APPENDIX A

HYDROLOGY AND HYDRAULICS

This page intentionally left blank

PICAYUNE STRAND ECOSYSTEM RESTORATION

(SOUTHERN GOLDEN GATE ESTATES RESTORATION)

COLLIER COUNTY, FLORIDA

APPENDIX A

HYDROLOGY AND HYDRAULICS APPENDIX

September 2004

This page intentionally left blank

PICAYUNE STRAND ECOSYSTEM RESTORATION
(SOUTHERN GOLDEN GATE ESTATES RESTORATION)
COLLIER COUNTY, FLORIDA

TABLE OF CONTENTS

I LIST OF FIGURES

I. LIST OF FIGURES Cont.

I. LIST OF FIGURES Cont.

I. LIST OF FIGURES Cont.

I. LIST OF FIGURES Cont.

II. LIST OF TABLES

This page intentionally left blank

III. INTRODUCTION

This report presents the basic hydrologic-hydraulic (H&H) data and analyses used to define the feasibility of implementing the hydrologic restoration plan for the Picayune Strand or Southern Golden Gate Estates (SGGE) in Collier County, Florida. It includes the methods, analyses and the results of the H&H assessment of the SGGE landscape under the natural (pre-development) condition, under the existing condition with the anthropogenic influence of roads, canals and water control structures, and under the future condition with the implementation of the SGGE restoration plan as an integral element of the Comprehensive Everglades Restoration Plan (CERP).

IV. DRAINAGE BASIN INFORMATION

A. WATERSHED DESCRIPTION

The Southern Golden Gate Estates project area encompasses an approximately 94 square-mile area of sensitive environmental landscape between Interstate Highway 75 and U.S. Highway 41 (Figure A-1). Located southwest of the Florida Panther National Wildlife Refuge, north of the Ten Thousand Islands National Estuarine Reserve, west of the Fakahatchee Strand State Preserve, and east of the Belle Meade State Conservation and Recreation Land Projects area, the SGGE constitutes the heart of the State of Florida's Picayune Strand State Forest. The historic watershed, including SGGE and part of the Northern Golden Gate Estates (NGGE), included an area of approximately 234 square miles. The generalized overland flow pattern was to the southwest. However, the extent of the historic drainage area (Figure A-2) has been reduced due to construction of roads, canals and urban and agricultural development. The existing Faka Union Canal watershed is approximately 189 square miles containing approximately 70 miles of canals with 12 weir structures, and the majority of the watershed includes a grid-like system of roads spaced every quarter mile. Generalized historic overland flow patterns are illustrated in Figure A-2.

B. TOPOGRAPHY

The topography for this study is referenced to the horizontal datum, 1983 North American Datum (NAD) Florida State Plane East and the vertical datum is referenced to 1988 North American Vertical Datum (NAVD).

The SGGE watershed gently slopes from the northeast at 40 feet to 0 feet NAVD at the southwest corner of the watershed. There are several sloughs that are 0.5 to 2 feet lower in elevation. Most of the roads in the watershed with roadbeds that are 1 to 2 feet above the native topography. With the associated ditches, these roads have sufficient relief to affect the surface runoff.

C. TRIBUTARIES

The Faka Union Canal system is made up of four major tributary canals (Miller, Faka Union, Merritt and Prairie) and extends north from the estuaries of the Ten Thousand Islands nearly to County Road 846, a distance of some 28 miles. The canals are trapezoidal in shape and have an average excavated depth of approximately 10 feet from top of bank to bottom of channel with surface widths ranging from 45 to over 200 feet. Canal discharge records measured at the gauging station located upstream from the outfall weir of the Faka Union Canal are available starting in 1969. The average discharges for the period of record are 115 cfs during the dry season (November through May) and 460 cfs during the wet season (June through October), with an extreme discharge of 3,200 cfs occurring right after the canals were built.

The purpose of the Golden Gate Estates canal system was to (1) provide rapid drainage of surface water, (2) lower the water table to reduce flooding, and (3) provide fill for development. They were made to intercept large volumes of surface flow and quickly divert them to the Gulf of Mexico. The construction of the weirs was intended to prevent overdrainage during the dry season. In spite of the operation of these low-head weirs, the effects of the canals on the area's hydrology have been significant and far reaching. The runoff that once slowly drained as overland sheet flow is now channelized in the canals and released as a point discharge at the south end of the Faka Union Canal. This channelization results in both increased runoff volumes and runoff rates. Less runoff is available for groundwater recharge.

Due to the shallowness of the Water Table Aquifer, the canals have affected the groundwater levels. Since many of the canals are 10 feet or more in depth, there is a direct hydraulic connection between the canal system and the upper portions of the shallow aquifer. Undoubtedly, construction of the GAC canal network has resulted in some drainage of the shallow aquifer, which has caused a general lowering of the groundwater table during the dry season. The water table was lowered 1.5 to 2 feet after the construction of the canals. A field investigation showed a drop in the water table of approximately 2 feet at a distance of 6,000 feet from the canal. After construction of the canals, annual runoff for the Faka Union watershed has increased to about 17 inches. Since the Water Table Aquifer is open to the land surface, it responds very quickly to changes in monthly rainfall, and direct infiltration from rainfall is the main source of recharge. Other sources of recharge are inflow from surface water bodies, such as canals, subsurface flow from adjacent areas, and upward seepage from semi-confined aquifers. Generally, recharge occurs after rainfall events when the canal levels immediately upstream from the weirs are higher than adjacent groundwater levels.

D. SOILS

The soils are poorly drained sandy and loamy soils with varying and intermittent layers of fractured and processed limestone. The limestone is within 50 inches of the surface throughout the watershed. Permeability of these soils is very high. Characteristic of the poorly drained soils of the Pompano-Charlotte association, Ochopee-Broward association, and Freshwater swamp association, these soils are subject to prolonged flooding.

E. LAND USE

The Faka Union Canal watershed is part of Golden Gate Estates Development, and is zoned for single-family residential land use (Figure A-3). Some previously farmed areas in the northern part of the watershed are now zoned residential and commercial. The residential zoning is low density with minimum lot size of 2.25 acres. The remaining area is used for agriculture, predominately truck farming, except in areas of persistent flooding. The most populated areas are north of Alligator Alley (I-75) especially near west of Everglades Boulevard. Telephone and electric services are not available in most areas south of Alligator Alley and the area remains generally undeveloped. A small urban area exists at the extreme southern end of the area called Port of the Islands.

South of Alligator Alley, the majority of the land cover is identified as wetlands. The vegetative community characteristics are described elsewhere in detail in the subsequent sections of this report. The loss of sufficient hydroperiods necessary to sustain wetland vegetation has caused a severe alteration of the historical plant species composition from that of wetland to upland or invasive exotics. As wetlands are drained, the organic soils that support wetland vegetation growth can be destroyed by fire, oxidation, shrinkage, and compaction. In addition, the processes responsible for the formation of these soils cannot take place during a shortened hydroperiod. The long inundation characteristic of cypress forests protects it from fire but once drained, the forests are burned more frequently. This can cause slower growth rates and hinder regeneration. Cypress forests cannot survive or develop in areas with frequent fires. Slash pines are more resistant to fire, and even require fire, to prevent natural succession to a hardwood hammock. Saw palmettos are extremely fire resistant. The more frequent and intense fires in SGGE have resulted in a large part of the previously dominant cypress forest to be invaded by pine and palmettos, and later by exotic species like Brazilian Peppers.

The shortened hydroperiod of wet prairies has resulted in an inhibited growth of periphytic algae, which sustain the small forage fish. Additionally, there is no standing water for these fish. Larger animals, particularly wading birds, cannot survive without this food source. The extensive roadway system in SGGE has resulted in a loss of canopy that has affected understory vegetation, air flows, and temperature. Many species, including some endangered orchids and bromeliads, require exact temperature and/or humidity conditions.

F. HYDROGEOLOGY

The geology of the area consists of a Surficial Aquifer system, Lower Tamiami aquifer and the Sandstone aquifer. The Surficial Aquifer System includes the Water Table Aquifer and some portion of the Lower Tamiami Aquifer that extends down to approximately 80 feet. The Water Table Aquifer is well connected with the canal systems and responds rapidly to rainfall, the only source of recharge, and canal drainage. The Surficial Aquifer System is separated from the lower aquifers by an aquiclude. The Lower Tamiami Aquifer is the primary source of regional public water supply. However, the rapid urban development in Collier County has stressed this aquifer to its safe yield limits, and a lower Mid-Hawthorne formation is now being tapped into for supplemental public water supply by reverse osmosis treatment.

G. REGIONAL FLOWS

It has been estimated that, of the 50+ inches of rain received in western Collier County, historical natural runoff is on the order of 0 to 10 inches annually. Historically, the general water movement can be characterized by slow, overland sheet flow a few inches to a few feet deep and several miles wide. Much of the drainage was concentrated in slightly lower sloughs and strands. The area was regularly inundated by several feet of water during the wet season. During the wet season, overland runoff would be stored in depressional areas and the peak flows would be attenuated and a longer hydroperiod would be maintained well into the dry season. The storage within these wetlands is a part of the hydrology of the watershed. Subsurface flow, groundwater recharge and evapotranspiration are major components in the hydrologic cycle. As the wet season ends and throughout the dry season, water stored in depressions is slowly depleted as it recharges the shallow Water Table Aquifer and is used by vegetation in the evapotranspiration process. This reduces the amount of surface runoff. Since the construction of the canals, the roads and canals largely control the surface flow patterns and the subbasin boundaries.

V. HYDROLOGIC AND HYDRAULIC MODELING FOR RESTORATION

A. GENERAL

The hydrogeology of the SGGE area is unique because the limestone is within 4 feet of ground surface. The drainage canals are within this limestone layer and they have a direct hydraulic connection with the aquifer.

Overdrainage occurs because this limestone layer is part of the surficial aquifer. During the dry season, the rapid rate of runoff caused by the overdrainage depletes groundwater storage, which causes an environmental strain on the ecosystem within SGGE. The swamp and marsh ecosystem has been degraded due to the shortened hydroperiod. To evaluate the effectiveness of the restoration to this area, an integrated surface water groundwater model is required. The proposed project is to environmentally restore the SGGE area. Thus, an enhanced surface water and groundwater flow model was required to simulate the complex interaction of surface and groundwater flow patterns of the watershed. An integrated SGGE model was formulated by the application of the integrated mathematical modeling system MIKE SHE version MIKE ZERO 2003 from the Danish Hydraulic Institute (DHI). The objectives of this modeling effort are to evaluate the effectiveness of the restoration plans re-establishing a wetland hydroperiod for the area, re-establishing historic sheet flow patterns, and reducing the amount of freshwater discharge at the outlet of the SGGE to the downstream estuaries.

The restoration of the SGGE will require flood control analysis and design to ensure that no adverse flooding is incurred to the adjacent areas, which currently utilize the existing canal system for flood control. The hydrologic analysis will be performed for the 10 year, up to the 100-year storm event. The impacts to the adjacent areas, with respect to flood control, will be done with hydraulic analysis.

B. MIKE SHE MODEL

The MIKE SHE modeling system is an integrated and distributed, physically based mathematical model with finite difference computational solution. The model can be applied for continuous simulation of the surface and sub-surface flow conditions over a long period of time. The MIKE SHE model application on this project is to quantify canal/aquifer interactions, to assess the impact of various water management strategies on flood dynamics, wetland hydroperiods, and water supply within the watershed.

The MIKE SHE modeling system comprises a number of flow modules, which may be combined to describe flow within the entire land-based part of the hydrological cycle. The main components which have been applied in SGGE restoration modeling studies are the MIKE SHE overland flow and channel module (MIKE SHE OC), the MIKE SHE unsaturated flow module (MIKE SHE UZ), the MIKE SHE saturated flow module (MIKE SHE SZ), the MIKE SHE evapotranspiration module (MIKE SHE ET), MIKE SHE irrigation demand module (MIKE SHE IR), the one-dimensional hydraulic model (MIKE 11), and the MIKE SHE pre- and post-processing modules (MIKE SHE PP). The simulation methods of these components are described below, and presented in Table A-1.

1. MIKE SHE Overland Flow / Channel Flow Module

The overland flow and channel (OC) component of the MIKE SHE model determines the sheet flow runoff and concentrated flow. The model calculates surface runoff as two-dimension flow of water over the watershed. The surface runoff is controlled by the slope, surface roughness and ponding. The land slope is determined by the surface topography. The topography remains the same for all simulation scenarios with the exception of the description of the changed physical features. The surface roughness is a function of the vegetation. Surface detention storage results from small depressions and irregularities in the relief of the landscape. Water ponds in these depressions until a threshold is met and surface runoff begins.

