that can be reported after the fact to conceptual plan modifications requiring prior approval. Variances are also allowed when the operator can demonstrate reasons why strict conformance to the rule meets variance criteria prescribed in Section 378.212, FS. Until 1993, all conceptual plan approvals, modifications, and variances had to be approved by the Governor and Cabinet. Since streamlining and the merger of DNR and DER into FDEP in 1993, the Secretary of the FDEP has made these decisions.

Following passage of the Phosphate Land Reclamation Act in 1986, DNR adopted rules to implement the new legislation. Much of this rule tracks the legislative language, which is quite specific, but the DNR rule also expanded on legislative language to require that wetlands disturbed by phosphate mining operations be restored at least acre-for-acre and type-for-type. After rule challenge, the wetland replacement requirement was upheld and the rule went into effect in 1987. Under the acre-for-acre and type-for-type requirement, DNR was able to require restoration of wetlands, even if restoration of isolated wetlands was often along the littoral zone fringe of created lakes. Forested wetlands could be replaced with 200 seedling trees per acre and protected from adverse impacts for five years or until the trees are 10 feet in height.

> *Under the acre-for-acre and type-for-type requirement, DNR was able to require restoration of wetlands, even if restoration of isolated wetlands was often along the littoral zone fringe of created lakes.*

The Mandatory Phosphate Reclamation Rule (Chapter 62C-16, FAC), which had not been updated since its inception in 1987, was revised in 2006. The changes reflect that the Secretary of the FDEP is the final decision-maker and clarify and strengthen a number of provisions. In particular, the changes:

- Track the statutory standard for reclamation as that “which will maintain or improve water quality and function of the biological systems present at the site”.
- Define wetlands consistent with subsection Section 373.019 (22), FS, and all other wetland permitting in the state.
- Define “disturbance” as modifying the land surface to conduct phosphate mining operations within a reclamation parcel and require notification of such at least 30 days prior.
- Clarify and strengthen the requirements for restoring wetlands and natural streams (even when previously altered).
- Specify appropriate uses of certain kinds of non-hazardous, non-water soluble solid waste.
- Remove the five-year delay that an operator could receive by designating a mine cut as a “future mineable face”.
- Raise the amount of financial security that may be required to $7,270 per acre, adjusted for inflation by 5 percent per year beginning January 1, 2007.
- Require mine operators to report differences in the rate of phosphate mining or the anticipated rate of mining from that proposed in the conceptual reclamation plan.

Even with the proposed changes, the Mandatory Phosphate Reclamation Rule falls short of requiring reclamation that would meet the mitigation requirements for Environmental Resource Permits. While wetlands are required to be replaced acre-for-acre and type-for-type, there is no analysis following the statewide Uniform Mitigation Assessment Methodology (UMAM) contained in Chapter 62-345, FAC, to determine whether wetland functions are fully replaced.

The UMAM takes into account the landscape setting, hydrology, the risk of unsuccessful replacement, and, except for phosphate reclamation, the time lag for successful replacement of wetland functions. The UMAM is, however, applied to new mines receiving an ERP approval.

5.4.2.2 Phosphate Mine Permitting

In the same year (1986) that SWFWMD and DNR were adopting the MOU dividing their phosphate land reclamation responsibilities, SWFWMD was adopting rules to regulate isolated wetlands under MSSW rules. In the spring of 1986, the Florida Legislature had adopted Section 373.414, FS, by enactment of Chapter 86-186, LOF. The new law mandated that by March 31, 1987 "those water management districts to which the department has delegated the responsibility for the administration of its stormwater rule . . . adopt a rule which establishes specific permitting criteria for certain small isolated wetlands which are not within the jurisdiction of the department for purposes of regulation of dredging and filling." During the time between legislative enactment of Section 373.414, FS, and its mandated implementation date of March 31, 1987, SWFWMD exempted phosphate mining from MSSW permitting. The effect of this exemption, of course, was to spare the phosphate mining industry from MSSW review, when such a review would soon include the legislatively mandated criteria for the protection of "certain small isolated wetlands."

The result of the exemption from MSSW permitting was that until Environmental Resource Permit rules became effective in 1995, no state agency made *a priori* decisions about phosphate mining in uplands and isolated wetlands that addressed potential wetland losses, fish and wildlife habitat, or natural hydrology. In cases where a proposed mine triggered a DRI review, the DCA, along with a regional planning council, would participate with local government to craft a development order for the mine. After 1993, regional planning councils lost the ability to directly appeal a development order issued by local governments.

The result of the exemption from MSSW permitting was that until Environmental Resource Permit rules became effective in 1995, no state agency made a priori decisions about phosphate mining in uplands and isolated wetlands that addressed potential wetland losses, fish and wildlife habitat, or natural hydrology.

Except for mining proposed in waters of the state or wetlands connected thereto, the decision to allow phosphate mining or to prescribe the conditions under which it would occur has only been vested with a state agency since 1995, when the Environmental Resource Permit rule went into effect. The industry received statutory "grandfathering" and additional protection for lands included in a conceptual reclamation plan submitted before July 1, 1996.

Today, FDEP reviews plans for phosphate mining under ERP rules. Most previous phosphate mine regulation by FDEP and its predecessor agencies was for mine reclamation pursuant to Chapter 378, FS, as described above. There are substantial differences between permitting reclamation and phosphate mining under ERP rules. The additional review includes, in part, that:

- Isolated wetlands are jurisdictional and their destruction requires mitigation.
- Wetland boundaries are delineated in accordance with methodology contained in Rule 62-340, FAC.
- Minimum flows and levels for surface and ground waters must be maintained.
- Cumulative impacts must be avoided.
- Secondary impacts to wetlands are considered and mitigated.
- Wetland dependent listed species have to be addressed.
- There is a public interest test.

Litigation over an Environmental Resource Permit for a site known as the Altman Tract resulted in a change in the way FDEP viewed its authority to review phosphate mining applications under ERP. The 2,367-acre Altman Tract is located in Four Corners/Lonesome Mine in Manatee County in the Peace River watershed at the headwaters to Horse Creek. On October 5, 2000, IMC Phosphates Company (now Mosaic Fertilizer, LLC) submitted an application to FDEP to mine the Altman Tract. The original Altman application and draft permit were challenged in a three-week administrative hearing. The permit was denied on September 15, 2003.

Litigation over an Environmental Resource Permit for a site known as the Altman Tract resulted in a change in the way FDEP viewed its authority to review phosphate mining applications under ERP.

The FDEP addressed deficiencies it found in the application. The deficiencies were in three general areas:

- Classification and characterization of the extent and quality of wetlands.
- Assurances that proposed reclamation activities maintain or improve the water quality and function of the biological systems present at the site prior to phosphate mining in accordance with Section 373.414(6)(b), FS, including adequate control of nuisance and exotic specie.s
- Financial assurance requirements under the environmental resource permitting rules set forth in Rule 40D-4.301, FAC.

IMC Phosphates resubmitted a revised application to FDEP to mine the Altman Tract in January 2004. In the revised application, a headwater marsh of Horse Creek, known as the Central Marsh, and a ditched natural stream that flows into the Central Marsh, were preserved from phosphate mining. IMC proposed to restore the ditched natural stream by filling ditched areas and restoring historic meanders, to preserve an upland area between two bay swamps that flow into the Central Marsh, and to preserve a corridor area (containing uplands and wetlands) between the Central Marsh and a property belonging to Manatee County (located southwest of the Altman Tract). In total, 560 acres would be placed under conservation easement, including all unmined areas (the Central Marsh, all portions of Horse Creek that are present on the property, some surrounding corridor areas and bay swamps, and the restored stream). Compared to the original application, an additional 378 acres would not be mined, and an additional 329 acres will be protected by a conservation easement.

As a consequence of the Final Order for the first Altman Tract ERP application, FDEP decided to reassess its Intent to Issue for another phosphate mine near the small community of Ona in Hardee County. From 1997 through 2003, IMC Phosphates had been engaged in an experimental permitting process called Team Permitting. The goal of Team Permitting was to build a consensus around the phosphate mining plan so that permitting would be more consensual among the interested parties, perhaps even avoiding litigation over the permit. After 92 meetings involving 38 different agencies and interest groups, IMC Phosphates filed applications in April 2000 for an ERP and Conceptual Reclamation Plan (CRP) Approval for the Ona Mine, covering 20,675 acres. On January 17, 2003, FDEP issued its Notice of Intent to Issue for the ERP and Approval of the CRP. Numerous interested parties petitioned against the phosphate mining permit and CRP approval. When the Final Order for the Altman Tract was issued in September 2003, FDEP initiated a reassessment of the Ona ERP/CRP application. As a result of the reassessment, IMC Phosphates submitted a revised application for a smaller mining area of 4,197 acres. The FDEP issued a revised Notice of Intent to Issue the ERP and Approve the CRP, and the petitioners continued their case to trial in 2004. After extensive review of the revised ERP and CRP, the ALJ submitted a Recommended Order to the FDEP on May 9, 2005 to issue a Final Order and approve the permit; this recommendation was again challenged. On August 5, 2005, FDEP sent the proceedings back to the ALJ for additional fact finding, and an evidentiary hearing was held in October 2005. Based on numerous factual findings, the ALJ rejected most of the objections raised by the various permit challengers and concluded that IMC Phosphates had provided reasonable assurances that its revised proposed phosphate mining/reclamation activities for the Ona Mine would comply with all applicable State permit criteria and standards. The Final Order directing the FDEP to issue the permits was signed on July 31, 2006.

The revised Ona application proposed avoiding 66 percent of wetland acres, including the 100-year floodplain of Horse Creek, 91 percent of bayhead wetlands, and 13 tributaries to Horse Creek. The application also included a comprehensive stream restoration plan, up-front financial assurance for all wetland mitigation, and innovative reclamation techniques. Some of the techniques include the alignment of mining cuts along the pattern of ground water flow, rapid reclamation of scrub areas, deep discing of overburden to soil surface, control of nuisance and exotic vegetation, and extensive use of sand tailings and native top soil at the surface.

5.4.3 Urbanization and Industrialization

Urbanization and industrialization refer to land use changes that support population densities and land use intensities that exceed those typical or necessary for agricultural production. The Peace

River watershed has experienced development during the period of this study, and as the effects of various activities have become understood, the number of regulations has grown in response.

5.4.3.1 Drainage

A hallmark of urban development is intolerance of flooding. Local, state, and federal agencies have historically enacted land use, building, and stormwater runoff regulations to prevent flooding. Local government has zoning authority, applies floodplain building ordinances in conjunction with the Federal Flood Insurance Program, and specifies stormwater regulations. State government, through FDEP, regulates water quality and quantity through delegation to SWFWMD.

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Chapters 40D-4, 40D-6, 40D-40, and 40D-400, FAC, provide the basis of water quantity control within SWFWMD. Much of the Peace River watershed falls under the general requirements that specify that for a 25-year, 24-hour duration design storm, the post-development condition peak runoff rate must not exceed the pre-development peak rate. There are also areas within the upper watershed where lakes with restricted outlets could experience increased flooding as a result of increased runoff volumes. Within these volume sensitive basins, the post-development runoff volume must not exceed the pre-development runoff volume for a 100-year, 24-hour duration design storm.

SWFWMD also regulates floodplain encroachment by requiring compensating storage for fill placed within the 100-year floodplain. Conveyance restrictions resulting from new facilities crossing the floodplain, such as roads, bridges, and pipelines, are also required to have no adverse impacts to floodplain levels.

Each of the counties and municipalities within the watershed regulates land use and development within their boundaries in accordance with a state-approved local comprehensive plan. Each local plan consists of eight basic elements including capital improvement, future land use, traffic circulation, public facilities and services, conservation, recreation and open space, housing, and intergovernmental coordination. The Growth Management Act (Chapter 163, FS) requires that all public facilities and services, including *drainage facilities*, needed to support development must be available, concurrent with impacts of development.

To participate in the National Flood Insurance Program, the Federal Emergency Management Agency (FEMA) specifies that participating local governments adopt floodplain management ordinances meeting FEMA's specifications. The local government then acts as FEMA's agent for floodplain information as it pertains to the flood insurance program. Where flood insurance study information is lacking, FEMA specifies that local participants regulate floor slab levels based on the best available information. All counties and municipalities within the Peace River watershed participate in these federal programs.

Local governments have also specified level-of-service standards for stormwater management systems within their jurisdiction. For example, Polk County specifies that existing stormwater systems be able to control runoff from the 10-year, 24-hour storm event, while the standard for new and reconstructed systems is the 25-year, 24-hour design storm. Charlotte County regulations, on the other hand, specify a 25-year, 24-hour design storm for arterial and collector roadways and a 5-year, 24-hour design storm event for residential streets. As illustrated by these requirements, design standards may vary with their particular application and are concerned with preserving the capacity of existing infrastructure, as well as designing systems to meet the needs of future development.

All of the above regulations address the objective of keeping water out of homes and off roadways during even relatively rare storm events. Achieving these objectives requires storage capacity and, historically, this storage capacity has been created by lowering water tables. During the past 20 years, rules have shifted towards reliance on storage in created lakes, but throughout much of the urbanized areas of the Peace River watershed, drainage ditches and canals had already been constructed to permanently lower water tables by providing direct discharge for vast areas of flat landscape.

Nothing could be worse for the shallow wetlands typical of the Peace River watershed than drainage of the surficial aquifer that keeps them hydrated through most of the year. Where urban development occurred, there was the need and the means to create drainage works. There was also the population (votes) to demand them.

Nothing could be worse for the shallow wetlands typical of the Peace River watershed than drainage of the surficial aquifer that keeps them hydrated through most of the year. Where urban development occurred, there was the need and the means to create drainage works. There was also the population (votes) to demand them.

5.4.3.2 Transportation

Several main interstates, U.S. highways, state roads, and railroads transect the Peace River watershed. U.S. Highway 17 is a north-south oriented road that connects Polk, DeSoto, Hardee, and Charlotte Counties. U.S. Highway 27 is a north-south oriented road that bisects Polk and Highlands Counties. From north to south, U.S. Highway 98 enters the northern portion of the watershed near Lakeland. It traverses south to Ft. Meade in southern Polk County, then east and south where it exits the watershed and merges with U.S. Highway 27 near Frostproof and turns south again. State Road (SR) 60 crosses the middle of Polk County in an east-west direction. Interstate 4 (I-4) and U.S. Highway 92 are present in northern Polk County. Interstate 75 and U.S. Highway 41 traverse Charlotte County in a north-south direction.

The watershed appears to be in the path of major, new transportation facilities. In March 2006, the Turnpike Enterprise, a division of the Florida Department of Transportation (FDOT), announced two proposed corridors for a north-south toll road called the Heartland Parkway, and an east-west route called the Heartland Coast-to-Coast. These roads would connect Lee County to the I-4 Corridor and Manatee County to the east coast, crossing in the northeastern reaches of the Peace River watershed.

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The Van Fleet International Airport Development Group presented plans to the Central Florida Regional Planning Council in 2005 to build the Florida International Airport. The $850 million airport would straddle Hardee and Polk Counties on former phosphate mining land, have a 15,000-foot runway, and be built primarily with federal aviation grant funding. Warehouse, office, industrial, and residential development are among plans on the 22,000 acres.

Legislation enacted in 1996 (Section 373.4137, FS) facilitates environmental permitting approval for transportation projects by allowing the FDOT to fund compensatory mitigation through the water management districts. For a set fee of $75,000 per acre of impact, adjusted annually for inflation since 1996, a water management district can accept all obligations for compensatory mitigation for specific impacts, even those permitted by the water management district receiving the funds. Alternatively, either the water management district or FDOT can contract directly with an approved wetland mitigation bank to purchase wetland mitigation credits. Transportation projects still have to reduce or eliminate impacts to wetlands and other surface waters, including the adjustments to alignments, but the readily available process for compensating for wetland impacts, and thus avoiding cumulative impacts within the watershed, removes an impediment to the construction of needed facilities. With an active Section 373.4137, FS, program in SWFWMD and three permitted wetland mitigation banks in the Peace River watershed, there are ample options to build transportation facilities without incurring cumulative impacts.

5.4.3.3 Power Generation

The single largest power generation facility in the Peace River watershed is Progress Energy's Hines Energy Complex. Located on 8,200 acres of previously mined phosphate lands in Polk County, the facility has completed two of its four units, with a third under construction. The facility is located in a remote area and over 3,000 acres are designated for wildlife habitat or watershed enhancement, yet there are still issues with its projected water demand.

At build out, the Hines Energy Complex will consume 32 mgd of water for cooling. The first two power blocks use 7.9 mgd, which includes no ground water. Alternative sources, such as reuse water from the City of Bartow, capture of stormwater, direct precipitation into cooling ponds, and other water cropping techniques, have helped the facility avoid using ground water. The facility is within SWUCA and subject to the rules adopted by SWFWMD in June 2006 to implement the Recovery Strategy. Progress Energy and SWFWMD are working to develop new alternative sources, such as the use of aquifer storage and recovery.

