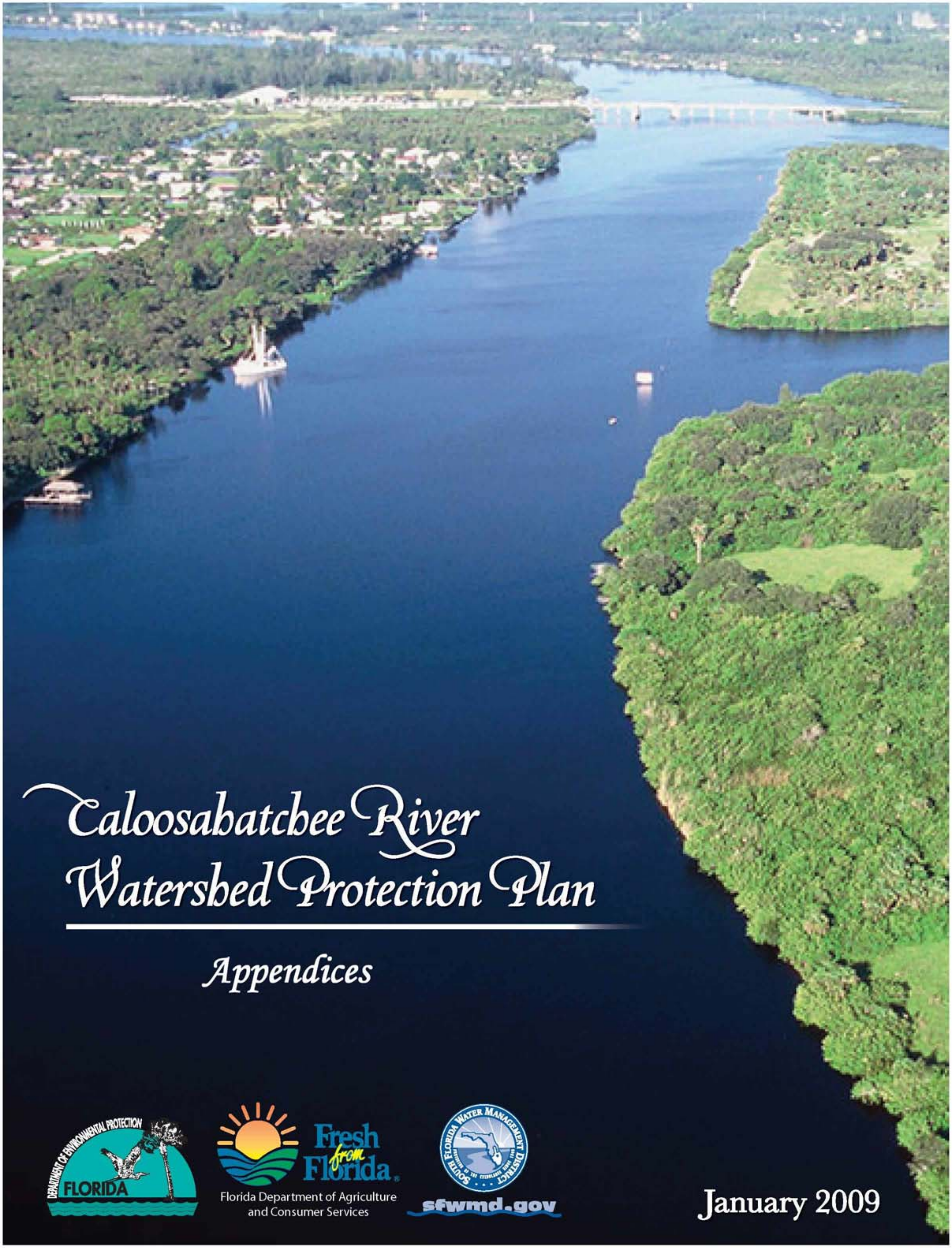

Caloosahatchee River Watershed Protection Plan

Appendices

Florida Department of Agriculture and Consumer Services

sfwmd.gov

January 2009

Caloosahatchee River Watershed Protection Plan

APPENDICES

January 2009

APPENDICES

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APPENDIX A

PERFORMANCE MEASURE AND PERFORMANCE INDICATOR FACT SHEETS

Caloosahatchee River and Estuary Performance Measures

Number of Times Caloosahatchee Estuary High Discharge Criteria Exceeded

Performance Measure: Number of Times Caloosahatchee Estuary High Discharge Criteria Exceeded – Mean Monthly Flows >2,800 cfs and Mean Monthly Flows > 4,500 cfs

Description – The Lake Okeechobee WSE Regulation Schedule is applied to regulate (flood control) discharges to the Caloosahatchee River, and subsequently to the Caloosahatchee Estuary, when lake stages are high. The Caloosahatchee River has primary capacity for local inflows and is only utilized for Caloosahatchee Estuary discharges when there is secondary capacity available. The number of times that the Caloosahatchee Estuary high discharge criterion is exceeded must be limited to prevent destructive impacts on the estuary.

Rationale – Researchers have observed an increased rate of eutrophication in Lake Okeechobee from 1973 to the present. Symptoms of this eutrophication include the following:

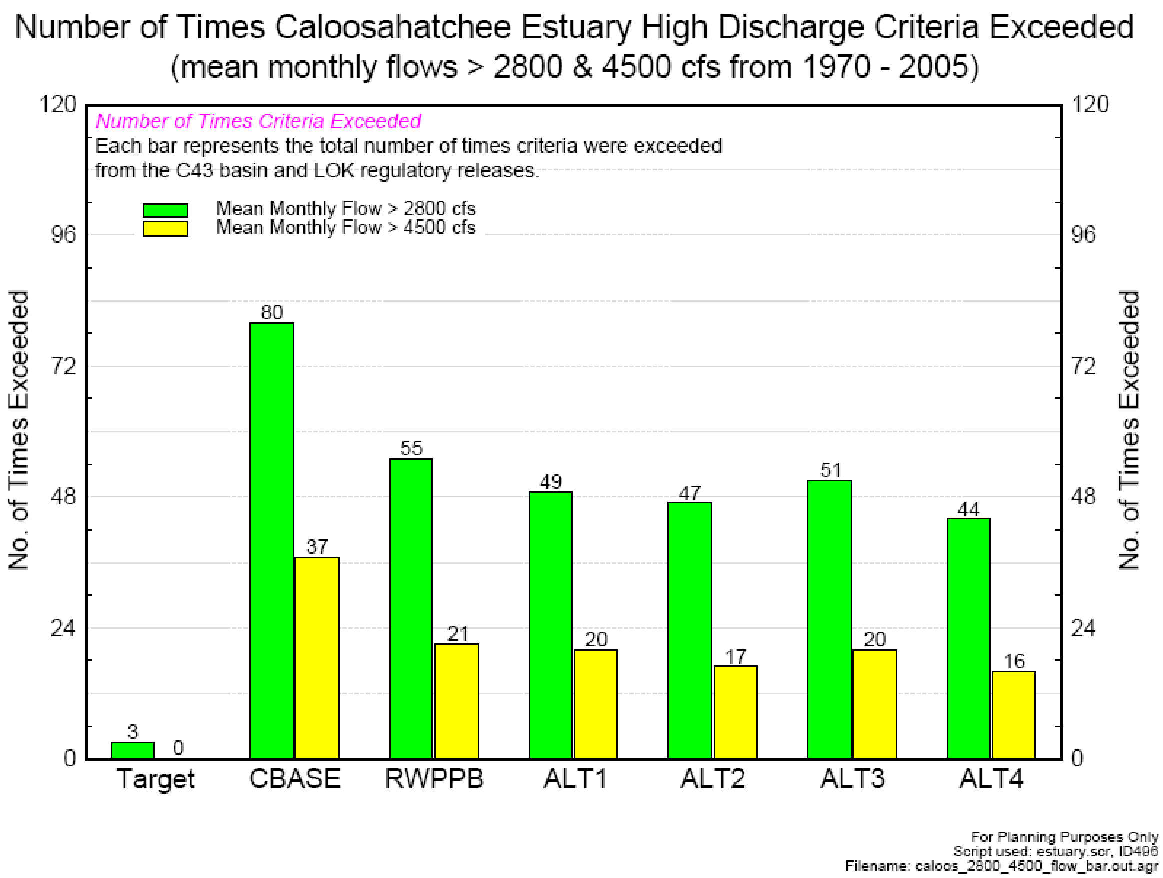
- increases in algal bloom frequency since the mid-1980s (with an algal bloom being defined as chlorophyll-*a* concentrations greater than 40 µg/L) (Maceina 1993, Carrick et al. 1994, Havens et al. 1995b),
- increases in the dominance of blue-green algae following a shift in the TN:TP ratio (Smith et al. 1995),
- increases in the lake water concentration of total phosphorus, and
- increases in average chlorophyll-*a* concentrations (Havens et al. 1995).

Phosphorus is considered to be the key nutrient contributing to the eutrophication of the lake (Federico et al. 1981). Increases in total phosphorus concentrations in the lake, coupled with decreases in nitrogen loading from reduced back pumping from the EAA, have shifted the TN:TP ratio from greater than 25:1 in the 1970s to around 15:1 in the 1990s. This shift has created conditions more favorable for the proliferation of nitrogen-fixing blue-green algae, which are responsible for the blooms occurring in the lake (Smith et al. 1995).

Target – No more than 3 events with mean monthly flows at S-79 greater than 2,800 cfs and no events with mean monthly flows greater than 4,500 cfs.

Evaluation Method – The Northern Everglades Regional Simulation Model (NERSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The number of average monthly S-79 flows between 2,800 cfs and 4,500 cfs will be tallied for each alternative.

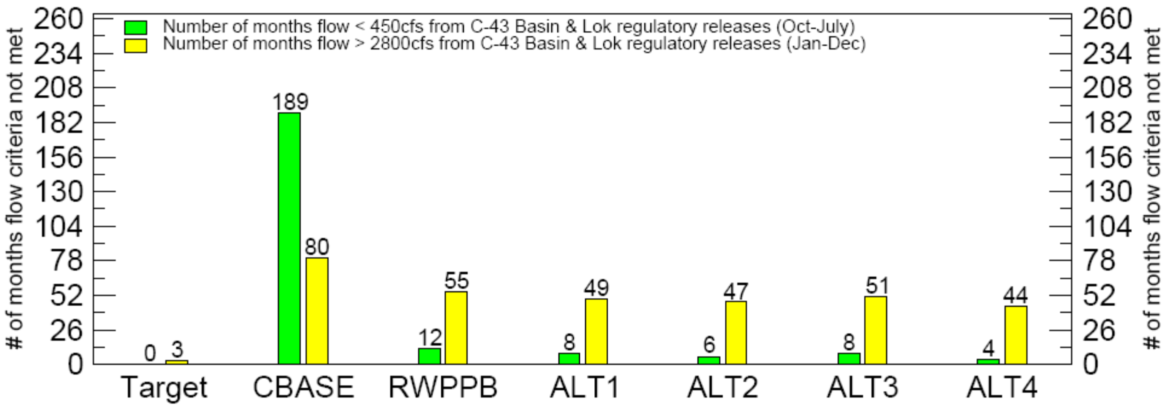
This graphic illustrates the number of times discharge criteria were exceeded from 1970 through 2005. Each bar represents the total number of exceedances from the C43 Basin and Lake Okeechobee regulatory releases.

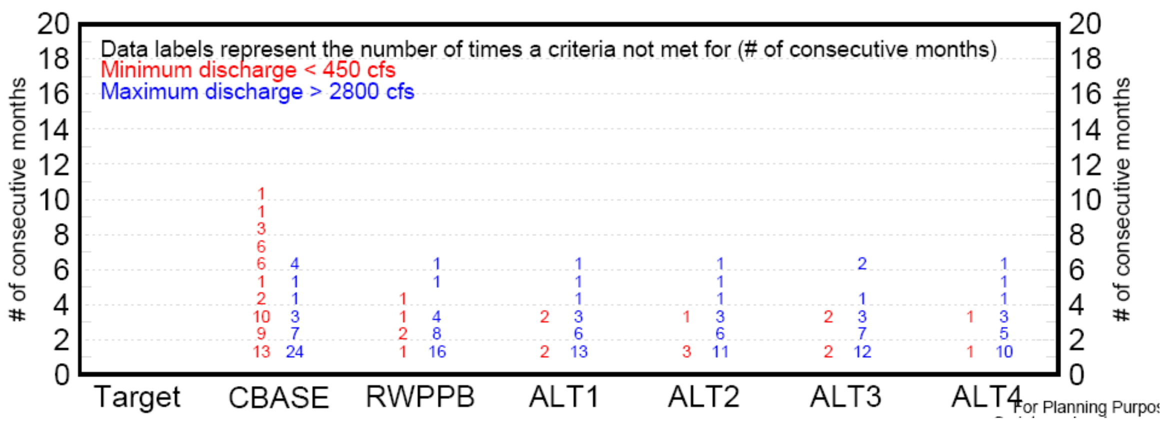


Caloosahatchee Estuary Salinity Envelope

Performance Measure: Number of Times Salinity Criteria Not Met for the Caloosahatchee Estuary – Mean Monthly Flows < 450 cfs and Mean Monthly Flows > 2,800 cfs
Description – A healthy, naturally-diverse and well-balanced estuarine ecosystem can exist only if the salinity regimes are controlled within the desirable range. Lake Okeechobee discharges have a significant impact on how well desirable salinity regimes are maintained in the Caloosahatchee Estuary.
Rationale – Extreme low lake stages prevent water from reaching the submerged aquatic vegetation populating the littoral zone and shoreline regions. Without submerged aquatic vegetation, the habitats of wading birds, reptiles, fish, amphibians, and apple snails are endangered, as these species rely on submerged aquatic plants for foraging and recruitment activities. Invasive plant species, such as torpedo grass and Melaleuca, flourish in times of extreme low lake stage, replacing the original native vegetation. There is no proven method to control torpedo grass, except the use of a general herbicide that kills all surrounding area vegetation. Torpedo grass is poor habitat for fish and other aquatic animals as the growth is so dense there is no room for animal mobility. Nighttime dissolved oxygen levels in the grass have been recorded at zero, a condition that is not suitable for aquatic life. Recovery from the adverse impacts of extreme low lake stage requires multiple years, including the grueling process of re-establishing a healthy submerged aquatic plant community.
Target – Maintain mean monthly flows at S-79 between 450 cfs and 2,800 cfs with no more than 3 events with mean monthly flows greater than 2,800 cfs.
Evaluation Method – The Northern Everglades Regional Simulation Model (NERSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The number of mean monthly flows outside of the desirable range from 450 cfs to 2,800 cfs will be tallied for each alternative.

This graphic shows the number of times the modeled salinity envelope criterion was not met for the Caloosahatchee Estuary. Under the Current Base (CBASE) Condition, average flows of less than 450 cfs occurred in 189 of the 360 months (Note: October through July are the critical months for low flows.) and watershed flows exceeded 2,800 cfs for 80 months of 432 months within the period record. Under the River Watershed Protection Plan Base (RWPPB) Condition, average flows of less than 450 cfs occurred in 12 of the 432 months and watershed flows exceeded 2,800 cfs for 55 times in the period of record.