2. MIKE SHE Unsaturated Zone Module

Water movement through the soil is calculated by the Unsaturated Zone (UZ) component of MIKE SHE. The UZ component computes flow and water content in the soil from the ground surface to the water table. Infiltration and percolation are calculated using soil physical properties of the soil. The properties include hydraulic conductivity and the soil moisture characteristic's curve. These data are specified in a database for each soil horizon of each soil type in the watershed.

3. MIKE SHE Evapotranspiration Module (ET)

Vegetation cover determines ET, which is the primary component of water loss in the watershed. It is the combination of evaporation from soil and water surfaces and the transpiration of water from plants. Two vegetation parameters, leaf area index and the rooting depth are used by MIKE SHE to calculate actual evapotranspiration. The leaf area index is a measure of the area of transpiring surface and the rooting depth determines the volume of soil from which moisture can be extracted. These two parameters are provided as monthly values, for each vegetation cover type used in MIKE SHE.

4. MIKE SHE Saturated Flow Module

Landscape drainage and interflow are important components of the watershed hydrology that contribute flow to the canals and the wetlands. Groundwater flow is calculated in the Saturated Zone (SZ) component of the MIKE SHE model. The groundwater flow and potential heads are computed using the standard finite-difference solution scheme. Water table aquifer information, such as bottom elevation, horizontal and vertical hydraulic conductivities, and storage coefficient, are the major input data in the model.

C. MODEL DOMAIN

The domain of the Big Cypress Basin (BCB) regional integrated model (Figure A-4) covers a 1200 square-mile area of the Faka Union Canal and Fakahatchee Strand Watershed. This model domain is set up on a 1500 feet by 1500 feet grid that has 6171 computational cells per layer. The model is set up in the State Plan NAD 1983 Florida East coordinates and NAVD 1988.

D. INPUT DATA AND MODEL SETUP

An extensive database of meteorological and land-based hydrologic-hydraulic data was utilized for the development of the BCB model. Some of the major input parameters are:

1. Meteorological Data

The driving forces for the integrated model are rainfall and evapotranspiration (ET). Continuous records of rainfall for the study area are available at 20 rainfall stations (Figure A-5) for a 13-year period of record (1988-2000). The objective was to run the model for typical weather data and runoff conditions for hydrologic restoration. The conditions modeled represent the hydrologic conditions for average, wet, and dry years in southwest Florida, which are 1994, 1995, and 2000, respectively. The measured rainfall from the 20 stations (Figure A-5) was spatially distributed with the triangulation method, Triangular Irregular Network – 10 (TIN –10). This method divides daily rainfall estimates into 2 mile by 2 mile grid cell into 10 by 10 sub-cells, thus the sub-cell size becomes 1056 feet by 1056 feet (Figure A-6). For a given day, a TIN is built whose vertices are rain gauge locations with non-missing values. For a given 2 mile by 2 mile grid cell, the above TIN is used to interpolate rainfall at the centroids of each of the 100 sub-cells covering that cell. The average of the 100 rainfall values is represented as the daily rainfall for a 2 mile by 2 mile cell. The operation is repeated to generate daily rainfall records for the entire model period.

Evapotranspiration accounts for the bulk of water loss from the modeling area. Water is lost to the atmosphere by evaporation from plant surfaces, evaporation from free water surfaces, by soil evaporation, and through transpiration from the plant root zone thereby reducing water available for runoff and groundwater flow. Two vegetation parameters, leaf area index and the rooting depth (Table A-2), are used by MIKE SHE to calculate actual evapotranspiration.

The BCB model requires a measure of daily potential evapotranspiration (ET). Measured potential ET rates are not available. Typically, the potential ET is calculated from weather data and adjusted for vegetation type, soil conditions, and time of growing season. It is also possible to use the measured data from evaporation pans in a humid, semi-tropical environment to estimate wet marsh potential ET. The estimation of the wet marsh potential ET for the BCB model was performed by the SFWMD Simple Method, which computes the long-term historical (1965-2000) wet marsh potential ET from the evaporation stations in the model domain (Figure A-5). Due to the difference in the roughness characteristics between marsh and grass surfaces, the crop coefficients developed were modified for use with wet marsh potential ET. Additionally, five National Oceanic and Atmospheric Administration (NOAA) stations with daily temperature data for long-term (1965-2000) were thoroughly checked and patched to correct systematic errors, trends, and missing values with the purpose of producing the best possible temperature dataset for ET parameters and ET estimates. The spatial distribution of the wet marsh potential ET values for the model domain was performed by the TIN-10 method across the five evaporation stations. A summary of the statistics of the wet marsh potential evapotranspiration for those NOAA stations is shown on Table A-3.

2. Land Use

The MIKE SHE land use distribution map (Figure A-3) in the BCB model was developed from the SFWMD 2000 land use Geographic Information System (GIS) coverage. The standard utilized for compiling this data was the Florida Land Use, Cover and Forms Classification system developed by Florida Department of Transportation Procedure No. 550-010-001-a, dated September 1985, Second Edition. The 2000 land use coverage contains 300 different land use types, which have been simplified into 23 vegetation cover classes that are hydrologically different. These codes have been used to convert land use into the MIKE SHE grid coverage using Table A-4. Additionally, pre-development (Natural) condition shown on Figure A-7 was developed into a digital vegetation coverage from the 2001 South Florida Water Management District Soil Classification Database. Future 2060 land use information was adapted from the Collier County Comprehensive Plan. Two future land use conditions were considered for this study, one with State (Florida) ownership of SGGE (Figure A-8) and the other condition without State (Florida) ownership, where the lands within SGGE were not acquired (Figure A-9).

3. Topographic Data

The ground surface elevation was interpolated to a 1500 feet grid based on topography generated from the USGS quadrangle data. However, this data was enhanced Lidar survey data (2000) from Collier County and USACE cross sectional surveys gathered in the Golden Gate Estates canal system (2003). The interpolated topographic digital grid input map is presented in Figure A-10. Overland detention storage also represents small depressions and irregularities in the surface; e.g., small ponds, which are not captured by the topographic maps. Ponded water will accumulate in depressions and local ponds until a certain topographic threshold is exceeded. This is expressed by the detention storage coefficient in the overland flow component.

4. Canal Network – Hydraulic Data

Channel flows in the BCB model are described by the 1-D hydrodynamic river/flood model MIKE 11, which is coupled dynamically to the integrated hydrologic MIKE SHE model. Input for the model consists of the canal network, as illustrated in Figure A-11, surveyed cross sections, appropriate boundary consistent with actual surface boundaries and bed resistance. Moreover, flow regulation structures such as culverts, bridges, and control gates that may significantly alter or modify river flows and stages are specified as input to the model. Finally the rivers exchange water with underlying aquifer. This may either be described entirely by the aquifer material properties or by a river lining leakage coefficient.

Cross sections in the MIKE 11 model were converted from existing BCB UNET model, which was developed by Dames & Moore (1995). As an improvement to the MIKE 11 model, an additional 150+ canal cross sections, weir, bridge and culvert structure details were gathered along the Miller, Faka Union, Merritt, and Prairie canals. The operational control structures in the basin model (Figure A-11) were specified according to the South Florida Water Management District - Big Cypress Basin Water Control Manual. Table A-5 gives the operational schedules of water control structures on the canal systems in the BCB model. Boundary conditions are specified at free upstream and downstream ends of the river network. Upstream is a zero flow boundary. A tidal stage boundary condition has been applied to all downstream of the channels (Figure A-12).

a. Roughness Coefficients

The bed conveyance factor, or Manning's M, is inversely proportional to the bed resistance, Manning's n, which has been used traditionally for roughness values for river branches and floodplains. The Manning's M is the roughness parameter of the MIKE SHE/MIKE 11 model. Typical Manning's M values for natural stream channels and floodplains range between 5 $m^{1/3}/s$ ($n=0.2\ s/m^{1/3}$) and 35 $m^{1/3}/s$ ($n=0.029\ s/m^{1/3}$) depending on the density of the vegetation in the flow ways. However, some areas of the model, such as Corkscrew Swamp will have values that fall below those values because of their very dense vegetated floodplain. The tradition Manning's n values for the rivers and canals in the BCB model are shown in Table A-6. Those values were based on aerial photographs, site inspections and engineering judgment.

5. Soil Properties in the Unsaturated Zone

The unsaturated zone is defined as extends from the ground surface to the groundwater table. The depth varies throughout the year with groundwater fluctuations. During the wet season, the unsaturated zone may disappear in depression areas where the water table rises above ground. Unsaturated flow in MIKE SHE is computed based on a calculated infiltration and simplified Richard's equation, and thus depends on a number of soil properties such as hydraulic conductivity, soil retention, residual soil moisture, and water content at field capacity (Table A-7). These data are specified in a database for each soil horizon of each soil type in the watershed.

There are over 50 different soil types in Collier County. However, not all of these soils are different hydrologically. An analysis of the runoff and drainage characteristics was conducted using the DRAINMOD model, which was developed by Dr. Wayne Skaggs at North Carolina State University to predict the effects of drainage and associated water management practices on the water table depths, the soil water regime and crop yields. It was determined that soils in Collier County could be classified into six different hydrologic response groups, where each of the six groups a characteristic soil profile was selected and the soil physical data from those horizons is used in the BCB model. The six soil type groups are shown on Table A-8.

The MIKE SHE soil distribution map shown on Figure A-13 was obtained from 2001 South Florida Water Management Soils Database for Collier County. Each of the soil hydrologic response groups was assigned to each soil type. The predominant soil group in each grid cell was assigned to the BCB model grid cell. The soil profile was discretized into small, 10-cm intervals for calculation of flows. There were thin layers in the upper horizon with gradually increasing layers with depth. The soil water flow was calculated for each grid cell.

6. Properties of Groundwater Flow in the Saturated Zone

Groundwater flow and potential head are computed in the BCB model using a 3-D finite-difference groundwater model. The hydrogeology of the area consists of the Water Table Aquifer (Figure A-14), Water Table Basal Confining layer (Bonita Springs Marl Confining Layer) (Figure A-15), the Lower Tamiami Aquifer (Figure A-16), C-1 Confining layer (Upper Peace River Confining Layer) (Figure A-17), and the Sandstone Aquifer (Figure A-18). In the BCB model, the hydrogeology strata divided into three layers:

- Layer 1: The Water Table Aquifer. The water table aquifer is well connected with the canal systems and responds rapidly to rainfall.
- Layer 2: The Lower Tamiami Aquifer.
- Layer 3 - The Sandstone Aquifer.

The hydro-geological parameters specified for each layer in the model include:

- Horizontal and vertical hydraulic conductivities, and
- Confined and unconfined storage coefficients.

Figures A-19 and A-24 illustrate the value and distribution of horizontal and vertical hydraulic conductivity in the three aquifer layers. The range of the hydro-geological parameters values used in the BCB model is listed in Table A-9.

The boundary conditions for the confining layer are an impermeable boundary. The boundary conditions for the three aquifer layers are specified as combinations of constant head and variable head no-flow boundaries. The initial water levels for the aquifer layers are given in Figures A-25 through A-27.

7. Drainage Parameters

Landscape drainage and interflow are important components of the watershed hydrology that contribute flow to the canals and the wetlands. Drainage flow is modeled using the simple linear reservoir approximation and depends on drainage constants, and drainage levels. The drainage area code map is presented in Figure A-28, which was delineated based on land use and subbasin maps. A map of drainage levels (Figure A-29) was prepared by subtracting a drain depth map prepared based on root depth from the topography. The drainage time constant are shown on Figure A-30.

8. Irrigation Data

The main types of irrigation occurring in the model area are residential and agricultural irrigation. The MIKE SHE irrigation module provides a method for assessing irrigation demands based on evapotransporation and crop water demands. Figure A-31 is the irrigation distribution map used in the model. The maximum allowable soil water deficit is used for assessing irrigation demand. The drip irrigation option has been used for the entire domain.

9. Summary of Model Parameters

Table A-9 summarizes the main parameters applied in the BCB model. The simulating process is dominated by a strong interaction between surface water and groundwater components. The model parameters in MIKE SHE/MIKE 11 will, therefore, affect the model results of the particular component in both realms of the surface and groundwater flow phenomena. The effect of changing one parameter, e.g.; in the saturated zone, may have an effect on surface water runoffs, evaporation, irrigation demands, and stage levels in flooded areas etc.

The soil property parameters listed in Table A-10 for the saturated zone including hydraulic conductivity and storage coefficients will mainly affect the general potential head level in the aquifers and the dynamics of water levels. In the upper shallow layers, however, changing these parameters will in turn have an effect on drainage flows to rivers, canal base flow and stages in flooded areas. Drawdowns due to well extraction for public water supply and agricultural irrigation will also be affected.