Land use and environmental approvals are provided as certifications signed by the Governor under Chapter 403, FS, Part II for Electrical Power Plant and Transmission Line Siting and Part VIII for Natural Gas Pipeline Siting. These certifications constitute the sole license of the state and any agency as to the approval of the site and the construction and operation of these types of facilities, and are in lieu of any license, permit, certificate, or similar document required by any agency pursuant to, but not limited to, Chapters 125, 161,163, 166, 186, 253, 298, 370, 373, 376, 380, 381, 387, and 403, FS. As a practical matter, these certifications include conditions that address the requirements of the above statutes, but allow only a single point of entry for challenges under Chapter 120, FS.

5.4.4 Public Water Supply

There are two large public water supply withdrawals in the lower Peace River watershed. Both divert and treat surface water using a color removal and alum coagulation process. The smaller of the two is on Shell Creek, the southernmost tributary to the Peace River. An earthen dam across Shell Creek creates a shallow reservoir and prevents saltwater from migrating upstream into the reservoir during normal high tides. The City of Punta Gorda withdraws and treats water from the reservoir, which lies at the lower extent of the Shell Creek basin. The larger withdrawal is from the Peace River below the confluence with Horse Creek. The history and issues affecting each of these public water supplies are discussed below.

5.4.4.1 Peace River Regional Water Treatment Facility

In the early 1970s, General Development Utilities (GDU) actively began to search for a major regional water supply that would support the projected population growth for a number of large communities in southwest Florida under construction or planned by its parent company, General Development Corporation (GDC). These developments included the City of North Port in Sarasota County, Port Charlotte in Charlotte County, South Gulf Cove in Charlotte County, and two large Developments of Regional Impact -- Myakka Estates in Sarasota County and Villages of DeSoto in DeSoto County. The latter two properties have since been purchased by public agencies and are known today as the Myakka Forest and R.V. Griffin Reserve, respectively. Projected population estimates in the early 1970s indicated that the number of new residents in these planned communities could well exceed a quarter of a million people by the year 2020. GDU sought to establish a reliable and expandable source of potable water to supply this projected population growth. After reviewing a number of potential alternatives, the site of the current facility in DeSoto County was selected because it provided the greatest opportunity for a sustainable water supply for the planned future population growth within the three-county area.

Professional staff of Rosenstiel School of Marine and Atmospheric Science (University of Miami) led by Dr. John Michel had been retained to evaluate the feasibility of locating a regional water supply system on the Peace River in DeSoto County near State Road 761, specifically to assess the potential environmental impacts of projected freshwater withdrawals (Michel *et al*. 1975). The specific objectives and goals of their study were to:

- Collect initial baseline biological and physical water quality data.
- Develop statistical relationships between freshwater flows, tides, and salinity for the areas of the Peace River downstream of the proposed withdrawal location.
- Onvestigate potential interactions between salinity and biological communities in the lower Peace River.
- Develop predictive models to assess potential effects of proposed freshwater withdrawals on the distribution of the downstream salinity gradient in the lower river.
- Provide initial data to form the basis for future long-term monitoring studies.

Information on biological communities and salinity/flow relationships were collected between 1973 and 1974. During this period, Peace River flows (measured at the Arcadia gage) ranged from a low of 62 cfs to more than 10,000 cfs. Fortuitously, the relationships between salinity and flow developed during this relatively short period of study, and subsequently used in calibrating these initial numerical models, were characteristic of the normal variation in flows that have subsequently occurred during both extended wet and dry periods.

Using a series of numerical models to predict changes in salinity at a series of points extending from near the mouth of the river upstream to the proposed point of withdrawal, the researchers predicted changes in salinities under worst-case conditions assuming freshwater withdrawals during naturally occurring periods of low river flow. Their report (Michel *et al*. 1975) documented the highly dynamic natural seasonal changes in salinity within portions of the lower Peace River due to natural patterns in flows during wet and dry periods. They concluded that “under these conditions of flow and withdrawal, biological data indicated that such slight salinity increases, above the naturally occurring values of low flow periods, should add little additional stress on the plants and animals of the study area.” Nevertheless, the final report also strongly recommended that GDU implement an extensive monitoring program to assess the validity of the predicted results.

5.4.4.1.1 Peace River Facility Permitting

In December 1975, GDU obtained permits for the construction and operation of the Peace River Facility, along with a consumptive use of 5.0 mgd average daily withdrawal, with a single day withdrawal not to exceed 18.0 mgd during July through October and 12.0 mgd during the remaining 8 months. In addition to these restrictions, there was a limit on withdrawals of 5 percent of the total daily flow from Rule 16J-2.11(4)(a), FAC. In addition to the 5 percent limit, SWFWMD had adopted by rule other withdrawal restrictions that prevented GDU from withdrawing any water when river flow at Arcadia fell below pre-determined levels.

At the time the permit was issued, Rule 16J-0.15, FAC, specified that minimum flows for withdrawals would be 70 per cent of the 5 lowest monthly mean flows for the preceding 20 years for the 4 wettest months (July through October) and 90 percent for the remaining 8 months. In this initial permit, these pre-set minimum flows, below which no withdrawals were allowed, changed each month. In September, for instance, withdrawals could only occur when river flows exceeded 624 cfs, while in May the limiting flow was 91 cfs. These limits, established by rule in 1974 for all streams in the SWFWMD, played havoc on GDU's withdrawal schedule. Instead of replenishing the reservoir in the wet season when flows were higher, the withdrawal limits often prevented wet season withdrawals simply because the flows were not high enough to be above the higher wet season limits (624 cfs in September). With an 18 mgd diversion limit, GDU had difficulty filling and keeping its reservoir full for the inevitable dry seasons. Then again, during the dry seasons when they could withdraw during low flows, the 5 percent limit would prevent them from taking the water needed.

These limits, established by rule in 1974 for all streams in the SWFWMD, played havoc on GDU's withdrawal schedule. Instead of replenishing the reservoir in the wet season when flows were higher, the withdrawal limits often prevented wet season withdrawals simply because the flows were not high enough to be above the higher wet season limits.

Construction of the water plant commenced in 1976 and it started supplying water to Port Charlotte and North Port in 1980. These problems with the withdrawal schedule, for what most would agree was a very small amount of water, were immediately apparent in the first year of operation after the plant opened in 1980.

By June 1981, GDU filed a timely and sufficient application for renewal of its consumptive use permit requesting an increase in its withdrawal to 6.12 mgd average with a 22 mgd maximum per day and a change in the withdrawal limitations. GDU proposed that withdrawals not be restricted to 5 percent, but be allowed their full pumping capacity of 22.0 mgd throughout the year when flows were above the cutoff point. The April and May minimum flows for withdrawal, however, were increased from 94 cfs and 91 cfs, respectively, to 100 cfs. The SWFWMD Governing Board granted GDU an exception to Rule 40D-2.301(3)(a), FAC, for the purpose of "increasing the likelihood that sufficient water will be available in reservoir storage during low flow periods." No percentage limit was imposed, leaving the possibility of withdrawing 22 mgd when river flows (at Arcadia) were only 100 cfs, which is approximately 65 mgd. Thus, for the period of this permit, GDU was approved to withdraw up to one-third of the river flow during periods of critically low flow to the estuary.

SWFWMD's initial and subsequent Consumptive Use Permits for the Peace River Facility have all required extensive data collection for flows, rainfall, water quality, and biological indicators. Collectively, these requirements and data comprise the Hydrobiological Monitoring Program (HBMP).

The need for adequate storage of potable water had been identified early in the initial evaluation and planning for the Peace River Facility. As part of the initial construction, an 84-acre, off-stream surface water reservoir was constructed. Soon thereafter construction began on a series of aquifer storage and recovery (ASR) wells to test the concept of storing treated water in a confined aquifer. Unlike many other water treatment facilities that utilize surface waters, there is no in-stream barrier in the Peace River to impound water during the typically dry winter and spring months. In addition, as an initial permit condition, SWFWMD mandated that no withdrawals could be made below certain low river flow levels. As a result, the Peace River Facility has always relied on off-stream storage to maintain drinking water supplies during the dry season and/or drought conditions.

The need for adequate storage of potable water had been identified early in the initial evaluation and planning for the Peace River Facility. As part of the initial construction, an 84-acre, off-stream surface water reservoir was constructed.

Prior to 1988, the regulatory limit for maximum daily withdrawals from the Peace River was 22 mgd (34 cfs). When the permit renewal application was submitted in 1988, GDU's consulting scientists and SWFWMD agreed that the existing withdrawal schedule caused the Peace River Facility to rely too heavily on periods of low to moderate flows. They agreed that site-specific information from the 12 years of HBMP data should be used to establish regulatory minimum flows and daily withdrawal limits from the Peace River. Using the long-term data collected under the HBMP, they developed a statistical model to analyze the location of the freshwater/saltwater boundary as a function of flow and predict salinity changes that might result from permitted withdrawals.

Based on these analyses, SWFWMD and GDU agreed that the withdrawal schedule should be modified. A minimum criterion was established with no withdrawals when flows at Arcadia were below 100 cfs during the spring months (March, April, and May) and 130 cfs during the remainder of the year. Beyond that, withdrawals could equal up to 10 percent of the daily measured flow at USGS gage at Arcadia, up to a maximum not to exceed 22 mgd (34 cfs). This schedule allowed withdrawals to more closely follow the natural variability of rainfall and flow, and established a low flow cutoff that increased low volume freshwater inflows to the estuary.

When the parent corporation to GDU filed for bankruptcy protection in 1990, Charlotte County used eminent domain to gain ownership of GDU facilities within Charlotte County and the Peace River Facility. In a settlement with neighboring counties over control of the Peace River Facility, Charlotte County transferred ownership and control under specific contractual conditions to the PRMRWSA, which had been constituted under Section 373.1962, FS, in 1982 by agreements among Charlotte, DeSoto, Hardee, Manatee, and Sarasota Counties. (Hardee County later withdrew.) As owners of the Peace River Facility, the PRMRWSA soon began making plans for expansion of the treatment facilities to provide more water to the region as originally envisioned by GDU. A further goal of the PRMRWSA has been to develop a series of interconnections among the member counties' water supplies to reduce risks of natural disasters and other interruptions in supply and allow improved regional management of water sources.

As owners of the Peace River Facility, the PRMRWSA soon began making plans for expansion of the treatment facilities to provide more water to the region as originally envisioned by GDU.

In January 1994, the PRMRWSA designed a plan called the Peace River Option (PRO). The plan identified how the PRMRWSA would develop the Peace River as an alternative source of water supply and requested that other public water supply utilities enter into agreements and commitments to a water allocation from the Peace River. The PRO allowed utilities and their customers:

- The ability to meet a portion of future water demands with water withdrawn from the Peace River.
- To accommodate for pending SWFWMD ground water restrictions.
- To maximize use of existing facilities at the Peace River Facility.
- To provide a framework for integrated, regional management of public water supply sources in the region.
- To phase construction so that water demand will be met as it develops.

One of the projects outlined in the PRO was to add ASR wells to increase the PRMRWSA's ability to store river water for use when it could not divert water from the Peace River. In addition to increasing the amount of water diverted from the river and increasing storage, the PRMRWSA also proposed maximizing use of the existing plant by incrementally increasing the treatment capacity.

To meet the goals of the PRO, the PRMRWSA identified a phased approach to the expansion, which included:

- Expanding the Peace River Facility's 12 mgd treatment capacity in 6 mgd increments.
- Expanding the ASR well field.

- Constructing a Regional Transmission Main (RTM) connecting the Peace River Facility to the Sarasota County Water Plant.

Since the 1994 report, the following progress has been made in meeting the goals of the PRO:

- The PRMRWSA has completed the initial treatment plant expansion, and a second expansion is currently pending.
- The ASR well field was expanded, but not to its full capacity due to regulatory constraints.
- A 42-inch RTM has been constructed and is fully operational.

Because of recent regulatory concerns surrounding arsenic levels in ASR wells, FDEP is not issuing permits for use of new ASR wells. Therefore, the PRMRWSA has commissioned consultants to design a 6 billion gallon offline reservoir to provide storage of river water. A permit for the reservoir is currently pending approval from FDEP.

The current Water Use Permit was issued by SWFWMD to the PRMRWSA in March 1996 as a renewal with modification to increase quantities to 32.7 mgd. This modification was for the inclusion of existing and proposed wholesale water purchasers (Charlotte County, DeSoto County, City of North Port, and Sarasota County) as co-permittees and an increase in public supply demand and associated quantities as a result of projected population growth in the existing and expanded service areas. In addition to the standard permit conditions, special conditions require the items listed below.

- Daily recording and monthly reporting of pumpage from the Water Supply Facility surface water intake structure on the Peace River, the Facility's surface reservoir water-intake structure, the Facility's untreated water meter, and the Facility's discharge meter.
- Daily recording and monthly reporting of Peace River flow as read at the Arcadia Station.
- Monthly recording and reporting of pumpage from all ASR wells.
- Restriction of water pumped via ASR to not exceed the amount of water stored.
- A minimum flow level of 130 cfs before a diversion of up to 10 percent of flow may occur.
- Allowing maximization of ASR for storage.
- The collection of background water quality data for new ASR wells.
- Continuation of recording and reporting of water levels for existing monitor wells.
- Water quality sampling and reporting on a monthly basis for ground water monitor wells and all ASR wells during recharge and recovery operations.
- Capping of unused wells.

- Specific well construction design and submittal of well completion reports and geophysical logs for the proposed ASR wells.
- Implementation of a Proposed 1995-2015 "Hydrobiological Monitoring Program".
- Specifying permit review time frames in regard to permitted quantities, projected demands, special conditions, diversion schedule, and ASR operations.
- The submittal of an "ASR Ground water Monitoring Program".
- The submittal of an "ASR Ground water Mitigation Plan".
- The submittal of an "ASR Ecological and Wetland Monitoring Program".
- The obtaining of all surface water permits prior to new construction.
- A report on the future use of a capped ASR well.
- Submittal of a report outlining a plan for alternate and supplemental sources of water for public supply.
- Submittal of a Water Conservation Plan.

The total withdrawal quantities authorized for public use under this permit are the following:

Average	32.7 mgd
Peak Monthly	38.1 mgd
Maximum	90.0 mgd

In summary, the PRMRWSA is allowed to divert surface water from the Peace River with the following limitations:

- No diversion from the Peace River may occur when the average daily flow as measured at Arcadia for the previous day is less than 130 cfs.
- The amount of diversion from the Peace River shall not exceed 10 percent of the average daily flow rate at Arcadia from the previous day.
- In no case shall the diversion amount exceed the difference between the previous day measurement at Arcadia and 130 cfs.

The Peace River Facility's permitted withdrawal limit casts a long "regulatory shadow" up the watershed. One of the criteria that an applicant for a water use permit must satisfy is that the proposed use of water "will not interfere with any presently existing legal use of water" (Section 373.223(1)(b), FS). The Peace River Facility is a presently existing legal use of water and under its permit conditions can withdraw up to 90 mgd, *provided that it not be more than 10 percent of river flow as measured at the Arcadia gage*. This condition has the regulatory effect of limiting other proposed withdrawals only to river flows that would exceed 900 mgd, or about 1,400 cfs, because any withdrawals from flows below this level would interfere with the Peace River Facility's permitted withdrawal regime. Average daily river flow at Arcadia is just under 1,000 cfs, and flow records suggest that any other proposed use would have to plan on withdrawing well under one-quarter of the days in an average year. Thus, under current statutory permitting criteria and permit conditions (the 10 percent withdrawal limit) deemed necessary to protect the estuary from over-withdrawal, the Peace River Facility is in the enviable position of virtually "owning" the right to withdraw exclusively from the Peace River for the duration of its permit. Even under a competing applications scenario at renewal of its permit, it would seem unlikely that any other proposed use would be deemed by the SWFWMD Governing Board to better serve the public interest than a public water supplier serving several hundred thousand customers across four counties.

> *…the Peace River Facility is in the enviable position of virtually "owning" the right to withdraw exclusively from the Peace River for the duration of its permit.*

5.4.4.1.2 Hydrobiological Monitoring Program (HBMP)

SWFWMD required the HBMP to ensure collection of long-term data needed to assess the potential for harm from withdrawals to various physical, chemical, and biological characteristics of the Charlotte Harbor Estuary. The HBMP was to evaluate the consequences and significance of natural changes in salinity, water quality, and biological characteristics that are inherently associated with seasonal variations in flow. In particular, a number of HBMP study elements have sought to establish the effects of natural, long-term variations in river flow on the overall health of aquatic fauna and flora communities in the lower Peace River and upper Charlotte Harbor. Once having established the influences of natural variations, a corollary goal of the long-term monitoring program has been to determine if freshwater withdrawals by the Peace River Facility have measurable impacts or result in quantifiable alterations of the biological communities of the lower Peace River/upper Charlotte Harbor Estuary. GDU initiated a background monitoring effort in 1975, the HBMP began in 1976 and construction of the Peace River Facility was completed and withdrawals began in the spring of 1980.

The current Water Use Permit issued by SWFWMD to PRMRWSA in March 1996, contains specific conditions for the continuation and enhancement of the HMBP. The HBMP study elements specified in the 1996 permit were designed to build upon and add to the HBMP monitoring activities that have been ongoing since 1975.

As defined by the SWFWMD permit, the primary focus and overall objective of the HBMP is to assess the following key issues.