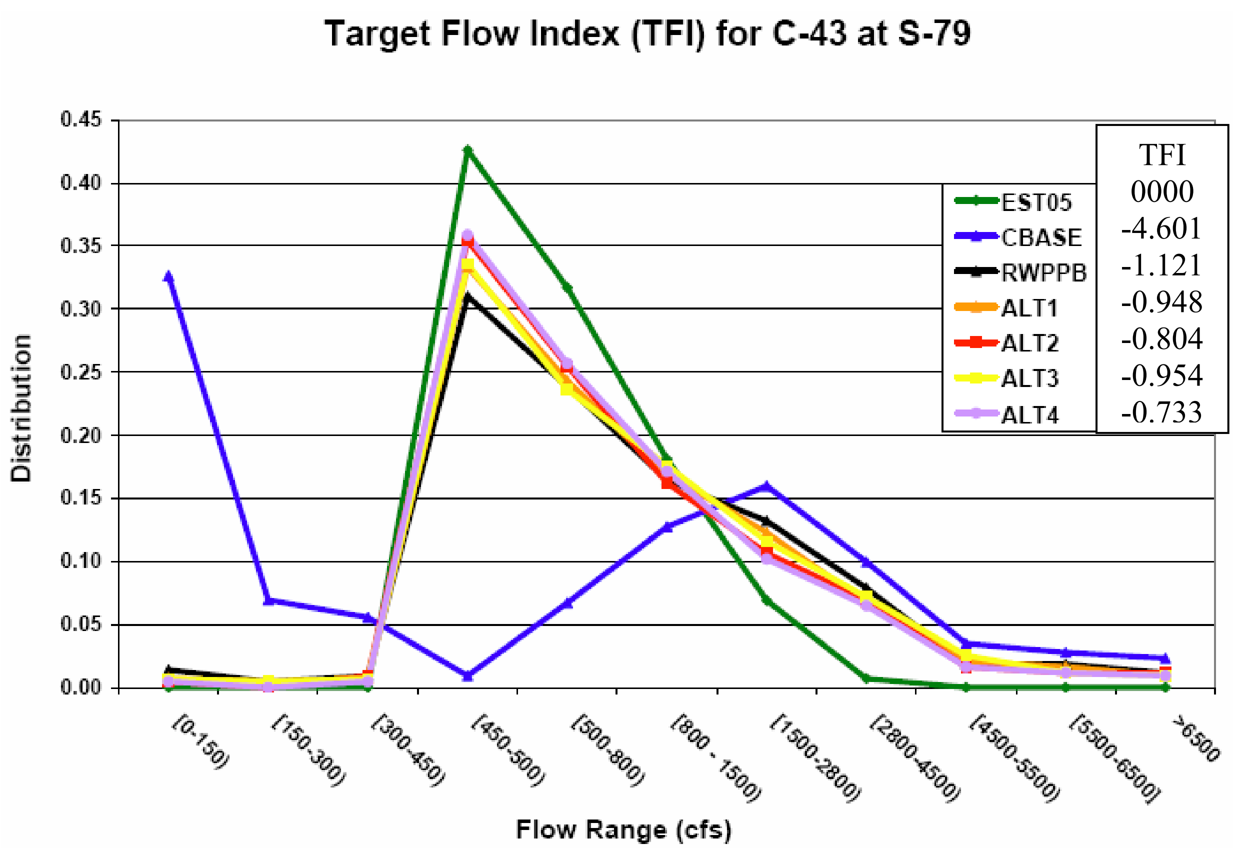




Caloosahatchee Total Flow Index

Performance Measure: Total Flow Index
Description – Compares alternative flow distribution to desired flow distribution
Target – Extreme high lake stage target is zero weeks with lake stages above 17 ft, NGVD.
Evaluation Method – The Northern Everglades Regional Simulation Model (NERSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005.

In this graphic, the green line below represents the desired flow distribution target at S-79, which is referred to as EST-05. Alternative flow distributions are compared to the EST-05 target distribution and a score is calculated, which reflects degree of similarity between the two. A value of zero signifies a perfect match to EST-O5. The TFI progressively becomes negative as the flow deviates from the target.



St. Lucie River and Estuary Performance Measures

Number of Times St. Lucie Estuary High Discharge Criteria Exceeded

Performance Measure: Number of Times St. Lucie River Estuary High Discharge Criteria Exceeded – Mean Monthly Flows >2,000 cfs and Mean Monthly Flows > 3,000 cfs

Description – The Lake Okeechobee WSE Regulation Schedule is applied to regulate (flood control) discharges to the St. Lucie River, and subsequently to the St. Lucie Estuary, when lake stages are high. The St. Lucie River has primary capacity for local inflows and is only utilized for St. Lucie Estuary discharges when there is secondary capacity available. The number of times that the St. Lucie Estuary high discharge criterion is exceeded must be limited to prevent destructive impacts on the estuary.

Rationale – Researchers have observed an increased rate of eutrophication in Lake Okeechobee from 1973 to the present. Symptoms of this eutrophication include the following:

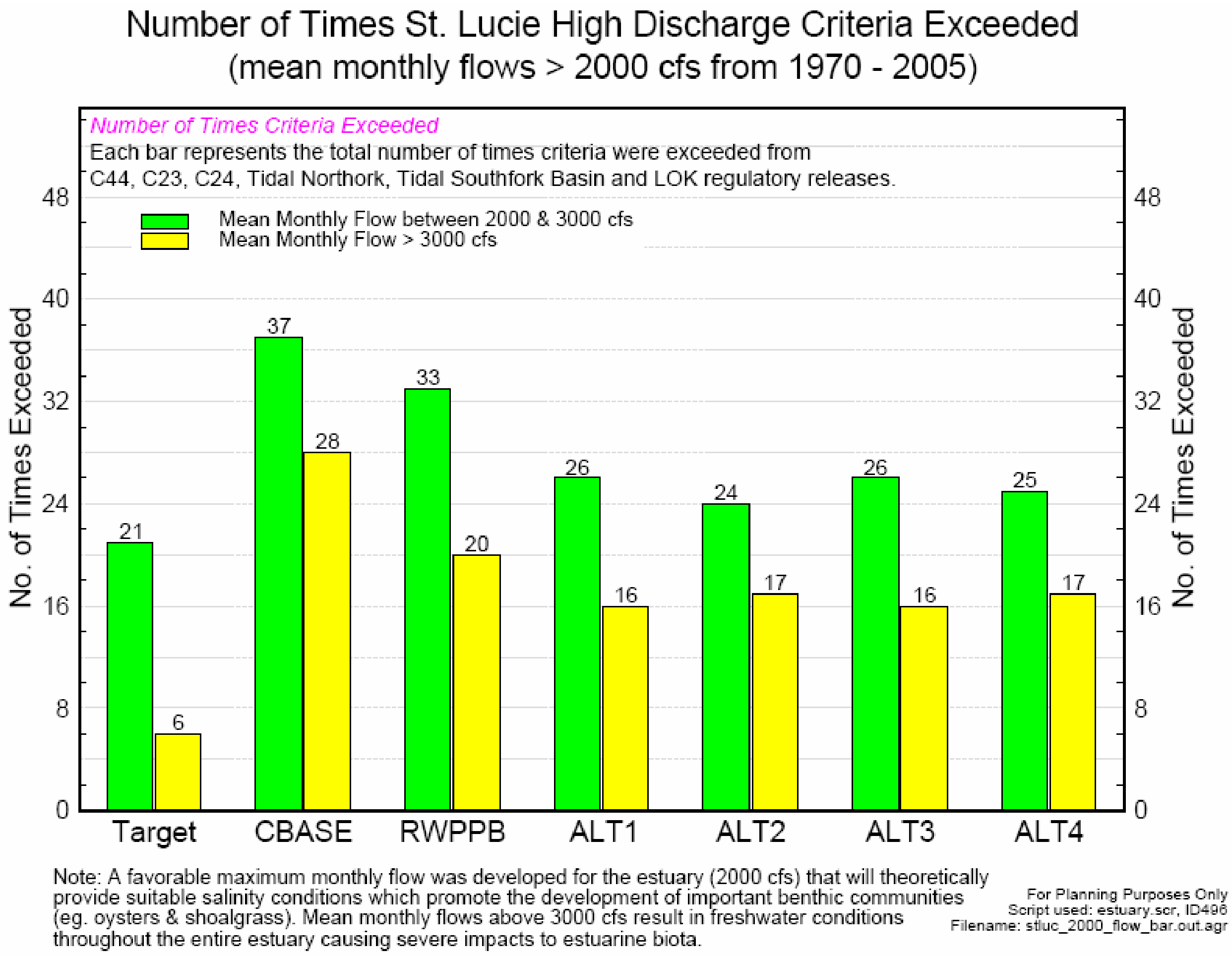
- increases in algal bloom frequency since the mid-1980s (with an algal bloom being defined as chlorophyll-*a* concentrations greater than 40 µg/L) (Maceina 1993, Carrick et al. 1994, Havens et al. 1995b),
- increases in the dominance of blue-green algae following a shift in the TN:TP ratio (Smith et al. 1995),
- increases in the lake water concentration of total phosphorus, and
- increases in average chlorophyll-*a* concentrations (Havens et al. 1995).

Phosphorus is considered to be the key nutrient contributing to the eutrophication of the lake (Federico et al. 1981). Increases in total phosphorus concentrations in the lake, coupled with decreases in nitrogen loading from reduced back pumping from the EAA, have shifted the TN:TP ratio from greater than 25:1 in the 1970s to around 15:1 in the 1990s. This shift has created conditions more favorable for the proliferation of nitrogen-fixing blue-green algae, which are responsible for the blooms occurring in the lake (Smith et al. 1995).

Target – 21 or fewer occurrences of mean monthly flows between 2,000 and 3,000 cfs and no more than 6 occurrences of mean monthly flows over 3000 cfs from the St. Lucie River Watershed for the model simulated 36 years (1970 – 2005) or 432 months.

Evaluation Method – The Northern Everglades Regional Simulation Model (NERSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The number of average monthly flows between 2,000 cfs and 3,000 cfs will be tallied for each alternative.

This graphic illustrates the number of times the model indicated that the high discharge criteria to the St. Lucie Estuary were exceeded for the CBASE, RWPPB, and each alternative. The base conditions (CBASE and RWPPB) and Alternatives (1 through 4) were each modeled over a 36-year period of record (432 months). The left bars represent a tally of the mean monthly flows between 2,000 and 3,000 cfs and the right bars represent a tally of the mean monthly flows greater than 3,000 cfs.



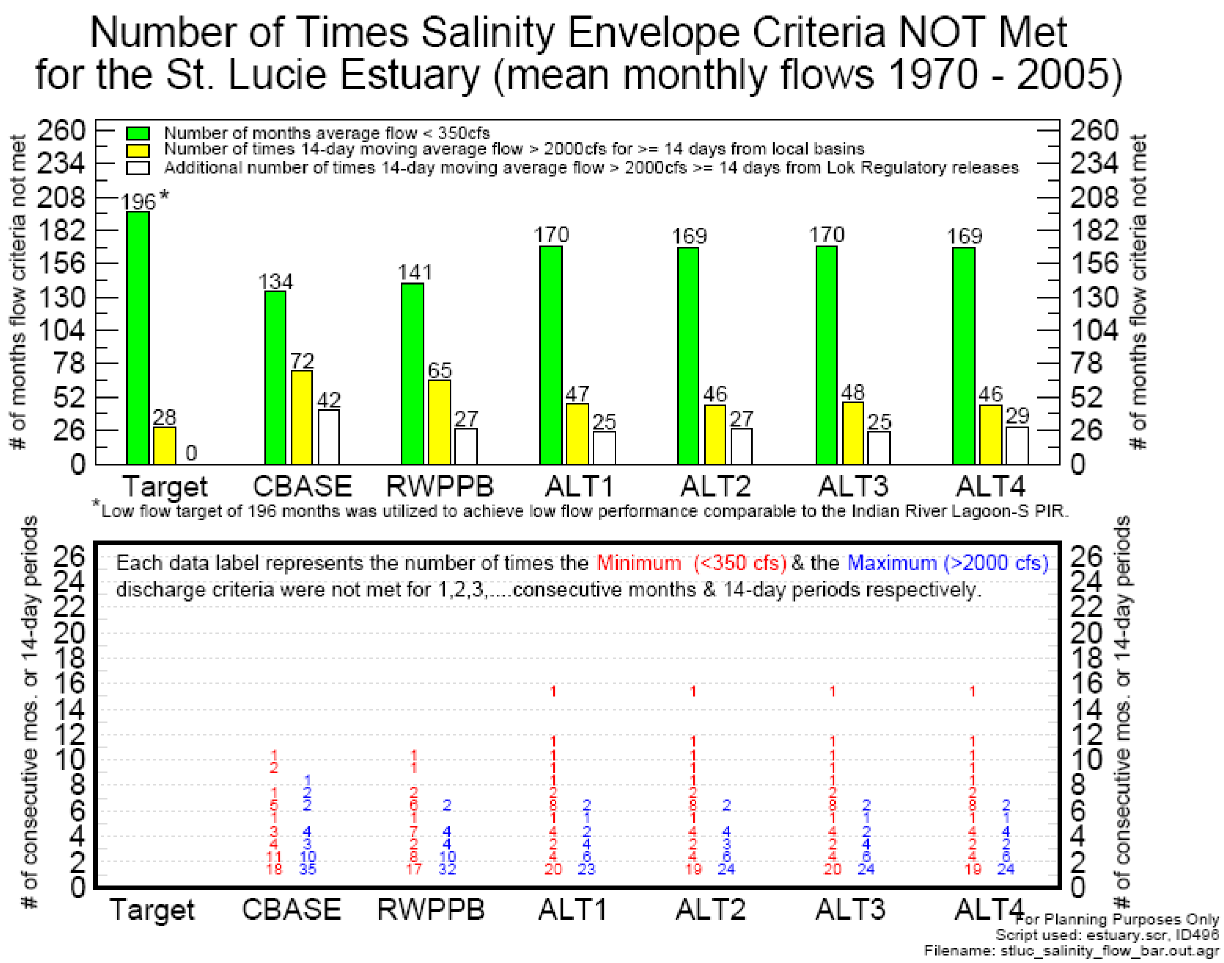
St. Lucie Estuary Salinity Envelope

Performance Measure: Number of Times Salinity Criteria Not Met for the St. Lucie Estuary – Mean Monthly Flows < 350 cfs and Mean Monthly Flows > 2,000 cfs
Description – A healthy, naturally-diverse and well-balanced estuarine ecosystem can exist only if the salinity regimes are controlled within the desirable range. Lake Okeechobee discharges have a significant impact on how well desirable salinity regimes are maintained in the St. Lucie Estuary.
Rationale – Extreme low lake stages prevent water from reaching the submerged aquatic vegetation populating the littoral zone and shoreline regions. Without submerged aquatic vegetation, the habitats of wading birds, reptiles, fish, amphibians, and apple snails are endangered as these species rely on submerged aquatic plants for foraging and recruitment activities. Invasive plant species, such as torpedo grass and Melaleuca, flourish in times of extreme low lake stage, replacing the original native vegetation. There is no proven method to control torpedo grass, except the use of a general herbicide that kills all surrounding area vegetation. Torpedo grass is poor habitat for fish and other aquatic animals as the growth is so dense there is no room for animal mobility. Nighttime dissolved oxygen levels in the grass have been recorded at zero, a condition that is not suitable for aquatic life. Recovery from the adverse impacts of extreme low lake stage requires multiple years, including the grueling process of re-establishing a healthy submerged aquatic plant community.
Target – Limit mean monthly flows below 350 cfs for 31 months or less over a 432-month period (salinity envelope low flow criterion), and limit the number of times flows from the St. Lucie River Watershed exceed 2,000 cfs for 14 days or more to 28, based on a 14-day moving average (salinity envelope high flow criterion). Because the NERSM model only accounts for surface water flows, an operational target of 196 months was used to achieve the low-flow performance comparable with the IRL-S PIR, not the ecological target of 31. Low flows are not a significant issue for the St. Lucie Estuary because the low-flow target is typically achieved through groundwater flows. It is more beneficial for the low-flow criterion to be met by groundwater flows instead of watershed runoff. The groundwater flow within the St. Lucie River Watershed provides a constant base flow to the St. Lucie Estuary and any supplemental flows needed from surface water sources to address low-flow conditions are ideally provided from the North Fork of the St. Lucie River.
Evaluation Method – The Northern Everglades Regional Simulation Model (NERSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The number of mean monthly flows outside of the desirable range from 350 cfs to 2,000 cfs will be tallied for each alternative.

The performance of the base conditions and the four alternatives compared to the salinity envelope target are provided in the following graphic. Lake Okeechobee flows were not used to meet the salinity envelope low flow criteria (350 cfs); therefore, the left bars only represent flows from the St. Lucie River Watershed.