Drainage depths and time constants are typically also varied during the calibration procedure. Too low drainage depths will produce very flat water levels and may result in a general decrease in simulated water levels far below observed water levels. The drainage depth also affects the volume of groundwater in the rivers and thus has a considerable effect on downstream peak levels in the river system. Drain flow during dry periods, where irrigation typically comes into play, is an indication that drain levels may be too low.

Soil properties in the unsaturated zone including hydraulic conductivity and soil moisture parameters affecting the retention curve and unsaturated hydraulic conductivity have an influence on evapotranspiration rates, groundwater recharge and shallow groundwater levels. In agricultural areas with irrigation, the irrigation demands may be affected and this may in turn influence pumping rates and groundwater levels in the lower aquifers in the dry season.

The evapotranspiration parameters are empirical and are typically kept constant at default values. The main calibration parameter is the root mass distribution, which may change the evapotranspiration distribution over the year.

The roughness or flow resistance of the surface is described by the Manning's M number, which depends mainly on land use. The Manning's M values used in this model ranged from .3 to 28.57 meter$^{1/3}$/second. A number of large roads run through the area impeding overland flow. The major roads may thus be perceived as ridges or walls and can either be included in the model by changing the topography or by using the separated overland flow options in the OC component, the latter option was chosen for the BCB model. Figure A-32 gives overland flow boundary condition and separated overland flow area distribution.

The detention coefficient is a threshold above which surface runoff is assumed to occur and may thus change the contributions of surface water to the rivers and to the subsurface in turn affecting groundwater levels. Similarly the leakage coefficient of the surface and river lining controls the exchange of surface water and groundwater.

The crop water stress factor in the irrigation module ensures that ample water is supplied to agricultural areas and thus has an effect on groundwater levels locally. The threshold value for pumping on the other hand will limit the available water for evapotranspiration and plant growth in the dry season.

E. MODEL CALIBRATION AND VERIFICATION FOR RESTORATION

1. Simulation Control

The simulation of surface and subsurface flow for the integrated BCB MIKE SHE model was performed in different time steps. A maximum time step of 8 hours was used in the saturated zone component, while the overland component and the unsaturated zone solver used a maximum of time step of 4 hours. A time step of 3 minutes was used in the MIKE 11 component throughout the simulation due to the complexity of the model. Default computational control parameters were elsewhere applied in the model.

2. Initial Boundary Conditions

The initial surface water boundary conditions are specified at free upstream- and downstream ends of the river network. Upstream, a flow boundary condition of 3.5 cubic feet per second (cfs) (=0.1 m^3/sec) has been specified for the first five days of simulation decreasing to 0.0 for the rest of the simulation period in order to avoid numerical instability. This flow in the beginning is insignificant and will not effect the whole watershed catchment water balance or runoff.

A tidal boundary condition has been applied at the downstream limit of the rivers that discharge into the Gulf of Mexico. No measurements of tidal data in the area were available from 1988-2000; consequently, values were generated based on older recordings found in the International Hydrographic Organization (IHO) database. The generated values for Little Hickory are assumed to be applicable for the downstream ends of Imperial River, Cocohatchee Canal, Golden Gate Main Canal, Henderson Creek, Faka Union Canal, Fakahatchee Strand and Barron River (SR29).

3. Boundary Condition for Subsurface Flow

For the subsurface flow there is in general an east-west flow gradient towards the coastal zone in the aquifers and as a result a constant head-boundary was applied on the western boundary. A tidal boundary condition would in principle provide more accurate results in terms of modeling the hydro-period in the wetland areas along the coast but sufficient information was not available to generate the time varying head boundary conditions. The northern boundary was set up as a time-varying constant head boundary. Measured groundwater data from wells along the boundary were used, and the time-varying head time series for cells in between locations with measured data were generated using the triangular linear integration. A no-flow boundary condition was specified for the eastern boundary. The boundary conditions for the confining layer are an impermeable boundary. The boundary conditions for the three aquifer layers are specified as combinations of constant head and variable head no-flow boundaries. The initial water levels for the aquifer layers are given in Figures A-25 through A-27.

4. Boundary Condition for the Overland Flow

In the MIKE SHE overland flow module the northern and eastern boundaries were modeled as no-flow boundaries. The default boundary condition in MIKE SHE is a constant head boundary or constant stage level. At the western and southern boundaries a constant water depth of 0.4 inches (10 mm) was applied where water can move freely into the Gulf of Mexico. The 1,500-foot model grid cell size is too coarse to capture fine-scale topographic features that can restrict overland flow. Therefore the proposed levee systems within the model were specified with no-flow boundary conditions.

The overland flow boundary was assigned initially and kept that way in the whole simulation period. Generally the depth of overland flow is considered small and the influence of the overland flow boundary is limited to the adjacent cells.

5. Calibration, Verification and Validation

The BCB Regional model has been calibrated with daily observations for a period from 1995-1999 and verified with hourly observations from the same period.

The input parameters for an integrated MIKE SHE model are listed on Table A-10. In order to simplify the calibration procedure and obtain a well-calibrated model within a reasonable time frame, some restrictions were imposed on the parameters. The number of primary calibration parameters was limited to available field observations, existing calibrated values used in other MIKE SHE models for watersheds located close to the SGGE area and based on representation of scenarios of the model. A number of key calibration parameters have been identified in the BCB model and are listed on Table A-11.

The calibration of the model illustrating the simulated and observed headwater stage and flow at Faka Union Weir No. 1 (FU-1) is presented in Figures A-33 and A-34, respectively. Figures A-35 and A-36 illustrate the groundwater observation wells locations. The results of the simulated and observed groundwater level for well C-690 (just south of I-75 between Miller and Faka Union Canals), and well C-496 (Fakahatchee Strand south of I-75) are shown on Figures A-37 and A-38, respectively.

F. SIMULATION SCENARIOS FOR RESTORATION

Four scenarios representing the natural, existing, no action (2060 land use condition without State ownership of SGGE) and the restored conditions were developed to evaluate the impact of restoration on surface and groundwater flow interactivity. The hydrology of those scenarios was simulated for an average meteorological condition. The 1994 year was considered to have average hydrologic conditions and not considered a hydrologic wet or dry year. The results from the natural systems conditions simulation provide a baseline for determining how well the restoration performed. Comparison between the existing conditions and the restored system provides a measure of how well the proposed plan has improved the hydroperiods of the wetlands.

1. Natural Systems Model

The Natural System Model (NSM) attempts to simulate the hydrologic response of the pre-drainage SGGE using records of rainfall and other climatic inputs. The NSM does not simulate the hydrologic response of the natural system prior to influence by man, but rather its hydrologic response due to the most recent climatic inputs. Although one may wish to recreate pre-development (Natural) hydrologic conditions (Figure A-7) of SGGE, climatic and other data necessary to perform such a simulation do not exist. The use of recent historical records of rainfall and other inputs allow modelers and environmental scientists to make meaningful comparisons between the responses of the current system to that of the natural system under conditions of identical climatic inputs. In this sense, the NSM can be a useful tool for restoring hydrologic conditions of the natural SGGE.

The present landscape of south Florida has been greatly affected by land development, flood control, and water management activities, which have occurred since the early 1990s. The NSM, in its current form, attempts to simulate the hydrologic system as it would function today without the existence of man's influence.

A Southwest Florida Pre-development Vegetation Map was incorporated in the NSM to represent the natural condition shown on Figure A-7. Topography data and geologic formation parameters are the same as existing regional BCB model, except, all of the dominant anthropogenic features like roads, canals and water control structures were removed to represent the historic landscape. The land cover simulated by the NSM is static, i.e., the model does not attempt to simulate vegetation succession.

2. Existing Systems Model

This simulation was developed to show the hydrologic conditions of the existing canals, major roads and water control structures. The wetland and channel system in the Big Cypress Basin is complex due to a large number of natural sloughs and man-made canals with water control structures. The BCB MIKE 11 channel network system includes 14 floodplains, all primary canals, major water control structures (culverts, weirs, gated spillways, etc.), and major bridges on these channels. The channel and floodplain configuration were set up in MIKE 11 with a level of detail that captures the physics of the surface water system, while keeping computational time to a minimum. Due to low relief terrain, floodplains were mainly defined where a specific flow direction could be established. The MIKE SHE overland flow component handles surface runoff in the remaining part of the system where no specific flow direction could be established. During the dry season when the groundwater table is low and the wetland system tends to dry up, the overland flow component will automatically handle flow in the MIKE 11 floodplain areas. Due to scale and computational requirements minor ditches and roads were not included in the model.

3. Future No Action Condition

A future no-action condition was simulated with year 2060 land use data obtained from the Collier County's Growth Management Plan. That plan has slated the SGGE area as a natural resources protection area. Although the population in the NGGE is going to increase, the future land use in the NGGE will still continue as Urban low-density (residential). The continued overdrainage by the canal system has the dominant impact on overall drainage and hydrologic conditions of the NGGE compared to the change in land use classification.

4. Restored Conditions

The planning process for restoring the SGGE project area has developed and evaluated numerous alternatives to formulate an optimized plan that will help achieve desired project objectives without adverse environmental, social, and economical impacts. The Alternatives 1, 2, 3A, 3B, and 3C of the 1996 Study completed by the South Florida Water Management District were not simulated by the integrated model since they were not considered effective. Also, simulation was not performed for Alternatives 4 (I-75 bridge enlargement), 5 (Alternative 3D with different pump sizes), 10 (all Obermeyer weirs), 14 (Obermeyer weirs on 3 canals, Prairie Canal plugged), 15 (Alternative 3D with Miller Canal left in place), 16 (Alternative 3D with Faka Union Canal and Miller Canal left in place) and Alternative 18 (land acquisition and management). It was determined by the project delivery team that these alternatives were not feasible for restoration.

The 2060 future (with State ownership) condition land use was used as the restoration condition for the simulations for Alternatives 3D, 6, 7 (a combination of Alternatives 3C and 6), 8 (Prairie Canal Plugged, Merritt Canal Pump Station, Faka Union Canal widen 100 ft. with Obermeyer Weirs, and Miller Canal with Obermeyer Weirs), 9 (Prairie, Merritt and Miller Canals Plugged, and Faka Union Canal widen 140 ft. with Obermeyer Weirs), 11 (a combination of Alternatives 9 and 3D), 12 (a variation of Alternative 11), 13 (a combination of Alternatives 11 and 12), 17 (Prairie Canal plugged), and 19 (a variation of Alternative 9). Those Alternatives were screened based on minimum restoration benefits and cost effectiveness. It was determined by the Project Delivery Team (PDT) that only the three most cost effective plans that met the threshold of restoration benefits would be further analyzed for maintenance of flood protection policy and regulations. The PDT determined Alternatives 3D, 6, and 12 would be further simulated for maintenance of flood protection. The major features and model conditions for Alternatives 3D, 6, and 12 are described below.

<u>Alternative 3D – Canal Blocks, Spreader Channel, Pump Stations, and Road Removal Plan</u>

Figure A-39 is the plan of Alternative 3D. The model setup for this alternative has the time-varying discharge, water levels, and potential head boundary conditions at a sub-regional scale model. Common features in regional scale model are:

- Remove existing Miller-2, FU-3 and Lucky Lake Weir structures.
- Three pump stations added on the Miller, Faka Union, and Merritt Canals. The 1 percent chance flood event design flows for the pumps stations were 1250 cfs for Miller Canal, 2630 cfs for Faka Union Canal, and 800 cfs for Merritt Canal. The restoration for Faka Union Canal, design flows for the pumps stations were 200 cfs for Miller Canal, 500 cfs for Faka Union Canal, and 160 cfs for Merritt Canal. Only a portion of the flood control pump capacity will be required for restoration.
- Downstream of the pumps, the existing channel cross-sections were replaced by spreader canal cross-sections and floodplain cross-sections extracted from the topography. In the proposed plan, there are 83 canal plugs in the project area. In order to model future conditions when the floodplain is fully established, the blocked portion and its cross sections were modeled as the actual floodplain cross-sections extracted from topography. Floodplain cross-sections were delineated, based on the topography, and were basically added at the location of the existing branches, including Merritt, Miller, Faka Union, and Prairie Canals from downstream of the spreader channels to the junction where the channels become one single main channel, Faka Union Canal. The downstream part of Faka Union Canal was maintained downstream of this point and so was the fixed crest weir, FU-1. As for the spreader channels, the lengths

were set to 4488 feet in Miller Canal, 7040 feet in Faka Union Canal, and 1425 feet in Merritt Canal.