- Monitor withdrawals from the Peace River at the Facility and evaluate data as provided by SWFWMD for the gaged tributary flows from Joshua, Horse, and Shell Creeks, as well as the primary Peace River flows measured at Arcadia and direct rainfall to the lower Peace River.
- Evaluate relationships between the ecology of the lower Peace River/upper Charlotte Harbor Estuary and freshwater inflows.

- Monitor selected water quality and biological variables in order to determine whether the ecological characteristics of the estuary related to freshwater inflows are changing over time.
- Determine the relative degree and magnitude of effects of Peace River withdrawals by the Facility on ecological changes that may be observed in the lower Peace River/upper Charlotte Harbor estuarine system.
- Evaluate whether consumptive freshwater withdrawals significantly contribute to any adverse ecological impacts to the estuary resulting from extended periods of low fresh inflows.
- Evaluate whether the withdrawals have had any significant effects on the ecology of the estuary, based on related information such as nutrient loadings, fish abundance, or seagrass distributions data collected by other studies conducted by SWFWMD or other parties.

Overall, the primary goal of the prescribed HBMP study elements is to provide SWFWMD with sufficient information to determine whether biological communities of the lower Peace River/upper Charlotte Harbor estuarine system have been, are being, or may be adversely impacted by permitted freshwater withdrawals by the PRMRWSA's water treatment facility. The expanding base of ecological information regarding the lower Peace River and upper Charlotte Harbor resulting from the ongoing HBMP will be further used to periodically evaluate the effectiveness of the withdrawal schedule with regard to preventing significant adverse estuarine impacts.

The permit specifies reporting requirements with respect to data collected and interpreted under the HBMP. Limited Midterm Interpretive Reports are to be submitted to SWFWMD after the third year of each five-year interval of the existing 20-year permit, while more extensive Comprehensive Summary Reports are expected to provide inclusive analytical data analyses and summaries of HBMP study element data to date following each five-year interval.

SWFWMD periodically convenes a scientific peer review panel to review the progress and findings of the HBMP. The panel provides non-binding technical input to SWFWMD regarding the monitoring program. The panel consists of five members selected from the scientific community who have recognized expertise in the areas of estuarine ecology and freshwater inflow assessments.

SWFWMD may revise the monitoring program at any time during the permit duration provided there is reasonable technical justification that a revision is warranted. Such revisions may result from scientific review of the monitoring program or to allow for better coordination with ecological studies conducted by federal, state, and local governments, or private institutions.

At the time of the first permit renewal in 1982, withdrawals had only recently begun and there were only a small number of changes made to the HBMP. With the second permit renewal in 1988, however, extensive amounts of data had been collected as part of the ongoing HBMP and these data were used to make significant modifications to both the monitoring efforts and withdrawal schedule.

5.4.4.2 Shell and Prairie Creek Watersheds Management Plan

The Shell Creek Reservoir is the sole source of drinking water for the City of Punta Gorda and portions of south Charlotte County. In 1964, the Hendrickson Dam was constructed across Shell Creek to create a storage reservoir to meet the City of Punta Gorda's water supply needs. By storing water in a reservoir during the wet season for use during the dry season, saltwater contamination of the water supply is also minimized.

The Shell Creek Reservoir is the sole source of drinking water for the City of Punta Gorda and portions of south Charlotte County. In 1964, the Hendrickson Dam was constructed across Shell Creek to create a storage reservoir to meet the City of Punta Gorda's water supply needs.

Since 1976, the City of Punta Gorda's water treatment facility has withdrawn water for public supply from the Shell Creek reservoir under six water use permit renewals from SWFWMD. The Punta Gorda Water Treatment Plant sits adjacent to the reservoir and currently produces 8.0 mgd. Under a proposed permit modification, the maximum peak monthly Facility withdrawal would be increased to 10.0 mgd.

Like the Peace River Facility, the Punta Gorda Water Treatment Plant is required to implement a hydrobiological monitoring program. The Shell Creek HBMP, implemented in 1991, incorporates a series of 19 sampling sites that provide a comprehensive network of information regarding seasonal and long-term variability in water quality in Shell Creek and the Peace River for the locations described below.

- Upstream of the Hendrickson Dam.
- Within the tidal portion of Shell Creek.
- Within the Peace River both upstream and downstream of its confluence with Shell Creek.

The HBMP includes monthly measurements of physical, chemical, and biological water quality characteristics under the following scenario:

- *In situ* physical water column profile characteristics are measured at each of the 19 sampling sites at 0.5-meter intervals from just below the surface (0.15 meter) to just above the bottom.
- Subsurface water quality samples are collected and analyzed for a suite of parameters at 9 sampling locations (stations 1 through 9).

- The penetration of light into the water column is inferred by measurements of Secchi Disk depths at 2 sampling locations (stations 1 and 2).
- More accurate determinations of the penetration of light into the water column are determined at 6 sampling locations (stations 3 through 9) from calculated extinction coefficients based on *in situ* profiles of photosynthetically active radiation (PAR).

The Shell Creek HBMP permit condition specifies that the monthly measurement of ambient physical, chemical, and biological water quality characteristics be made within two calendar days of the "fixed" station sampling element of the Peace River HBMP. This coordination provides SWFWMD monthly comparable measurements of water quality characteristics throughout the lower Peace River and Shell Creek areas of the Charlotte Harbor Estuary.

Additional historic water quality data are also available from both the USGS and the City of Punta Gorda. These data, combined with additional information from the three HBMP sites located upstream of the Hendrickson Dam, and more recent SWFWMD ambient monitoring information, were used to assess long-term changes in water quality in the freshwater reaches of the Shell/Prairie Creek system.

The results of statistical analyses indicate that there have been long-term increases in base flow in Shell Creek. These findings are not unexpected, given previous and ongoing studies that have concluded that Prairie Creek and Shell Creek flows are and continue to be augmented during the typical dry winter/spring periods by discharges associated with agricultural use.

> *…Prairie Creek and Shell Creek flows are and continue to be augmented during the typical dry winter/spring periods by discharges associated with agricultural use.*

Prairie Creek is a major tributary to Shell Creek and is an important part of the water supply. In the mid-1970s, both Prairie and Shell Creeks with their associated tributaries were classified as Class I water bodies designated for use as potable water supplies. The classification of water bodies allows regulatory authorities to establish water quality standards protective of the designated use. Class I water quality standards have been in place since the late 1970s.

In recent years, development of irrigation wells in both the Prairie Creek and Shell Creek basins has added mineralized water to the creeks by pumping ground water to the surface, which eventually reaches the creeks. The degradation of water quality and the violation of Class I standards for chloride, conductance, and total dissolved solids were amplified during the drought of 2000-2001.

During the 1980s and 1990s, the demand for agricultural well water increased dramatically in the Shell and Prairie Creek basins. SWFWMD has issued 168 permits for about 57 mgd of pumping from the lower intermediate and Floridan aquifers for irrigation of citrus, pasture, and row crops.

This quantity represents approximately 89 percent of the water use permitted in these basins, with the remaining use being primarily surface water supply for the City of Punta Gorda.

During the 1980s and 1990s, the demand for agricultural well water increased dramatically in the Shell and Prairie Creek basins. SWFWMD has issued 168 permits for about 57 mgd of pumping from the lower intermediate and Floridan aquifers for irrigation of citrus, pasture, and row crops.

The Floridan aquifer becomes deeper and more mineralized as one moves from the northern to southern reaches of the Peace River watershed. At the latitude that the Floridan underlies Shell and Prairie Creeks, water quality is marginal for some types of agricultural use and well below the standards for potable drinking water. Mineralization in water is similar to “hardness” and affects the way the water tastes, how soaps produce lather. and how some fish reproduce. In general, ground water use in Florida brings minerals to the surface where they may be concentrated by evaporation during the dry season. Florida’s ample annual rainfall generally keeps ground water minerals from accumulating to toxic levels for most agricultural plants, but because these minerals are chemically “conservative”-- meaning they do not change form or have a gaseous phase -- every molecule of mineral removed from the deep aquifer to the surface eventually finds its way into the streams draining to the ocean. Hence, the result of all ground water pumping from mineralized aquifers is the increased mineralization of surface waters.

The Peace River and Manasota Basin Citrus BMP Manual describes the problem best:

> It is important that growers understand the issues related to the quantity and quality of irrigation water used and the potential impacts that the use may have on downstream receiving water bodies. Managing irrigation with high salinity water requires frequent irrigations with excess water applications that leach accumulated salts from the soil. As a result, these salts move off with surface water drainage and impact downstream water users. (Boman *et al*. 2004)

The BMP Manual describes how the problem arises and management practices needed to control adverse effects on citrus trees:

> In coastal and southern portions of the basin, it is not uncommon for ground water quality to degrade when wells are pumped at high rates or for long periods of time. The degradation is generally attributed to “up-coning” of denser, saline water as the fresher water above is pumped out of the aquifer. If these conditions exist, the well may be conducive to back plugging of the highly saline zone to improve water quality. . . . However, the sustainability of wells that have been back plugged is unknown. (Boman *et al*. 2004)

Thus, “irrigation with high salinity water requires applications to be more frequent and of greater amounts than when good water quality is used.” Otherwise, salts tend to accumulate in the soil water. Leaching them, of course, removes salts from the root zone, but ultimately puts more salts in the receiving streams.

Mineral concentrations increase rapidly in Prairie Creek below depths of 1,200 feet below land surface. A review of well construction records indicates that approximately 101 of 191 wells (53 percent) in the Prairie Creek watershed exceed 1,200 feet in total depth. In Shell Creek, high mineral concentrations occur at depths in excess of 450 feet, resulting in a higher percentage of wells at risk. In Shell Creek, 113 of the total 173 wells (65 percent) exceed 450 feet (Shell, Prairie, and Joshua Creeks Watershed Management Plan Stakeholders Group 2004).

Mineralization of Shell and Prairie Creeks was brought to light with the exceedance of chloride, total dissolved solids (TDS), and specific conductance standards during the 2000-2001 drought. Exceedance of these standards resulted in corresponding exceedance in the secondary standards for the City of Punta Gorda’s drinking water supply, requiring the City to petition FDEP for an Emergency Final Order in April 2001 to allow the finished drinking water to exceed secondary drinking water standards.

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FDEP and SWFWMD worked together to address the issues and resolve a potential conflict between the needs of agricultural landowners and the City of Punta Gorda. Both agencies pulled stakeholders together in a productive working group intent on finding solutions. Collectively, they developed the Shell and Prairie Creek Watersheds Management Plan (December 2004), which emphasizes voluntary, incentive-based programs to meet the Class I surface water quality standards by 2014. In addition, the agencies and stakeholders recognized that Joshua Creek has similar characteristics of mineralization from well water and have included it in their planning. This process is a prime example of the successful use of public agency leadership to solve a problem utilizing maximum stakeholder involvement.

The goal of the Management Plan “is to reduce levels of specific conductance, chloride, and TDS below the maximum Class I criterion . . . at all times throughout” the Shell, Prairie, and Joshua Creek watersheds. According to the Plan, measures now in place to achieve that goal include more restrictive well construction stipulations for new irrigation wells, additional ground water quality sampling, more rigorous Water Use Permit review, and the promotion of several management options including the Facilitating Agricultural Resource Management Systems (FARMS) and Back-Plugging programs.

Water quality testing of irrigation well water indicates that water quality in these watersheds is highly dependent on well construction and deteriorates with depth. Wells that indicate poor water quality can, therefore, be improved by reducing the depth of the well by “back-plugging”. This program was initiated in 2002 with SWFWMD Governing Board approval of the Back-Plugging Funding Assistance Initiative to locate, “back-plug”, and improve water quality in wells that exhibit elevated levels of chloride, TDS, and specific conductance.

According to the Management Plan, “Back-plugging is seen as an immediate remediation technique for poor water quality wells.” Water quality improvement results can be dramatic and properties where back-plugging has been successful have shown substantial improvement in crop growth and yield. As of March 2004, post back-plugging results indicate average reduction in chloride concentration of approximately 62 percent, with reductions in TDS and conductance averaging approximately 44 percent and 46 percent, respectively (Shell, Prairie, and Joshua Creeks Watershed Management Plan Stakeholders Group 2004).

There are 214 wells in the Shell and Prairie Creek watersheds alone that are deep enough to potentially contribute to a water quality problem. As of 2006, only 22 wells have been back-plugged in the Prairie Creek watershed, 19 in the Joshua Creek watershed, and 2 in the Shell Creek watershed. As indicated by wells that have been back-plugged, this process has its highest potential for improving water quality in the Prairie and Joshua Creek watersheds. In the Shell Creek watershed, however, which has inherently poor water quality and shallower irrigation wells that are generally not conducive to back-plugging, alternative methods associated with the FARMS programs and the NRCS Environmental Quality Incentives Program (EQUIP) are seen as critical for restoring water quality.

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In October 2002, the FARMS Program was created by approval of SWFWMD’s Board Procedure No 13-9, in accordance with a Memorandum of Agreement between SWFWMD and DACS signed in 2001. An Operating Agreement was signed that recognized the Shell, Prairie, and Joshua Creek watersheds as resource priority areas. A renewed operating agreement in January 2004 that extends until December 2014 expanded the FARMS program to cover SWUCA while still recognizing the Shell, Prairie, and Joshua Creek watersheds as two priority areas.

The FARMS program is a voluntary public/private partnership designed to provide financial assistance for Best Management Practices (BMPs) that provide water quality improvements, and/or reductions in Upper Floridan aquifer withdrawals, and/or conservation, restoration, or augmentation of water resources and ecology. According to the Management Plan, cost-share rates are generally capped at 50 percent for water quality or water quantity BMPs, and at 75 percent for projects that incorporate both water quality and quantity components.

The basic goal of FARMS is a 40 mgd offset over 20 years at a total shared cost of $80 million. Participants are required to enter into a contract with SWFWMD extending from 5 to 25 years depending on the type of project, the service life of the components, and specified cost-benefit ratios based on SWFWMD’s 2001 Regional Water Supply Plan. The success of the FARMS projects is anticipated to result in water quality improvements through the development of alternative irrigation sources primarily supported by surface water and/or tailwater recovery. According to the Management Plan, “FARMS projects are seen as a means to offset and/or dilute mineralized ground water sources and can serve as a primary means for addressing impairment, or as an enhancement to other management activities. . . These types of projects are seen as particularly useful in achieving load reduction in the Shell Creek Watershed, since hydrogeologic conditions make individual source load reductions through well back-plugging difficult.”

As of the 2004 Management Plan, over 312 million gallons of ground water had been offset by three completed FARMS projects. The current FARMS agreement between SWFWMD and DACS is estimated to manage and fund 15 to 20 projects per year until 2014, with prioritization of projects in the Shell, Prairie, and Joshua Creeks.

While the solution emphasizes voluntary, incentive-based programs, there is a strong regulatory element for new well construction. Well construction permits are being issued with total depth and specific conductance (water quality) requirements. The water quality trigger requires that the depth of the well cannot be advanced after the water quality threshold has been reached.

While the solution emphasizes voluntary, incentive-based programs, there is a strong regulatory element for new well construction.

Now alerted to the water quality issue associated with well pumping, SWFWMD asserts in its discussion of water use permitting in the Management Plan, “A key component of these criteria is that the use of water will not cause quantity or quality changes, which adversely impact the water resources, including both surface and ground waters.” Under this interpretation, it is the applicant’s burden to provide reasonable assurances that water quality criteria are met both on an individual and cumulative basis. This potentially ushers in a new way of connecting consumptive use permitting to surface water quality, which is not currently addressed in the Basis of Review for Water Use Permits.

In order to examine regulatory effectiveness and derive lessons learned, one must examine more fully how a cumulative water quality impact occurred within the context of statutory restraint on cumulative impacts and water use permitting criteria that expressly require that a proposed water use “will not interfere with any presently existing legal use of water.”

Until recently, SWFWMD rules encouraged an applicant to use “the lowest quality water available, which is acceptable for the proposed use.” Thus, applicants for irrigation well water were encouraged to evaluate the mineral content of waters at various depths and to take water from the depth that represented the lowest quality acceptable for their crop. The purpose of this rule was to reserve higher quality water for other potential users whose use might actually be dependent on the higher quality. Until recent changes were made, SWFWMD rules did not explicitly take into account the environmental effect that the use of lower quality water might have. Grove operators favored the higher yielding aquifers and had developed BMPs to deal with salinity. The water supply for the City of Punta Gorda is, of course, a presently existing legal use of water and its degradation from augmentation of low quality irrigation water (along with Class I water quality standard exceedances) was clearly not anticipated by any of the involved parties. Permit reviewers at SWFWMD simply did not make the connection between their permitting practices and the adverse effects they would have. SWFWMD staff also believes that the amount of exempt ditching may have played a role in the transport of salts from the groves to the reservoir.

Recent rule changes now require that the lowest quality water only be used when "environmentally feasible." That change coupled with the language cited above from the Management Plan indicates that the issue is now better understood. The broader question may now be how the pumping of mineralized water affects other parts of the Peace River watershed and other aspects, such as fish and wildlife.

5.5 Gaps in Regulatory Effectiveness

As demonstrated in earlier sections of this report, cumulative adverse impacts to the hydrology, water quality, and native land covers within the Peace River watershed have been documented. Many of these cumulative impacts were in existence long before the baseline period for the study (1940s), but most seem to have accelerated within the study period. The loss of spring flows, the conversion of 136,000 acres of wetlands to other uses, and the mineralization of streams are prime examples of these trends.