Because the NERSM model only accounts for surface water flows, an operational target of 196 months was used to achieve the low-flow performance comparable with the Imperial River Lagoon - South Project Implementation Report (IRL-S PIR), not the ecological target of 31. Low flows are not a significant issue for the St. Lucie Estuary because the low-flow target is typically achieved through groundwater flows. It is more beneficial for the low-flow criterion to be met by groundwater flows instead of watershed runoff. The groundwater flow within the St. Lucie River Watershed provides a constant base flow to the St. Lucie Estuary and any supplemental flows needed from surface water sources to address low-flow conditions are ideally provided from the North Fork of the St. Lucie River.

From the St. Lucie River Watershed, the high-flow criterion was reduced by 7 occurrences with the RWPPB Condition compared to the CBASE Condition. From Lake Okeechobee regulatory releases, the high-flow criterion was reduced by 15 occurrences with the RWPPB Condition compared to the CBASE Condition. Both the high-flow criterion and the low-flow criterion improved with the alternatives. Exceedances of the high-flow criterion were reduced by 24 to 26, compared to the CBASE Condition, and by 17 to 19, compared to the RWPPB Condition. However, the high flow target of 28 is exceeded with the four alternatives by 18 to 20 occurrences.



Lake Okeechobee Performance Measures

Total Surface Phosphorus Loading to Lake Okeechobee

Performance Measure: Total surface phosphorus loading to Lake Okeechobee
Description – This performance measure addresses the total surface phosphorus inflow to Lake Okeechobee on an average annual basis. FDEP (2001) has established a total maximum daily load (TMDL) for phosphorus loading to Lake Okeechobee as 140 mt/yr. Attainment of the TMDL will be calculated using a 5-year rolling average based on monthly loads calculated from measured flows and phosphorus concentrations. This includes 35 mt/yr phosphorus loading from atmospheric deposition.
Rationale – Researchers have observed an increased rate of eutrophication in Lake Okeechobee from 1973 to the present. Symptoms of this eutrophication include the following: • increases in algal bloom frequency since the mid-1980s (with an algal bloom being defined as chlorophyll-*a* concentrations greater than 40 µg/L) (Maceina 1993, Carrick et al. 1994, Havens et al. 1995b), • increases in the dominance of blue-green algae following a shift in the TN:TP ratio (Smith et al. 1995), • increases in the lake water concentration of total phosphorus, • increases in average chlorophyll-*a* concentrations (Havens et al. 1995). Phosphorus is considered to be the key nutrient contributing to the eutrophication of the lake (Federico et al. 1981). Increases in total phosphorus concentrations in the lake, coupled with decreases in nitrogen loading from reduced back pumping from the EAA, have shifted the TN:TP ratio from greater than 25:1 in the 1970s to around 15:1 in the 1990s. This shift has created conditions more favorable for the proliferation of nitrogen-fixing blue-green algae, which are responsible for the blooms occurring in the lake (Smith et al. 1995).
Target – Maintain average annual surface phosphorus loading to Lake Okeechobee no greater than 105 mt/yr.
Evaluation Method – A spreadsheet model has been developed and applied during the development of the Lake Okeechobee Protection Plan in 2004 and the 2007 update. This spreadsheet accounts for all phosphorus reduction measures that have been implemented and calculates the remaining load reduction required to meet the TMDL. The spreadsheet has been updated to include the 2000 through 2005 period of record. The water quality measures contained in each alternative will be added to the spreadsheet to evaluate to what extent the phosphorus reduction goal has been achieved.

Lake Okeechobee Extreme Low Lake Stage

Performance Measure: Lake Okeechobee Extreme Low Lake Stage

Description – Ideally, lake stages fluctuate within a determined envelope based on an annual hydrograph. Research (Havens 2002) has confirmed that lake stages should ideally vary seasonally between 12.5 ft, NGVD (June-July low) and 15.5 ft, NGVD (November-January high). Extreme low lake stages fall below this envelope, with lake stage below 10 ft, resulting in negative impacts on the living communities in the littoral zone, the shoreline fringing bulrush zone, and all of the lake areas that support valuable submerged aquatic vegetation.

Rationale – Extreme low lake stages prevent water from reaching the submerged aquatic vegetation populating the littoral zone and shoreline regions. Without submerged aquatic vegetation, the habitats of wading birds, reptiles, fish, amphibians, and apple snails are endangered as these species rely on submerged aquatic plants for foraging and recruitment activities.

Invasive plant species, such as torpedo grass and Melaleuca, flourish in times of extreme low lake stage, replacing the original native vegetation. There is no proven method to control torpedo grass, except the use of a general herbicide that kills all surrounding area vegetation. Torpedo grass is poor habitat for fish and other aquatic animals as the growth is so dense there is no room for animal mobility. Nighttime dissolved oxygen levels in the grass have been recorded at zero, a condition that is not suitable for aquatic life.

Recovery from the adverse impacts of extreme low lake stage requires multiple years, including the grueling process of re-establishing a healthy submerged aquatic plant community.

Target – For extreme low lake stage, below 10 ft, the target is zero weeks.

Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005.

In the case of extreme low lake stage, the maximum value of the raw score is 52 weeks / year x 36 years = 1,872 weeks. Based on observations of the impacts of only 15 weeks of extreme low lake stage during a drought in 2001, this value can be assigned as the worst-case scenario, as it requires multiple years for full recovery. An extensive loss of apple snails and woody vegetation in shoreline areas was documented. The duration for < 10 ft stage (15 weeks / year = 540 weeks in a 36 year model run) can be set as the point equivalent to a score of 0 on the standardized scale. To convert from a raw score to a standardized score, the following regression equation is applied:

$$\text{Standardized score} = \text{raw score} * -0.185 + 100$$

A linear increase in risk of ecological damage is assumed between the optimal conditions (0 weeks) and the most severe condition (540 weeks). This method is the most conservative approach to take until more data is acquired to support a more complex relationship. Thus, the equation will need to be re-calculated if the model period is extended beyond 36 years.

Lake Okeechobee Extreme High Lake Stage

Performance Measure: Lake Okeechobee Extreme High Lake Stage

Description – Lake stages commonly fluctuate in response to a combination of seasonal, annual, and inter-annual variations in climatic conditions and water management operations. Published research (Havens 2002) states that lake stages should vary seasonally between 12.5 ft (National Geodetic Vertical Datum - NGVD, June-July low) and 15.5 ft (November-January high). Extreme high lake stage refers to a stage level above 17 ft, NGVD creating a dangerous condition prone to high waves, uplifted suspended solids, and unconsolidated mud deposition.

Rationale – Extreme high lake stages allow strong, wind-driven waves to impact the littoral emergent plant and shoreline submerged plant communities. Uprooting of submerged and shoreline plants can occur, compromising the habitats of fish, apple snails, amphibians, reptiles, and wading birds. These species all rely on a healthy population of submerged vegetation for areas of foraging and recruitment.

Submerged aquatic vegetation is also at risk from the uplifting of thick suspended solids to the littoral zone from the mid-lake region where they usually settle. The suspended solids in the littoral zone reduce water quality and decrease light penetration needed for submerged aquatic vegetation to flourish (James and Havens 2005).

The transfer of nutrient-rich suspended solids into the littoral zone can also affect the periphyton biomass and taxonomic structure as a result of high stage events. Cattail is known to thrive in times of extreme high lake stage, compromising plant diversity by encouraging the dominance of one species.

Finally, the deposition of unconsolidated mud over the natural peat and sand sediment at the bottom of the lake creates a shift in the balance of a healthy vegetative system. In general, extreme high lake stages result in reductions of submerged aquatic plants, prevention of germination of submerged plants, reductions in fish spawning, cattail plant dominance, compromised periphyton biomass, and an endangered habitat of amphibians, reptiles, apple snails, and wading birds.

Target – Extreme high lake stage target is zero weeks with lake stages above 17 ft, NGVD.

Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005.

For extreme high lake stage (above 17 ft NGVD), the response algorithm relates the raw scores for each component of the performance measure to a standardized scale of 0 to 100. The maximum value for the raw score is 52 weeks / year x 36 years = 1,872 weeks. It is believed that maximum impacts occur at a low frequency. In 1998 and 1999, almost 100% of the lake's submerged aquatic vegetation community and over 100 m of littoral emergent vegetation were uprooted when the lake stage was extreme high for only 16 and 7 weeks, respectively. These recordings were the most severe cases of extreme high lake stage damage in 30 years. Therefore, the duration for > 17 ft stage is set as the point equivalent to a score of 0 on the standardized scale. To convert from a raw score to a standardized score, the following regression equation is applied:

Standardized score = raw score * -0.253 + 100

A linear increase in risk of ecological damage is assumed between the optimal conditions (0 weeks) and the most severe condition (396 weeks). This approach is the most conservative method to follow until data is acquired to support a more complex relationship. If the model period is extended beyond 36 years, the equation must be re-calculated. For each component of this performance measure, results for planning alternatives can be displayed as simple bar graphs. The height of the bars corresponds to standardized scores for this performance measure.

Lake Okeechobee Stage Envelope – Score Below Envelope

Performance Measure: Lake Okeechobee Stage Envelope – Score Below Envelope

Description – Lake stages fluctuate in response to a combination of seasonal, annual, and inter-annual climatic conditions and operational practices. Research (Havens 2002) has confirmed that lakes stage should ideally vary seasonally between 12.5 ft, NGVD (June-July low) and 15.5 ft, NGVD (November-January high). A healthy variation of lake stages result in annual flooding and drying of the littoral zone, promoting development of diverse plant and animal communities. Decreasing water levels toward the end of winter and spring allow wading birds to easily prey on resources in the littoral zone. However, if the lake stage falls below the envelope too frequently, the littoral zone is threatened.

Rationale – The littoral zone and shoreline areas of Lake Okeechobee support submerged plant life. If the lake stage is frequently below the envelope, the vegetation does not receive the water it requires to flourish. Without submerged aquatic vegetation, the habitats of wading birds, reptiles, fish, amphibians, and apple snails are endangered. These species rely on a surplus of aquatic plants for foraging and recruitment activities.

When the lake stage falls below the envelope, it creates optimal conditions for invasive plant species, such as torpedo grass and Melaleuca, to replace the original native vegetation. There is no proven method to control torpedo grass, except the use of a general herbicide that kills all surrounding area vegetation. Torpedo grass is poor habitat for fish and other aquatic animals as the growth is so dense there is no room for animal mobility. Nighttime dissolved oxygen levels in the grass have been recorded at zero, a condition that is not suitable for aquatic life.

When the lake stage falls below 12.56 ft, NGVD, navigation of the Okeechobee Waterway becomes impaired. At levels below 11 ft, NGVD, access to the lake for fishermen and recreational boaters becomes limited to channels and boat trails. It should be noted that the Lake Okeechobee commercial and recreational fishery is valued at over $480 million dollars (Furse and Fox 1994).

Lake stages below the envelope are beneficial in moderate occurrences. Periodic exposure of seed banks helps control plant dominance and can provide nutrition to animal communities. Low lake stage also exposes the littoral zone to oxidation of the organic material that accumulates over time, creating a healthy and clean system. Fires can arise in times of low lake stage, which - in moderation - can prevent plant dominance such as cattail. A decrease in lake level during spring time helps to concentrate prey resources and promote wading bird nesting on the lake.

Target – For deviations of lake stages below the envelope, the target is established at 192 ft weeks. This score allows for the optimal range of both dry and flooded periods to encourage a thriving and diverse community.

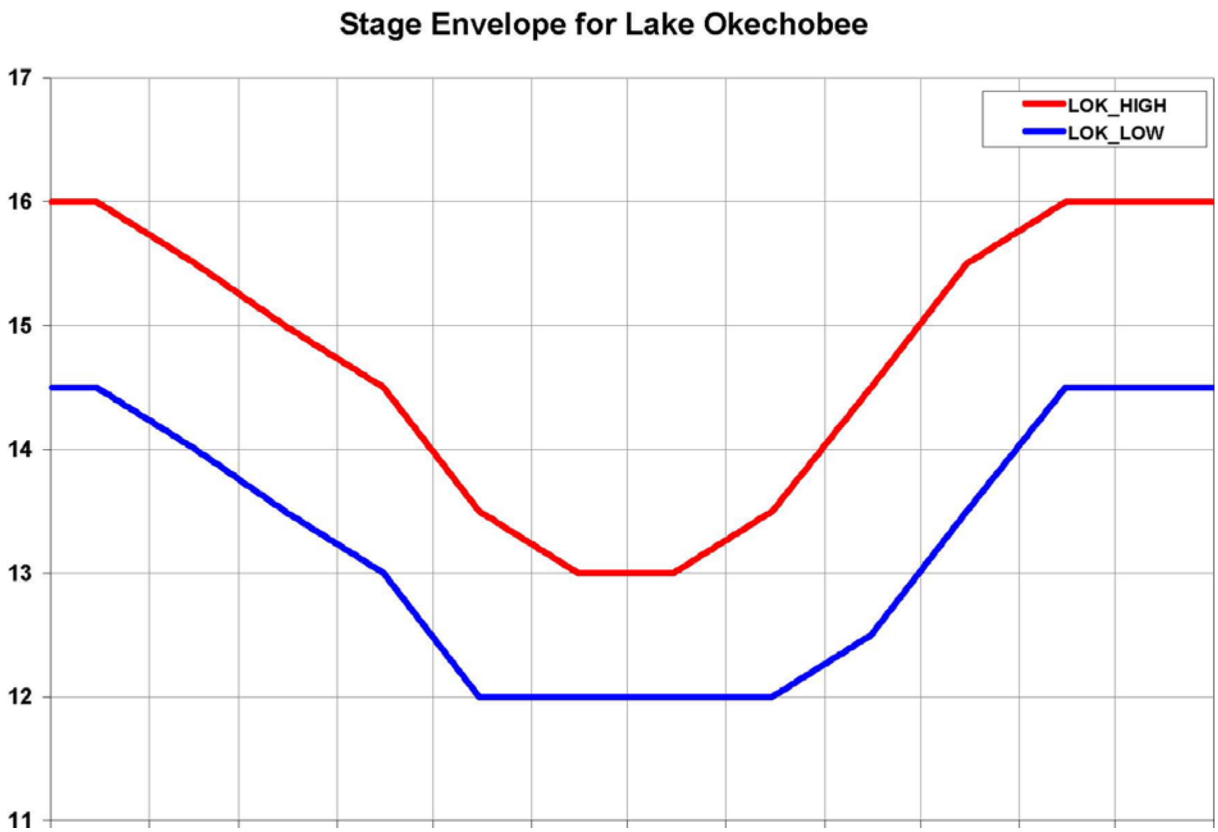
Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluations will be based on simulation of the period from 1970 through 2005. For each week of the model simulation, the absolute value of the deviation (ft) of lake stage from the envelope is determined. The number of weeks below the envelope is tallied and the response curve is developed from the performance measure graphic. Zero values represent favorable conditions, the adjacent bands of 0.5 ft represent fair conditions, and the subsequent 1.0 ft band represents poor conditions. The worst case scenario occurs when the hydrograph remains constantly in the poor zone (1,872 ft weeks). Therefore, the response curve is a line between the target (192 ft weeks) and the worst-case scenario (1,872 ft weeks). Raw scores are calculated from the following equation:

$$\text{Standardized score (\%)} = \text{raw score} * -0.0595 + 111.429$$

Except where the score falls below 192, the score remains at 100%. For each component of this performance measure, results for planning alternatives can be displayed as simple bar graphs. The height of the bars corresponds to standardized scores for this performance measure.

Lake Okeechobee Stage Envelope

This graphic illustrates how the evaluation is performed for the lake stage envelope, where the vertical axis is stage in ft, NGVD and the horizontal axis is in months of the year. The shaded central area is the stage envelope. In this example, hydrograph A has a score of 86 ft-weeks for stages above the envelope and a score of 0 for stages below the envelope. Hydrograph B has a score of 22 ft-weeks for stages above the envelope and a score of 0 for stages below the envelope. Hydrograph C has a score of 0 for stages above the envelope and a score of 110 ft-weeks for stages below the envelope. Actual scoring is based on a smooth envelope boundary.