- Due to the one-dimensional MIKE 11 approach, another modification to the setup was made. The main flow direction in the system is from north to south, but flow between the floodplains may also occur. Consequently, floodplain codes were established at the between the canal overbanks to allow for east-west flow, thereby artificially creating one large wetland system.
- Each cell size for the model is 1500 feet by 1500 feet; the minor road widths are generally much smaller than the model cell. It is very difficult to simulate the road removal because of the resolution.

Alternative 6: Partial Canal Blocks on Four Canals, and Road Removal Plan

Figure A-40 is the plan of alternative 6. The model setup for this alternative has the time-varying discharge, water levels, and potential head boundary conditions at a sub-regional scale model. Common features in regional scale model are:

- Filled entire Prairie Canal, the Miller, Faka Union, and Merritt Canals were blocked south of I-75 near Stewart Boulevard, as shown on Figure A-40. There are 46 canal plugs in the project area. In order to model future conditions when the floodplain is fully established, the blocked portion and its cross sections were modeled as the actual floodplain cross-sections extracted from topography. Floodplain cross-sections were delineated, based on the topography, and was basically added at the location of the existing branches, including Merritt, Miller, Faka Union, and Prairie Canals. The canals/sloughs were extended all the way to the Faka Union Bay and have tidal boundary conditions. Floodplain codes were included between the canal cross sections in order to allow water flowing from one flood plain to another.
- Removed existing Miller-2, FU-3, and Lucky Lake Weir structures.

Alternative 12 – Canal Blocks, Pump Stations, Obermeyer Weirs, and Road Removal Plan

Figure A-41 is the plan of Alternative 12. The model setup for this alternative has the time-varying discharge, water levels, and potential head boundary conditions at a sub-regional scale model. Common features in regional scale model are:

- Remove existing Miller-1, Miller-2, FU-3 and Lucky Lake Weir structures.

  Three pump stations added on the Miller, Faka Union, and Merritt Canals. The 1 percent chance flood event design flows for the pumps stations were 2000 cfs for Faka Union Canal and 800 cfs for Merritt Canal. The restoration for Faka Union Canal, design flows for the pumps stations were 100 cfs for Miller Canal, 500 cfs for Faka Union Canal, and 160 cfs for Merritt Canal. Only a portion of the flood control pump capacity will be required for restoration.
- Added three Obermeyer Weirs structures on the Miller Canal. Each structure has been modeled as combined weir and gates. In order to achieve the maximum restoration, the control strategy of these structures was modeled as such: In both wet and dry seasons, the control structures were set to a level corresponding to top of bank elevation at its location. When the water level exceeds this level, the control structures will open. The structures will close when the water level drops below that level. During the storm event, all the Obermeyer gates will be kept completely open corresponding to no restriction of conveyance.
- Downstream of the pumps, the existing channel cross-sections were replaced by spreader canal cross-sections and floodplain cross-sections extracted from the topography. In the proposed plan, there are 64 canal plugs in the project area. In order to model future conditions when the floodplain is fully established, the blocked portion and its cross sections were modeled as the actual floodplain cross-sections extracted from topography. Floodplain cross-sections were delineated, based on the topography, and were basically added at the location of the existing branches, including Merritt, Miller, Faka Union, and Prairie Canals from downstream of the Obermeyer Weirs and spreader channels to the junction where the channels become one single main channel, Faka Union Canal. The downstream part of Faka Union Canal was maintained downstream of this point and

so was the fixed crest weir, FU-1. As for the spreader channels, the lengths were set to 7040 feet in Faka Union Canal and 1425 feet in Merritt Canal.

- Due to the one-dimensional MIKE 11 approach, another modification to the setup was made. The main flow direction in the system is from north to south, but flow between the floodplains may also occur. Consequently, floodplain codes were established at the between the canal overbanks to allow for east-west flow, thereby artificially creating one large wetland system.
- Each cell size for the model is 1500 feet by 1500 feet; the minor road widths are generally much smaller than the model cell. It is very difficult to simulate the road removal because of the resolution.
-

G. MODELING RESULTS FOR RESTORATION

The spatial and temporal distributions of the simulated hydrologic responses on surface and groundwater flow characteristics are illustrated in the following series of graphics and tables. These results represent the hydrologic conditions and differences for natural, existing, future without project, and Alternatives 3D, 6 and 12 the restored condition at the year 2060.

Figure A-36 illustrates 32 monitoring well locations and transects Miller, Faka Union, Merritt and Fakahatchee Strand floodplains.

Figures A-42 through A-46 illustrate the average annual overland flows through those five transects for the average hydrologic year (i.e. Average Year (1994)).

Figures A-47 through A-78 illustrate ground water level hydrographs for the Average Year for the 32 monitoring wells.

Figures A-79 through A-84 illustrate the water depths during an average wet season for the Average Year condition for the natural, existing, future without, Alternative 3D restoration, Alternative 6 restoration, and Alternative 12 restoration conditions.

VI. HYDROLOGIC AND HYDRAULIC MODELING FOR FLOODING

A. EXISTING CONDITIONS

The flood simulation for the Southern Golden Gates Estates (SGGE) project evaluated the proposed changes to the canal network within the SGGE project area and its impacts to the adjacent area outside of the project areas. One of the main project goals was to achieve environmental restoration without adversely impacting the existing level of flood protection in the neighboring areas of the SGGE project. The existing and restored conditions were analyzed for the wet season condition and the 10 year, 25 year, and 100 year storm events. The hydrology of those conditions was simulated for a wet meteorological condition. The results from the existing conditions simulation provided a baseline for determining the level of flooding due to the proposed plan.

This hydrologic-hydraulic assessment of the spatial and temporal distribution of depth and area of inundation was performed within the purview of certain limitations of data and simulating methods of representing the surface and groundwater flow characteristics in an integrated fashion for the SGGE region. Some of these features are discussed below.

There was a time-varying boundary condition applied for the groundwater and channel flow. The default overland flow boundary condition in MIKE SHE is constant stage-level. The value at boundary cells are assigned initially and kept that way for the entire simulation period. It is generally considered that depth of the overland flow is very small and the influence of the overland flow boundary will be mainly limited to the adjacent cells.

The topographic data used in this study were created by interpolation from the compilation of USGS five-foot contour data, two-foot Lidar contour data, and cross-sectional survey data. Although the topographic database was enhanced by recent field survey data, an accurate representation of the topography at the modeled grid level may not have been attained due to the 1500-foot by 1500-foot grid cell discretization. A previous study concluded that micro-topography is the dominant factor causing spatial variation in overland flow depth, velocity, and direction, the measurement and representation of elevation and flow resistance in sufficient detail to be meaningful is essential in modeling the surface hydrodynamics of wetland-type flow. More detailed topographic data was gathered to help verify the final plan during the detailed design stage of the project.

1. Basin Description

The existing Faka Union Canal basin includes SGGE and part of NGGE and is approximately 189 square miles with an integrated canal network that flows through flat urban, agricultural, and swamp lands. The primary canal network is comprised of the Miller, Faka Union, Merritt and Prairie Canals. The predominant land use within the basin is identified as residential estates. An extensive roadway and canal system was installed throughout the basin during initial construction to serve these areas. The NGGE area, north of Interstate 75 (I-75), has undergone rapid residential development. The SGGE area, south of Interstate 75, has little development to date. Historically, the Faka Union canal basin was swampland that contained cypress trees, islands of pine forests, and wet and dry prairie. The storage within these wetlands is the predominant hydrology of the basin. The water flowed overland in a general southwest direction, which was characterized by slow, overland sheet flow a few inches to a few feet deep and several miles wide. In much of the undeveloped land the drainage was concentrated in slightly lower sloughs and strands. As the wet season ended and throughout the dry season, water stored in depressions was slowly depleted as it recharged the shallow water table aquifer and was used by the vegetation in the evapotranspiration process.

a. Land Use

The baseline land use for this analysis was the 2000 SFWMD land use GIS coverage. There were two analyses that the 2000 land use coverage was applied to assess the level of flooding. The two analyses were the Real Estate Takings analysis and the Savings Clause analysis. The Real Estate Takings analysis condition was based on the existing canal system in the year 2004 and the proposed new FU-4 gated spillway structure, which was programmed by SFWMD to be built with FY-04 funds. The Savings Clause analysis condition was based on the date of enactment of that statute, 11 December 2000.

b. Rainfall

It has been estimated that approximately 50+ inches (in.) of rainfall was received annually in western Collier County. The historic natural runoff was approximately between 0 to 10 inches, annually.

The spatial and temporal distributions for the 5-day point precipitation for the 10 year, 25 year, and 100-year return periods are based on extensive frequency analysis of local rainfall data tested with several widely used probability distribution methods.

The South Florida Water Management District (SFWMD) operates some rain gages in the State of Florida and provides technical documentation based on those gages. The SFWMD developed the synthetic rainfall spatial distributions from their Technical Publication EMA # 390 Frequency Analysis of Daily Rainfall Maximum for Central and South Florida, dated 2001 and later modified for the BCB model in June 2003. The spatial distribution for the 5-day point precipitation for the 10 year, 25 year, and 100-year return periods for the BCB model are shown on Figures A-85 through A-87. The SFWMD developed the temporal distribution from 5-day rainfall distribution patterns for three major tropical storms in the recent years at five recording rainfall gage stations in the Collier County. Those rainfall distributions were compared with the SCS Type II (modified for Florida) distribution and another prepared recently for the EAA Storage Reservoir - CERP project. The Collier County tropical storms demonstrated a somewhat distinctly different temporal distribution pattern showing that approximately 85 percent of the five-day total rainfall occurring on the third day and also a much steeper slope than the other rainfall distributions. Therefore, a composite rainfall distribution curve (Figure A-88) was developed using local storm patterns, and was recommended for use in the BCB model.

c. Antecedent Moisture Conditions

The antecedent moisture condition was set 1 month, 1 August, into the 1995 wet season, which was considered a very wet season where approximately 80+ inches of cumulative rainfall was recorded in collier county area. The scenarios for the 10, 25 and 100-year storms were run for 2 months from 1 August to 1 October, which was considered a wet antecedent condition for the storms. The average wet season runs were run for 26 months from 1 June 1993 to 31 July 1995. The hydrology of that time period determined to be an average meteorological condition.

The results for the existing conditions simulation provided a baseline for determining the level of flooding for the Savings and Takings Analyses.

2. Discharge and Stages for Existing Conditions

The peak stage and discharge data for the 100-year frequency were estimated by the MIKE SHE / MIKE 11 at the outlet of SGGE, weir structure FU-1, are shown on Figures A-89 and A-90 for the Takings and Savings Analyses Condition, respectively. At the FU-1 weir the 100 year Taking Analysis condition showed the peak headwater stage and discharge to be 5.2 feet (1.58 meters) and 3426 cfs (97.08 cms), respectively. For the 100 year Savings Analysis condition the peak headwater stage and discharge at the FU-1 weir were 5.2 feet (1.58 meters) and 3433 cfs (97.28 cms), respectively.

The hydraulic modeling of existing flood stages and were compiled by using MIKE SHE/MIKE 11 model. The canals in the Faka Union basin and SGGE study area primarily consist of 4 canals, the Miller Canal, the Faka Union Canal, the Merritt Canal, and the Prairie Canal. These canals convey floodwaters in the north through the SGGE Project area out to the Faka Union Bay and the Ten Thousand Island Estuary of the Gulf of Mexico. The flooded areas for the Existing Conditions are shown on Figures A-159 through A-162 for the Takings Analysis condition for the Average Wet Season Maximum Stage, 10 year storm event, 25 year storm event, and the 100 year storm event, respectively. That condition (Taking Analysis condition) represent proposed new FU-4 weir that is to be built with appropriated funds. The flooded areas Existing Conditions are shown on Figures A-175 through A-178 for the Savings Analysis condition for the Average Wet Season Maximum Stage, 10 year storm event, 25 year storm event, and the 100 year storm event, respectively. That condition (Saving Analysis condition) represent 11 December 2000 baseline condition for the Comprehensive Everglades Restoration Plan (CERP) Programmatic Regulation for the Savings Clause Condition.