One of the challenges of the study was to determine the adverse effects that occurred before regulations were enacted versus those that occurred after regulation as a result of an exemption, permit, or reclamation plan. This challenge to compare before and after the start of regulatory controls would be easier had regulations been enacted and implemented within a relatively short time. In reality, regulations have accumulated over the study period. Over the course of five decades, agencies worked legislative enactments into rules, rules into policies, and policies into programs. Throughout this period, the Legislature enacted new regulations as new concerns arose. This dynamic of an active governmental process responding to environmental concerns during a period of population growth and land use change within the Peace River watershed is integral to our society, but it makes a comparison less concise because of the frequent revisions. The approach, therefore, is to discuss cumulative impacts and the way they are *currently* addressed. A constructive evaluation of current regulations and non-regulatory programs in light of their history and the causes of cumulative impacts is included in this study.

It is, of course, possible that these cumulative impacts resulted from past practices that have since been curtailed, but there is little or no data to support this assumption. While some cumulative impacts are probably still occurring as delayed response to past practices, they would seem to be a minor part of the overall picture.

The analysis of land form changes was built around three sets of aerial photographs from the 1940s, 1979, and 1999. These photographs provide snapshots of empirical evidence about land use. Interpreted and cross-checked by the same company using the same techniques and many of the same photo-interpreters, the amount of interpretation error is minimal and well below the level that would change conclusions. While the 1940s aerials represent the earliest available baseline and the 1999 aerials are a reasonably close current view, the 1979 aerials fall in a period when many regulations in place today were still being developed. Protection of isolated wetlands, for instance, only became effective in 1987, and even then not for phosphate mining until 1995. While caution is needed in interpreting the wetland losses in this period between 1979 and 1999, they are, nevertheless, noticeably large and need to be addressed.

A simple and efficient way to address any lingering uncertainty about the current rate of change in land forms would be to use the same interpretation methods on 2005 aerial photographs (which were not available for this study) and compare them to the 1999 results. This would provide a six-year period-of-change analysis under virtually the same regulations as are in effect today.

> *A simple and efficient way to address any lingering uncertainty about the current rate of change in land forms would be to use the same interpretation methods on 2005 aerial photographs (which were not available for this study) and compare them to the 1999 results.*

5.5.1 Reductions in Base Flow

Base flows have diminished over the period-of-record for Peace River flow measurements. Since 1992, SWFWMD has identified over-allocation of the Upper Floridan Aquifer System, which once contributed significant base flows to the upper Peace River. SWFWMD adopted the Southern Water Use Caution Area (SWUCA) Recovery Strategy in March 2006 in part to achieve the minimum flows established for the upper Peace River. Currently, SWFWMD calculates that the upper river fails to meet minimum flows about 28 percent of the time. Minimum flows are those flows at which further withdrawals would be significantly harmful to the water resources or ecology of the area, and were established for the upper Peace River in 2004. The Recovery Strategy aims to meet adopted minimum flows by 2025 through a combination of regulatory and programmatic measures. The regulatory component of the SWUCA Recovery Strategy is described in section 5.3.1.5 of this study.

The Recovery Strategy also comprises non-regulatory programmatic initiatives that SWFWMD is undertaking to achieve recovery, including strong components of education and outreach, conservation, water supply planning, and restoration projects. The restoration projects addressing the upper Peace River watershed include the Lake Hancock Lake Level Modification and Ecosystem Restoration Project; the Lake Hancock Water Quality Treatment Project; the Peace Creek Restoration via the USDA/NRCS Wetlands Reserve Program; and the Upper Peace Resource Development Project. Both of the Lake Hancock projects are in advanced planning stages with funding sources identified.

The Lake Hancock projects provide about 9,300 acre-feet of new water storage that can be released through a treatment system for delivery to the upper Peace River as flow augmentation to achieve minimum flows during dry periods. Current cost estimates are around $115 million, mostly funded through SWFWMD. SWFWMD estimates that releases from Lake Hancock will provide about half of the flow augmentation needed to meet the established minimum flows for the upper Peace River.

The Lake Hancock projects provide about 9,300 acre-feet of new water storage that can be released through a treatment system for delivery to the upper Peace River as flow augmentation to achieve minimum flows during dry periods. Current cost estimates are around $115 million, mostly funded through SWFWMD.

The other half of flow augmentation will presumably come from the Peace Creek Project and the Upper Peace Resource Development Project. While advanced project plans are not yet available for these projects, a reasonable cost to provide enough surface water storage to achieve minimum flows is estimated to be about one-quarter billion dollars.

This admittedly rough cost calculation for the creation of surface water storage to achieve minimum flows is useful to illustrate the value of wetlands that have been lost. Between 1979 and 1999, this study documents wetland losses of 4,567 and 5,485 acres in the watersheds above Bartow and Zolfo Springs, respectively. Thus, in the area contributing base flows to the sections of the river where SWFWMD is working to achieve minimum flows by 2025, over 10,000 acres of wetlands and their storage capacity were lost. While neither the storage capacity of the wetlands that have been lost nor their contribution to base flow can be known with exactitude, the loss of these wetlands was a factor – even if not the main causal factor – causing the upper Peace River to experience loss of base flow. Wetlands with an average water depth of 1.5 feet over 10,000 acres would store 15,000 acre-feet of water that could contribute to base flow, presumably without further treatment.

…in the area contributing base flows to the sections of the river where SWFWMD is working to achieve minimum flows by 2025, over 10,000 acres of wetlands and their storage capacity were lost.

As it is developed, SWFWMD’s Upper Peace Restoration Development Project may include the hydrological restoration of many of these wetlands, along with some drained before 1979. SWFWMD could, for instance, purchase flowage easements and strategically place structures to restore normal wetland hydrology to the original wetland acreage. The cost and benefits of this strategy have been demonstrated in mitigation projects permitted by SWFWMD, SWFWMD’s own restoration efforts, and mitigation on the R.V. Griffin Reserve currently being permitted by

FDEP as compensation for wetland impacts associated with the PRMRWSA proposed above-ground reservoir. New regulatory tools may be needed to facilitate these restoration projects. Currently, for instance, the addition of surface storage in natural wetlands is treated the same as increasing the impervious area by asphalt and rooftops for meeting design storm discharge criteria. This creates a regulatory obstacle to restoration of wetlands.

The premise of most regulatory analysis is that development will increase rates of runoff unless it provides enough attenuation by creating storage. Regulatory agencies employ single-event models to predict the changes in runoff after development. These models are convenient and useful in the urban environment for protecting the public from unwanted flooding. In the natural landscape, however, they rely on unrealistic assumptions that often result in false predictions. The purpose of wetland restoration, for instance, is to increase the amount of inundated surface, but the single-event models treat this inundated surface as an impervious area – the same as if had been paved.

Mitigation bankers, who are in the business of restoring wetlands, have developed and proven continuous models that are better for predicting surface flows over natural landscapes than the simpler, convenient single-event models used for urban areas. SWFWMD is currently contracting to have a continuous model developed, as it has many restoration projects for which the single-event models are inadequate.

Base flow declines are not confined to the upper Peace River. This study shows that over the period-of-record (since 1932) at Arcadia, there have been declines in base flow as represented by the lowest flows per month and the 90 percent annual exceedance (Q90) flows. Most of the declines occurred early in the period-of-record (before 1960). There has been no statistically significant increase in Q90 flows at Arcadia since these declines, even though the water quality signatures of many contributing basins indicate substantial augmentation from ground water pumping. Several of the contributing basins with water quality signatures indicating ground water augmentation show statistically significant increases in base flow.

These factors indicate the potential of confounding effects. Contributions of base flow from the upper Peace River are lower than in the 1940s, yet ground water augmentation from irrigation pumping is higher and potentially offsetting some of this loss. Of considerable importance, wetland storage throughout the Peace River watershed has been diminished by over 136,000 acres since the 1940s, with its corresponding loss of contribution to base flow. These three factors interplay with mixed results on base flow. Ground water pumping for irrigation may be currently augmenting base flows and masking the adverse effects of the continuing loss of wetland storage in the watershed. Should ground water pumping ever be curtailed, or should tailwater recapture and reuse systems become widespread in agricultural practice, the effect of widespread wetlands losses expressed in even lower base flows might be seen.

Of considerable importance, wetland storage throughout the Peace River watershed has been diminished by over 136,000 acres since the 1940s, with its corresponding loss of contribution to base flow.

In addition to over-allocation of the Upper Floridan in SWUCA, there are water quality issues associated with ground water augmentation of streams discussed in Section 5.5.2. Both water quality and base flow issues pose threats to public water supplies dependent on surface flows, as discussed in section 5.5.4.

5.5.2 Water Quality Degradation

There are two significant cumulative impacts to surface water quality affecting the Peace River watershed: nitrogen loads and mineralization (salinity) of surface waters. While mineralization is not a problem in the upper Peace River watershed, both of these effects seem to be associated with agricultural practices in contributing basins where there have been large increases in the acreage of intensive agriculture and losses of wetlands to agriculture (9,761 acres between 1979 and 1999): Charlie Creek, Joshua Creek, and Shell Creek. SWFWMD and FDEP have already identified problems in the latter two basins with elevated specific conductance (the measurement of electrical conductance in water used to measure mineralization efficiently) and developed a management plan to reduce specific conductance to an acceptable target level by 2014.

Shell (including Prairie) and Joshua Creek basins have large increases in nitrate + nitrite – the highly reactive form of nitrogen that has been the target of control by agricultural BMPs for over a decade. While the remainder of the Peace River watershed shows some signs of improvement or no change in water quality parameters for which there is historical information, water quality leaves much to be desired.

Lake Hancock water quality is “poor” based on the Florida Trophic State Index and water quality in the lake has been a concern as far back as the 1950s. Dissolved oxygen concentrations in the Peace River are conspicuously lower toward the northern end of the watershed, and the occurrence of low oxygen levels are both more frequent and extend further downstream as flows increase. The high concentrations of chlorophyll (algae) and organic material associated with discharges from Lake Hancock result in both the very high and low dissolved oxygen levels observed in the upper Peace River.

Ortho-phosphate – the highly reactive form of phosphorus – is declining from generally higher levels in the past. Past levels are generally associated with greater direct discharges to the river from publicly owned wastewater treatment facilities, phosphate mining operations, and fertilizer production facilities. Phosphorus levels are expected to be high in the Peace River watershed because of the natural occurrence of phosphate deposits. Except for statistically significant long-term declines in phosphorus levels and recent significant increases in silica concentrations, the overall water quality characteristics of the lower Peace River and upper Charlotte Harbor have remained relatively unchanged over the past quarter century.

SWFWMD’s Lake Hancock Water Quality Treatment Project has a budget of over $20 million to remove nitrogen from Lake Hancock water released to augment the minimum flows in the upper Peace River. SWFWMD will build over 1,000 acres of treatment wetlands and commit to approximately $700,000 annual operating costs to remove approximately 27 percent of the nitrogen from the highly enriched waters discharged from Lake Hancock into the upper Peace River.

SWFWMD has identified nitrogen “as the primary target nutrient in restoring water quality to the Peace River and preventing degradation of Charlotte Harbor . . . .” (SWUCA Recovery Strategy, SWFWMD, 2006). SWFWMD believes that the “Peace River ecosystem routinely suffers from algae blooms during periods of low flows and warm weather. These events not only affect the fish and wildlife associated directly with the river and estuary, but also affect the regions largest potable water supply system, operated by the Peace River/Manasota Regional Water Supply Authority.” (ibid.)

FDEP has identified nutrient impairment of several water bodies in the upper Peace River drainages and has established Total Maximum Daily Loads (TMDL). The next step is to limit the loading of nutrients by the development and implementation of Basin Management Action Plans. In its TMDL Report for Lake Hancock and Lower Saddle Creek (Shelly *et al*. 2005), FDEP has identified the need for nutrient load reductions of 75 percent, all from reductions in stormwater loading.

FDEP has identified nutrient impairment of several water bodies in the upper Peace River drainages and has established Total Maximum Daily Loads (TMDL).

In the lower contributing basins, impairments for nutrients have only been identified for Shell Creek below the Henderson Dam. While the trend for nitrate + nitrite concentrations in Charlie, Joshua and the freshwater portions of Shell Creeks is upward, FDEP has not yet identified them as impaired for nutrients. Portions of Shell and Prairie Creeks are scheduled for TMDL development in 2009.

The specific conductance water quality standard has been exceeded regularly in Joshua, Prairie, and Shell Creeks. While there are only three stream segments (two in Shell Creek and one in Prairie Creek) that have been listed as “verified impaired,” there are 12 additional segments under consideration for listing (three in Shell Creek, two in Prairie Creek, and seven in Joshua Creek), pending a sufficient data record. Preliminary indications are that while high specific conductance values in Joshua Creek do not affect Class I waters (designated for drinking water use) or a public water supply, they actually represent the most acute water quality impact. Specific conductance in Joshua Creek regularly exceeds the state water quality standard for Class III waters (designated for the propagation of fish and wildlife) with greater frequency and magnitude than in Shell and Prairie Creeks. When specific conductance fails to meet water quality standards, other constituents like chlorides and total dissolved solids are also often exceeding their water quality standards.

The fact that irrigation wells permitted by SWFWMD bring highly mineralized water to the surface, and this water then causes streams in the lower Peace River watershed to become mineralized to the point of exceeding state water quality standards, raises a couple of regulatory issues. First, one part of the three-prong test in Section 373.223, FS (the “interference test”), requires a permit applicant to establish that the proposed use of water will not interfere with any presently existing legal use of water. Clearly, the City of Punta Gorda water supply is a presently existing legal use of water from Shell Creek – since the mid-1960s – and mineralization interfered with its use. These issues have been addressed in detail in section 5.4.4.2 above, and the cooperative and measured responses of the agencies and growers are commendable. The cumulative impact seems to have occurred because the cause-effect connection between agricultural pumping and water quality was unrecognized at the time new irrigation wells were approved over the course of a dozen or more years.

The cumulative impact seems to have occurred because the cause-effect connection between agricultural pumping and water quality was unrecognized at the time new irrigation wells were approved over the course of a dozen or more years.

Second, how should mineralization from agricultural pumping that creates a violation of state water quality standards be viewed, even if it does not interfere with another permitted user? All waters in the state have been classified for a designated use. Class I waters are designated for potable water supply; Class II for shellfish propagation or harvesting; Class III for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife; Class IV for agricultural water supplies; and Class V for navigation, utility, and industrial use. Water quality criteria are established to protect these designated uses and are arranged in the order of degree of protection required. Classes I, II, and III share water quality criteria that protect a healthy, well-balanced population of fish and wildlife. These criteria are the *minimum* conditions necessary to assure the suitability of water for the designated use of the classification. If these classifications are “existing legal uses” for the public, then it follows that exceeding water quality criteria from operation of a water use permit may be interference with that public use.

Historically, the “interference test” has been used to look at other permit holders who may be adversely affected by the proposed use. An applicant for a water use permit, for instance, would have to demonstrate that adjacent property owners would be able to achieve their permitted uses without interference. In the example cited in section 5.4.4.1 of this report, new proposed withdrawals from the Peace River would have to demonstrate that their withdrawals did not interfere with the withdrawals allowed under the permit to the PRMRWSA.

Application of the “interference test” to maintenance of water quality criteria would implicitly recognize that the public is enjoying a “presently existing legal use” of waters according to their classification. Applicants for water use permits would have to provide the same reasonable assurance for water quality that applicants provide under ERP review. Currently, SWFWMD’s Basis of Review provides a close scrutiny of potential impacts of water use permits on quantities but not quality of water. Performance standards demonstrating no interference with existing legal users deal with quantity issues and ways to mitigate quantity conflicts. Even in the review of environmental impacts, evaluations of potential impacts of proposed water use permits to wetlands, lakes, and streams assume the impacts will be quantity-related. SWFWMD has made much progress with adoption of the Watershed Management Plan to abate mineralization of these streams and the expenditure of public and private funds to implement the Watershed Management Plan. Given the above experience in Shell, Prairie, and Joshua Creeks, the lack of water quality review standards in SWFWMD's Basis of Review would appear to be a gap in regulatory effectiveness.

> *…the lack of water quality review standards in SWFWMD's Basis of Review would appear to be a gap in regulatory effectiveness.*

5.5.3 Native Habitat Losses

The conversion of natural habitats to other uses in the Peace River watershed over Florida's post-World War II period tracks the region's economic development. The predominant land covers in the 1940s were Native Upland Habitats and Wetlands, which comprised 60 percent and 25 percent, respectively. Today, they are barely one-third combined. Native Upland Habitat is not regulated, of course, but as the predominant land cover for the watershed in the 1940s, understanding its conversion is good background for understanding changes to streams and wetlands, which became regulated in the 1970s and 1980s.