Stage (ft NGVD29)

J F M A M J J A S O N D

Lake Okeechobee Stage Envelope – Score Above Envelope

Performance Measure: Lake Okeechobee Stage Envelope – Score Above Envelope

Description – Lake stages fluctuate in response to a combination of seasonal, annual, and inter-annual climatic conditions and operational practices. Research (Havens 2002) has confirmed that lakes stage should ideally vary seasonally between 12.5 ft, NGVD (June-July low) and 15.5 ft, NGVD (November-January high). A healthy variation of lake stages result in annual flooding and drying of the littoral zone, promoting development of diverse plant and animal communities. However, lake stage deviations above the envelope result in over flooding, which is destructive to the littoral zone, including aquatic vegetation and specie habitat.

Rationale – Lake stages above the envelope produce an excess of water creating wind-driven waves that impact the littoral emergent plant and shoreline submerged plant communities. Uprooting of submerged and shoreline plants can occur, compromising the habitats of fish, apple snails, amphibians, reptiles, and wading birds. These species all rely on a healthy population of submerged vegetation for areas of foraging and recruitment.

Submerged aquatic vegetation is also at risk from the uplifting of thick suspended solids to the littoral zone from the mid-lake region where they usually settle. The suspended solids in the littoral zone reduce water quality and decrease light penetration needed for submerged aquatic vegetation to flourish (James and Havens 2005). Without a population of healthy submerged aquatic vegetation, the sediment cannot be stabilized and specie habitat is endangered.

The transfer of these nutrient-rich suspended solids into the littoral zone can also affect the periphyton biomass and taxonomic structure. Cattail is known to thrive in times of high lake stage, compromising plant diversity by encouraging the dominance of one species.

Finally, the deposition of unconsolidated mud over the natural peat and sand sediment at the bottom of the lake creates a shift in the balance of a healthy vegetative system. In general, high lake stage results in a reduction of submerged aquatic plants, prevention of germination of submerged plants, reductions in fish spawning, cattail plant dominance, compromised periphyton biomass, and an endangered habitat of amphibians, reptiles, apple snails, and wading birds.

Target – The target is zero weeks for deviation of lake stage above the envelope.

Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation is based on simulations for the period from 1970 through 2005. For each week of the model simulation, the absolute value of the deviation (ft) of lake stage from the envelope is determined. Zero values represent favorable conditions, the adjacent bands of 0.5 ft represent fair conditions, and the subsequent 1.0 ft band represents poor conditions.

The worst-case scenario is one in which the lake stage hydrograph is always in the poor zone. This situation equates to a total score of 1.0 ft x 52 weeks / year * 36 years 1,872 ft weeks. The response curve is a line between the target (0 weeks) and the worst-case scenario (1,872 ft weeks). Raw scores can be calculated from the following equation:

$$\text{Standardized score (\%)} = \text{raw score} * -0.0534 + 100$$

For each component of this performance measure, results for planning alternatives can be displayed as simple bar graphs. The height of the bars corresponds to standardized scores for this performance measure.

Number of Times Proposed Minimum Water Level and Duration – Criteria Exceeded

Performance Measure: Number of Times Proposed Minimum Water Level & Duration – Criteria Exceeded
Description – To determine the MFL for Lake Okeechobee, the following water resource functions were considered: provide water that can be used to maintain water levels in coastal canals, meet human needs, and protect the Biscayne aquifer against saltwater intrusion; and supply water and provide water storage for the Everglades. The lake is a regionally important ecosystem that provides fish and wildlife habitat, supports commercial and sport fisheries, and maintains navigation and recreational use. Water supply to the Biscayne aquifer, Caloosahatchee River, St. Lucie Canal, the Seminole Indian Tribe, and the Everglades Agricultural Area were important considerations in the establishment of an MFL for Lake Okeechobee. Relationships were considered in defining significant harm (a loss of specific water resource functions resulting from a change in surface or groundwater hydrology) and the proposed MFL was determined.
Rationale – Lake Okeechobee is a critical source of freshwater to maintain coastal groundwater levels, preventing saltwater intrusion of the Biscayne aquifer. During dry periods, freshwater is discharged from the lake, helping to maintain a freshwater head within the coastal groundwater aquifer, which prevents inland movement of the saltwater front. Records show that when lake levels fall below 11 ft NGVD, the levels continue to decline rapidly, threatening the ability for SFWMD to deliver water to coastal canals as a result of the physical limitations of the lake's outlet structures. During dry periods, the Everglades have been found to not be receiving sufficient water amounts to maintain viable aquatic ecosystems and to protect vegetation and wildlife from the threat of fires. SFWMD's Best Management Practice Make-Up Water Rule, Part II of Chapter 40E-63, F.A.C quantifies the necessary amount of water to ensure a healthful Everglades system. The established MFL must support the littoral zone and the following fish and wildlife values: a commercial and recreational fishery valued at over $480 million dollars; a rich avifauna community that includes wading birds, migratory waterfowl, and federally-designated endangered snail kite and wood stork; and ecotourism and recreation, including fishing, hunting, and bird and wildlife observation. When the lake stage falls below 12.56 ft NGVD, navigation of the Okeechobee Waterway becomes impaired. At levels below 11 ft NGVD, access to the lake for fishermen and recreational boaters becomes limited to channels and boat trails. However, when the lake stage reaches an extreme low condition, recreational access to the lake becomes significantly restricted, as much of the littoral zone is exposed as dry land. It is important to consider the dependency of the Everglades Agricultural Area, the Seminole Indian Tribe, and the Caloosahatchee and St. Lucie basins on freshwater flow from Lake Okeechobee. During drought conditions, agricultural water needs in these basins are determined based on weather, soil, and crop conditions.
Target – The lake level should not fall below 11 ft, NGVD for more than 80 days duration more often than once every six years.
Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The number of years when Lake Okeechobee stages fall below 11 ft, NGVD for 80 days or more will be counted.

Lake Okeechobee Performance Indicators

Water Year (Oct-Sep) LOSA Demand Cutback Volumes

Performance Indicator: Water Year (Oct-Sep) LOSA Demand Cutback Volumes
Description – Lake Okeechobee is the primary source of supplemental irrigation for four major adjacent agricultural basins: North Shore, Caloosahatchee, St. Lucie and EAA. Collectively, these basins are referred to as the Lake Okeechobee Service Area (LOSA). During the dry season, when precipitation is low, local sources of irrigation become scarce and the need for supplemental irrigation becomes necessary. With the current absence of substantial off-site storage, Lake Okeechobee is presently the only source of supplemental irrigation for these basins. Average annual supplemental irrigation requirement from Lake Okeechobee amounts to about half a million acre-ft.
Rationale – Water levels in Lake Okeechobee are compared to a seasonally fluctuating Supply Side Management Zone in the WSE Regulation Schedule. If water levels fall into the Supply Side Management Zone, projections of rainfall, ET, and water supply demands are made for the remainder of the dry season and water supply cutbacks are applied as appropriate. During seven years of the 1970 to 2005 period of record, substantial water restrictions were imposed on the LOSA. These restrictions were implemented to protect the region's water resources on a long-term basis. However, the water supply demands that were not met during these drought periods resulted in significant economic impacts to the water users.
Target – Minimize the water supply cutback volumes during the seven years of the period of record with the largest cutbacks.
Evaluation Method - The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The volume of water supply demand that is not met will be tallied for each of the seven years that caused the largest unmet demands.

Mean Annual EAA/LOSA Supplemental Irrigation Demands Not Met

Performance Indicator: Mean Annual EAA/LOSA Supplemental Irrigation Demands Not Met
Description – Lake Okeechobee is the primary source of supplemental irrigation for four major adjacent agricultural basins: North Shore, Caloosahatchee, St. Lucie and Everglades Agricultural Areas. Collectively, these basins are referred to as the Lake Okeechobee Service Area (LOSA).
Rationale – During the dry season when precipitation is low, local sources of irrigation become scarce and the need for supplemental irrigation becomes absolutely necessary. With the current absence of substantial off-site storage, Lake Okeechobee is presently the only source of supplemental irrigation for these basins. Average annual supplemental irrigation requirement from Lake Okeechobee amounts to about half a million acre-ft (SFWMD, 2000a). Lake Okeechobee also provides urban water supply to the Lower East Coast and to several municipalities surrounding the lake. Additionally, the Seminole Tribe of Florida is entitled to water supply based on the Water Rights Compact (Pub. L. No. 100-228, 101 Stat. 1556, and Chapter 87-292, Laws of Florida, and codified in Section 285.165, F.S.
Target – Minimize the percentage of water supply demands that are not met in the EAA and LOSA.
Evaluation Method – The Regional Simulation Model (RSM) will be employed for all evaluations. The evaluation will be based on the period of record from 1970 through 2005. The percentages of demands not met will be tallied for the EAA and LOSA.