3. Calibration, Verification and Validation

The calibration was based on comparisons of measured versus predicted data at 57 groundwater-monitoring locations, 26 river/canal staff gages, and 5 flow gages. Figures A-91 and A-92 show the locations of wells and surface water stations, respectively. Tables A-12 and A-13 present the errors between the recorded and modeled data for the groundwater and surface water stations (stages and flows), respectively. The 2003 BCB model shows a mean error of approximately 1.0 feet. The model error statistics were based on 12-hour time intervals for the groundwater and surface water elevations. The calibration period for the BCB model was from 1995 through 1999.

a. Rainfall

The model was verified and validated by comparing the modeled data to the observed data for two storm events, tropical storm Jerry (August 23-25, 1995) and tropical storm Harvey (September 19-21, 1999). Figures A-93 and A-94 shows the rainfall stations used in the verification, which distributed the observed and synthetic hourly rainfalls with Thiessen Polygons and Tables A-14 and A-15 detail the stations used in the verification runs. Table A-16, illustrates the observed rainfall amounts at those precipitation gages for those two tropical storms. The frequency analysis performed determined those events to be approximately 25-year event for Tropical Storm Jerry (1995) and the 10-year event for Tropical Storm Harvey (1999).

Observed rainfall was used to validate the model. The observed hourly data was compared to the measured daily and hourly values. This comparison was done to confirm that the hourly data is consistent with the daily data that was used during model calibration. Figure A-95 shows the locations of the hourly gages used in the storm validation runs. The stations shown are Cocohatchee Canal Weir #1 headwater (COCO1), Faka Union Canal Weir #1 headwater (FU-1), Faka Union Canal Weir #4 headwater (FU-4), BYCP7 in Miller Canal, and Golden Gate Canal Weir #1 headwater (GG-1). Discharge data was also available for three of those stations, COCO1, FU-1 and GG-1.

b. Initial Conditions and Simulation Period

Initial conditions for both storm validation runs were based on wet season water levels and a warm-up period of 2 months. Use of a 2-month warm-up period was sufficient to minimize the potential effects of poor initial conditions. As a result the simulated stages and discharge were noted to be close to the observed values at most of the observation locations after a couple of weeks of simulation time. The level of accuracy of the initial conditions would have been much more important if hourly data were only available for the storm events and storm verification simulation times were restricted to the actual period of the events. However, the simulation period was extended 2 to 3 months after the storms of interest to ensure that the flood events have sufficient time to travel through the system.

The simulation period for model validation during tropical storm Jerry is from June 1, 1995 to December 25, 1995. The simulation period for model validation during tropical storm Harvey is from July 1, 1999 to December 25, 1999.

c. Results

Tropical storm Jerry occurred from 23-25 August 1995, the rainfall ranged from 3.75 inches at the RSW airport station to 13.83 inches at the Collier County station (Table A-15). A maximum rainfall intensity of 1.30 in/hr was observed at the Golden Gate at I-75 hourly rainfall station during tropical storm Jerry. A maximum synthetic hourly rainfall rate of 2.33 in/hr was used in the model at the Everglades City daily rainfall station during tropical storm Jerry. Validation plots from the three gage stations are shown on Figures A-96 through A-102 with hourly and daily observation data during tropical storm Jerry. Table A-17 shows the statistical error of the 1995 validation event.

Tropical storm Harvey occurred from 19-21 September 1999, the rainfall ranged from 1.37 inches at the Collier WWTP hourly station to 11.45 inches at the Golden Gate at I-75 station (Table A-16). A maximum rainfall intensity of 1.01 in/hr was observed at the Golden Gate Fire Station rainfall station during tropical storm Harvey. A maximum synthetic hourly rainfall rate of 1.86 in/hr was used in the model at the Immokalee daily rainfall station during tropical storm Harvey. Validation plots from the five gage stations are shown on Figures A-103 through A-112 with hourly and daily observation data during tropical storm Harvey. Table A-18 shows the statistical error of the 1999 validation event.

4. Hydrology of Interior Flooding

These analyses address the management of interior surface runoff from areas that are protected by project levees. The US Army Corps of Engineers Hydrologic Engineering Center Interior Flood Hydrology (HEC-IFH) was utilized for the analyses and design of the interior drainage systems. HEC-IFH is a comprehensive computer program that performs most of the components of an interior flooding analysis. It is a framework on which the analyst can model rainfall-runoff, routing, interior area ponding, and gravity outlet performance as a dynamic simulation integrated with the changing flood conditions of the receiving stream.

Various gravity outlet configurations were analyzed for the 10 year, 25 year and 100 year frequency events and the 10 year exterior flood stage hydrographs for the with-project condition were used as a downstream tailwater boundary condition. Figures A-39 through A-41 show the areas protected by levee systems for Alternatives 3D, 6 and 12, respectively. A culvert outlet structures will be required for drainage of 3 of the 5 interior area (6L Ranch Levee, Private Lands Levee, and the Port of the Islands (US 41 North) Levees). All culvert structures will be fitted with flap gate controls. The Private Lands Levee system will be supplemented with a small pump station and a detention basin will be required for the interior storm runoff.

5. Tidal Flooding

The SGGE project area can also be flooded by hurricane tides from the Gulf of Mexico. The 100-year base flood elevation north of Tamiami Trail is 7.0 feet National Geodetic Vertical Datum (NGVD) 1929, which is based on the Flood Insurance Study for Collier County by the Federal Emergency Management Agency (FEMA), dated 3 June 1986. Tidal flooding effects were not considered in the analysis. Tidal flood protection was not within the scope of the environmental restoration project.

B. HYDRAULIC DESIGN

1. Hydraulic Design Criteria

The hydraulic design criteria and procedures used herein are in accordance with standard engineering practice and applicable Corps of Engineers manuals, regulations and criteria relative to design and construction for civil works projects. Engineering criteria adopted to meet special local conditions are in accordance with that previously approved for similar projects.

2. Design Objective

The main design objective was to optimize ecosystem restoration through rehydrating historic wetlands without adversely impacting the adjacent private lands with respect to flood control. The 100-year return frequency event was the maximum stage analyzed for Alternatives 3D, 6, and 12 for this project. Takings and Savings Analyses were performed on those alternatives, with respect to the stage and duration comparison to the existing flood protection levels of the project areas and adjacent lands.

3. Project Features for Alternatives

a. Alternative 3D

This alternative is shown on Figure A-39. The primary features of flood control are pump stations and levees. The primary features of environmental restoration are the canal plugs, pump stations and spreader channels.

i. Pump Stations

Three pump stations have been designed to accommodate restoration and flood control to the area to the north of the project area and I-75. This flood control is based on the existing land use of the area, which is primarily residential. These pump stations will be built on the Miller, Faka Union and Merritt canals and will have the flood control capacities of 1250, 2630 and 800 cubic feet per second (cfs), respectively for flood control. The capacities of those pump station were designed to not adversely impact the existing levels of flood protection up to the 100-year 5-day synthetic storm. These pump stations have been optimized to meet the environmental restoration demands of the project area.

A fourth small 100 cfs pump station will be required for interior drainage to the private lands levee system, PL Levee, at the northwest corner of the project. A 6 acre-foot detention basin will be required for sump and drainage collection requirements.

ii. Spreader Channels

Spreader channels will be located immediately downstream of the pump stations. Figure A-113 shows a typical profile drawing of the pump station with the spreader channels. The pumps have been designed to have discharge pipe free fall into the spreader channels, which would act as a plunge pool for energy dissipation and to aerate the water. The discharge waters would then be conveyed overland to the downstream project area. The spreader canals lengths were optimized for restoration pumping rates. For the Miller, Faka Union and Merritt pump stations the spreader canal lengths will be approximately 4500 feet, 7000 feet and 1400 feet, respectively.

iii. Levees

There will be five project levee segments. The first levee system, 6L Levee, will be near the 6L Ranch in Belle Meade. This site was selected due to the existing levee system in place. However, site investigations to the area determined that the existing levee system would be difficult to rehabilitate. Therefore a new levee system will be constructed adjacent to the restored lands and a seepage collection system will be incorporated between the proposed levee and the existing levee. This levee will protect the lands to the west of that levee from the 100-year flooding due to the proposed project.

The second levee system, PL Levee, will protect the private lands on the boundary with Belle Meade at the northwest corner of the project. The levee system will encircle those private lands to protect the area from the 100 year flooding do to the project. A seepage collection system will be part of the levee system.

The third levee system, 41 N Levee, will be built to protect the private lands on the southern end of the project area, which is just northeast of the FU-1 structure. This area will be encompassed by the proposed levee to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of the levee system.

The fourth and fifth levee systems, 41 W Levee and 41 E Levee, will be built to protect the private lands on the western and eastern banks of the Faka Union Canal just south of US 41 at the Port of the Islands at the southern end of the project area. Those areas will be protected on the backsides with levees to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of these levee systems.

vi. Culverts

Culvert structures are required to provide interior drainage to the protected lands. The 6L Ranch levee has a series of existing culverts through US 41 that allows for the existing drainage to be conveyed downstream and away from the site. However, 6 – 72 inch (in.) corrugated metal pipe (cmp) culverts and 2 – 48 in. culverts with flap gate controls will be require to convey flow on the north side of US 41 (Tamiami Trail) through the 6L Levee. The PL Levee will require 2 – 36 in. cmp culverts with flap gate controls. The 41 N Levee will require 3 – 72 in. culverts with flap gate control at the outfall at the Faka Union Canal and another uncontrolled 3 – 72 in. culvert structure at the entrance into the protected area from US 41. The two levee systems south, 41 W Levee and 41 E Levee, of US 41 adjacent to the Faka Union canal will have a hardened concrete outfall apron to protect against head cutting from the interior drainage ditch discharges.

An additional culvert structure will be required on the southern abutment to connect the east and west borrow canals at I-75. This structure will have 3 - 72 in. cmp with no control. This structure is part of the restoration effort to allow water to flow between the Faka Union Canal and the Miller Canal.

v. Removal of Existing Structures

The Miller-2, FU-3 and Lucky Lake weir structures will be removed. These existing structures are fixed concrete weirs. The Lucky Lake weir has steel plated sluice gates mounted to the crest, which will require additional demolition work.

vi. Removal of Existing Roads

The existing roads within the project area will be removed and degraded to enhance the restoration of sheet flow through the project area. Only the roads to the pump station structures, the private lands levee and the access roads required by the State of Florida Division of Forestry (DOF) for maintenance will remain within the project area.

vii. Canal and Swale Plugs

The existing swales adjacent to the roads and canal within the project area would be filled with plugs. The source material for those plugs would be obtained from the original side cast that exists adjacent to the canals and swales. Additional material for the plugs will be utilized from degrading the roads. It is anticipated that there will not be enough material to completely fill the canals and swales, therefore the plugging was considered the only alternative to enhance sheet flow and flowway restoration.

There approximately 83 canal plugs that are to be placed in the Miller, Merritt, Faka Union and Prairie Canals. The plugs were designed to block conveyance downstream of the pump stations and assist in providing a sheet flow flow regime to that area. The canal plugs also were implemented to assist in elevating the water table along the canals and limit the groundwater drawdown to the adjacent lands.

b. Alternative 6

This alternative is shown on Figure A-40. The primary features of this alternative is road removal and to allow the water to inundate the lower elevation land south of I-75 in the southern region of the SGGE property by plugging canals in that area. This alternative was designed as a passive water management system for flood control and restoration.

i. Pump Stations

A small 100 cfs pump station will be required for interior drainage to the private lands levee system, PL Levee, at the northwest corner of the project. A 6 acre-foot detention basin will be required for sump and drainage collection requirements.

ii. Removal of Existing Roads

The existing roads within the project area will be removed and degraded to enhance the restoration of sheet flow through the project area. Only the roads to the pump station structures, the private lands levee and the access roads required by the State of Florida Division of Forestry (DOF) for maintenance will remain within the project area.

iii. Canal Plugs

The existing swales adjacent to the roads will be filled with the source material adjacent to those swales. The Miller, Faka Union and Merritt canals below Stewart Blvd. and the Prairie canal will be filled with canal plugs. The source material for those plugs would be obtained from the original side cast that exists adjacent to the canals. Additional material for the canal and swale plugs will be utilized from degrading the roads. It is anticipated that there will not be enough material to completely fill the canals and swales, therefore the plugging was considered the only alternative to enhance sheet flow and flowway restoration.

There approximately 46 canal plugs that are to be placed in the Miller, Merritt, Faka Union and Prairie Canals. The plugs were designed to block conveyance downstream of the pump stations and assist in providing a sheet flow flow regime to that area. The canal plugs also were implemented to assist in elevating the water table along the canals and limit the groundwater drawdown to the adjacent lands.

iv. Levees

There will be five project levee segments. The first levee system, 6L Levee, will be near the 6L Ranch in Belle Meade. This site was selected due to the existing levee system in place. However, site investigations to the area determined that the existing levee system would be difficult to rehabilitate. Therefore a new levee system will be constructed adjacent to the restored lands and a seepage collection system will be incorporated between the proposed levee and the existing levee. This levee will protect the lands to the west of that levee from the 100-year flooding due to the proposed project.