5.5.3.1 Native Upland Habitat

Most of the early changes in the Peace River watershed were from agricultural development. Between the 1940s and 1979, conversion to Improved Pasture and Intensive Agriculture accounted for over 80 percent of the loss of Native Upland Habitat. Mining and Urban Land Uses only accounted for 7 percent and 8 percent, respectively. While over 450,000 acres of Native Upland Habitat was converted to agriculture during this period, another 41,000 acres accrued to Native Upland Habitat from Wetlands, presumably by drainage. Over 280,000 acres of Native Upland Habitat were converted to improved pasture, representing a tremendous investment in lands developed for cattle grazing. Over this 30-year period, this represents approximately 14 square miles per year of arduous clearing, burning, root raking, stump-pulling, grading, ditching, and planting. At the same time, another 100,000 acres were converted from native lands to crop land and groves. In all likelihood, much of the original conversion was to crop land, which was later rotated to improved pasture.

> *Over this 30-year period, this represents approximately 14 square miles per year of arduous clearing, burning, root raking, stump-pulling, grading, ditching, and planting.*

During the 20-year period from 1979 to 1999, the pace of conversions to agriculture slowed, but other uses became more prevalent. During this period, 60 percent of the 211,000 acres of Native Upland Habitat that were lost went to agriculture, 22 percent to mining, and 12 percent to urban.

Wetland drainage continued at a slower rate, adding over 8,300 acres to Native Upland Habitat, probably through the encroachment of upland vegetation into wetlands with reduced periods of inundation.

Interestingly, more Native Upland Habitat reverted back to Wetlands (9,400 acres) than were drained, creating a net gain in Wetlands. Also, some agricultural land from the previous period reverted to Native Upland Habitat as owners quit mowing or burning and allowed fields to overgrow. These reversions comprised about 25,000 acres.

While Native Upland Habitat was by far the predominant land cover in the 1940s, by 1979 it was second to all agricultural land covers (Improved Pasture and Intensive Agriculture). By 1999, it was second to Improved Pasture alone and roughly comparable to Intensive Agriculture. Loss of over 70 percent of Native Upland Habitat – mostly to agricultural improvements – was the predominant land cover change of the study period.

5.5.3.2 Wetlands

As discussed above, there was significant investment in land cover conversions after World War II, and it should not be surprising that some of that investment went to drain wetlands. Regulation of the filling or drainage of freshwater wetlands did not become pervasive until the mid-1980s. Before this, it was common practice to drain property to increase its agricultural production and to dredge and fill wetlands in the course of land development. Phosphate mining enjoyed an exemption from permitting by the State for isolated wetland impacts until 1995, even though starting in 1987, mine operations were required to reclaim wetlands at least acre-for-acre and type-for-type.

The loss of 31,000 acres (48 square miles) of wetlands between 1979 and 1999 could be attributed to the portion of that 20-year interval before regulations. It is at least theoretically possible that these losses all occurred between 1979 and the advent of regulatory controls. A deeper look into the wetland loss data on a basin-by-basin basis raises some questions, however, about the causal factors of this loss. These questions suggest that there may be a continuing net loss of wetlands.

Phosphate Mining Wetland Losses

The net amount of wetland loss attributed to phosphate mining between 1979 and 1999 is 13,397 acres. Phosphate mining is a dynamic process involving numerous steps from land clearing to mining the ore to the final contouring and planting for reclamation. Once the land is cleared of vegetation, very little detailed information is discernable from the aerial photographs; hence, the broad category of Extractive Lands. The photo-interpreter cannot tell, for instance, whether land has actually been mined or whether it has only been cleared for mining but not yet mined. Once the land is disturbed in the context of phosphate mining, it remains in the Extractive Lands Category until it is recognized by the photo-interpreter as another category, such as Wetlands, Improved Pasture, Urban. The net wetland loss of 13,397 acres to phosphate mining, therefore, represents a loss of 14,810 acres and a corresponding gain of 1,413 acres from lands classified as Extractive Lands on the 1979 aerial photographs. Industry representatives have suggested that their records of mined and reclaimed lands would better represent the transitional nature of their lands in the phosphate mining process. They undoubtedly have more detailed data supporting their reclamation obligations than the photo-interpreters can glean from the aerial photographs. On the other hand, there is an element of reality check in the aerial photo-interpretations. Discovering any discrepancies between regulatory requirements and outcomes on a landscape scale is one of the purposes of this study. Substituting industry data for photo-interpretation data would compromise that purpose, and it would disrupt the continuity of method for comparisons across the entire Peace River watershed.

As described in sections 5.2.4 and 5.4.2.2 of this report, SWFWMD adopted a phosphate mining exemption from review under Chapter 373, FS, Part IV requirements for Management and Storage of Surface Waters (MSSW) in October 1986. As a result, when the requirement pursuant to Section 373.414, FS, to regulate isolated wetlands under MSSW went into effect on March 31, 1987, the phosphate industry was exempted on the condition that they complied with reclamation requirements administered by the DNR. Not until after the final adoption of the Environmental Resource Permitting Rule in 1995 was phosphate mining subject to isolated wetland permitting and mitigation requirements. Following some phase-in lags associated with mines already in the planning process, phosphate mining was regulated the same as other industries for wetland impacts in the late 1990s. With knowledge of this history, no inferences about current wetland regulation can be derived from changes in wetland acreages attributable to phosphate mining between 1979 and 1999, since current regulations (ERP) were not applicable until the last few years.

> *…no inferences about current wetland regulation can be derived from changes in wetland acreages attributable to phosphate mining between 1979 and 1999, since current regulations (ERP) were not applicable until the last few years.*

The question remains, however, how such losses occurred under the application of a wetland reclamation standard of at least acre-for-acre and type-for-type. Definitive answers would come from a review of the phosphate reclamation, perhaps by selecting a random sample of wetland reclamation projects and simply evaluating: (1) whether they meet the wetland criteria under Rule 62-340, FAC, and (2) whether they were recognized as wetlands by aerial photo-interpreters for this study. There are a number of ways this discrepancy might be resolved, including finding that:

- Littoral zones around lakes counted as wetland reclamation, but were included in the acreage for lakes (More than 4,500 acres of lakes appeared between 1979 and 1999 aerial photographs in the three basins with active phosphate mining.).
- Release from reclamation requirements were too early and the sites have continued to change from wetlands to other categories (lakes or uplands).
- Early successional plant communities on disturbed sites (such as dense willow heads) are being misclassified.

- All reclamation requirements are being met, but expression on aerial imagery lags the more subtle changes on the ground; and/or
- All losses occurred before reclamation rules became effective in 1987.

These and other possibilities need to be addressed to evaluate the past efficacy of the mined lands reclamation program. Under current regulation generally not reflected in 1999 aerial photographs, the standards for wetland replacement are the more stringent ERP mitigation standards.

Agricultural Wetland Losses

The second highest loss of wetland acreage between 1979 and 1999 is attributed to agriculture – both Improved Pasture and Intensive Agriculture. Net losses of wetlands converted to these agricultural categories were 12,707 acres. Gross losses were higher, but as with phosphate mining lands, some lands classified as agricultural in 1979 (approximately 5,500 acres) presumably reverted to wetlands between 1979 and 1999. (Reversion to wetlands can occur when drainage conveyances are not maintained, such as culverts becoming clogged or ditches filling with vegetation.) Nevertheless, the net loss of wetlands to agricultural uses is substantial and requires examination.

The second highest loss of wetland acreage between 1979 and 1999 is attributed to agriculture – both Improved Pasture and Intensive Agriculture.

Agriculture enjoys a limited exemption from Part IV of Chapter 373, FS. The exemption is for normal agricultural practices that are not "for the sole or predominant purpose of impounding or obstructing surface waters." The exemption comes from the original legislative enactment (Chapter 72-299, LOF) and would seem to be intended to protect normal field preparation, bedding, ditching, and tilling for the production of food and fiber from regulation, but not the conversion of wetlands to uplands. A possible problem with the exemption language is that it is based on "the sole or predominant purpose" or intent, rather than outcomes. This invites substantial latitude of judgment to determine the "sole or predominant purpose" of an activity. Unintentional drainage or drainage that occurs as "collateral damage" is at least disputable and under some interpretations may be explicitly exempt. Under such a broad legislative exemption that relies upon the intent of the actor, regulatory agencies have difficulty defining the limits of the exemption.

A possible problem with the exemption language is that it is based on "the sole or predominant purpose" or intent, rather than outcomes. This invites substantial latitude of judgment to determine the "sole or predominant purpose" of an activity.

SWFWMD has developed a cooperative approach for working with agricultural operations. In recognition of low agricultural margins, the spirit of land stewardship that permeates the industry, and the value of partnerships, SWFWMD has engaged operators in the Agricultural Ground and Surface Water Management (AGSWM) program described in 5.3.4 of this report. There is no doubt that many agricultural operators cooperate with SWFWMD because of this approach. While this approach works well with most agricultural operators, there appears to be a gap between what is required by law and the desired outcomes. The State may need a better defined regulatory backstop to stem the loss of wetlands and provide a greater incentive for the cooperative approach.

In addition to the net 12,707 acres of wetlands converted to Improved Pasture and Intensive Agriculture categories, another dynamic is underway that may help to understand the economics of agricultural drainage. More than 8,300 acres of Wetlands were converted to Native Upland Habitat between 1979 and 1999, but this was more than offset by over 9,400 acres of Native Upland Habitat that were converted to Wetlands. These figures – each representing over a dozen square miles – would suggest that drainage works from before 1979 are still operative. As old ditches continue to create fringes where upland vegetation encroaches into wetlands, Wetland acreage is converted to Native Upland Habitat acreage. But more interestingly, there is more land going the other way. Drainage systems have to be maintained to continue working, and the fact that more Native Upland Habitats are "reverting" to Wetlands may imply that the economics of agricultural drainage is changing with the cost of energy and labor and the price of commodities. If this indication proves true, there may be landowners receptive to the idea of selling flowage easements to reverse drainage works, or otherwise contracting to store water on their land to improve the base flow characteristics of the river.

> *…there may be landowners receptive to the idea of selling flowage easements to reverse drainage works, or otherwise contracting to store water on their land to improve the base flow characteristics of the river.*

Urban Land Use

More than 4,000 acres of wetlands were lost to urban land use between 1979 and 1999. It is not known by looking at aerial photographs how many of these losses received regulatory approval, how many were effectively mitigated, or the rate of wetland loss to urbanization under current regulations. Except for wetlands under 0.5 acre, there are no exemptions for urban development. As such, this amount of loss seems high in light of the highly restrictive regulation of urban development.

Not surprisingly, the greatest conversion of wetlands to urban land use occurs in the two most urbanized basins: Bartow and Lower Coastal. Bartow includes all lands draining into the Peace River at Bartow, and Lower Coastal includes those many small drainages contributing to the Peace River below Arcadia, but excluding Joshua, Horse, and Shell Creeks. Together these two basins comprise 79 percent of all urban lands in the Peace River watershed and 79 percent of the wetland to urban land use conversions between 1979 and 1999. This amount of wetland losses to urbanization greatly exceeds permit authorizations by FDEP and SWFWMD, and suggests a gap in regulatory effectiveness that should be reviewed.

The economic value gain of converting natural or agricultural land to urban uses creates a substantial threat to wetlands. Through the regulatory approval process, developers are required to fully compensate for wetland losses on a functional basis. These full compensation requirements are costly, however, and it stands to reason that agricultural land in the path of development can stand the economic burden of fully exploiting the agricultural exemption. Where it was speculated above that some agricultural landowners may not be fully maintaining their drainage systems, allowing some uplands and improved pasture to revert to wetlands, there is no reason to think this is the case for land on the urban fringe. As land prices rise in anticipation of development opportunities, the agricultural exemption may provide a cost-effective path for converting wetlands to urban uses. The agricultural exemption in Part IV of Chapter 375, FS, is a likely gap in regulatory effectiveness allowing over 4,000 acres of wetlands to be converted to urban development.

> *As land prices rise in anticipation of development opportunities, the agricultural exemption may provide a cost-effective path for converting wetlands to urban uses.*

5.5.3.3 Streams

Stream losses for the period from the 1940s until 1999 were approximately 343 miles. The least impacted basins are largely agricultural with little urban development or phosphate mining.

Stream losses were highest in Lower Coastal basin where urban land uses appear to have directly replaced nearly 25 miles of streams. The Bartow basin has also lost over 8 miles of streams to urban land, although with the large amount of phosphate mining in that basin, it is unclear whether phosphate mining or urbanization was the original cause. These two most urbanized basins within the Peace River watershed also showed an unexpected conversion of streams to wetlands and upland habitats, an anomaly suggesting that the cause of these stream losses may be more the effect of the large-scale drainage associated with urban development than the direct destruction through earthmoving or culverting. The large scale of stream loss in urban environments begs additional study to understand its cause, especially in light of the significant regulation of land development activities.

> *Stream losses were highest in Lower Coastal basin where urban land uses appear to have directly replaced nearly 25 miles of streams.*

The basins that have been mined for phosphate show relatively high levels of stream loss as well. The Payne Creek and Bartow basins currently have less than half of their original streams. Payne Creek is only about 1 percent urban, compared to over 25 percent for the Lower Coastal and Bartow basins, yet it is over 60 percent mined and has lost nearly 55 miles of stream channel just to phosphate mining. Payne Creek with 66.9 miles lost is second only to Lower Coastal in total stream miles lost. Lower Coastal with no phosphate mining has lost over 77 miles of stream channel.

These data, while alarming, do not shed much light on how these stream losses have occurred. With only data from the 1940s and 1999, it is difficult to determine whether losses have occurred under regulation. Most phosphate mining in Payne Creek, however, has occurred since 1979 (83 percent occurred after 1979), and one might assume that because phosphate mining directly impacts streams by excavation, this activity was acknowledged and mitigation was required. As long as phosphate mining has been regulated for dredge and fill activities in waters of the state (since the mid-1970s), the FDEP and its predecessors appear to have had legislative authority to either deny mining in stream channels or require full replacement of the stream channel. Various industry tours of reclamation sites include a successfully restored stream channel in the Payne Creek basin. A more detailed look at specific examples of permitted stream alterations would, perhaps, provide the information needed to understand how these losses have occurred in Payne Creek since regulations were in place.

The same questions can be asked for the more urban basins. Dredge and fill permitting requirements in the mid-1970s interrupted a spree of coastal dredging in the Lower Coastal basin to create residential finger canals from mangrove swamps and high coastal marshes. This study does not provide the detail to understand how much of the loss occurred before regulation, but again it appears that sufficient regulatory authority has existed from the mid-1970s to curb these losses.

> *Dredge and fill permitting requirements in the mid-1970s interrupted a spree of coastal dredging in the Lower Coastal basin to create residential finger canals from mangrove swamps and high coastal marshes.*

There is not enough information from this study to definitively determine the effectiveness of regulation in stream beds, although as the above discussion implies, there is reason to suspect less than adequate fulfillment of regulatory expectations. The scale of stream losses suggests that the timeframes of losses should be further investigated to establish how much loss may have occurred after regulations were in place. As with wetlands, updating the study to 2005 would estimate the rate of loss under current regulations.

5.5.4 Threats to Public Water Supply

A central feature of the SWUCA Recovery Strategy is the conversion of public water supply from reliance on ground water to "alternative water supplies." The most common alternative to ground water for public supply is the diversion and storage of surface water from natural streams. As described in section 5.4.4 above, two public water suppliers in the Peace River watershed have invested in considerable infrastructure and developed significant customer dependencies based upon the availability of surface water as a potable supply source. Indeed, an area comprising over 88 percent of the Peace River watershed contributes to these two public water supply diversions in DeSoto and Charlotte Counties.

These public water suppliers depend upon a reliable quantity of good quality water. Both have developed storage capacity to allow them to meet a relatively predictable customer demand from a highly variable and much less predictable source – stream flows. The investment in surface storage and aquifer storage is driven by the need to reach a level of statistical reliability based on the historical record of streams flows. The permit issued by SWFWMD for the Peace River Facility limits diversions to no more than 10 percent of any flow above 130 cfs (as measured at Arcadia). Below 130 cfs, the Peace River Facility cannot divert water and is entirely dependent upon stored water. These limitations protect the estuary in the lower Peace River and Charlotte Harbor from the cumulative impacts of withdrawals. In addition to regulatory limits, the Peace River Facility does not divert water when the quality has fallen to a point that jeopardizes the treatment efficacy.

A combination of water demand projections and statistical reliability estimates for these projected demands dictates the Peace River Facility's need for storage. River flows are highly variable between seasons and years. During the drought of 2000-2001, the Facility was unable to divert flows for nearly 250 days in 2000 and 219 days in 2001, for which time it relied entirely on stored water. During the subsequent wetter period of 2002-2005, however, the Facility enjoyed ample access to river water, even during the typically drier late winter and spring months.

These characteristics mean the Peace River Facility is extremely sensitive to changes in low flows or base flow. The PRMRWSA makes capital investments in storage facilities based on a 74-year period-of-record of flow measurements at Arcadia. This relatively long period-of-record provides estimates of future variability, but if base flows are in fact diminishing due to the continuing loss of wetlands, the disconnection of contributing basins, or the increase in losses to sinkholes in the upper Peace River, these reliability estimates may not hold.