APPENDIX B

MANAGEMENT MEASURE TOOLBOX TABLE AND FACT SHEETS

Table B-1. Management Measures Toolbox Table

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE-LO 01,02,49	B-1	Agricultural BMPs- Owner Implemented, Funded Cost Share, and Cost Share Future Funding	Implementation of agricultural BMPs and water quality improvement projects to reduce the discharge of nutrients from the watershed.	1	√	√	√	√
CRE-LO 03	B-3	Urban Turf Fertilizer Rule [Lake Okeechobee Estuary and Recovery (LOER)]	Florida Department of Agriculture and Consumer Services (FDACS) rule which regulates the content of P and N in urban turf fertilizers to improve water quality.	1	√	√	√	√
CRE-LO 04	B-5	Land Application of Residuals	Subsection 373.4595(4)(b)2.of the NEEPP requires that after December 31, 2007, the FDEP may not authorize the disposal of domestic wastewater residuals within the Caloosahatchee River Watershed unless the applicant can affirmatively demonstrate that the nutrients in the residuals will not add to nutrient loadings in the watershed.	1	√	√	√	√
CRE-LO 05	B-7	Florida Yards and Neighborhoods	Provides education about the land-use design to the citizens by promoting the Florida Yards & Neighborhood programs to minimize the pesticides, fertilizers and irrigation water.	1	√	√	√	√
CRE-LO 07	B-8	Environmental Resource Permit (ERP) Regulatory Program	The ERP program regulates activities in, on, or over wetlands or other surface waters and the management and storage of all surface waters. This includes activities in uplands that alter stormwater runoff as well as dredging and filling in wetlands and other surface waters. Generally, the program's purpose is to ensure that activities do not degrade water quality, compromise flood protection, or adversely affect the function of wetland systems. The program applies to new activities only, or to modifications of existing activities, and requires an applicant to provide reasonable assurances that an activity will not cause adverse impacts to existing surface water storage and conveyance capabilities, and will not adversely affect the quality of receiving waters such that any applicable water quality standards will be violated.	1	√	√	√	√
CRE-LO 08	B-10	National Pollutant Discharge Elimination System (NPDES) Stormwater Program	To reduce stormwater pollutant loads discharged to surface waters, especially from existing land uses and drainage systems. This is especially true for the master drainage systems owned and operated by cities, counties, FDOT, and Chapter 298 water control districts. This also can help to reduce stormwater pollutant loads from existing industrial sites and from new construction sites.	1	√	√	√	√
CRE-LO 09	B-12	Coastal & Estuarine Land Conservation Program	To protect important coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses (CELCP Final Guidelines, 2003)..	1	√	√	√	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE-LO 12g	B-14	Alternative Water Storage (LOER) - Barron Water Control District	This project will provide 5,000 acre-feet of water storage on 6,129 acres. Includes weir construction and ditch retention to enable water quality improvements and reuse by growers. Water quality benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits is undetermined.	1	√	√	√	√
CRE-LO 15	B-16	Proposed Caloosahatchee River Watershed Regulatory Nutrient Source Control Program	To implement a nutrient source control program utilizing BMPs for the Caloosahatchee River Watershed. Ongoing activities include revising 40E-61 Rule to reflect the requirements of the Northern Everglades Protection Act and to expand the rule boundary to include the Caloosahatchee River Watershed as defined by the act.	2	√	√	√	√
CRE-LO 21	B-18	Lake Okeechobee and Estuary Watershed Basin Rule (LOER)	In February 2008, SFWMD initiated rule development for an ERP basin rule. The intent is to develop specific supplemental permit criteria for new permitted projects to demonstrate that no increase in total runoff volume will occur from new development that ultimately discharges to Lake Okeechobee or the Caloosahatchee or St. Lucie estuaries.	3	√	√	√	√
CRE-LO 40	B-20	West Lake Hicpochee Project	Project comprises a reservoir and stormwater treatment area along the C-19 and C-43 canals, degradation of berms and exotic removal and control. This project could potentially create 55,090 acre-feet of above ground storage and will result in 27.6 and 1.95 mt/yr of TN and TP, respectively.	4	--	√	--	√
CRE-LO 41	B-23	C-43 Distributed Reservoirs	The project involves storage reservoirs to capture the excess run-off. This project will result in 39.4 and 2.65 mt/yr of TN and TP, respectively.	4	√	√	√	√
CRE-LO 63	B-25	Wastewater & Stormwater Master Plans	Implement urban stormwater retrofitting projects or wastewater projects to achieve additional nutrient reductions and water storage basin wide by working with entities responsible for wastewater and stormwater programs in the service area.	4	√	√	√	√
CRE-LO 64	B-26	Proposed Unified Statewide Stormwater Rule	Intended to increase the level of nutrient treatment of stormwater from new development and thereby reduce the discharge of nutrients and excess stormwater volume. Treatment rule will be based on a performance standard of post-development nutrient loading that does not exceed pre-development nutrient loading.	4	√	√	√	√
CRE-LO 68	B-28	Comprehensive Planning - Land Development Regulations (LDR)	Basin-wide work with state agencies, cities and counties to review current plans and ensure promotion of low impact design through coordinated comprehensive planning and growth management initiatives.	3	√	√	√	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE-LO 87c	B-29	Florida Ranchlands Environmental Services Project (FRESP)	The Florida Ranchlands Environmental Services Project will design a program in which ranchers in the Northern Everglades sell environmental services of water retention, nutrient load reduction, and wetland habitat expansion to agencies of the state and other willing buyers. Pilot project program is currently underway.	1	√	√	√	√
CRE-LO 91	B-32	Farm and Ranchland Partnerships	There are two USDA Natural Resources Conservation Service (NRCS) programs that help farmers and ranchers keep their land in agriculture, the Farm and Ranchlands Protection Program and the Wetlands Reserve Program. Both programs provide funds to purchase conservation easements.	4	√	√	√	√
CRE-LO 92	B-34	Clewiston STA	The State of Florida currently owns 766 acres of land along the southwestern boundary of Lake Okeechobee in Clewiston that can be used as a stormwater treatment area to treat stormwater that is currently discharging to Lake Okeechobee. Water quality benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits is undetermined.	4	√	√	√	√
CRE 01	B-36	Recyclable Water Containment Areas (RWCA)	Utilizes the agricultural lands for reduction of nutrient loads into the Caloosahatchee River. This project will result in 67.5 and 14.3 mt/yr of TN and TP, respectively.	4	--	√	--	√
CRE 02	B-38	Centralized Recycled Water Containment Area in the S-4 Basin	Utilizes the agricultural or other lands for temporary storage to remove nutrients and treat agricultural stormwater runoff from the S-4 Basin to help reduce nutrient loading to the Caloosahatchee River, aquifer recharge and add a temporary back up water supply for irrigation. This project will result in 11.9 and 2.41 mt/yr of TN and TP, respectively.	5	--	√	--	√
CRE 04	B-40	Caloosahatchee Area Lakes Restoration (Lake Hicpochee)	Restore historical lake bed of Lake Hicpochee using 5,300 acres within footprint of state-owned lands, which will treat runoff from agricultural canals that currently flow into Lake Hicpochee and the Caloosahatchee River. Total load reduction is estimated as 100.4 mt/yr for TN and 24.7 mt/yr for TP.	3	--	--	√	√
CRE 05	B-42	East Caloosahatchee Water Quality Treatment Area	The project consists of a constructed wetland designed for optimal removal of N within Lake Hicpochee and the Caloosahatchee River, and to reduce the nutrient pollutants loading to the downstream estuary. This project will result in 80.1 and 19.2 mt/yr of TN and TP, respectively.	3	--	--	--	√
CRE 10	B-44	C-43 Water Quality Treatment and Demonstration Project (BOMA property)	The project consists of a constructed wetland designed for optimal removal of N from the Caloosahatchee River and to reduce the nutrient pollutants loading to the downstream estuary. Total load reduction is estimated as 47.8 mt/yr for TN and 9.21 mt/yr for TP.	3	√	√	√	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE 11	B-47	Caloosahatchee Ecoscape Water Quality Treatment Area	The project consists of a constructed wetland designed for optimal removal of N from the Caloosahatchee River and to reduce the nutrient pollutants loading to the downstream estuary. Total load reduction is estimated as 50.0 mt/yr for TN and 12.0 mt/yr for TP.	4	--	--	√	√
CRE 13	B-49	West Caloosahatchee Water Quality Treatment Area	The project consists of a constructed wetland designed to treat water from the reservoir to reduce nutrient concentrations from the Caloosahatchee River and nutrient pollutants loading to the downstream estuary. Total load reduction is estimated as 58.5 mt/yr for TN and 13.9 mt/yr for TP.	3	--	--	√	√
CRE 18	B-51	Harns Marsh Improvements, Phase I & II	Construction of a control weir at the outlet of Harns Marsh into the Orange River, which will raise water levels in Harns Marsh and create 1,450 acre-feet of storage capacity in the canal. This project also includes replacement of other outlet structures (S-HM-2) and (S-HM-3); along with the addition of a controllable gate structure next to the existing inlet to the South Marsh structure (S-HM-1). This project will result in 1.52 and 0.24 mt/yr of TN and TP, respectively.	1	√	√	√	√
CRE 19	B-54	Harns Marsh Improvements, Phase II Final Design - ECWCD	Repair the Able Canal weirs, replacement of structure (S-OR-1) and (S-OR-1SE), and install pump station to lift water during dry period. This project could help to reduce discharge into the Orange River at least 20 percent for the 25-year design storm. This project will result in 0.61 and 0.09 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 20	B-57	Yellowtail Structure Construction - ECWCD	The Yellowtail Structure will replace an old, failing broad crest weir with a new sheet pile weir with operable gates that will allow a better control of canal water quantity and quality, and will help on water recharge purposes. This project will result in 0.32 and 0.03 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 21	B-59	Hendry County Storage	Buy land for additional storm water storage and treatment during the rainy season and to provide base flows for the ECWCD's outfalls along with additional groundwater recharge in the dry season. This project will result in 2.72 and 0.68 mt/yr of TN and TP, respectively.	3	√	√	√	√
CRE 22	B-62	Hendry Extension Canal Widening (Construction) - ECWCD	This proposed canal widening project will help to address additional stormwater storage in the 5.5 mile section of Hendry Extension Canal. Water quality benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits is undetermined.	2	√	√	√	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE 29	B-65	Lehigh Acres Wastewater Treatment and Stormwater Retrofit	This project consists of the installation of stormwater treatment features in Lehigh Acres and updates the current stormwater management system. This project also consists of the conversion of high-density septic tanks to centralized wastewater treatment including installation of the infrastructure for a treated wastewater reuse system. This project will result in 68.4 and 13.7 mt/yr of TN and TP, respectively.	3	--	--	√	√
CRE 30	B-67	Aquifer Benefit and Storage for Orange River Basin (ABSORB) - ECWCD	Project primarily oriented to increase stormwater storage capacity and SW Lehigh Acres groundwater recharge. This project will result in 3.72 and 0.37 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 44	B-70	Spanish Creek/ Four Corners Environmental Restoration	Restore flow ways, build 400-acre deep reservoir and remove citrus grove. This project will result in 42.8 and 6.79 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 45	B-72	Billy Creek Filter Marsh Phase I & II	This project includes construction of a filter marsh facility and a water control structure. The water control structure diverts flows into the filter marsh facility, providing additional attenuation of stormwater flows within the channel itself. The filter marsh facility will consists of an 8-acre open water lake, 13-acre wetland marsh and incorporate/restore an existing 12-acre cypress hammock. This project will result in 2.05 and 0.51 mt/yr of TN and TP, respectively.	1	√	√	√	√
CRE 48	B-74	Manuel's Branch Silt Reduction Structure	Install a silt reduction structure near the mouth of the creek to reduce the silt associated with the stream bank scour, erosion and degradation. This project will result in 0.14 and 0.11 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 49	B-76	Manuel's Branch East and West Weirs	The project involves the installation of two weir water control structures within the existing canal. This project will result in 0.42 and 0.16 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 53	B-77	Caloosahatchee Creeks Preserve Hydrological Restoration	This project will consist of culvert construction and plugging existing ditches to increase the retention time on the Caloosahatchee Creeks Preserve to help in the rehydration of the wetland and in the quality of water that later discharges into the Caloosahatchee River. It is estimated that this will contribute 1,200 acres of storage capacity and will result in 21.8 and 5.44 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 57	B-79	Powell Creek Algal Turf Scrubber	This project proposes to install a mobile unit of Algal Turf Scrubber system to remove nutrients, based on the results of a pilot project. This project will result in 0.06 and 0.02 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 59	B-81	North Fort Myers Surface Water Restoration Project	The proposed management measure includes channel improvements, construction of weirs to control runoff form Palermo and to incorporate filter marsh to reduce contaminants. This project will result in 0.68 and 0.06 mt/yr of TN and TP, respectively.	1	√	√	√	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE 64	B-83	Yellow Fever Creek/Gator Slough Transfer Facility (#208509)	Construct an interconnection facility between the Gator Slough Canal and Yellow Fever Creek to transfer the surface waters during the high flow periods. This project will result in 1.26 and 0.15 mt/yr of TN and TP, respectively.	1	√	√	√	√
CRE 69	B-85	Cape Coral Wastewater Treatment and Stormwater Retrofit	The City of Cape Coral is implementing a program that involves conversion of septic systems to gravity sewers. This project also includes replacement of older stormwater inlets with the newer inlets designed to assist stormwater. This project will result in 27.0 and 5.40 mt/yr of TN and TP, respectively.	2	--	--	√	√
CRE 77	B-87	Cape Coral Canal Stormwater Recovery by ASR	Using aquifer storage and recovery wells in Cape Coral to overcome water shortfall during dry season and to provide flood attenuation during wet season. This project will result in 4.13 and 0.82 mt/yr of TN and TP, respectively.	1	--	√	--	√
CRE 121	B-89	City of LaBelle Stormwater Master Plan Implementation	This project will include stormwater conveyance and water quality storage improvements within the City of La Belle consisting in approximately 149 acres resulting in 34.8 and 5.80 mt/yr of TN and TP, respectively.	2	√	√	√	√
CRE 122	B-92	Rehydrate Lee County Well Fields (south of Hwy 82)	Redirecting water from Lehigh Acres to rehydrate Lee County well fields to the south of SR 82. This project will result in 1.27 and 0.23 mt/yr of TN and TP, respectively.	3	--	√	--	√
CRE 123	B-95	North Ten Mile Canal Stormwater Treatment System	Stormwater storage/detention 12 acre-feet area for urban and commercial area. Estimated at 0.82 mt/yr for TN and 0.33 mt/yr for TP for 3-year event.	2	--	--	√	√
CRE 124	B-96	Carrell Canal (FMCC) Water Quality Improvements	Stormwater treatment area to contribute with 0.13 mt/yr for TN and 0.14 mt/yr for TP reduction coming to Carrel Canal.	2	--	--	√	√
CRE 125	B-98	Shoemaker-Zapato Canal Stormwater Treatment	Installation of weir/control structures to increase channel storage providing peak flow attenuation, reducing erosion and siltation into Billy Creek. This project will result in 0.54 and 0.14 mt/yr of TN and TP, respectively.	2	--	--	√	√
CRE 126	B-100	Fort Myers-Cape Coral Reclaimed Water Interconnect	Installation of a 20-inch diameter transmission line from Fort Myers Treatment Plant to Cape Coral Reclamation Treatment Plant. This will help prevent discharging 9 MGD treated water into Caloosahatchee River. Water quality benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits is undetermined.	5	--	--	--	√
CRE 128	B-102	East Caloosahatchee Storage	Construction of distributed reservoirs on 7500 acres of private properties. The project could potentially create 100,000 acre-feet of above ground storage and will result in 69.1 and 5.16 mt/yr of TN and TP, respectively.	4	--	√	--	√
CRE 128a	B-104	Caloosahatchee Storage - Additional	Creation of 50,000 acre-feet of above ground storage in the Caloosahatchee Watershed. This project will result in 58.0 and 4.30 mt/yr of TN and TP, respectively.	4	--	--	--	√

ID	Page #	Management Measure	Management Measure Description	Level	Alternative Plans			
					Alt 1	Alt 2	Alt 3	Alt 4
CRE 129	B-106	Wastewater Treatment Plant Upgrade and Reclaimed Water	Upgrade existing wastewater treatment plants to reduce the effluent loadings. Includes the potential for distribution as reclaimed water. Also construct future plants to higher treatment levels. Water quality benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits is undetermined.	5	--	--	--	√
CRE 130	B-109	Animal Manure Application Rule	Landowners who apply more than one ton per acre of manure must develop conservation plans, approved by the US Department of Agriculture/National Resource Conservation Service (USDA/NRC), that specifically address the application of animal wastes and include soil testing to demonstrate the need for manure application.	1	√	√	√	√
CRE 131	B-111	Application of Septage Rule	FDOH rule which regulates the regarding application of septage in the Caloosahatchee and St. Lucie rivers. Entities disposing of septage within the watersheds must develop and submit to FDOH an agricultural use plan that limits applications, based upon nutrient loading.	1	√	√	√	√

CRE-LO 01-02-49

<u>Northern Everglades- Potential Management Measure</u>

Project Feature/Activity: Agricultural BMPs - Owner Implemented, Funded Cost Share, and Cost Share Future Funding

Level: 1

General Description/Background: The Florida Watershed Restoration Act (section 403.067, F.S.), first enacted in 1999, authorized the FDACS to develop, adopt by administrative rule, and implement agricultural BMPs statewide. Through the Office of Agricultural Water Policy (OAWP), FDACS develops, adopts, and implements agricultural BMPs to reduce water quality impacts from agricultural discharges and enhance water conservation.

The OAWP's role involves assisting agricultural producers in selecting, funding, properly implementing, and maintaining BMPs. The OAWP employs field staff and contracts with service providers to work with producers to identify and implement BMPs appropriate for their operations.

The two major categories of commonly used BMPs are nutrient management and irrigation management. Nutrient management is the amount, timing, placement, and type (source) of fertilizer. Irrigation management is the maintenance, scheduling, volume, and overall efficiency rating of irrigation systems.

Purpose: Improve water quality by reducing transport of nutrients via runoff and leaching into regional system from agricultural land uses

Location/Size/Capacity: Caloosahatchee River Watershed and Estuary

Initiative Status:

The OAWP has adopted by rule BMPs that address the following operations in the basin:

- Container Nurseries (Chapter 5M-6, F.A.C.)
- Vegetable and Agronomic Crops (Chapter 5M-8, F.A.C.)
- Citrus (Chapter 5M-2, F.A.C.)

The OAWP is currently developing and will be adopting BMP manuals of statewide application for cow/calf, equine, container nursery, and sod operations. All agricultural land uses in this basin are expected to have adopted BMPs available for implementation by early 2009.

When the Florida legislature in 2007 enacted the NEEPPA, significant portions of agricultural acreage within the Caloosahatchee River Watershed were already implementing water resource protection BMPs previously adopted by FDACS. At the time this protection plan went to press, agricultural acreage within Glades, Hendry, Charlotte and Lee counties enrolled in the FDACS

BMP program totaled 242,000 acres. Enrolled acreage is expected to increase dramatically when the beef cattle BMP manual is adopted in early 2009.

Estimate of Water Quality Benefits
- Minimum:
- Maximum:
- Most Likely:
- Level of Certainty: Conceptual
- Assumptions: Water quality benefits will be rolled up into a single "agricultural" category

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Screening Criteria
- Proof of Concept: 1
- Other Impacts: 0

Contact: Rich Budell; FDACS; 850-617-1704.

Final Water Quality Method and Summary: N/A
Final Water Quantity Method and Summary: N/A

Method: Included in the BMP load reduction estimates (Soil and Water Engineering Technology Inc. 2008).

CRE-LO 03

Northern Everglades – Potential Management Measure

Project Feature/Activity: Urban Turf Fertilizer Rule [Lake Okeechobee Estuary and Recovery (LOER)]

Level: 1

General Description/Background: In August 2007, FDACS adopted a statewide Urban Turf Fertilizer Rule [5E-1.003(2) F.A.C]. The rule limits the P and N content in fertilizers for urban turf and lawns, thereby reducing the amount of P and N applied in urban areas and limiting the amount of those compounds reaching Florida's water resources. It requires that all fertilizer products labeled for use on urban turf, sports turf, and lawns be limited to the amount of P and N needed to support healthy turf maintenance. FDACS expects a 20 to 25 percent reduction in N and a 15 percent reduction in P in every bag of fertilizer sold to the public.

The rule was developed by FDACS with input from UF/IFAS, FDEP, the state's five water management districts, the League of Cities, the Association of Counties, fertilizer manufacturers, and concerned citizens. It enhances efforts currently underway to address excess nutrients in the northern and southern Everglades. As a component of the Lake Okeechobee and Estuary Recovery (LOER) Plan established in October 2005 by former Governor Jeb Bush, the new rule is an essential component to improve water quality through nutrient source control.

Purpose: Improve water quality by reducing phosphorus and nitrogen runoff and leaching resulting from application of fertilizers to urban turf.

Location/Size/Capacity: Statewide within urban settings.

Initiative Status: Rule adopted in August 2007

Cost: Not applicable

Documentation: Urban Turf Fertilizer Rule [5E-1.003(2) F.A.C]

Estimate of Water Quality Benefits

- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Conceptual
- Assumptions: Water quality benefits will be rolled up into a single "urban" category

Estimate of Water Quantity Benefits

- Minimum: N/A
- Maximum: N/A
- Most Likely: N/A
- Level of Certainty: Final

- Assumptions: N/A

Screening Criteria

- Proof of Concept: N/A
- Other Impacts: N/A

Contact: Rich Budell; FDACS; 850-617-1704

Final Water Quality Method and Summary: N/A
Final Water Quantity Method and Summary: N/A

Method: Included in the BMP load reduction estimates (Soil and Water Engineering Technology Inc. 2008).

Note: FDACS has adopted by administrative rule, agricultural best Management Practices addressing containerized nursery, vegetable and agronomic crop and citrus land uses in the Caloosahatchee River Watershed. FDACS is currently developing and will be adopting BMP programs for cow/calf, sod and equine operations. BMP's for all agricultural land uses are expected to be adopted by early 2009.

CRE-LO 04

Northern Everglades – Potential Management Measure

Project Feature/Activity: Land Application of Residuals

Level: 1

General Description/Background: Subsection 373.4595(3)(c)6. of the NEEPA requires that after December 31, 2007, the FDEP may not authorize the disposal of domestic wastewater residuals within the Caloosahatchee watershed unless the applicant can affirmatively demonstrate that the nutrients in the residuals will not add to nutrient loadings in the watershed. This demonstration shall be based on achieving a net balance between nutrient imports relative to exports on the permitted application site. Experts shall include only nutrients removed from the Caloosahatchee River watershed through products generated on the permitted application site. This prohibition does not apply to Class AA residuals that are marketed and distributed as fertilizer products in accordance with department rule.