The second levee system, PL Levee, will protect the private lands on the boundary with Belle Meade at the northwest corner of the project. The levee system will encircle those private lands to protect the area from the 100 year flooding do to the project. A seepage collection system will be part of the levee system.

The third levee system, 41 N Levee, will be built to protect the private lands on the southern end of the project area, which is just northeast of the FU-1 structure. This area will be encompassed by the proposed levee to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of the levee system.

The fourth and fifth levee systems, 41 W Levee and 41 E Levee, will be built to protect the private lands on the western and eastern banks of the Faka Union Canal just south of US 41 at the Port of the

Islands at the southern end of the project area. Those areas will be protected on the backsides with levees to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of these levee systems.

v. Culverts

Culvert structures are required to provide interior drainage to the protected lands. The 6L Ranch levee has a series of existing culverts through US 41 that allows for the existing drainage to be conveyed downstream and away from the site. However, 6 – 72 inch (in.) corrugated metal pipe (cmp) culverts and 2 – 48 in. culverts with flap gate controls will be require to convey flow on the north side of US 41 (Tamiami Trail) through the 6L Levee. The PL Levee will require 2 – 36 in. cmp culverts with flap gate controls. The 41 N Levee will require 3 – 72 in. culverts with flap gate control at the outfall at the Faka Union Canal and another uncontrolled 3 – 72 in. culvert structure at the entrance into the protected area from US 41. The two levee systems south, 41 W Levee and 41 E Levee, of US 41 adjacent to the Faka Union canal will have a hardened concrete outfall apron to protect against head cutting from the interior drainage ditch discharges.

An additional culvert structure will be required on the southern abutment to connect the east and west borrow canals at I-75. This structure will have 3 - 72 in. cmp with no control. This structure is part of the restoration effort to allow water to flow between the Faka Union Canal and the Miller Canal.

vi. Removal of Existing Structures

The Miller-1, Miller-2, FU-3 and Lucky Lake weir structures will be removed. These existing structures are fixed concrete weirs. The Lucky Lake weir has steel plated sluice gates mounted to the crest, which will require additional demolition work.

c. Alternative 12

This alternative is shown on Figure A-41. The primary features of flood control are pump stations, Obermeyer weirs and levees. The primary features of environmental restoration are the canal plugs, pump stations, Obermeyer weirs and spreader channels.

i. Pump Stations

Two pump stations have been designed to accommodate restoration and flood control to the area to the north of the project area and I-75. This flood control is based on the existing land use of the area, which is primarily residential. These pump stations will be built on the Faka Union and Merritt canals and will have the flood control capacities of 2000 and

800 cubic feet per second (cfs), respectively for flood control. The capacities of those pump station were designed to not adversely impact the existing levels of flood protection up to the 100-year 5-day synthetic storm. These pump stations have been optimized to meet the environmental restoration demands of the project area.

A third small pump station will assist environmental flow southward at the northern most Obermeyer weir structures to convey flows southward into the restoration area when excess water is available. The capacity of this pump station is 100 cfs.

A fourth small 100 cfs pump station will be required for interior drainage to the private lands levee system, PL Levee, at the northwest corner of the project. A 6 acre-foot detention basin will be required for sump and drainage collection requirements.

ii. Spreader Channels

Spreader channels will be located immediately downstream of the pump stations. Figure A-113 shows a typical profile drawing of the pump station with the spreader channels. The pumps have been designed to have discharge pipe free fall into the spreader channels, which would act as a plunge pool for energy dissipation and to aerate the water. The discharge waters would then be conveyed overland to the downstream project area. The spreader canals lengths were optimized for restoration pumping rates. For the Faka Union and Merritt pump stations the spreader canal lengths will be approximately 7000 feet and 1400 feet, respectively.

iii. Levees

There will be five project levee segments. The first levee system, 6L Levee, will be near the 6L Ranch in Belle Meade. This site was selected due to the existing levee system in place. However, site investigations to the area determined that the existing levee system would be difficult to rehabilitate. Therefore a new levee system will be constructed adjacent to the restored lands and a seepage collection system will be incorporated between the proposed levee and the existing levee. This levee will protect the lands to the west of that levee from the 100-year flooding due to the proposed project.

The second levee system, PL Levee, will protect the private lands on the boundary with Belle Meade at the northwest corner of the project. The levee system will encircle those private lands to protect the area from the 100 year flooding do to the project. A seepage collection system will be part of the levee system.

The third levee system, 41 N Levee, will be built to protect the private lands on the southern end of the project area, which is just northeast of the FU-1 structure. This area will be encompassed by the proposed levee to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of the levee system.

The fourth and fifth levee systems, 41 W Levee and 41 E Levee, will be built to protect the private lands on the western and eastern banks of the Faka Union Canal just south of US 41 at the Port of the Islands at the southern end of the project area. Those areas will be protected on the backsides with levees to protect against 100-year flooding due to the proposed project. A seepage collection system will be part of these levee systems.

iv. Culverts

Culvert structures are required to provide interior drainage to the protected lands. The 6L Ranch levee has a series of existing culverts through US 41 that allows for the existing drainage to be conveyed downstream and away from the site. However, 6 – 72 inch (in.) corrugated metal pipe (cmp) culverts and 2 – 48 in. culverts with flap gate controls will be require to convey flow on the north side of US 41 (Tamiami Trail) through the 6L Levee. The PL Levee will require 2 – 36 in. cmp culverts with flap gate controls. The 41 N Levee will require 3 – 72 in. culverts with flap gate control at the outfall at the Faka Union Canal and another uncontrolled 3 – 72 in. culvert structure at the entrance into the protected area from US 41. The two levee systems south, 41 W Levee and 41 E Levee, of US 41 adjacent to the Faka Union canal will have a hardened concrete outfall apron to protect against head cutting from the interior drainage ditch discharges.

An additional culvert structure will be required on the southern abutment to connect the east and west borrow canals at I-75. This structure will have 3 - 72 in. cmp with no control. This structure is part of the restoration effort to allow water to flow between the Faka Union Canal and the Miller Canal.

v. Removal of Existing Structures

The Miller-2, FU-3 and Lucky Lake weir structures will be removed. These existing structures are fixed concrete weirs. The Lucky Lake weir has steel plated sluice gates mounted to the crest, which will require additional demolition work.

vi. Removal of Existing Roads

The existing roads within the project area will be removed and degraded to enhance the restoration of sheet flow through the project area. Only the roads to the pump station structures, the private lands levee and the access roads required by the State of Florida Division of Forestry (DOF) for maintenance will remain within the project area.

vii. Canal and Swale Plugs

The existing swales adjacent to the roads and canal within the project area would be filled with plugs. The source material for those plugs would be obtained from the original side cast that exists adjacent to the canals and swales. Additional material for the plugs will be utilized from degrading the roads. It is anticipated that there will not be enough material to completely fill the canals and swales, therefore the plugging was considered the only alternative to enhance sheet flow and flowway restoration

viii. Obermeyer Weirs

Three Obermeyer weir structures will be required on the Miller canal. The locations of these structures were based on the topography for the area. These structures were sited in areas that would most benefit the restoration goal of enhancing sheet flow through the project area. Between these structures water can be pooled and water can be diverted through the existing swales to hydrate the historic flowways. Under flood conditions these structures can be lowered to give full canal conveyance. The crest elevation of this type of structure has the ability to be adjusted from bank to channel invert elevations.

There approximately 64 canal plugs that are to be placed in the Merritt, Faka Union and Prairie Canals. The plugs were designed to block conveyance downstream of the pump stations and assist in providing a sheet flow flow regime to that area. The canal plugs also were implemented to assist in elevating the water table along the canals and limit the groundwater drawdown to the adjacent lands.

C. PERFORMANCE OF ALTERNATIVES

1. Alternative 3D

a. With Project Conditions

The existing flood conditions north of the project area would not be adversely impacted under Alternative 3D for the Takings and Savings Conditions as shown in the stage hydrographs at chainage points (cross sections) 8716, 21799 and 19788 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm (Figures A-119 through A-136 and (Savings) and A-139 – A-156 (Takings)). Figures A-137 through A-138 (Savings) and A-157 through A-158 (Takings) show the stage hydrographs at various locations within the project area under Alternative 3D for the 100-year storm. The flooded areas for the Takings Analysis condition for Alternative 3D are shown in Figures A-163 through A-166 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm, respectively. The flooded areas for the Savings Analysis condition for Alternative 3D are shown in Figures

A-179 through A-182 for the Average Wet Season Maximum, 10-year storm, 25 year storm and 100 year storm, respectively. The flood recession for a 100-year event of would last for more than 30 days. The pump stations would continually pump through the 30+ day period.

This alternative was selected as the recommended plan therefore, more in depth analysis on the interior drainage and the levee protection design was performed on this alternative.

b. Levee Protection Design

Design water surface elevations within the project area are up to and including the 1% chance flood to prevent from overtopping the levees. The levee profiles for all of the levee systems are shown on figures A-114 – A-118. Events that exceed the design capacity are rare but do occur. In the event of a flood greater than the 1% chance flood overtopping the project levees occur. A portion along the proposed levee has a lower crest elevation. Overtopping reaches of all of the levee systems will be designed in the Detailed Design Phase of this project. The overtopping area will be designated in an area to minimize loss of life and property, as well as, serve to provide warning that the design event has been exceeded.

c. Residual Flooding

Runoff from the protected side of the levees would collect in designated ponding areas and discharge to the flood plain through culverts and/or pumps. The culvert drainage structures would be fitted with flap gate controls that would prohibit flow from the flood plain into the protected areas.

The interior drainage was designed for the 25-year storm using HEC-IFH. The interior runoff was calculated using the Soil Conservation Service (SCS) method. For that analysis Curve Numbers (CN) ranged from 70 to 98. Seepage rates were based on the Darcy Equation, where the average horizontal hydraulic conductivity (k_h) was equal to $3.28x10^{-6}$. The exterior hydrographs were extracted from the MIKE 11/MIKE SHE model. The residual flooded area are shown on plates A-191 through A-195 for all of the levee system, 6L Levee, PL Levee, 41 N Levee, 41 W Levee and the 41 E Levee.

d. People at Risk

Each levee system primarily protects residential communities. The 6L Levee system does protect some farmlands and residential areas. The 41 N Levee, 41 W Levee and 41 E Levee systems adjacent to the Faka Union Canal protect a water treatment facility, commercial and residential properties. The PL Levee system protects residential properties.

Each levee system will have egress for access and emergency evacuation. It is planned that each levee system will use the following evacuation routes. The levee systems adjacent to the Faka Union Canal should use US 41 to SR 29 for evacuation. The PL Levee should use 52nd Ave. to Everglades Blvd. for evacuation. The 6L levee system should use US 41 to CR 951 for evacuation.

2. Alternative 6

a. With Project Conditions

The existing flood conditions north of the project area would be adversely impacted under Alternative 6 for the Takings and Savings Conditions as shown in the stage hydrographs at chainage points (cross sections) 8716, 21799 and 19788 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm (Figures A-119 through A-136 and (Savings) and A-139 – A-156 (Takings)). Figures A-137 through A-138 (Savings) and A-157 through A-158 (Takings) show the stage hydrographs at various locations within the project area under Alternative 6 for the 100-year storm. The flooded areas for the Takings Analysis Condition Alternative 6 are shown in Figures A-167 through A-170 for the Average Wet Season Maximum, 10-year storm, 25-year storm and 100-year storm, respectively. The flooded areas for the Savings Analysis Condition Alternative 6 are shown in Figures A-183 through A-186 for the Average Wet Season Maximum, 10-year storm, 25-year storm and 100-year storm, respectively. The flood recession for a 100-year event of would last for more than 30 days.

This alternative was not analyzed for further in depth analysis on the interior drainage and the levee protection design was performed on this alternative.

b. Levee Protection Design

Levee protection was not fully developed or designed for this alternative because it was not selected as the recommended plan.

c. Residual Flooding

The residual flooding analysis was not fully analyzed or designed for this alternative because it was not selected as the recommended plan.

d. People at Risk

Each levee system primarily protects residential communities. The 6L Levee system does protect some farmlands and residential areas. The 41 N Levee, 41 W Levee and 41 E Levee systems adjacent to the Faka Union Canal protect a water treatment facility, commercial and residential properties. The PL Levee system protects residential properties.

Each levee system will have egress for access and emergency evacuation. It is planned that each levee system will use the following evacuation routes. The levee systems adjacent to the Faka Union Canal should use US 41 to SR 29 for evacuation. The PL Levee should use 52nd Ave. to Everglades Blvd. for evacuation. The 6L levee system should use US 41 to CR 951 for evacuation.