The relationships between base flow characteristics and land use changes are not straightforward. There may be non-linear relationships, such as tipping points, exponential relationships, offsetting relationships, or step functions that describe the complex interaction between land uses and base flow. For example, over 12,000 acres of wetland storage have been lost in the Charlie Creek basin since the 1940s, but as a result of the agricultural development associated with this loss, the contribution to base flow from irrigation pumping has also increased. It is not known how much the base flow contribution from agricultural irrigation is offsetting the loss of wetland storage or whether these ground water flows are sustainable. It is suspected that the base flow contributions from agricultural irrigation during extreme droughts may exceed the base flow that would have been contributed by wetland storage, but that during normal dry seasons, the base flow would likely be more extended by contributions from wetland storage. These kinds of complex relationships need further investigation.

> *The relationships between base flow characteristics and land use changes are not straightforward. There may be non-linear relationships, such as tipping points, exponential relationships, offsetting relationships, or step functions that describe the complex interaction between land uses and base flow.*

In a 2005 presentation to the Florida Water Resources Conference, representatives from the PRMRWSA estimated that for every 1 percent increase in reliability between 80 percent and 95 percent, capital costs to deliver its currently permitted quantity of 32.7 mgd increase by $3.33 million. Thus, if reliability were reduced to 80 percent and had to be restored to 95 percent by the addition of surface and aquifer storage, the cost would be approximately $50 million in 2005 purchasing power. The cost of maintaining a certain level of reliability would be expected to increase substantially as the PRMRWSA commits to a higher level of potable water delivery from the Peace River, but it may be offset by diversification of sources and interconnections that allow the PRMRWSA to shift demand among sources with greatly different limitations and costs.

There seems little doubt that the loss of streams and wetlands in the Peace River watershed, as well as the loss of base flow contributions from the upper Peace River, impair the ability of the Peace River to provide sustainable public water supplies. Many of these impairments have been decades in the making and SWFWMD has recognized the economic dependencies that have developed around water use allocations in the upper Peace River watershed. While it may be tempting to frame this issue as a competition for water resources between upper Peace River and lower Peace River users, SWFWMD has recognized the interdependencies within the whole Peace River watershed in its SWUCA Recovery Strategy. Shifting public supply to surface water as an "alternative water supply" can be more readily accomplished in the lower Peace River watershed where there is a greater contributing watershed to the points of diversion. At the same time, SWFWMD is funding large projects to augment flows to the upper Peace River from Lake Hancock with water of better quality than is released from the lake today.

> *There seems little doubt that the loss of streams and wetlands in the Peace River watershed, as well as the loss of base flow contributions from the upper Peace River, impair the ability of the Peace River to provide sustainable public water supplies.*

Water quality is another critical factor for water supply. Most water treatment facilities are designed to treat the quality of water expected from the supply source. If that quality changes, the water treatment may not be able to convert the raw water to an acceptable quality for drinking water customers. A color removal and alum coagulation facility, for instance, cannot remove salts. Changes in water quality in streams that provide source water to public water supply systems can, therefore, be a threat to public water supply.

As has been discussed in 5.4.4.2 of this report, the increased mineralization of Shell and Prairie Creeks creates just such a threat to the City of Punta Gorda's water supply. The City's treatment plant is not designed to remove ions, and when these ions are present, they pass directly into the public water supply. SWFWMD and FDEP worked with many, but not all, grove operators in the contributing basins, and there is much promise to what will be achieved through this measured and cooperative approach. So far, many of the cooperators have found the remedial measures in their economic interest, or at least not contrary to it. There could soon come a time, however, when a stronger regulatory backstop is needed to bring more operators into the program and to fairly distribute the cost of remedial measures among the sources of high salinity water.

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5.6 Use of Buffers Within The 100-Year Floodplain

5.6.1 Floodplain Restrictions

5.6.1.1 Flood Protection

Flooding is a natural occurrence. It usually occurs when rainfall exceeds the capacity of wetlands, streams, lakes, ditches, canals, and other natural and man-made features to store and convey stormwater runoff. Large rainfall events cause normally dry areas to be inundated, becoming temporary storage for excess stormwater. Flooding may also occur when abnormally high tides or storm surges cause seawater to rise and move inland, inundating low lying coastal areas. Only when there are human activities in these temporary storage areas does flooding become a management problem.

The two most effective approaches to flood protection are to avoid siting incompatible land uses within flood-prone areas and to ensure that land development does not alter natural patterns of water movement and storage. This preventive strategy is commonly referred to as the "non-structural' approach, because the emphasis is placed on harmonizing growth and development with the natural environment. Conversely, a "structural" approach involves the intentional alteration of natural surface water systems though construction of facilities, such as ditches, canals, dams, and control structures, to ensure that formerly flood-prone areas are less prone to inundation. This can be a long, costly process with significant environmental impacts, including the alteration of natural aquatic and terrestrial habitats and the acceleration of stormwater pollution of water bodies.

The two most effective approaches to flood protection are to avoid siting incompatible land uses within flood-prone areas and to ensure that land development does not alter natural patterns of water movement and storage.

5.6.1.2 Floodplain Permitting

One of the most common yet complex issues dealt with in an Environmental Resource Permit (ERP) application involves floodplains. Floodplains are normally dry or semi-dry land areas to which water naturally flows as water levels rise. Floodplains are typically found near rivers, lakes, and the coast; however, many of Florida's flood-prone lands are simply low-lying areas or depressions where water naturally collects when it rains. Some of the benefits of floodplains are that they:

- Provide natural storage areas for flood waters, thus minimizing flood damage to other areas.
- Serve as recharge areas for the aquifer, the main source for drinking water.
- Improve water quality, by allowing sediments to settle out of the flood water as it flows across the floodplain; and
- Provide important natural habitats for animals and plant life.

5.6.1.3 Restrictions on Floodplain Development

Florida law does not prohibit construction within delineated floodplain areas. Regulatory criteria, however, require that "no net encroachment" occur as a result of the proposed activity. Specifically, Sections 40D-4.301 and 40D-4.302, FAC, Conditions for Issuance of ERP Permits, require that to obtain a permit, an applicant must provide reasonable assurance that the surface water management system will not cause adverse flooding to on-site or off-site property.

Section 4.4 of SWFWMD's Basis of Review (BOR) provides the following guidance regarding "flood plain encroachment":

> …No net encroachment into the flood plain, up to that encompassed by the 100-year event, which will adversely affect either conveyance, storage, water quality or adjacent lands will be allowed. Any required compensating storage shall be equivalently provided between the seasonal high water levels and the 100 year flood level to allow storage function during all lesser flood events…

5.6.1.4 Floodplain Compensation

When needed, ERP permit applicants may propose "flood plain compensation" to offset or mitigate the adverse effects of their encroachment to conveyance, water storage, water quality, or adjacent lands, and to satisfy the "Conditions for Issuance of ERP Permits." The method of floodplain compensation envisioned by Section 4.4 of the BOR, and most commonly used when development activities occur within a floodplain, involves "equivalent excavation", defined as excavation provided "cup for cup" to offset the filling/blockage caused by project floodplain encroachment. As a result of high land values and the technical convenience of computer analytical modeling, some applicants attempt to demonstrate than an alternative means other than "cup for cup" compensation will provide equivalent floodplain compensation and avoid impacts. The following paragraphs briefly discuss some of the common alternative compensation methodologies.

5.6.1.5 Floodplain Compensation in Detention Ponds

Some applicants propose floodplain compensation in detention ponds that are built below floodplain levels (stages) by showing that the timing differential between stages in the pond and the receiving water body can cause the pond to be empty when flood levels occur in the receiving stream or water body. In this case, the applicant will perform a computer modeling analysis to show that due to the project location in a downstream area of the watershed, the pond(s) in the floodplain can fill up and drain down during any storm event without being affected by tailwater in the floodplain. If the pond volume becomes theoretically empty, then the pond capacity above the interconnection level may be available for floodplain storage during a design flood event. Critical components to this scenario are both the timing of stages in the pond and in the receiving waters and adequate sizing of the pond/stream interconnection. Few applicants are able to spend the time and expense to provide sufficient and accurate stage/time analysis and supporting information. Actual data is usually lacking, and the modeling results are commonly based on relatively simple hydrologic assumptions. For example, the applicant may assume that a design storm will produce uniform rainfall depth over the project area and entire watershed. Most storm events that cause flooding produce uneven rainfall, which occurs at random and does not happen according to the modeling assumptions. In general, ponds located within the floodplain of receiving waters are more likely to cause floodplain impacts rather than to provide compensation.

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5.6.1.6 Minimal Impacts by Single Projects vs. Cumulative Impacts

A method that has been used by highway bridge crossings and others in an effort to justify the floodplain encroachment impacts involves computer modeling analysis of the pre-and post-development cross-sections of a creek/river to show the local rise in floodplain levels due only to the subject property's encroachment. Then the argument is made that the increased level of the hydrologic line due to the individual project should only cause minimal resource and flooding impacts, thereby negating the need to provide specific "cup for cup" floodplain compensation. This individual project analysis does not account for the more significant cumulative effects due to loss of floodplain storage/conveyance caused by other similar projects in the area. Although stage changes in the receiving waters due to encroachment by a single project may be individually minimal, the cumulative effects of floodplain encroachment caused by several projects are often not recognized until after they occur.

5.6.2 Ecological Value of Buffers

As development in Florida continues to expand, natural water resources are increasingly threatened by human disturbances. Development can cause the degradation of water quality, increased erosion, and habitat loss for water-dependant species. For these reasons, establishing riparian buffers is often considered a crucial element to protect water resources from the adverse effects of adjacent land use.

Riparian buffers have been defined as the areas adjacent to flowing water that contained both aquatic and terrestrial ecosystems. This definition has since been expanded to include areas surrounding wetlands and estuaries as well (PENTEC 2001). Buffers provide many benefits to aquatic systems such as improving water quality, moderating stream flow, and establishing wildlife habitat for water-dependent wildlife species, many of which are protected by regulations.

Buffers are a key factor in protecting and preserving Florida's rivers, streams, and wetlands. They maintain a unique position in the landscape representing the transition between aquatic and terrestrial habitats and provide a wide range of ecological benefits (Anderson and Masters 1992). These complex ecosystems function to improve water quality, regulate hydrology, and protect habitat for fish and wildlife that might otherwise be compromised by adjacent land uses.

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5.6.2.1 Water Quality

Natural water resources are often found in close proximity to agricultural lands, industrial facilities, and commercial and/or residential developments. Inevitably, the utilization of these areas increases the accumulation of sediments, nutrients, and other pollutants within stormwater runoff that can be harmful in excess amounts. The vegetation and soils within riparian buffers however, can reduce these inputs before they reach surface waters (Castelle *et al*. 1992).

Sediment, Nutrient, and Pollutant Removal

The vegetation within buffer zones reduces the velocity of runoff from uplands allowing sediments, nutrients, and other pollutants to settle out before reaching the rivers, streams, and wetlands (Anderson and Masters 1992). Studies have shown that the vegetation and soils within a buffer can, depending upon the width, absorb 50 percent to 100 percent of sediments and nutrients (Connecticut River Joint Commissions 1998).

Buffers can be especially beneficial in areas of Florida where agriculture is the primary form of land use. Agricultural practices result in the presence of phosphorus and nitrogen from fertilizers and animal wastes (Connecticut River Joint Commissions 1998). Excessive quantities of nitrogen and phosphorus in the water are quickly taken up by phytoplankton, often resulting in algal blooms. These blooms block needed sunlight and reduce the dissolved oxygen content in the water, adversely affecting aquatic ecosystems and the wildlife species dependant upon them (WNR 2005). When buffer soils and vegetation are present, this nutrient input is significantly reduced.

Plants require phosphorus for growth and it is often used in fertilizers. Phosphorus binds to soil particles and is relatively immobile as it is gradually utilized by vegetation. When erosion occurs, the soil particles wash into the waterways and the excess phosphorus, attached to the soil, is released into the water (WNR 2005). Buffer vegetation slows water velocity and traps soil particles and the associated phosphorus before it enters the waterway (Klapproth and Johnson 2000). As much as 80 percent to 85 percent of phosphorus can be removed as sediment is filtered from runoff as it passes through the buffer (Connecticut River Joint Commissions 1998).

Nitrogen is also a key component in fertilizers used for agriculture. In many cases, the nitrogen is applied in quantities higher than plants can utilize. Unlike phosphorus, nitrogen is soluble and the excess can leach into ground water (Klapproth and Johnson 2000). Excess nitrogen that does not absorb into the soil can enter surface waters as it is washed off the lands during heavy rain events.

Excess nitrogen, in addition to contributing to algal blooms, can also be toxic to aquatic animals when found in high levels, and can lead to human and livestock health concerns (WNR 2005). Nitrogen is commonly found in runoff waters as nitrate (NO^{3-}), the most oxidized chemical form in natural systems. Humans ingest nitrate from food and water where it is steadily absorbed in the digestive tract and excreted in the urine (Zublena *et al*. 1993). Infants under six months of age have bacteria in their digestive tracts that convert nitrate to nitrite, which is toxic. When nitrite enters the bloodstream, it reacts with hemoglobin and forms the compound methemoglobin. This compound reduces the blood’s ability to transport oxygen (Zublena *et al*. 1993). As oxygen levels decrease, infants show signs of suffocation and a bluish tint to the skin, and if not detected in time, this condition can eventually lead to death.

Nitrite poisoning can also occur in ruminant (four-compartment stomach) livestock such as cattle and sheep (Zublena *et al*. 1993). Similar to human infants, the bacteria in the first compartment of the stomach convert nitrate to nitrite. In livestock, when the nitrite binds with hemoglobin to form methemoglobin, high levels of the compound can result in a lack of coordination, labored breathing, spontaneous abortion, and reduced milk production.

Vegetated buffers provide a medium for denitrification, the process of converting nitrate into nitrogen gas that is released into the atmosphere. Denitrification requires specific soil conditions often found in buffers, which include a high or perched water table with alternating aerobic and anaerobic cycles, populations of appropriate bacteria, and available amounts of organic carbon. (Klapproth and Johnson 2000). Denitrication results in the permanent removal of excess nitrogen before it can enter the surface water.

Nitrogen can also be removed through uptake from vegetation and soil microbes in the buffer that utilize it to promote plant growth. Forested buffers are often the most useful in removing the excess nitrogen before it contaminates surface water because long roots can take up nitrogen that has leached deep into the soil and ground water supply.

5.6.2.2 Stream Flow Moderation

Large fluctuations in the water level of rivers, streams, and wetlands can cause erosion, the destruction of native vegetation, and increased flooding. Buffers function to moderate stream flow and thereby decrease the occurrence of these undesirable effects.

Erosion Control

Roots and vegetative cover in the buffer zone bind to soil sediments that occur along the edges of rivers, streams, and wetlands. Sediment binding contributes to bank and wetland edge stability. The vegetation and woody debris reduce flow velocities, thus reducing erosion. The reduced water velocity also promotes sediment deposition that is necessary for creating river and stream banks (Connecticut River Joint Commissions 1998). In Florida, where boating is a frequent activity, buffers are even useful in reducing the effects of wake, which can destroy bank vegetation and eventually lead to erosion, by deflecting wave action (Connecticut River Joint Commissions 1998).

Native Vegetation

Buffers also protect native vegetation at the edges of rivers, streams, and wetlands by moderating stream flow. Native vegetation at the edges of water bodies is a critical source of food and shelter for fish and wildlife. When native vegetation is destroyed by extreme fluctuations in water levels, nuisance and exotic vegetation can quickly establish in its place. The presence of nuisance and exotic vegetation can be detrimental to wildlife that is dependant on native vegetation for food or nesting (PENTEC 2001).

Nuisance and exotic vegetation spreads aggressively and can rapidly create a vegetative monoculture in wetlands that can deter wildlife. In Florida for example, the federally endangered Everglade snail kite (*Rosthramus sociabilis plumbeus*) is a species of hawk that is being adversely affected by nuisance and exotic species. The snail kite is uniquely adapted to a diet that almost exclusively consists of freshwater apple snails (*Pomacea paludosa*) (FWS 1986). The snail kite feeds entirely by sight in open freshwater marshes where the large snails occur near the surface of the water.

Many of these marshes in the snail kite's historic range are now infested with nuisance and exotic water hyacinth (*Eichornia crassipes*). Water hyacinth, native to South America, was introduced into Florida in the 1880s**.** Its growth rate is among the highest of any plant known and population size can double in as little as 12 days, forming dense mats on the water's surface (FWS 1986). Because snail kites rely on open water for hunting, the marsh quickly becomes unusable. Significant hyacinth infestation in Florida marshes has reduced the number of areas suitable for snail kites to feed, which in turn, has contributed to the population decline (FWS 1986). Establishing native buffers around these marshes would protect native vegetation and reduce the likelihood of hyacinth infestation.

Flooding Effects

In addition to reducing erosion and sustaining native vegetation, buffers are useful in lessening the effects of flooding. The vegetation and woody debris within the buffer zone reduce flood water velocities. The decrease in flood water velocity allows some of the water to percolate through the soil and enter underground storage areas (Anderson and Masters 1992). This can significantly reduce the height of flood waters downstream.

5.6.2.3 Wildlife Function

Buffer zones provide food and shelter for a variety of animal species. Many of these species utilize both aquatic and upland habitats during the course of their lifetime. For example, bald eagles (*Haliaeetus leucocephalus*) require large pine trees in upland areas for nesting but feed predominately in open waters of rivers, streams, and wetlands. Other species that are entirely water dwelling, such as fish and macro invertebrates, also depend on buffers for survival.