Purpose: Improve water quality by reducing the transport of nutrients via runoff & leaching into regional systems from land application of residuals

Location/Size/Capacity: Basin wide

Initiative Status: Not initiated

Cost: To be determined **(**TBD)

Estimate of Water Quality Benefits
- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Conceptual
- Assumptions: NA

Estimate of Water Quantity Benefits
- Minimum: NA
- Maximum: NA
- Most Likely: NA
- Level of Certainty: Final
- Assumptions: NA

Level of Certainty: Level 1- Already constructed/implemented or construction/implementation imminent.

Screening Criteria
- Proof of Concept: NA
- Other Impacts: NA

Contact: Maurice Barker; FDEP; 850-245-8614

Included in BMP reduction estimates

CRE-LO 05

<u>Northern Everglades – Potential Management Measure</u>

Project Feature/Activity: Florida Yards and Neighbors

General Description/Background: The Florida Yards & Neighborhoods program is an excellent example of a nonstructural program that is helping to minimize the use of pesticides, fertilizers, and irrigation water by educating citizens and builders about proper landscape design. This promotes “right plant-right place” and minimizes the amount of fertilizer, pesticide, and irrigation needed for a successful landscape. FDEP has an ongoing monitoring program to determine the effectiveness of this program in reducing nutrient loads.

Purpose: Reduce the use of nutrients and pesticides, and irrigation, thereby reducing nutrient loading and reducing water use.

Location/Size/Capacity: Statewide

Initiative Status: On-going

Cost: TBD

Estimate of Water Quality Benefits
- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Conceptual
- Assumptions: Projected benefits will roll up under urban category

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Level of Certainty: Level 1

Screening Criteria
- Proof of Concept: NA
- Other Impacts: NA

Contact: Michael Scheinkman, FDEP Environmental Specialist - Clean Lakes program, lake management. Florida Yards and Neighborhoods. Phone 850-267-2075 Eric Livingston, FDEP, on monitoring project for FYN

Included in BMP reduction estimates

CRE-LO 07

Northern Everglades – Potential Management Measure

Project Feature/Activity: Environmental Resource Permit (ERP) Regulatory Program

Level: 1

General Description/Background: The Environmental Resource Permit (ERP) program regulates activities involving the alteration of surface water flows. This includes activities in uplands that alter stormwater runoff, as well as dredging and filling in wetlands and other surface waters. ERP applications are processed by either the Department or the water management districts, in accordance with the division of responsibilities specified in operation agreements between the Department and the water management districts.

Purpose: The purpose of this measure is to ensure that activities do not degrade water quality, impact flood protection or adversely impact the function of wetland systems.

Location/Size/Capacity: SFWMD jurisdiction

Initiative Status: Existing Program Activity

Cost: N/A

Estimate of Water Quality Benefits

- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Conceptual
- Assumptions: No increase in phosphorus loads resulting from new development; Applies to new development only; Conversion of intense agricultural uses (dairies, row crops, improved pasture, sod, citrus) with little or no water quality treatment to urban uses with modern surface water management systems with treatment; Projected benefits will roll up under the urban category

Estimate of Water Quantity Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Conceptual
- Assumptions: Applies to new development only; Conversion of intense agricultural uses (dairies, row crops, improved pasture, sod, citrus) with little or no stormwater storage to urban uses with modern surface water management systems with storage; Projected benefits will roll up under urban category

Level of Certainty: Level 1- Already constructed/implemented or construction/implementation imminent.

Screening Criteria

- Proof of Concept: NA
- Other Impacts: NA

Contact: Damon Meiers; SFWMD; 561-682-6876

CRE-LO 08

Northern Everglades – Potential Management Measure

Project Feature/Activity: National Pollutant Discharge Elimination System (NPDES) Stormwater Program

Level: 1

General Description/Background: In 1987, the Federal Clean Water Act was amended requiring the U.S. Environmental Protection Agency (EPA) to develop rules to implement the federal National Pollutant Discharge Elimination System (NPDES) stormwater permitting program. Phase I, promulgated in 1990, addresses the following sources:

"Large" and "medium" **municipal separate storm sewer** systems (MS4s) located in incorporated places and counties with populations of 100,000 or more, and eleven categories of **industrial activity**, one of which is large **construction activity** that disturbs 5 or more acres of land.

Phase II, promulgated in 1999, addresses additional sources, including MS4s not regulated under Phase I, and small construction activity disturbing between 1 and 5 acres.

In October 2000, EPA authorized the Florida Department of Environmental Protection (DEP) to implement the NPDES stormwater permitting program in the State of Florida (in all areas except Indian Country lands). FDEP's authority to administer the NPDES program is set forth in Section 403.0885, Florida Statutes (F.S.).

Important note**:** The NPDES stormwater permitting program is separate from the State's stormwater/environmental resource permitting programs (found under Part IV, Chapter 373, F.S. (593KB) and Chapter 62-25, F.A.C. and local stormwater/water quality programs, which have their own regulations and permitting requirements.

Purpose: To reduce stormwater pollutant loads discharged to surface waters, especially from existing land uses and drainage systems. This is especially true for the master drainage systems owned and operated by cities, counties, FDOT, and Chapter 298 water control districts. Also can help to reduce stormwater pollutant loads from existing industrial sites and from new construction sites.

Location/Size/Capacity: Basin wide

Initiative Status: Being implemented by FDEP

Cost: TBD

Documentation: For more information, please see:
http://www.dep.state.fl.us/water/stormwater/npdes/index.htm

Estimate of Water Quality Benefits

- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Conceptual
- Assumptions: Projected benefits will roll up under urban category

Estimate of Water Quantity Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Conceptual
- Assumptions: Depends if infiltration BMPs or stormwater reuse is done; Projected benefits will roll up under urban category

Level of Certainty: Level 1- Already constructed/implemented or construction/implementation imminent.

Screening Criteria

- Proof of Concept: NA
- Other Impacts: NA

Contact: Steven Kelly, Program Administration, NPDES Stormwater Section, Tallahassee, 850-245-7518

CRE-LO 09

Northern Everglades – Potential Management Measure

Project Feature/Activity: Coastal &Estuarine Land Conservation Program

Level: 1

General Description/Background: The Coastal and Estuarine Land Conservation Program (CELCP) was established in 2002. The Federal Office of Ocean and Coastal Resource Management (OCRM) will administer the program which provides up to $3 million dollars for each eligible project. CELCP federal funds will be provided for eligible activities related to state planning, program administration and project acquisition. Any project approved through the program must provide non-federal matching dollars.

Purpose: Protecting important coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses" (CELCP Final Guidelines, 2003).

Location/size/capacity: Statewide

Initiative Status: On-going

Cost: $3 million dollars for each eligible project.

Documentation: For more information, please see:
http://coastalmanagement.noaa.gov/land/welcome.html

Estimate of Water Quality Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Estimate of Water Quantity Benefits
- Minimum: Incidental
- Maximum: Incidental
- Most Likely: Incidental
- Level of Certainty: Unknown
- Assumptions: NA

Level of Certainty: Level 1-

Screening Criteria
- Proof of Concept: NA
- Other Impacts: NA

Contact: W. Kennedy; FDEP; 561-681-6706

CRE-LO 12g

Northern Everglades – Potential Management Measure

Project Feature/Activity: Alternative Water Storage (LOER) – Barron Water Control District (BWCD)

Level: 1

General Description/Background: The 2005 Lake Okeechobee Estuary and Recovery (LOER) action plan was developed to help restore the ecological health of Lake Okeechobee and adjoining estuaries, through a series of fast-track water quality improvement projects and several other far-reaching and innovative components. Among these additional components is an initiative to identify options for storage and/or disposal of excess surface water to aid in reducing lake levels and high discharge volumes to the estuaries. Assessments of available public and tribal lands for storage of excess surface water have been completed for the watershed, with assessments continuously ongoing for private lands. Eight water storage/disposal projects have been completed including Lykes Basinger Grove, Phase II Indiantown Citrus Growers Association. Additional water storage projects are under way (i.e. Avon Park Air Force Range, Kissimmee Prairie Preserve State Park, etc.), with investigations and designs continuing for additional water storage projects with a goal of 450,000 ac-ft.

Purpose: To assess, plan, design, and construct water storage/disposal projects on public, private, and tribal lands.

Location/Size/Capacity: BWCD is constructing a water storage project within its system which includes the construction of two weirs in an existing canal to retain more water within the BWCD canal system. Excess water in the Caloosahatchee River due to Lake Okeechobee regulatory regional releases will be pumped into BWCD for disposal when conditions support additional capacity. Retention within the existing ditch system and detention areas will result in water quality improvements and enable reuse by individual growers, thereby promoting water conservation and reducing the volume of discharge to the Caloosahatchee River.

Initiative Status: 5,000 ac-ft of water storage on 6,129 acres of project area

Cost: Total $400,000 (District contributed $200,000 and BWCD contributed $200,000).

Estimate of Water Quality Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: Not determined

Estimate of Water Quantity Benefits

- Minimum: 5,000 ac-ft
- Maximum: 5,000 ac-ft

- Most Likely: 5,000 ac-ft
- Level of Certainty: Final
- Assumptions: Not determined

Level of Certainty: 1

Screening Criteria:
- Proof of Concept: 1
- Other Impacts: 1

Contact: Benita Whalen; SFWMD; 863-462-5260

Source: Management Measure description.

Effective Storage Area: 5000 ac-ft of additional storage capacity.

WQ Benefits: None

CRE-LO 15

Northern Everglades – Potential Management Measure

Project: Proposed Caloosahatchee River Watershed Regulatory Nutrient Source Control Program

Level: 2

Description: To implement a regulatory nutrient source control program utilizing best management practices for the Caloosahatchee River Watershed complementary to the Coordinating Agencies collective efforts. Ongoing activities include revising Chapter40E-61 of the Works of the District Rule to reflect the requirements of the Northern Everglades Protection Act and to expand the rule boundary to include the Caloosahatchee River Watershed as defined by the act.

Purpose: To implement a phosphorus source control program utilizing best management practices for the Caloosahatchee River Watershed complementary to the Coordinating Agencies collective efforts.

Location/Size/Capacity: The location is the Caloosahatchee River Watershed as defined by the Northern Everglades Protection Act.

Initiative Status: The Governing Board has authorized staff to initiate rule amendments to Chapter 40E-61 to reflect recent changes in the legislation. Staff will need to obtain authorization to expand the program to the Caloosahatchee River Watershed. Rule amendments will incorporate permitting, monitoring and BMP implementation verification program.

Cost: FY08 $891,986 (LOK program) Ad Valorem

Estimate of Water Quality Benefits:
- Minimum – TBD
- Maximum- TBD
- Most Likely- TBD
- Level of Certainty- conceptual/final/unknown - unknown
- Assumptions leading to benefit estimate- n/a (Based on experience in other predominately agricultural areas with phosphorus limited BMP programs, we might expect to accomplish a 25% load reduction when comparing pre and post BMP periods. Less reduction would be anticipated for urban areas.)

Estimate of Water Quantity Benefits:
- Minimum – Unknown
- Maximum- Unknown
- Most Likely- Some changes may result from implementation of water management BMPs, but not quantifiable at this time.
- Level of Certainty- conceptual/final/unknown - unknown
- Assumptions leading to benefit estimate- n/a

Contact: Steffany Gornak; SFWMD; 561-682-6600

CRE-LO 21

Northern Everglades – Potential Management Measure

Project Feature/Activity: Lake Okeechobee and Estuary Watershed Basin Rule (LOER)

Level: 3

General Description/Background: This management measure originated as a component of the Lake Okeechobee and Estuary Recovery (LOER) plan. The component was titled Environmental Resource Permit (ERP) Revisions. The intent is to develop specific supplemental permit criteria for new permitted projects to demonstrate that no increase in total runoff volume will occur from new development that ultimately discharges to Lake Okeechobee or the Caloosahatchee or St. Lucie estuaries.

Purpose: The purpose of this measure is to not increase total runoff volume from new development that discharge ultimately to Lake Okeechobee or the Caloosahatchee or St. Lucie estuaries.

Location/size/capacity: The basin rule would cover the Lake Okeechobee Watershed and the Caloosahatchee and St. Lucie Estuary Watersheds

Initiative Status: In March 2008, the South Florida Water Management District (SFWMD) initiated rule development for an ERP Basin Rule with supplemental criteria designed to result in no increase in total runoff volume from new development that ultimately discharges to Lake Okeechobee or the Caloosahatchee or St. Lucie Estuaries.

Cost: TBD

Documentation: For more information, follow: https://my.sfwmd.gov/portal/page and choose the Lake Okeechobee and Estuary Watersheds Basin Rule.

Estimate of Water Quality Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: Projected benefits will roll up under urban category

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Level of Certainty: Level 3- Implementation Certainty unknown; Conceptual level of design/activity development complete; Location defined.

Screening Criteria

- Proof of Concept: 0
- Other Impacts: 0

Contact: Damon Meiers; SFWMD; 561-682-6876

CRE-LO 40

Northern Everglades – Potential Management Measure

Project: West Lake Hicpochee Project

Level: 3

General Description/Background: The Lake Hicpochee project is located on approximately 7,500 acres, which is currently in private ownership. This project comprises a reservoir and stormwater treatment area along the C-19 and C-43 canals, degradation of berms, exotic plant removal and control. The treatment area will be designed for the optimal removal of nitrogen from water diverted to the facility from the C-19 Canal. The treated water will then flow to the Caloosahatchee River bypassing Lake Hicpochee. The project could potentially create 55,090 ac-ft of above ground storage. The assumption has been made that a feature targeting nitrogen removal will also successfully reduce concentrations of both phosphorus and suspended solids.

Purpose: The primary objectives are to restore the ecological functioning of Lake Hicpochee, provide more water to the Caloosahatchee Estuary during the dry season and reduce nutrient concentrations within Lake Hicpochee and the Caloosahatchee River. Additional benefits include improved areas for potential recreation and public use, improvement of an already diverse wildlife area and lake fisheries. This feature, in conjunction with others within the basin, are designed to have the cumulative effect of reducing nutrient concentrations and loads significant enough to meet water quality targets within the Caloosahatchee Estuary.

The Water Quality component of this project is captured under CRE 05 in Alternative 4.

Location/Size/Capacity:

- Location: Glades County on the west side of C-19, north of the Lake and along the north side of the Caloosahatchee River, west of the Lake.
- Size and Capacity: The facility will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status:

• Advance planning phase and associated field work	TBD
• PIR/BODR	TBD
• Preliminary Plans and specifications	TBD
• Intermediate Design for the PS and Reservoir	TBD
• Intermediate Design for the STA	TBD
• Pre-final Design	TBD

Cost: Costs of storage capacity are based on the costs established in the C-43 West Basin Storage Reservoir project of $2,982 per acre foot of storage. The cost of the stormwater treatment area is to be determined when appropriately sized.

Documentation: Evergladesplan.org: C-43 West Basin Storage Reservoir Project and Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Conceptual
- Assumptions leading to benefit estimate: STA's have been shown to effectively remove phosphorus concentrations. Applying methods to target nitrogen is assumed to increase nitrogen removal efficiencies.

Estimate of Water Quantity Benefits

- Minimum: 21,490 ac-ft of above ground storage (2,880 acres)
- Maximum: 55,090 ac-ft of above ground storage (7,500 acres)
- Most Likely: 21,490 ac-ft
- Level of Certainty: Conceptual
- Assumptions leading to benefit estimate: Acquisition of approximately 7500 acres immediately adjacent to Lake Hicpochee.

Level of Certainty: Level 3- implementation certainty unknown; conceptual level of design/activity development complete; location defined

Contact: Janet Starnes; SFWMD; 239-338-2929 *7735

Date: 6-11-08 **Source:** Management Measure description.

Effective Storage Area: Current configuration is two reservoirs to the northwest of Lake Hicpochee, with a total area of 5700 ac. As an example, the two potential areas could be: I – about 2500 ac, and II – about 3200 ac.

WQ Benefits: Calculated using SWFFS reductions for "deep reservoir" (currently 4 lb/ac/yr for TN and 1 lb/ac/yr for TP). In the water-quality spreadsheet, each reservoir has one line.