3. Alternative 12

a. With Project Conditions

The existing flood condition north of the project area may be adversely impacted under Alternative 12 for the Takings and Savings Conditions as shown in the stage hydrographs at chainage points (cross sections) 8716, 21799 and 19788 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm (Figures A-119 through A-136 and (Savings) and A-139 – A-156 (Takings)). Figures A-137 through A-138 (Savings) and A-157 through A-158 (Takings) show the stage hydrographs at various locations within the project area under Alternative 12 for the 100-year storm. The flooded areas for the Takings Analysis condition Alternative 12 are shown in Figures A-171 through A-174 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm, respectively. The flooded areas for the Savings Analysis condition Alternative 12 are shown in Figures A-187 through A-190 for the Average Wet Season Maximum, 10 year storm, 25 year storm and 100 year storm, respectively. The flood recession for a 100-year event of would last for more than 30 days. The pump stations would continually pump through the 30+ day period.

This alternative was not analyzed for further in depth analysis on the interior drainage and the levee protection design was performed on this alternative.

b. Levee Protection Design

Levee protection was not fully developed or designed for this alternative because it was not selected as the recommended plan.

c. Residual Flooding

The residual flooding analysis was not fully analyzed or designed for this alternative because it was not selected as the recommended plan.

d. People at Risk

Each levee system primarily protects residential communities. The 6L Levee system does protect some farmlands and residential areas. The 41 N Levee, 41 W Levee and 41 E Levee systems adjacent to the Faka Union Canal protect a water treatment facility, commercial and residential properties. The PL Levee system protects residential properties.

Each levee system will have egress for access and emergency evacuation. It is planned that each levee system will use the following evacuation routes. The levee systems adjacent to the Faka Union Canal should use US 41 to SR 29 for evacuation. The PL Levee should use 52nd Ave. to Everglades Blvd. for evacuation. The 6L levee system should use US 41 to CR 951 for evacuation.

VII. DRAFT OPERATING MANUAL

This Draft Operating Manual is for the recommended plan, Alternative 3D. It describes the proposed operating criteria for structures located in the Southern Golden Gate Estates area and Picayune Strand Project vicinity. All elevations referenced in this Draft Operating Manual are from the 1988 North American Vertical Datum (NAVD 88) unless otherwise stated.

A. INTRODUCTION

This Draft Operating Manual focuses on how this project will function during the operational testing and monitoring phase. This Draft Operating Manual may be modified during the Pre-construction and Detailed Design Phase, as appropriate. This plan includes the flexibility to make incremental changes to the proposed operating criteria throughout the operational testing and monitoring phase to achieve the desired project benefits while maintaining the existing level of flood protection in the NGGE.

The Programmatic Regulations for the Comprehensive Everglades Restoration Plan require that the Operating Manual be consistent with the water reservations or allocations and savings clause provision described in the Project Implementation Report (PIR) and the Project Cooperation Agreement (PCA). This manual was developed based on the hydrologic model used in the Project Assurances Analysis found in Section 12 of the PIR. Structural operations in this manual are based on the hydrologic modeling results for selected plan Alternative 3D. In the development of this manual, the project operators and water managers worked with the hydrologic modelers to develop operating criteria that reflected the intent of the operations represented in the hydrologic model.

This project consists of constructing several project features, including a combination of spreader channels, canal plugs, flow impediment removal, pump stations, levees, culverts and weir structures in the Western

Basin and Big Cypress, Collier County, south of Interstate (I-75) and north of US 41 between the Belle Meade Area and the Fakahatchee Strand State Preserve.

B. GENERAL OBJECTIVES

The purpose of this project is to restore and enhance the wetlands in Golden Gate Estates through enhanced surface water and groundwater flow, re-establish a wetland hydroperiod for the area, re-establish historic sheet flow patterns, and reduce the amount of freshwater discharge at the outlet of the Southern Golden Gate Estate to the downstream estuaries while maintaining the existing level of flood protection in NGGE, and North and South Belle Meade.

Restoration of hydrology will restore vegetation communities, wildlife populations, protected species populations, and the downstream estuary condition to a more historic state. Implementation of the restoration plan will also benefit the water quality of downstream coastal estuaries by moderating the large salinity fluctuations caused by freshwater point discharge of the Faka Union Canal. The plan would also aid in protecting the city of Naples' Eastern Golden Gate well field by improving groundwater recharge.

C. PROJECT FEATURES

1. Existing Project Features

Within the project area there are four basin canals, 8 water control structures and a series of existing culverts. The four basin canals are the Miller, Faka Union, Merritt and Prairie Canals. The eight water control structures are weir structures consisting of 4 various types, 3 fixed crest weirs with operable gates, 2 fixed crest weirs with V-notches, 2 fixed crest weirs with stop logs and 1 fixed crest weir. The purpose of the weir structures is to prevent over drainage. These existing weir structures in SGGE are Miller 2, FU-3, Lucky Lake, Prairie 1, Merritt 1, FU-2, Miller 1 and FU-1.

The series of existing culverts are located in the 6L Ranch levee through US 41 and allows for the existing drainage to be conveyed downstream and away from the site.

2. Proposed Project Features

Recommended plan, Alternative 3D, project features include four pump stations, three spreader channels, 83 canal plugs (Figure A-39), fifteen 72 inch (in.), corrugated metal pipe (CMP) culverts, two 48 in. CMP culverts, two 36 in. CMP culverts and two hardened concrete outfall aprons.

The three spreader channels will be located immediately downstream of each pump station located on the Miller, Faka Union and Merritt Canals, respectively. The purpose of the spreader channels shown on Figures A-39 and A-113) is to act as plunge pools for energy dissipation and to aerate the water discharging from the pump stations. They will also redirect the water from flowing southward within the canals to east and west direction perpendicular to the canals. As the water rises within the spreader channel, the water would overtop the southern, downstream bank of the channel and then flow over the land as sheet flow.

Three of the four pump stations will be located in the Miller, Faka Union and Merritt Canals south of existing structures Miller 2, FU-3 and Lucky Lake, respectively. The capacities of the pump stations, 1250 cubic feet per second (cfs) at the Miller Canal, 2630 cfs at the Faka Union Canal and 800 cfs at the Merritt Canal, were designed to be large enough so that the spreader channels and other construction features would not reduce the drainage of NGGE that is provided by the canals. The fourth pump station will be located at the southeast corner of the Private Lands area in the Private Lands Levee (PL Levee). This Private Lands area pump station will be used to discharge seepage from the PL Levee borrow canal and for flood control purposes.

Existing structures Miller 2, FU-3 and Lucky Lake will be removed. Existing structures Miller 1, FU-2, Merritt 1 and Prairie 1 will remain as non-functional structures. FU-1, an existing weir located south of the SGGE Project will remain as a salt-water barrier and serve as the outflow structure for the SGGE Project.

Six 72 in. corrugated metal pipe culverts and two 48 in. culverts with flap gate controls will convey flow on the north side of US 41 (Tamiami Trail) through the 6L Levee. Two 36 in. cmp culverts with flap gate controls will allow flow through the PL Levee. Three 72 in. culverts with flap gate control will be installed at the outfall at the Faka Union Canal. Three uncontrolled 72 in. culvert structures will be installed at the 41 N Levee and another at the entrance into the protected area from US 41. Three 72 in. cmp uncontrolled culvert structure will be installed on the southern abutment to connect the east and west borrow canals at I-75. This structure is part of the restoration effort and will allow water to flow between the Faka Union Canal and the Miller Canal.

The two levee systems south, 41 W Levee and 41 E Levee, of US 41 adjacent to the Faka Union canal will have a hardened concrete outfall apron to protect against head cutting from the interior drainage ditch discharges.

D. MAJOR CONSTRAINTS

1. Flood Protection

Structural flood protection in the NGGE includes the SGGE canals, which are the Miller, Faka Union, and Merritt canals. The existing infrastructure of drainage systems was never intended to totally eliminate flooding in developed area. While flood protection is not the primary intent of this project, the evaluation of project features and operations does include the analysis of those improvements and their effects on the existing level of flood protection. The project will not adversely impact the existing level of protection, and although it was not a specific goal of the study to increase the level of protection, some ancillary benefits may be achieved. This constraint strongly influenced the features in the restoration alternatives.

2. Storm Events

Hurricane and tropical storm events can occur in the Project area, resulting in tidal flooding and storm surge from the Gulf of Mexico. The 100-year base flood elevation north of Tamiami Trail is 7.0 feet Nation Geodetic Vertical Datum (NGVD) 1929, which is based on the Flood Insurance Study for Collier County by the Federal Emergency Management Agency (FEMA), dated 3 June 1986. During hurricane and tropical storm events storm surges and tidal flooding may reduce the discharge capacity of the SGGE Project due to increased stages downstream of structure FU-1.

3. Availability of Flow from NGGE

The SGGE Project is dependent on flow from NGGE to achieve project objectives. NGGE flows will extend the hydroperiods in the SGGE Project area. In addition, flow fro NGGE on a seasonal basis will affect groundwater recharge in the SGGE Project area. Operations for existing structures may need to be revised to allow for SGGE Project objectives. These revised operations have not been identified at this point and are not included in this manual.

E. OVERALL PLAN FOR WATER MANAGEMENT

The SGGE project conveys water from NGGE to SGGE through Miller, Faka Union, Merritt Canals, and Prairie Canal. The water is then pumped into spreader channels (Figure A-113) that will act as plunge pools for energy dissipation and to aerate the water discharging from the pump stations. These spreader channels will also redirect the water from flowing southward within the canals to east and west directions perpendicular to the canals. As the water rises within the spreader channel, the water would overtop the southern, downstream bank of the channel and then flow over the land southward as sheet flow. As water flows south it will encounter the 83 canal plugs strategically placed throughout the Miller Faka Union, Merritt and Prairie Canals and will spread as sheet flow toward structure FU-1 at the southern extent of the Project. The pump stations on the Miller, Faka Union and Merritt Canals will be used to maintain optimum canal stages upstream of the pump station (Table A-19) maintaining the existing levels of flood protection in NGGE residential areas. The term "optimum" refers to the water levels associated with water management operations resulting from extensive modeling that includes the Big

Cypress Basin Manual of Water Control Structures dated July 2000 (Table A-5). This operations plan was written for the recommended plan shown on Figure A-39.

The Miller Canal is located on the western extent of the project area approximately 2 miles west of the Faka Union Canal and is used to convey NGGE basin and SGGE basin runoff to the south. The Miller Canal runs south from the NGGE area north of I-75 into SGGE and approximately 11 miles south of I-75. The Miller Canal then runs east approximately 2 miles and terminates at the Faka Union Canal. The Miller Canal will contain approximately twenty-six canal plugs used to retard and spread waters, creating an overland flow regime. Existing structures Miller 2 will be removed and Miller 1 will be non functional. An optimum stage of 7.2 will be maintained upstream of the Miller Canal pump station in the Miller Canal during the dry season and an optimum stage of 4.9 will be maintained upstream of the Miller Canal pump station during the wet season. The Miller Canal pump station is located on Miller Canal approximately 2.9 miles south of I-75 and will be used to regulate the stages in the Miller Canal.

The Faka Union Canal runs south from the NGGE area north of I-75 into SGGE and approximately 11 miles south of I-75. The Faka Union Canal then runs east approximately 1 mile and south again, terminating at structure FU-1. The Faka Union Canal will contain approximately eighteen canal plugs used to retard and spread waters, creating an overland flow regime. Existing structure FU-3 will be removed and existing structure FU-2 will be non functional. Existing structure FU-1 will remain functional as a saltwater barrier at the southern extent of the project. An optimum stage of 7.2 will be maintained upstream of the Faka Union Canal pump station in the Faka Union Canal during the dry season and an optimum stage of 4.9 will be maintained upstream of the Faka Union Canal pump station during the wet season. The Faka Union Canal pump station is located on Faka Union Canal approximately 2.9 miles south of I-75 and will be used to regulate the stages in the Faka Union Canal.

The Merritt Canal runs south from I-75 approximately 11 miles then runs west approximately 1 mile and terminates at Faka Union Canal. The Merritt Canal will contain approximately twenty-three canal plugs used to retard and spread waters, creating an overland flow regime. Existing structure Lucky Lake will be removed and existing structure Merritt 1 will remain as non functional. An optimum stage of 8.0 will be maintained upstream of the Merritt Canal pump station in the Merritt Canal during the dry season and an optimum stage of 5.2 will be maintained upstream of the Merritt Canal pump station during the wet season. The Merritt Canal pump station is located on Merritt Canal approximately 1.5 miles south of I-75 and will be used to regulate the stages in the Merritt Canal.