Wildlife Corridors

Buffers serve wildlife by establishing wildlife corridors available between habitats, providing nesting, feeding, and breeding grounds, and offering areas of protection from human disturbances (Castelle *et al*. 1992). Wildlife corridors are features that connect two or more otherwise segregated patches of habitat (KFW 2004). These corridors are vital for wildlife to access available habitats and travel safely from one habitat area to another. When traveling between habitats, wildlife can be exposed to predators, areas where there is no food or water, and even fail to locate another area of suitable habitat (American Wildlands 2005).

Buffers play an important role in serving as wildlife corridors by providing suitable vegetative cover between isolated wetlands. Buffer zones between systems create an area of protection from predators and human disturbances, as well as provide feeding and resting grounds for species while traveling.

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One species of particular concern that relies on wildlife corridors is the Florida black bear (*Ursus americanus*), listed as threatened by the State of Florida. The bear requires corridors for shelter as it travels between wetlands where the species often feeds (Parkhurst 1999). Other wildlife species that depend on corridors include small mammals such as raccoons and otters, larger mammals such as deer, Florida panther, and bobcat, and several species of birds, reptiles, and amphibians.

Nesting and Breeding Habitat

The diversity of vegetation and landforms within a buffer provides nesting and breeding habitat for various species of wildlife. Several species in Florida, such as the great blue heron (*Ardea herodias*), require upland or transitional habitat for breeding and nesting, but feed in wetlands (Castelle *et al*. 1992). When buffers are present, they provide the upland and/or transitional grounds for nesting within close proximity to waters for feeding. This ecological benefit attracts wildlife and increases the number of species utilizing the associated water body (Castelle *et al*. 1992).

Buffers also stabilize banks and edge-dwelling vegetation, which provide habitat for macro invertebrates. The vegetation provides adequate cover for the macro invertebrates to lay eggs that sustain populations that are crucial in aquatic food chains.

Water Temperature and Dissolved Oxygen

Riparian buffer vegetation, especially in forested habitat, also improves the water quality environment for aquatic species by providing shading. Shading helps regulate water temperatures by keeping them lower during warmer months. Areas of cooler water tend to retain more dissolved oxygen, which is fundamental in supporting populations of fishes and other aquatic organisms (Castelle *et al*. 1992).

The water quality function provided by buffers reduces excessive nutrient input responsible for causing most algal blooms. The algae are generally short-lived and, as they die off, large masses of decaying material accumulate in the water. This decomposition produces high levels of bacteria that utilize significant quantities of dissolved oxygen, reducing the available amount for fishes and macro invertebrates. When the fish and macro invertebrates die, their decay further compromises the water quality and inevitably affects all species that depend on it. Areas that are protected by buffers tend to have fewer algal blooms and therefore maintain adequate amounts of dissolved oxygen (WNR 2005).

Human Disturbance

One of the most important functions buffers provide to wildlife is to act as a safeguard between the water and human disturbances. Human activity can disrupt breeding, feeding, and nesting of wildlife. This disruption can gradually lead to a reduction in the number and diversity of the species that utilize the area. The buffer helps to filter noise, light, and motion associated with human disturbances (PENTEC 2001).

5.6.2.4 Buffer Width

There is no generic buffer width for regulating water quality, moderating stream flow, and serving as wildlife habitat (Connecticut River Joint Commissions 1998). The appropriate width for a buffer is dependant on the desired function of the buffer. Further, the minimum acceptable buffer width is one that provides the needed level of protection but can also be obtained and managed at a reasonable cost. Numerous studies have shown that a buffer should be *at least* 50 feet wide to be effective (Connecticut River Joint Commissions 1998). Narrower buffers are not clearly recognized because of their small size and are intruded upon by development, recreational activities, and other human disturbances. Even smaller buffer zones with posted boundary signs are ignored because the diminutive area appears insignificant. Further, most protective guidelines focus on the water resource and not the actual buffer and therefore, the significance of the buffer is often overlooked.

Castelle *et al*. (1992) found that nearly all buffers less than 50 feet wide at the time they were established demonstrated a significant decrease in effective size within a few years because of gradual human encroachment and/or lack of appropriate management, both unintentional and intentional.

Currently, the State of Florida only requires a vegetated buffer averaging 25 feet, with a minimum of 15 feet, maintained between the edge of the water and upland activities. Buffer impacts are allowed if supporting information can be proposed to provide reasonable assurance that the construction and associated use will not adversely impact the ecological value of uplands to aquatic or wetland dependent listed animal species (Basis of Review 3.2.7). Based on several studies, this width requirement is not conducive to protecting the majority of Florida's water resources or providing the full scale of buffer functions.

In contrast to this, legislation has been passed to protect buffer areas of the Wekiva River. The Wekiva River is one of the few remaining near-pristine riverine systems in central Florida. Its headwaters begin at the confluence of Wekiva Spring Run and Rock Spring Run and it is a major tributary of the St. Johns River.

An extensive floodplain of hardwood forest, approximately three miles wide in some areas, provides natural habitat for a diverse array of wildlife including several species designated as endangered, threatened, or species of special concern. Threatened plant species are also found along the Wekiva. The Wekiva Watershed with its upland, wetland, and riverine habitats provides an important wildlife corridor connecting thousands of acres of publicly owned conservation land to the Ocala National Forest.

The Wekiva River Aquatic Preserve was established by the Florida Legislature on June 23, 1975 through the Florida Aquatic Preserve Act (Chapter 258.35-258.45, FS). In June 1985, the Legislature passed Senate Bill 762, which expanded the boundary of the Wekiva River Aquatic Preserve to include approximately 20 miles of the St. Johns River.

Citizen efforts to protect the Wekiva River led to the passage of the Wekiva River Protection Act (Chapter 369.301, FS) in 1988 to address the protection of the natural resources of the Wekiva

Basin by establishing the Wekiva River Protection Area, declared to be a natural resource of state and regional importance.

> *Citizen efforts to protect the Wekiva River led to the passage of the Wekiva River Protection Act (Chapter 369.301, FS) in 1988 to address the protection of the natural resources of the Wekiva Basin by establishing the Wekiva River Protection Area, declared to be a natural resource of state and regional importance.*

Development activities within the Protection Area must protect listed species habitat, native vegetation, and rural character including open space, intact woodlands, low density residential areas, farmlands, and agriculture. The Legislature directed Orange, Lake, and Seminole Counties to revise their comprehensive plans and land development regulations by April 1, 1989 to protect the Wekiva River Protection Area. The comprehensive plans are to include restrictions on the clearing of native vegetation within the 100-year floodplain as well as restrictions on filling and altering wetlands in the Wekiva River Protection Area.

5.6.2.5 Buffer Width Determination

Studies have shown that buffer effectiveness increases with buffer width. The width of the buffer should be based on the function and uniqueness of the water resource with which it is associated (Castelle *et al*. 1992). The needs of each ecosystem should be evaluated to determine the necessary buffer width required to provide water quality treatment, stream flow moderation, and/or wildlife habitat.

Water Quality and Stream Flow Moderation

Buffers intended for water quality function and stream flow moderation do not require extensive buffer width. Vegetated buffers, as narrow as 50 feet, can stabilize eroding banks, filter sediment and contaminants from runoff, and reduce the downstream height of flooding (Connecticut River Joint Commissions 1998). The area of interest should still be evaluated to determine how prone it is to water fluctuations and flooding and the ecological value of controlling such events. If the ecological value is significant, then the buffer width should be adjusted accordingly. If needed, a wider buffer would provide greater distance and more vegetation to reduce flow velocities before reaching the water.

> *If the ecological value is significant, then the buffer width should be adjusted accordingly.*

According to Castelle *et al*. (1992), buffer widths effective in preventing significant water quality impacts from nutrients and pesticides should generally be 100 feet or greater. Most pollutants are removed within 100 feet; however, greater widths may be needed for systems with steeper slopes and less permeable soils. The increased width allows runoff to sufficiently absorb into the soil and a greater expanse of vegetation and microbes to convert nutrients and pesticides (PENTEC 2001).

Wildlife

In general, buffers that are proposed to sustain a full range of wildlife habitat functions are greater than those required for water quality or stream flow moderation (PENTEC 2001). In most cases, the width of the buffer depends on the wildlife species present because species have different habitat requirements. Information provided by the Connecticut River Joint Commissions (1998) suggests that 300 feet is generally the accepted minimum to provide feeding, breeding, and nesting grounds for most species. The uniqueness of the wildlife present should be evaluated when buffer widths are considered. For instance, threatened or endangered wildlife are more sensitive to human disturbances and should be provided with a wider buffer to ensure undisturbed breeding and feeding.

In Florida, the widespread loss of wetlands over the past century has greatly reduced the number of wood storks (*Mycteria americana)* and as a result the federal government listed the species as endangered in 1984 (FWS 1996). Therefore, a water body that has wood stork rookeries would be considered highly sensitive and important to protect. Greater buffer width would ensure that the rookery had a sufficient area of little to no disturbance so that nesting and feeding would not be adversely affected by human disturbances.

Buffers that are necessary for shading fish habitat and maintaining dissolved oxygen generally require less width. This function only requires that adequate vegetation be present immediately adjacent to the water. The width of this type of buffer should be based on the width of the stream though wider buffers are known to provide healthier aquatic food chains (Connecticut River Joint Commissions 1998).

5.6.3 Mitigation Potential of Floodplains

5.6.3.1 Introduction

The following section evaluates the mitigation potential of preserving floodplain areas in the Peace River and Myakka River Watersheds. Specifically, this section explores the methods of generating mitigation credits from upland and wetland habitat using the Uniform Mitigation Assessment Method (Chapter 62-345, FAC) and the potential values of mitigation credits in each watershed.

The Uniform Mitigation Assessment Method (UMAM) provides a standardized procedure for assessing the functions provided by wetlands and the amount that those functions are reduced by a proposed impact, thereby quantifying the number of UMAM credits required to offset that loss. Similarly, the UMAM method is used to calculate the number of mitigation credits generated by mitigation activities such as wetland preservation, enhancement, restoration, and creation. The rule also allows the evaluation of uplands for mitigation credit based on the benefits provided to the fish and wildlife of the associated wetlands or other surface waters. This analysis will focus on the generation of mitigation credit by preserving wetland and upland habitat specifically located within floodplain areas.

5.6.3.2 Mechanics of UMAM

UMAM is the mitigation assessment methodology adopted by the State in February 2004. In August 2005, the U.S. Army Corps of Engineers recognized UMAM as an accepted assessment methodology. Application of the UMAM methodology results in an overall wetland score between 0 and 1, with 1 representing full wetland function. Therefore, the overall wetland score can be thought of as a percentage of full function. In simplest terms, UMAM is used to quantify the change in the percentage of value that a wetland provides under either impact or mitigation scenarios. This change is then multiplied by the acreage of the wetland to yield the number of debits or credits. A complete description of the mechanics of using UMAM for the generation of mitigation credits from setting aside buffers is provided in Appendix I.7. This analysis focuses on the nuances of the UMAM methodology and specific examples of mitigation credit generation based on the application of the UMAM rule. Every proposal to preserve upland habitat in the 100-year floodplain must be evaluated on site-specific characteristics such as width, landscape setting, connectivity, habitat quality, and measures to minimize risk factors.

5.6.3.3 Mitigation Credit Value

The preservation examples presented in Appendix I.7 provide forested mitigation credit because the wetland resource involved was entirely forested. Preservation and enhancement of herbaceous wetlands and supporting upland habitat would similarly generate herbaceous credit based on the preservation considerations discussed above. The preservation of mixed wetland systems would generate both forested and herbaceous credits.

The value of UMAM mitigation credits has been established by markets for mitigation credits in the Peace River and Myakka River Watersheds. While the cost of generating mitigation credits can vary widely based on land and restoration costs, mitigation credit prices set a benchmark replacement value for credits. The current market values for credits in each watershed are provided below:

	Peace River watershed	Myakka River Watershed
Forested	$120,000/credit	$135,000/credit
Herbaceous	$ 72,000/credit	$ 90,000/credit

The value of UMAM mitigation credits has been established by markets for mitigation credits in the Peace River and Myakka River Watersheds.

5.6.5.1 Mitigation Value Summary

In the analysis in Appendix I.7, the preservation of upland portions of the 100-year floodplain is an ecologically-beneficial activity that has been shown to generate mitigation credit. Though there are restrictions on the uses of floodplain uplands, they are susceptible to, and are often used for, such activities as cattle grazing, row crops, and phosphate mining. As described above, preservation of a variety of habitat types, cleared or intact, would provide beneficial buffering to the floodplain wetland systems in the region.

To more clearly quantify the range of mitigation credit that can be generated from the preservation and enhancement of upland or wetland floodplain habitat, and the synergy that can be created with a combination of preserving uplands and wetlands together, the following table has been prepared. The table presents a sampling of possible mitigation scenarios and is not meant to represent a comprehensive list of mitigation alternatives, required mitigation criteria, or standardized credit values for specific mitigation activities. The ranges are simply estimates that can be used to explore the value of floodplain mitigation.

The table shows, for example, that preservation of native upland floodplain habitat could generate 0.42 credit per acre. Based on current UMAM credit values for forested wetlands in the Peace River watershed, this equates to a value of $50,400 per acre. Costs to consider include items such as initial fencing and the up-front funding of the perpetual management trust. Preserving forested upland floodplains may represent the best-case example. By comparison, the preservation of pasture in the floodplain would generate only $3,600 per acre. Restoring native cover on the pasture, however, could generate another $27,600 per acre, for a total value of $31,200.

Preservation of native floodplain wetlands could generate $14,000 to $18,000 per acre provided substantial upland buffering is preserved as well. Wetland enhancement would generate slightly more raw value, however enhancement costs would likely offset the difference. It should be noted that wetland preservation without corresponding upland supporting habitat would receive substantially less credit than preservation of a synergistic combination of upland and wetland habitats.

Table 5.1. Summary of Potential Mitigation Credit Generated from Preservation and Enhancement of Floodplain Habitat

Current Condition	Expected Preservation RFG*	Enhancement Activity	Expected Enhancement RFG	Cumulative RFG
Upland**				
Forested with native understory	0.42	High-quality habitat, no enhancement necessary	0.00	0.42
Rangeland	0.17	Remove pasture grasses, remove cattle, seed groundcover, supplemental tree planting	0.17	0.33
Cleared pasture	0.03	Remove pasture grasses, remove cattle, seed groundcover, tree planting	0.23	0.26
Row crop	0.00	Convert to pasture	0.08	0.08
Wetland				
Forested, high quality with upland buffer	0.15	High-quality habitat, no enhancement necessary	0.00	0.15
Forested, high quality without upland buffer	0.05	High-quality habitat, no enhancement necessary	0.00	0.05
Forested, moderate exotic cover with upland buffer	0.13	Remove exotic vegetation	0.05	0.18
Forested, moderate exotic cover without upland buffer	0.04	Remove exotic vegetation	0.02	0.06
Herbaceous, high quality with upland buffer	0.19	High-quality habitat, no enhancement necessary	0.00	0.19
Herbaceous, high quality without upland buffer	0.06	High-quality habitat, no enhancement necessary	0.00	0.06
Herbaceous, hydrologically altered with upland buffer	0.03	Restore hydrology and remove exotic vegetation	0.20	0.23
Herbaceous, hydrologically altered without upland buffer	0.01	Restore hydrology and remove exotic vegetation	0.08	0.09

* Relative Functional Gain (RFG) score can be interpreted as credits/acre (a RFG of 0.15 is the same as 0.15 credits/acre)

** For all upland preservation, it is assumed that adjacent wetland habitat is also preserved and managed

By no means is this analysis comprehensive; it simply provides an approximation of the range of mitigation values possible in floodplain lands. Another critical consideration is that the USACOE does not implement the UMAM rule in the same manner as State agencies. Its decisions on upland and wetland preservation are made on a case-by-case basis. Therefore, less federal credit per acre may be generated by the same mitigation activities.

5.7 Potential Changes and Recommendations

5.7.1 Recommendations for the Peace River watershed Management Plan and Future Actions

The final portion of this section of the Cumulative Impact Study (CIS) proposes a number of actions for consideration in conjunction with the upcoming Peace River watershed Management Plan or future FDEP/SWFWMD programs and actions.

General

- Update the land use change analysis with 2005 aerial photography to measure the rate of change since 1999 under current regulations.

  Environmental regulations were being developed and implemented between 1979 and 1999, the dates of the two sets of aerial photographs from which we made comparisons of land cover. Losses of wetlands were unexpectedly large and raise a question about regulatory effectiveness because one cannot definitively determine whether those losses occurred after protective isolated wetlands protection was phased in. By comparing 1999 land covers to 2005 land covers, however, researchers will be able to assess definitively the effectiveness of wetlands protection regulation.

- Monitor cumulative impacts at the watershed level, not at the individual permit level, and adjust existing or develop new regulatory and non-regulatory programs to minimize or eliminate cumulative impacts of continued development.