Further benefit for removal of land from existing agricultural use, including approximately 1200 ac of sugar cane and 1100 ac of improved in area I, and approximately 3000 ac of sugar cane in area II. Removal is calculated using an estimated net source-load reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, and reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting improved pasture to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 59300 lb/yr for TN and 8450 lb/yr for TP.

Date: 8-8-08

Effective Storage Area: Current configuration is two reservoirs to the northwest of Lake Hicpochee, with a total area of 5700 ac. As an example, the two potential areas could be: I – about 2500 ac, and II – about 3200 ac.

Source: Management Measure description.

WQ Benefits: Estimated as 11 Mton/yr for TN and 0.7 Mton/yr for TP for reservoir, as modeled by WSI (written commun., 8/6/08). In the water-quality spreadsheet, each reservoir has one line.

Further benefit for removal of land from existing agricultural use, including approximately 1200 ac of sugar cane and 1100 ac of improved in area I, and approximately 3000 ac of sugar cane in area II. Removal is calculated using an estimated net source-load reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, and reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting improved pasture to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 60800 lb/yr for TN and 4300 lb/yr for TP.

This management measure includes information provided in CRE 03.

CRE-LO 41

Northern Everglades – Potential Management Measure

Project Feature/Activity: C-43 Distributed Reservoirs

Level: 4

General Description/Background: The Caloosahatchee Water Management Plan and preliminary work on the Caloosahatchee.

Purpose: The project objectives are to capture excess run-off within the Caloosahatchee River Watershed Protection Plan's Freshwater Southeast sub-basin which will then be operated to achieve both environmental flows to the Caloosahatchee Estuary and agricultural demands.

Location/Size/Capacity: The reservoirs are located south of the Caloosahatchee River in Hendry and Glades counties, between S-77 (Lake Okeechobee) and S-78 (Ortona Lock and Dam). The project components include up to 4 reservoirs with a total storage capacity of 85,410 ac-ft.

- Reservoir (up to)
    - Acreage
    - Water Depth
    - Storage volume 85,410 ac-ft (total all reservoirs)
    - Embankment length
    - Pump Station

Initiative Status:

- Advance planning phase and associated field work TBD
- BODR TBD
- Preliminary Plans and specifications TBD
- Intermediate Design for the PS and Reservoir TBD
- Intermediate Design for the STA TBD
- Pre-final Design TBD

Cost: TBD

Estimate of Water Quality Benefits

- Minimum: TBD
- Maximum: TBD
- Most Likely: TBD
- Level of Certainty: Unknown
- Assumptions: TBD

Estimate of Water Quantity Benefits

- Minimum: TBD
- Maximum: TBD
- Most Likely: TBD

- Level of Certainty: Conceptual
- Assumptions: TBD

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Screening Criteria

- Proof of Concept: NA
- Other Impacts: NA

Contact: Janet Starnes; SFWMD; 239-338-2929 *7735

Source: Management Measure description.

Effective Storage Area: Current configuration is two reservoirs with a total area of 6600 ac. As an example, the two potential areas could be: I – about 5000 ac located well south of Lake Hicpochee; and II – about 1600 ac located slightly west of Lake Hicpochee.

WQ Benefits: Calculated using SWFFS reductions for "deep reservoir" (currently 4 lb/ac/yr for TN and 1 lb/ac/yr for TP). In the water-quality spreadsheet, each reservoir has one line.

Further benefit for removal of land from existing agricultural use, including approximately 3100 ac of citrus and 1000 ac of sugar cane in area I, and approximately 1200 ac of citrus in area II. Removal is calculated using an estimated net source-load reduction of 6.89 lb/ac/yr for TN and 0.56 lb/ac/yr for TP in converting citrus to open water, and reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 62500 lb/yr for TN and 9400 lb/yr for TP.

August 8, 2008

Effective Storage Area: Current configuration is two reservoirs with a total area of 6600 ac. As an example, the two potential areas could be: I – about 5000 ac located well south of Lake Hicpochee; and II – about 1600 ac located slightly west of Lake Hicpochee.

WQ Benefits: Estimated as 23 Mton/yr for TN and 1.4 Mton/yr for TP for reservoir, as modeled by WSI (written commun., 8/6/08). In the water-quality spreadsheet, each reservoir has one line.

Further benefit for removal of land from existing agricultural use, including approximately 3100 ac of citrus and 1000 ac of sugar cane in area I, and approximately 1200 ac of citrus in area II. Removal is calculated using an estimated net source-load reduction of 6.89 lb/ac/yr for TN and 0.56 lb/ac/yr for TP in converting citrus to open water, and reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 87000 lb/yr for TN and 5800 lb/yr for TP.

CRE-LO 63

Northern Everglades – Potential Management Measure

Project Feature/Activity: Wastewater & Stormwater Master Plans

Level: 4

General Description/Background: Initiative to work with entities (e.g. Cities and Counties) in the Caloosahatchee River Watershed responsible for wastewater & stormwater programs. Work with those entities to review existing wastewater & stormwater Master Plans to identify planned or possible projects that will provide additional phosphorus reductions that could be implemented in the service area.

Purpose: Implement urban stormwater retrofitting projects or wastewater projects to achieve addition phosphorus and nitrogen reductions and water storage.

Location: Basinwide

Initiative Status: Not initiated

Cost: TBD

Estimate of Water Quality Benefits
- Minimum: Urban Rollup
- Maximum: Urban Rollup
- Most Likely: Urban Rollup
- Level of Certainty: Unknown
- Assumptions: Projected benefits will roll up under urban category

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: Projected benefits will roll up under urban category

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Screening Criteria
- Proof of Concept:
- Other Impacts:

Contact: Frank Nearhoof; FDEP

CRE-LO 64

Northern Everglades – Potential Management Measure

Project Feature/Activity: Unified Statewide Stormwater Rule

General Description/Background: Florida's stormwater treatment rules are technology-based and rely upon BMP design criteria that are presumed to achieve a specified level of stormwater treatment. The rule's original performance standard was "secondary treatment", or 80 percent average annual load reduction of Total Suspended Solids (TSS). However, the minimum level of treatment in Chapter 62-40, F.A.C., is "80 percent average annual load reduction of pollutants that cause or contribute to violations of water quality standards". Nutrients are the biggest source of water body impairment throughout the state and the Governor has directed FDEP to increase the level of stormwater nutrient treatment. Accordingly, FDEP and SFWMD staff are working on a statewide stormwater treatment rule that will be based on a performance standard of post-development nutrient loading does not exceed pre-development nutrient loading.

Purpose: To increase the level of nutrient treatment of stormwater from new development and thereby reduce the discharge of nutrients and excess stormwater volume.

Location: Basinwide

Initiative Status: Beginning July 07, Rule in effect mid to late 2010

Cost: TBD

Estimate of Water Quality Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Conceptual
- Assumptions: Rule will be adopted

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Conceptual
- Assumptions: Depends on how much infiltration and reuse is done

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Screening Criteria
- Proof of Concept:
- Other Impacts:

Contact: Eric Livingston, FDEP, Tallahassee, 850/245-8430

CRE-LO 68

Northern Everglades – Potential Management Measure

Project Feature/Activity: Comprehensive Planning – Land Development Regulations (LDR)

Level: 3

Description: Initiative to work with entities (e.g. Cities and Counties) in the Caloosahatchee River Watershed responsible for comprehensive planning and land development approvals. Work with those entities to review current comprehensive plans and associated land development regulations to assure that they promote low impact design and proper stormwater treatment.

Purpose: Implement low impact design measures in Caloosahatchee River Watershed to achieve addition phosphorus reductions and water storage.

Location: Basin wide

Initiative Status: Not initiated

Cost: TBD

Estimate of Water Quality Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: Assume LDRs are changed to promote LID

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: Assume LDRs are changed to promote LID

Level of Certainty: **Level 3-** Implementation Certainly unknown; Conceptual level of design/activity development complete; Location defined.

Screening Criteria
- Proof of Concept:
- Other Impacts:

Contact: Eric Livingston; FDEP; 850/245-8430

CRE-LO 87c

Northern Everglades – Potential Management Measure

Project Feature/Activity: Florida Ranchlands Environmental Services Project (FRESP)

Level: 1

General Description/Background: Launched in October 2005, the Florida Ranchlands Environmental Services Project (FRESP) will design a program in which ranchers in the Northern Everglades' sell environmental services of water retention, phosphorus load reduction and wetland habitat expansion to agencies of the state and other willing buyers.

These ranches can bring services on line quickly as compared to other options and will complement public investment in regional water storage and water treatment facilities. The sale of the services will be additional income for ranchers who face low profit margins and will provide an incentive against selling land for more intensive agriculture and urban development—land uses that will further aggravate water flow, pollution, and habitat problems.

FRESP is being implemented through collaboration between World Wildlife Fund (WWF), 8 participating ranchers, USDA's Natural Resources Conservation Service and state agencies – the Florida Department of Agriculture and Consumer Services, the South Florida Water Management District, and the Florida Department of Environmental Protection. Technical support is being provided by scientists from the MacArthur Agro-Ecology Research Center and the University of Florida. Funding from Federal, state and private sources exceeds $5 mil for Phase One – pilot project implementation and program design.

Key Accomplishments

Developed procedures to compare different protocols for documenting environmental services from ranchlands. FRESP will field test different methods of using monitoring and modeling of hydrology, water and soil chemistry, and vegetation change to document the level of environmental services provided by ranch water management projects.

Completed the design, permitting and construction of water management projects on 4 ranches; additional water management projects will be implemented by four additional ranchers. Projects include rehydrating drained wetlands, water table management, and pumping water from a nearby canal through existing ranch wetlands and flowing back into the canal. Based on available information the 8 water management projects occupy some 8,500 acres not including drainage acres. A planning level estimate of the static water retention capacity of the eight projects is 8,260 ac-ft of water for a single storm event with the average ac-ft of storage per acre being 0.98 ft.

Watershed Static Water Retention Potential

Planning level estimates generated by the existing pilot projects were used to derive conservative estimates of potential static storage – maximum capacity to hold water from a single storm event.

If FRESP contracts covered only 15 percent of improved pasture acreage in the Northern Everglades, using the average ac-ft/acre estimate of the 8 existing FRESP sites of 0.98, the potential storage estimate is 118,000 ac-ft of water (800,500 X 15 percent = 120,000 acres X 0.98 ac-ft / ac). If 15 percent of the unimproved pasture acreage is included the potential storage is 151,800 ac-ft (1,029,500 X 15 percent = 154,400 acres X 0.98 ac-ft /ac). Because these estimates are for a single storm event, they are conservative estimates of annual on-ranch water retention.

Location/Size/Capacity:

	Improved Pasture in LOPP Watershed	**Acre-Ft Static Storage on Improved Pasture (0.98 ac-ft/ac)**	**Improved and Unimproved Pasture**	**Acre Ft Static Storage on Improved & Unimproved Pasture (0.98 ac-ft/ac)**
Total Acres	800,464		1,029,509	
Assumptions re percent Acres in FRESP for Different Land Use Combinations				
10%	80,046	78,706	102,951	101,226
15%	120,070	118,058	154,426	151,840
20%	160,093	157,411	205,902	202,453

Initiative Status: Developed procedures to compare different protocols for documenting environmental services from ranchlands. FRESP will field test different methods of using monitoring and modeling of hydrology, water and soil chemistry, and vegetation change to document the level of environmental services provided by ranch water management projects.

Completed the design, permitting and construction of water management projects on 4 ranches; additional water management projects will be implemented by four additional ranchers. Projects include rehydrating drained wetlands, water table management, and pumping water from a nearby canal through existing ranch wetlands and flowing back into the canal. Based on available information the 8 water management projects occupy some 8,500 acres not including drainage acres. A planning level estimate of the static water retention capacity of the eight projects is 8,260 ac-ft of water for a single storm event with the average ac-ft of storage per acre being 0.98 ft.

Developing the design of a pay for services program. Essential program design questions—such as how to assure a dedicated, multiyear funding source to meet contract payment obligations; how to establish what prices that will be paid for services and how to integrate a new pay-for-services program with other state and federal programs will be addressed and answered though the deliberations of the collaboration team, in cooperation with multiple stakeholders and with state agency officials.

Estimate of Water Quantity Benefits
- Minimum: TBD
- Maximum: TBD

- Most Likely: TBD
- Level of Certainty: conceptual/final/unknown
- Assumptions: Planning level estimates generated by the existing pilot projects were used to derive conservative estimates of potential static storage – maximum capacity to hold water from a single storm event. If FRESP contracts covered only 15 percent of improved pasture acreage in the Northern Everglades, using the average ac-ft/acre estimate of the 8 existing FRESP sites of 0.98, the potential storage estimate is 118,000 ac-ft of water (800,500 X 15 percent = 120,000 acres X 0.98 ac-ft / ac). If 15 percent of the unimproved pasture acreage is included the potential storage is 151,800 ac-ft (1,029,500 X 15 percent = 154,400 acres X 0.98 ac-ft / ac). Because these estimates are for a single storm event, they are conservative estimates of annual on-ranch water retention.

Level of Certainty: Level 1- Already constructed/implemented or construction/implementation imminent.

Contact: Benita Whalen; SFWMD; 863-462-5260

CRE-LO 91

<u>Northern Everglades – Potential Management Measure</u>

Project Feature/Activity: Farm and Ranchland Partnerships

Level: 4

General Description/Background: There are two USDA Natural Resources Conservation Service (NRCS) programs that help farmers and ranchers keep their land in agriculture: the Farm and Ranchlands Protection Program (FRPP) and the Wetlands Reserve Program (WRP). Both programs provide funds to purchase conservation easements. The proposal is that the NRCS, the District, local agricultural landowners, and other partners enter into agreements to contribute funding and resources toward a long-term partnership.

Purpose: The partnership would acquire easements on private lands to remain in agriculture and provide water quality and storage benefits in support of the Northern Everglades initiative.

Location/Size/Capacity: The Caloosahatchee River Watershed

Initiative Status: FRPP and WRP are established programs and landowners are waiting to participate pending federal appropriations.

Cost: The proposal is that the NRCS, the District, and local agricultural landowners, enter into agreements to contribute resources toward a long-term partnership. The partnership would leverage existing federal and state funding.

Estimate of Water Quality Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Estimate of Water Quantity Benefits
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions:

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Screening Criteria
- Proof of Concept: NA
- Other Impacts: NA

Contact: Benita Whalen; SFWMD; 863-462-5260

CRE-LO 92

Northern Everglades – Potential Management Measure

Project Feature/Activity: Clewiston STA

Level: 4

General Description/Background: The State of Florida (TIITF) currently owns a parcel of land along the southwestern boundary of Lake Okeechobee in Clewiston (see attached site map Parcel HH200-004). This land in both Hendry and Glades Counties is approximately 766 acres in size and is bordered by Lake Okeechobee on the north side and Canals C-21 and C-20 on the south side. The land is currently in a natural state although it is reportedly impacted by invasive plant species. The potential exists for this land to be used as a natural treatment area for water that is currently discharged to Lake Okeechobee.

Purpose: The purpose of this potential Management Measure is to convert existing State owned land into a Stormwater Treatment Area to treat storm water from the S4 Basin and surrounding area that is currently sent to either Lake Okeechobee (via Culvert 2, S-310 lock Structure and/or S4 Pump Station) or the Caloosahatchee River (via S-235).

Location/Size/Capacity: The land area is approximately 766 acres of which approximately 700 – 750 acres could be used as "treatment area" with the remaining area used for levees and other infrastructure. The current estimated average load is 6.87 mt/yr from the S-4 Basin. It is assumed that a percentage of this water could be routed through the proposed STA.

Initiative Status: Conceptual

Cost: To Be Determined – Note: Other efforts (public and private) in the immediate area could potentially provide funding for all or portions of this proposal. The two main efforts include the S-169 Relocation Study – General Reevaluation Report by the U.S. Army Corps of Engineers and a development proposal by a private developer in Clewiston.