The Prairie Canal begins approximately 1.7 miles south of I-75 and runs south approximately 7 miles then runs west approximately 1.1 miles then south approximately 1.1 miles then west approximately 1 mile and terminates at Merritt Canal. The Prairie Canal will contain approximately sixteen canal plugs used to retard and spread waters, creating an overland flow regime. Existing structure Prairie 1 will remain as non-functional. Stages in the Prairie Canal will remain unregulated.

F. STANDING INSTRUCTIONS TO PROJECT OPERATORS

Once the operational testing and monitoring phase of components of the SGGE Project has been completed, the SFWMD Big Cypress Basin will be responsible for day-to-day water management operations. The SGGE Project is a system of conveyance canals designed to benefit the project area, while maintaining existing flood control. The canal pump stations are operated to maintain optimum stages in canals. The optimum stage essentially represents the regulation of the project for the planned purposes. The optimum levels were derived from extensive modeling based on the Big Cypress Basin Manual of Water Control Structures dated July 2000 (Table A-5). The optimum stages in this manual were analyzed for their effect on flood control, low water regulation, seepage, and fish and wildlife. The minimum levels are set to maintain flood control and enhance conditions within the project area.

During normal conditions the project structures shall be operated in accordance with the approved Operating Manual (Draft and Project) and in accordance with the structure design criteria. Optimum elevations in the plan shall be followed. Deviation from the normal operations will be permitted only under emergency conditions or prior approval.

G. FLOOD DAMAGE REDUCTION

1. Normal Operations

The Miller Canal pump station is a five bay pump station with four 125 cfs pumps and two 375 cfs pumps. The total pumping capacity of the Miller Canal pump station is 1250 cfs. The pump station was modeled with a phased pumping rate based on the surface water elevation at a water stage recorder gage (upstream gage) located at I-75, approximately 3.0 miles upstream of the pump. Pumping rates at the Miller Canal pump station shall be increased incrementally as needed to maintain optimum stages in the canal. During the wet season, pumping at the Miller Canal pump station shall commence when stages at the upstream gage exceed 4.9 feet and terminate when stages at the upstream gage recede to 4.9 feet. During the dry season, pumping at the Miller Canal pump station shall commence when stages at the upstream gage recede to 7.2 feet. A summary of operations for the Miller Canal pump station is shown on Table A-20.

The Faka Union pump station is an eight bay pump station comprised of four 470 cfs pumps, two 250 cfs pumps and two 125 cfs pumps. The total pumping capacity of the Faka Union pump station is 2630 cfs. The pump station was modeled with a phased pumping rate based on the surface water elevation at the upstream gage located at I-75, approximately 2.9 miles upstream of the pump. Pumping rates at Faka Union Canal pump station shall be increased incrementally as needed to maintain optimum stages in the canal. During the wet season, pumping at the Faka Union Canal pump station shall commence when stages at the upstream gage exceed 4.9 feet and terminate when stages at the upstream gage recede to 4.9 feet. During the dry season, pumping at the Faka Union Canal pump station shall commence when stages at the upstream gage exceed 7.2 feet and terminate when stages at the upstream gage recede to 7.2 feet. A summary of operations for the Faka Union Canal pump station is shown on Table A-20.

The Merritt Canal pump station is a two bay pump station comprised of two 80 cfs pumps and three 213 cfs pumps. The total pumping capacity of the Merritt Canal pump station is 800 cfs. The pump station was modeled with a phased pumping rate based on the surface water elevation at an upstream gage located at I-75, approximately 1.5 miles upstream of the pump. Pumping rates at Merritt Canal pump station shall be increased incrementally as needed to maintain optimum stages in the canal. During the wet season, pumping at the Merritt Canal pump station shall commence when stages at the upstream gage exceed to 5.2 feet and terminate when stages at the upstream gage recede to 5.2 feet. During the dry season, pumping at the Merritt Canal pump station shall commence when stages at the upstream gage exceed 8.0 feet and terminate when stages at the upstream gage recede to 8.0 feet. A summary of operations for the Merritt Canal pump station is shown on Table A-20.

The PL Levee system interior drainage pump station is located on the southeast corner of the Private Lands Area. The pump station is comprised of two 50 cfs pumps, one for seepage and one for flood control. The PL Levee system interior drainage pump station was modeled to operate based on the surface water elevations in the levee borrow canal. Pumping at the PL Levee system interior drainage pump station shall commence, for purposes of seepage control, at a rate of 50 cfs when stages in the levee borrow canal exceed 7.8 feet. When stages in the levee borrow canal exceed 8.5 feet the pumping rate shall be increased to a rate of 100 cfs, for purposes of flood control. When stages in the levee borrow canal recede below 8.5 feet the pumping rate shall be decreased to 50 cfs. When stages in the levee borrow canal recede below 7.8 feet pumping shall cease. A summary of pump operations for the PL Levee interior drainage pump is shown on Table A-21.

No pumping shall occur at those pump stations beyond what is shown except by approved deviation as noted in the Deviation From Normal Regulation section of this Manual.

Existing structure FU-4 is a fixed crest weir with operable steel gates. The structure is located approximately 600 feet south of the easterly terminus of 16th Avenue SE, east of Everglades Boulevard in Golden Gate Estates. This structure prevents over drainage from the northern Faka Union Canal basin and provides groundwater recharge to the City of Naples eastern Golden Gate Estates well field. This structure will be modified and relocated approximately 2000 feet south near the terminus of 20th Ave SE and the Faka Union Canal. This structure will be an automated gated, spillway with six vertical roller gates. Each gate will be 10 feet tall and 13.3 feet wide. Each gate will operate independently as needed to maintain the target water stages upstream of the proposed structure (FU-4 New). During the dry season, surface water upstream of FU-4 New will be maintained at an optimum stage of 11.4 to 12.2 feet. During the wet season, surface water upstream of FU-4 New will be maintained at an optimum stage of 11.3 feet. During the dry season gates on FU-4 New shall be opened when stages rise above 12.2 feet and close when stages recede to 11.4 feet or below. During the wet season gates on FU-4 New shall be opened when stages rise above 11.3 feet and closed when stages recede below or are equal to 11.3 feet. A summary of FU-4 New gate operation is shown in Table A-22.

2. Hurricane or Tropical Storm Operations

Water management operations within the SGGE Project area for hurricanes or tropical storms should follow the SFWMD BCB's Emergency Preparedness Manual – Suggested Hurricane Operating Procedures, April 2004. Pre-storm canal drawdowns for the SGGE project may be conducted in conjunction with hurricane and tropical storm operations as described in the Pre-storm Canal Drawdown section of this Manual.

H. PRE-STORM CANAL DRAWDOWN

The hurricane season is from 1 June through 30 November. When there are tropical depressions, tropical storms, and or hurricanes in the Atlantic/Caribbean Basin or Gulf Cost of Florida, the National Hurricane Center (NHC) issues tropical cyclone public advisories, forecast advisories, forecast discussions, and strike probability forecasts. The maximum strike forecast probabilities are 10-15% at 72 hours, 20-25% at 48 hours, 25-35% at 36 hours, 40-45% at 24 hours, and 74-85% at 12 hours.

Pre-storm canal drawdowns may be initiated based upon these NHC products and conditions within the SGGE and NGGE basins. Pre-storm canal drawdown operations should cease once the stage at the upstream control gage of corresponding pump station(s) has reached 0.5 below the optimum stage.

Additional operational guidance for pre-storm drawdown procedures will be provided in the Draft Operating Manual for Operations During Construction and in the Project Operating Manual. The pre-storm drawdown procedures and operational criteria in this Draft Operating Manual are subject to change.

I. CONSISTENCY WITH WATER RESERVATION OR ALLOCATION AND SAVINGS CLAUSE PROVISIONS

This Draft Operating Manual will be consistent with the water reservations or allocations of water and the savings clause provision described in the PIR and the PCA.

This Draft Operating Manual was developed based on the hydrologic model used in the Project Assurances analysis found in Section 12 of the PIR. The project operators and water managers coordinated with the hydrologic modelers to develop operating criteria that reflected the intent of the operations represented in the hydrologic model.

J. WATER QUALITY

The SGGE Project does not have specific water management operations for the purpose of improving water quality. However, an important goal of the project is to improve water quality in the receiving waters of the Ten Thousand Islands Estuary downstream of the SGGE Project, by reducing shock loads of freshwater discharges. This project will reduce freshwater point discharges, and enhance the salinity balance in the Faka Union Bay and nearby estuaries.

K. RECREATION

SGGE Project water management operations do not include operations specifically for the benefit of recreational activities within the Project area.

L. FISH AND WILDLIFE

Other than maintaining optimum canal levels, the SGGE Project does not have specific water management operations to enhance fish and wildlife species. Typical operation of the SGGE Project will provide an enhancement of hydroperiods in the SGGE Project area. The enhanced hydroperiod in their habitat will benefit indigenous animal and plant species as well as assist in the prevention of exotic plant species. Structure operating guidelines currently followed in the project area for manatee protection will be implemented at all relevant structures of the SGGE Project.

M. DROUGHT CONTINGENCY PLAN

The SFWMD Big Cypress Basin drought procedures will be referred to for operations during drought events. The Drought Contingency Plan for the SGGE Project is the Lower West Coast Water Supply Plan, SFWMD, dated April 2000.

N. DEVIATION FROM NORMAL REGULATION

The Jacksonville Corps of Engineers District Engineer may be requested to deviate from the normal regulation procedures for water control structures and canals of the SGGE Project. This request is normally received from the South Florida Water Management District Big Cypress Basin and will be coordinated with appropriate Federal, State, and local agencies. Approval for a deviation is to be obtained from the South Atlantic Division (SAD) of the Corps of Engineers except as noted below. Deviation requests usually fall into the following categories.

1. Emergencies

Some emergencies that can be expected are drowning and other accidents, failure of operation facilities, fire control, and flushing or containment of pollution. Necessary action under emergency conditions is taken immediately unless such action would create equal or worse conditions. The Jacksonville District of the Corps of Engineers shall be informed as soon as practicable. A written confirmation showing the deviation and conditions will be furnished to SAD after the incident.

2. Unplanned Minor Deviations

There are unplanned instances that create a temporary need for minor deviation from normal regulation of the canals, although they are not considered emergencies. Changes in water control structure releases are sometimes necessary for maintenance and inspection. Requests for release rate changes are generally for a few hours or a few days. Each request is analyzed on its own merits. Consideration is given to upstream watershed conditions, potential flood threat and possible alternative measures. In the interest of maintaining good public relations, the requests are complied with, providing there are no adverse effects on the overall regulation of the project for the authorized purposes. Approval for these minor deviations will normally be obtained from SAD by telephone. A written confirmation showing the deviation will be furnished to SAD.

3. Planned Deviations

Each condition will be analyzed on its own merits. Sufficient data on flood potential, groundwater effects, watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes will be presented by letter, telephone, or electronic mail to SAD along with recommendations for review and approval.

O. SEEPAGE CONTROL

A levee borrow canal will be constructed around the interior of the Private Lands levee to control seepage from this feature. The Private Lands levee system interior drainage pump station is located on the southeast corner of the Private Lands Area. The pump station is comprised of two 50 cfs pumps, one for seepage and one for flood control. The Private Lands levee system interior drainage pump station was modeled to operate based on the surface water elevations in the levee borrow canal.

Pumping at the Private Lands levee system interior drainage pump station shall commence, for purposes of seepage control, at a rate of 50 cfs when stages in the levee borrow canal exceed 7.8 feet. Pumping shall continue at a minimum rate of 50 cfs until stages in the levee borrow canal recede below 7.8 feet.

P. WATER CONTROL DATA ACQUISITION SYSTEM PLAN

For the SGGE Project, all operable water control structures will be equipped with remote automation components and operated by use of a remote telemetry system. The automation components of all the structures will eventually be operated and maintained by the SFWMD Big Cypress Basin and must conform to SFWMD standards. Equipment used in data acquisition essential to the water control management function will be included in the Water Control Data Acquisition System Plan. This includes all hardware and software to be used for acquisition, transmission, processing, display, and dissemination of hydrologic, meteorological, water quality, and project data for the purpose of supporting the water control mission. For the SGGE Project this includes, but is not limited to, uninterruptible power supplies, field data collection platforms, and data communication devices and circuits.

The Water Control Data Acquisition System Plan will also identify site location of all hardware included within the plan. Hardware siting will be determined through coordination with appropriate agencies including the U.S. Geological Survey and the Big Cypress Basin. The Water Control Data Acquisition System Plan will be completed during the Plans and Specifications phase and will be a subset of the Water Control Data System that is specific to the SGGE Project.