  The current regulatory framework has failed to minimize cumulative impacts. One reason for this is undoubtedly the current practice of addressing cumulative impacts for each permit action. This straw-that-breaks-the-camel's-back approach is a mismatch of scales and begs issues of fairness to applicants. The mismatch of scales means it is harder to attribute a cumulative effect to many small users than to find that a single large user may have a cumulative effect. The fairness and efficacy of permitting decisions is questioned, of course, when one user is denied after many have been issued permits. A better approach is the one used by SWFWMD in its SWUCA Recovery Plan. The agency will evaluate permits against rule criteria, while continuously reviewing the resource impacts as a guide for changing the criteria. Should the resource continue to decline, the agency will adjust permitting criteria for all applicants – not simply deny the permit that "breaks the camel's back." This approach relies, of course, on a completely objective analysis of cumulative trends and the periodic adjustment of rule criteria in response to these trends.

- Continue to use voluntary, incentive-based programs, such as Quality of Water Improvement Program (QWIP), Back-Plugging Funding Assistance initiative and Facilitating Agricultural Resource Management Systems (FARMS), to augment regulation, but strengthen the regulatory "backstop" to ensure compliance and equitable distribution of burdens.

> Participation in remedial programs offered by SWFWMD for the Shell Creek, Prairie Creek, and Joshua Creek Watershed Management Plan has been far from universal (about 30 percent of landholdings) and the burden of meeting water quality goals may not, therefore, be equitably distributed. Without a more clearly discernable regulatory alternative for non-participation, many operators are apparently taking a wait-and-see approach. In the event that water quality goals are not met within the management plan timeframe, the regulatory controls implemented as a result will seem severe. This recommendation is to gradually increase the regulatory pressure for participation in an effort to avoid a more severe regulatory outcome that is already authorized under state law in the event that voluntary participation is insufficient to meet water quality goals.

Stopping Wetland and Stream Losses

- FDEP, in coordination with SWFWMD, should audit wetland losses since 1979 to understand how more than 4,000 acres of wetlands were lost to urban development, and over 13,000 acres were lost each to mining and agriculture.

  By example, this study found that more than 4,000 acres that were wetlands in 1979 were converted to urban development by 1999, an amount of wetland loss much higher than permitting records would indicate. By selecting specific instances of these conversions and tracking the parcels through intermediate period aerial photographs, one could learn how these wetlands were converted. There are a number of possibilities:
    - Permitted wetland loss without effective offsetting mitigation
    - Impacts occurred in isolated wetlands before March 31, 1987
    - Delayed effect of drainage not previously regulated
    - Illegal activities not detected by enforcement
    - Use of the agricultural exemption before urban development

  These possibilities, and perhaps others, should be explored on a sample of conversion sites to determine the nature of this regulatory gap.

  Losses to mining and agriculture should be examined to determine whether exemptions have been properly applied and reclamation has been efficacious.

- FDEP, in coordination with SWFWMD, should audit the efficacy of existing regulated wetland mitigation.

  Large wetland losses to highly regulated land uses begs the question of mitigation efficacy. Mitigation is required to avoid cumulative impacts, yet there were over 4000 acres of wetlands lost to urban land uses in the 20 years between 1979 and 1999. While there is the possibility that some acreage losses are justified through the creation, restoration, or preservation of greater wetland function, it seems unlikely that this would be the case for large acreages. This recommendation is to verify the efficacy of a sample of wetland mitigation projects that have been built and determined complete by the permitting agencies.

- FDEP, in conjunction with SWFWMD, should audit changes in wetland acreage on agricultural production lands to ascertain the rate and cause of change in wetland acreage and determine opportunities to work with agricultural operators to minimize the loss and alterations to wetlands and improve base flows from wetlands.

  By auditing a sample of agricultural lands using successive aerial photographs over two decades, one could test some of the macro-scale observations in this report about trends in agricultural drainage. A research approach (non-enforcement) to interview operators about the costs and benefits of maintaining drainage may discover opportunities to store more water on agricultural land by modifying management practices. This could lead to opportunities for agricultural landowners to realize income by meeting the base flow needs for water supply.

- FDEP, in conjunction with SWFWMD, should audit losses in stream channels to understand the dynamics that have allowed 343 miles of loss during a period of increasing regulation.

  The CIS design does not reveal the current rate of stream loss, but comparisons of aerial photographs between 1999 and the present would help quantify the currency of the problem. The audit should be carefully designed to sample specific stream segments that have been lost to determine the cause(s) of their demise and possible approaches to stem these losses. Possible causes of stream loss include:
    - Ineffective mitigation of permitted stream alterations
    - Illegal activities not detected by enforcement
    - Reductions in surficial aquifer by drainage
    - Unintended impacts from ditching and channelization authorized by exemptions

Protecting and Enhancing Public Water Supply

- Pursue mineralization abatement through QWIP, Back-Plugging Funding Assistance, and FARMS to improve the quality of surface water for both aquatic life and water supply.

  This study found that increased mineralization was widespread throughout the middle and lower Peace River watershed, and that the impacts are both to aquatic life and water supply. This recommendation is to pursue mineralization abatement throughout the watershed, not just in the areas were critical water quality problems have been manifested.

- Reinforce the need for water use permit applicants to provide reasonable assurance that water quality standards will be maintained in natural waters affected by the water use.

> While there is ample statutory authorization for considering water quality impacts in the issuance of the water use permit, updating the Basis of Review to reinforce this requirement would be a public service. Applicants rely on water use permits to support their capital investments, and the additional cost to address unexpected water quality concerns can be a hardship.

Phosphate Industry Regulation and Reclamation

- Combine Conceptual Reclamation Plans with Environmental Resource Permits to ensure that wetland mitigation required under the Environmental Resource Permit review is implemented in the best way for long-term resource management.

  > Phosphate regulations for reclamation of wetlands are currently overlapping and conflicting with the beneficial application of ERP mitigation requirements. Because both sets of regulations address the same loss of wetlands, they should be combined and streamlined to be more effective and straight-forward. The ERP standards for mitigation were adopted in 1995 and apply to all activities statewide. They should be adopted in place of reclamation rules originally adopted in 1987 and updated in 2006.

- Develop land planning options to combine mine permits with post-mining land use approvals.

  > Decisions made in the Conceptual Reclamation and Environmental Resource Permits affect the options for land use after phosphate mining. The post-mining economic viability of communities, the quality and quantity of waters, and the possibilities to create beneficial improvements during the reclamation process should be reviewed by all affected parties before the mining is approved. Currently, the Development of Regional Impact review addresses many of these issues, but parties outside of affected regional planning councils are not enfranchised. This recommendation is for a soup-to-nuts review process that addresses phosphate mining and post-mining land use issues.

- Audit FDEP-released mandatory wetland reclamation sites to understand the apparent discrepancy between photo-interpretations and reclamation records (aerial photography is dated 1999, while reclamation records are current through 2006, a seven-year difference).

  > This study identified a gap between the records of completed wetland reclamation and the identification of such from the aerial photographs. There are definite limitations to aerial photo-interpretation, for sure, but the size of the wetland losses in mined watersheds was much larger than expected. This recommendation is for an audit of randomly selected "signed-off" wetland reclamation sites to determine how they compare with the photo-interpretation, as well as whether they represent the quality of wetlands expected from the program.

- Sunrise the Nonmandatory Reclamation Program to allow additional applications for the donation, acquisition, and/or reclamation of Nonmandatory parcels.

  As this study documents, there are unfunded projects in the Nonmandatory Reclamation Program totaling approximately 8,200 acres. According to the FDEP, each of these projects has the potential to improve surface water bodies of regional importance.

- Accept additional applications for parcels whose reclamation is in the public interest to provide significant benefits to surface water bodies supplying water for environmental and public purposes.

  Changed circumstances, including land values, insights from this study, and revised population projections justify re-opening the application process with a revised set of criteria to address long-term concerns about water supply, habitat connectivity, and sustainable tax base.

- Identify Nonmandatory parcels within the Integrated Habitat Network (IHN), and develop a plan for the strategic acquisition of critical parcels.

  Because native habitats are disrupted over large areas by phosphate mining operations, the Integrated Habitat Network is especially important in areas that have been mined. The Nonmandatory Reclamation Program is not specific to the restoration of land for habitat, but where funds from the program can be applied to the IHN, the FDEP needs to acquire strategic parcels to complete critical linkages.

- Identify sites whose current conditions have potential for improving Peace River watershed hydrology.

  This study documents large historical losses in wetlands and stream segments, which have adverse effects on the ability of the Peace River to sustain natural communities and to be a regional water supply. Fortunately, many of these losses are reversible, and this recommendation is to address opportunities to restore hydrology on parcels mined before July 1, 1975.

- Fund the Nonmandatory Reclamation Program to meet current and future needs.

  The funding formula for a sunrised Nonmandatory Reclamation Program should be developed to meet the goals in the above recommendations. New criteria for eligibility will likely be needed to achieve these goals through the Program. The Program addresses only issues related to the lack of reclamation from phosphate mining occurring before July 1, 1975.

Restoring Wetlands to Increase Low Flows

- Identify and prioritize opportunities to restore hydrology (reverse drainage) and re-connect wetlands to the Peace River.

  Over 136,000 acres of wetlands – 10 percent of the watershed – have been lost in the Peace River watershed since the 1940s. The majority of this loss has been from conversion of wetlands to improved pasture, intensive agriculture, or native uplands by the construction of drainage works to lower water tables and reduce the periods of inundation. This loss represents a corresponding loss in the surficial aquifer storage that feeds the base flow of the Peace River. Identifying and prioritizing opportunities to restore a more natural hydrology to these wetlands would be a first step to protect and enhance the long-term base flow of the Peace River. In phosphate mined areas, the opportunity may be to re-connect reclaimed wetlands to the river to provide an extended base flow.

- Create regulatory incentives for the restoration of drained wetlands and non-regulatory incentives to achieve Best Management Practices through cost-share programs.

  Restoring drained wetlands throughout the basin would increase base flows, creating a more natural flow regime and providing more days of "safe yield" for water supply from the Peace River. Most of the drained wetlands are on lands in agricultural production, which rely on permits for irrigation water. This recommendation is to explore ways to combine the goals of Water Use Permitting and Environmental Resource Permitting by providing a regulatory incentive in Water Use Permitting for restoration of drained wetlands. In addition, non-regulatory incentives should be explored to achieve Best Management Practices that promote natural flow regimes and improved water quality.

- Acquire flowage easements and fund restoration of wetland hydrology on private lands.

  This study identified unexpectedly high losses of wetlands both since the 1940s and between 1979 and 1999. These losses were part of a widespread historic conversion of native land to agricultural use. Some evidence in the pattern of reversion of drained wetlands indicates that the economics of drainage that spurred the earlier conversions through construction of drainage works may now be different. If this is the case, there may be an opportunity to work with landowners to acquire flowage easements and reverse drainage works to store more water on agricultural lands. A strictly voluntary program could provide ancillary income to cooperating landowners.

- Develop alternatives to address the drainage rights of landowners adjacent to wetland restoration projects.

  For land that has been legally drained, landowners enjoy a right to the benefits of that drainage. Therefore, restoration of wetlands cannot impair the drainage on adjacent properties. Some restoration projects can become too costly or be deemed ineffective because of the need to protect the drainage rights on neighboring land. This recommendation is to limit the application of those rights to uplands, so that restoration projects could cause *de minimis* changes to drainage patterns on neighboring property. *De minimis* for agricultural land would be defined as any change that would not cause the extent of wetlands on the neighboring property to expand. Typically, this is the temporary storage of stormwater in existing wetlands following exceptionally heavy rain events.

- Develop specific engineering standards for ERP permits to restore wetlands.

  Regulatory agencies typically employ single-event models to predict the changes in runoff after development. These models are convenient and useful in the urban environment for protecting the public from unwanted flooding. This recommendation is to have a continuous model developed, which would be applicable to restoration projects for which the single-event models are inadequate.

Floodplain Protection

- Develop criteria for the protection of uplands within the 100-year floodplain based on the size of the stream protected, the width of wetlands adjacent to the stream, the cover type of the uplands, and the land use context.

  Buffers serve a number of beneficial uses to adjacent streams and wetlands. Protection of uplands within the 100-year floodplain would be generally beneficial to water quality, flood control, and wildlife, but the exact prescription for these upland buffers needs to be developed. Should the protection of upland buffers be just from mining or development, or should it extend to other less intensive uses? What about uplands that have already been converted to pasture? Should the amount and width of upland buffer protection be defined solely by the theoretical 100-year flood level, or by other characteristics like slope, soil type, or vegetation that can be measured on a site? Should the width of an upland buffer reflect the use being buffered from the wetland or stream, should an intensive land use have more buffer than a less intensive land use? These questions should be raised and resolved as criteria for upland buffers.

- Work with Florida Forever program to apply severance tax funds to floodplain acquisition.

  Under the current allocation of severance tax revenues, the CARL program receives $10 million annually. Most of this revenue is generated by phosphate mining within the Peace River watershed, yet only a small amount of these funds are retuned to the watershed as land acquisition. This recommendation is to find a way to return more severance tax money to the Peace River watershed through CARL program acquisitions.

5.7.2 Potential Water Quality/Habitat Related Studies

- FDEP and SWFWMD should conduct a synoptic study of benthic invertebrate and fish populations in the following representative watershed stream systems to compare and contrast the influences of highly mineralized ground water discharges to the biological communities of the receiving streams.

  - Charlie Creek – low/moderate agricultural influences
  - Payne Creek – phosphate and power facility influences
  - Horse Creek – low phosphate mining and moderate agricultural influences
  - Prairie, Shell, and Joshua Creeks – large agricultural influences

  The results of this investigation should be then used to re-evaluate current Class III total dissolved solids and conductivity standards to more fully protect natural in-stream habitat.

- The Florida Fish and Wildlife Conservation Commission (FWC), in cooperation with FDEP and SWFWMD, should update the document “Habitat Reclamation Guidelines: A Series of Recommendations for Fish and Wildlife Habitat Enhancement on Phosphate Mined Land and Other Disturbed Sites.”

- A synoptic watershed-wide study should be conducted to establish baseline in-stream toxic pollutant levels in sediments (trace metals, herbicides, pesticides) against which to assess potential current and future risks.

5.7.3 Development of Additional Hydrologic and Other Data Sources

The Peace River Cumulative Impacts Study included extensive searches and reviews of available data, records, and literature. During the course of this effort, certain data gaps became apparent. Given the comprehensive nature of the study, these identified historic and existing data gaps probably cannot be significantly filled or reconstructed by additional research and analysis. The following recommendations are suggested towards improving the current level of understanding of the Peace River watershed hydrology for future analysis.

Land Use/Land Cover Mapping

- It is recommended that FDEP, SWFWMD, and the phosphate mining industry work together to develop comprehensive detailed GIS information of historic and current active and post-mining land uses.

- SWFWMD should develop land use layers with greater detailed FLUCCS coding in areas of specific identified impacts such as basins with high discharges of mineralized ground water.

Hydrologic Mapping

- Develop better mapping of control structures including elevations and operational details.

- Create enhanced mapping of hydrologic features in active and post-mining areas as well as areas of intense agriculture (ditches, canals, control structures).

Rainfall

- Develop better determinations to quantify the quantity and distribution of rainfall across the Peace River watershed. National Weather Service watershed rain gages have the longest historical records, but the information from these and SWFWMD rain gage data, as well as NEXRAD derived rainfall estimates, needs to be better integrated to determine better basin specific seasonal rainfall estimates.

- Investigate augmentations from irrigation return flows, septic system drainfields, and reclaimed water use. A significant portion of extracted ground water (and surface water) is returned to the hydrologic system in the form of excess irrigation. Little or no actual data is available, and hydrologic analyses depend on estimated fractions of return flow.

Evapotranspiration

- Development of crop and land use coefficients specific to FLUCCS categories in the Peace River watershed (different mining activities, native vegetation types, agricultural practices, and urban land uses).

Karst Losses

- Continue SWFWMD support for USGS investigations quantifying karst losses in the Peace River channel between Bartow and Fort Meade.

- Quantify additional karst losses outside of the river channel (leakage through karst lakes and through other forms of epikarst).

- Field investigations to better understand the character of the karst sinks and conduits (depth, drainage capacity, and relationship to the intermediate aquifer system and the Upper Floridan aquifer system).

Base Flow

- Conduct a more detailed investigation of basin base flows comparing the results from hydrograph separation methods with evidence gathered from field investigations using physical and geochemical methods.

Urban Area Hydrology

- The hydrology and modifications from the previous natural conditions in the urban areas of the Peace River watershed are largely unknown. As the Peace River watershed undergoes accelerated urbanization, an understanding of the hydrologic effects of such development becomes increasingly important.

- Development of hydrological coefficients specific for different urban land use categories (low-density residential and industrial) in different areas of the watershed based on topography and soils.

Irrigation

- Develop details on irrigation methods utilized in urban and agricultural areas in the watershed with specifics on related crop coefficients and application volumes and times.

Water Use

- Better quantify ground water pumping rates enabling enhanced spatial and temporal resolution.

- Continue to examine impacts of land use changes on runoff and base flow contributions to the Peace River with specific emphasis on wetlands loss or structural alterations to wetland and lake flows. The fully integrated surface water/ground water flow model of the watershed currently under development by SWFWMD, along with other research efforts, should be used to better quantify these impacts.

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