Documentation: Lake Okeechobee Protection Plan Evaluation Report – February 23, 2007

Estimate of Water Quality Benefits

- Minimum: 0 mt/yr
- Maximum: 6.87 mt/yr
- Most Likely: 2.5 mt/yr
- Level of Certainty: Conceptual
- Assumptions: Flow rate = 40 cfs; Inflow P Concentration = 200 ppb; STA size = 750 acres; Outflow P Concentration = 130 ppb

Estimate of Water Quantity Benefits

- Minimum: 1,013 ac-ft
- Maximum: 1,013 ac-ft
- Most Likely: 1,013 ac-ft

- Level of Certainty: Conceptual
- Assumptions: STA storage volume based on 90 percent of footprint acreage X 1.5 ft standard operating depth

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Screening Criteria

- Proof of Concept: 1
- Other Impacts: 1

Contact: Mike Voich, SFWMD, 681-2563 *3720

Source: Management Measure description.

Effective Storage Area: STA of 750 ac on site of 766 ac.

WQ Benefits: The management-measure description estimates a load reduction of 2.5 metric tons per year for TP, with a flow through rate of 40 cfs and TP concentrations of 0.20 mg/L input and 0.13 mg/L output. Those numbers are internally consistent. For TN, a load reduction of 0.5 mg/L is estimated, which is generally considered reasonable, and calculated for a flow through rate of 40 cfs. This works out to 52 lb/ac/yr for a 750-ac reservoir, which is less than the SWFFS typical values of 100 lb/ac/yr for an STA, but it would be overly optimistic to expect a reduction of more than 0.50 mg/L.

Total load reduction for the STA project is estimated as 39400 lb/yr for TN and 5500 lb/yr for TP. However, little if any of this reduction could be applied to the Caloosahatchee watershed. All of the outflow from this project is currently modeled as being pumped into Lake Okeechobee at S-4, with none into the C-43 via S-235. Therefore, for purposes of the CRWPP and for consistency with other plans, the net load reductions for this project to the Caloosahatchee are presumed nil.

CRE 01

Northern Everglades – Potential Management Measure

Project: Recyclable Water Containment Areas (RCWA) in the Freshwater Caloosahatchee

Level: 4

Description: This project consists of management measures that can be applied to agricultural areas for reduction of nutrients to receiving waters. This concept utilizes the agricultural lands for temporary water storage and for water quality benefits. The project consists of Recyclable Water Containment Areas which acts as a reservoir within the agricultural lands. These areas are constructed with temporary earthen berms on the agricultural fields using on-site material with ~2' water depth. RWCAs will remain in operation for approximately 5 years, at which time the area will come back into production of traditional ag products utilizing the nutrients that have built up in the soil through settling when water was present in the RWCA.

Purpose: The purpose of this feature is reduction of nutrient loads into the Caloosahatchee River.

Location/Size/Capacity:

- Sub-basin:
    - Freshwater Caloosahatchee Southeast
    - Okaloacoochee Slough North
    - Gum Slough
    - Freshwater Caloosahatchee Southwest
    - Hickey Creek
    - Freshwater Caloosahatchee Northeast
    - Freshwater Caloosahatchee Tributaries
    - Bee Branch
    - Jacks Branch
    - Otter Creek
    - Freshwater Caloosahatchee Okeechobee
    - Telegraph Swamp
    - Tidal Caloosahatchee Tributaries
- Location: Agricultural properties within each of these sub-basins
- Size and Capacity: Specific management measures from the ag suite will be implemented on a percentage of ag properties an any given time, and the capacity will be dependent upon that percentage, the measure implemented, and the acreage of ag land in the sub-basin.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress).
Also see documents produced by IFAS (Sanjay Shukla and Ed Hanlon)

Estimate of Water Quality Benefits:

- Nutrient load reduction to Caloosahatchee River and Estuary. The specific water quality benefits will be dependent upon the total area of ag lands operating RWCAs
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Work by UF and IFAS has shown this system to have potential water quality benefits as well as benefits to agricultural operations.

Estimate of Water Quantity Benefits:

- Water quantity benefits include the storage of water during peak flows on land that would otherwise continue down the River to the Estuary. This system has the potential for very large quantities of water to be stored.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Work by UF and IFAS has shown this system to have potential water quantity benefits as well as benefits to agricultural operations.

Level of Certainty: Level 4- implementation certainty unknown; conceptual idea; may have rough order of magnitude cost and/or general basin location

Contact Person – Jennifer Nelson

Source: Management Measure description and further discussions with Ed Hanlon (IFAS).

Effective Storage Area: Estimate 5000 ac, distributed equally among 5 subregions, with 4-ft berms able to hold water up to 2-ft depth.

WQ Benefits: Calculated using estimated reductions for "RWCA" (currently 20 lb/ac/yr for TN and 5 lb/ac/yr for TP). (Note: These numbers are simply guesses.)

Further benefit for removal of land from existing improved pasture, calculated as 5000 ac of improved pasture times an estimated net source-load reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting pasture to water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 149000 lb/yr for TN and 31600 lb/yr for TP. These reductions are split evenly between FW NE, FW SE, FW NW, FW SW, and Telegraph Swamp.

This management measure considered information included in CRE 93.

CRE 02

<u>Northern Everglades – Potential Management Measure</u>

Project: Recycled Water Containment Area in the S-4 Basin

Level: 5

Description: The Recycled Water Containment Area (RWCA) concept utilizes agricultural or other lands for temporary water storage for water quality and storage benefits. The land is later returned to other uses after a period of time. This concept could be rotated through lands within the S-4 basin so that one land is not taken out of production for an extended period of time. RWCAs have numerous benefits including recycling nutrients, water storage, aquifer recharge, and decreasing excessive flows to the estuaries. In addition, this concept could be used as backup water supply for agriculture and eliminate the need for back pumping into Lake Okeechobee. Currently the S-4 basin, depending on hydrologic conditions, drains into or uses irrigation water from the Caloosahatchee River.

Purpose: Remove nutrients and treat agricultural stormwater runoff from the S-4 basin to help reduce nutrient loading to the Caloosahatchee, aquifer recharge, and add a temporary back-up water supply for irrigation.

Location/Size/Capacity: Located in S-4 Basin. Size and capacity to be determined by discharge volume during peak rain events.

Initiative Status: Conceptual Phase

Cost: N/A

Documentation:

Estimate of Water Quality Benefits:

- **Minimum –** Remove agricultural runoff from the S-4 basin and reduce nutrient loading to the eastern Caloosahatchee. Reduce high flows during rain events and when the S-4 basin is pumping water off agricultural lands into adjacent canals that empty into the Caloosahatchee.
- **Maximum-** N/A
- **Most Likely-** N/A
- **Level of Certainty-** conceptual/final/unknown
- **Assumptions leading to benefit estimate-** (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)

Estimate of Water Quantity Benefits:

- **Minimum –** May add additional storage for irrigation by adjacent land owners.
- **Maximum-** N/A

- **Most Likely-** N/A
- **Level of Certainty-** conceptual/final/unknown
- **Assumptions leading to benefit estimate-** (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 5- implementation certainty unknown; conceptual idea with limited information

Contact: Jennifer Nelson

Source: Management Measure description and further discussions with Ed Hanlon (IFAS).

Effective Storage Area: Estimate 1000 ac within the S-4 subregion, with 4-ft berms able to hold water up to 2-ft depth.

WQ Benefits: Calculated using estimated reductions for "RWCA" (currently 20 lb/ac/yr for TN and 5 lb/ac/yr for TP). (Note: These numbers are simply guesses.)

Further benefit for removal of land from existing improved pasture, calculated as 1000 ac of sugar cane times an estimated net source-load reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 26000 lb/yr for TN and 5300 lb/yr for TP.

CRE 04

Northern Everglades – Potential Management Measure

Project: Caloosahatchee Area Lakes Restoration (Lake Hicpochee)

Level: 3

Description: This project addresses restoring the historic lake bed of Lake Hicpochee. The restored areas will collect runoff from agricultural canals that currently flow into Lake Hicpochee and the Caloosahatchee River. Once collected, the water could be released back into the Caloosahatchee River. The restoration of Lake Hicpochee would include diverting some of the flow from the Caloosahatchee River to the northern and southern portions of the lake to create open wetland. Deeper areas of the lake could be used to attenuate high flows and the littoral zones created would also provide additional habitat for wading birds during the dry season.

Purpose: The purpose of this project is to regain storage from Lake Hicpochee and to restore a range of unique habitats in the historic lake bed.

Location/Size/Capacity:
- Location: Glades County on the historical site of Lake Hicpochee.
- Size and Capacity: The treatment facilities will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status: Conceptual Phase

Cost: To be determined.

Documentation: Caloosahatchee Area Lakes Restoration/Alternative Water Storage (Contract # 3600000406-WO-11) Development of Alternatives (Draft) - 03/2008
Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: WQ Plan Formulation Document-(Draft) - 10/24/07 (STA concept)

Estimate of Water Quality Benefits:
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty**:** Conceptual
- Assumptions leading to benefit estimate: Unknown

Estimate of Water Quantity Benefits:
- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty**:** Conceptual

- Assumptions leading to benefit estimate: This project would provide water quantity benefits by restoring the historical lake bed as well as providing storage within the STAs.

Level of Certainty: **Level 4-** implementation certainty unknown; conceptual idea; may have rough order of magnitude cost and/or general basin location

Contact: Janet Starnes; SFWMD; 239-338-2929 *7735

Source: Management Measure description and Lake Hicpochee preferred alternative H-1B.

Effective Storage Area: 5300 ac within footprint of State-owned lands.

WQ Benefits: Calculated using SWFFS reductions for "filter marsh" (currently 40 lb/ac/yr for TN and 10 lb/ac/yr for TP).

Further benefit for removal of land from existing improved pasture, calculated as 1050 ac of improved pasture times an estimated net source-load reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting pasture to wetland, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 221000 lb/yr for TN and 55000 lb/yr for TP.

This management measure considered information included in CRE 06, CRE 07 and CRE 08.

CRE 05

Northern Everglades – Potential Management Measure

Project: East Caloosahatchee Water Quality Treatment Area

Level: 3

Description: This project consists of a constructed wetland designed for optimal nitrogen removal from water diverted to the facility from the C-19 canal that currently flows into Lake Hicpochee. The water will be diverted to the treatment facility and then back to the Caloosahatchee River, bypassing Lake Hicpochee. The downstream estuary is generally limited by nitrogen, and therefore the treatment feature will be designed for optimal nitrogen removal. The assumption has been made that a feature targeting nitrogen removal will also successfully reduce concentrations of both phosphorus and suspended solids.

Purpose: The purpose of this project is to reduce nutrient concentrations within Lake Hicpochee, the Caloosahatchee River, and nutrient pollutant loading to the downstream estuary. This feature, in conjunction with others within the basin, are designed to have the cumulative effect of reducing nutrient concentrations and loads significantly enough to meet water quality targets within the Caloosahatchee Estuary.

This management measure captures the water quality benefits associated with CRE-LO 40 which is an Alternative 2 Water Storage Feature.

Note: This project is one of many developed by the SWFFS WQ sub-team to address the nutrient enrichment issues of the Caloosahatchee Basin. The strategy of this effort was to formulate both structural and non-structural features that, once implemented, will collectively lead to restoration through pollutant load reductions (primarily nutrients). The cumulative effect of these pollutant reductions are to achieve water quality targets set forth by the SWFFS WQ sub-team (based either on an ecological resource, historical conditions, or reference conditions).

Location/Size/Capacity:
- Sub-basin: Freshwater Caloosahatchee NorthEast
- Location: northwest of Lake Hicpochee
- Size and Capacity: The facility will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits:

- Nutrient load reduction to Caloosahatchee River and Estuary, as well as Lake Hicpochee itself which contains a range of valuable habitats that have been degraded by nutrient pollution. The specific water quality benefits will be dependent upon the size of the feature, the effectiveness of the design and operation for removal of nitrogen (as well as other constituents), and on the concentration of pollutants in the inflow water to the feature (Caloosahatchee River and/or sub-basin runoff)
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Constructed wetlands have been shown to be effective phosphorus removal features. Applying methods/technologies to target nitrogen is assumed to be able to increase N removal efficiencies. This sub-basin has been determined to be an appropriate place for a water quality treatment feature due to its location within the basin.

Estimate of Water Quantity Benefits:

- Water quantity benefits may be achieved through the water storage capabilities of the feature (reducing peak flows or providing flows to downstream estuary depending upon season/conditions). Any potential water quantity benefits should be considered incidental because the feature's main purpose is water quality treatment and should be operated as such.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- It is assumed that the Caloosahatchee River and/or sub-basin sources will be able to adequately supply this feature with the water necessary for effective operation. It should be noted that during times of drought, competing water uses may have an impact on the operation of this feature and/or the water use of this feature may impact other water uses (e.g. MFL at S-79)

Level of Certainty: Level 3- implementation certainty unknown; conceptual level of design/activity development complete; location defined

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West Lake Hicpochee Water Quality Treatment Area

CRE 05 – Alt 4, Regional

Description / Purpose: Constructed wetland or STA optimized for nitrogen removal.

Source: Management Measure description

Effective Storage Area: 1600 ac

WQ Benefits: Calculated using SWFFS reductions for "STA" (currently 100 lb/ac/yr for TN and 25 lb/ac/yr for TP).

Further benefit for removal of land from existing improved pasture, calculated as 1696 ac of improved pasture times an estimated net source-load reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting pasture to water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 176500 lb/yr for TN and 42200 lb/yr for TP.

CRE 10

Northern Everglades – Potential Management Measure

Project: C-43 Water Quality Treatment and Demonstration Project (BOMA property)

Level: 4

Description: This project consists of a constructed wetland designed for optimal nitrogen removal from water diverted to the facility from the Caloosahatchee River and/or the Freshwater Caloosahatchee Southeast sub-basin. The downstream estuary is generally limited by nitrogen, and therefore the treatment feature will be designed for optimal nitrogen removal. The assumption has been made that a feature targeting nitrogen removal will also successfully reduce concentrations of both phosphorus and suspended solids.

Purpose: The purpose of this project is to reduce nutrient concentrations within the Caloosahatchee River and nutrient pollutant loading to the downstream estuary. This feature, in conjunction with others within the basin, are designed to have the cumulative effect of reducing nutrient concentrations and loads significantly enough to meet water quality targets within the Caloosahatchee Estuary.

Note: This project is one of many developed by the SWFFS WQ sub-team to address the nutrient enrichment issues of the Caloosahatchee Basin. The strategy of this effort was to formulate both structural and non-structural features that, once implemented, will collectively lead to restoration through pollutant load reductions (primarily nutrients). The cumulative effect of these pollutant reductions is to achieve water quality targets set forth by the SWFFS WQ sub-team (based either on an ecological resource, historical conditions, or reference conditions).

Location/Size/Capacity:

- Sub-basin: Freshwater Caloosahatchee Southeast
- Location: Boma Property (see BAT ID SLG04 – Long Hammock Slough)
- Size and Capacity: The facility will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits:

- Nutrient load reduction to Caloosahatchee River and Estuary. The specific water quality benefits will be dependent upon the size of the feature, the effectiveness of the design and operation for removal of nitrogen (as well as other constituents), and on the concentration of pollutants in the inflow water to the feature (Caloosahatchee River and/or sub-basin runoff)

- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Constructed wetlands have been shown to be effective phosphorus removal features. Applying methods/technologies to target nitrogen is assumed to be able to increase N removal efficiencies. This sub-basin has been determined to be an appropriate place for a water quality treatment feature due to its location within the basin.

Estimate of Water Quantity Benefits:

- Water quantity benefits may be achieved through the water storage capabilities of the feature (reducing peak flows or providing flows to downstream estuary depending upon season/conditions). Any potential water quantity benefits should be considered incidental because the feature's main purpose is water quality treatment and should be operated as such.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- It is assumed that the Caloosahatchee River and/or sub-basin sources will be able to adequately supply this feature with the water necessary for effective operation. It should be noted that during times of drought, competing water uses may have an impact on the operation of this feature and/or the water use of this feature may impact other water uses (e.g. MFL at S-79)

Level of Certainty: Level 4

Contact: Jennifer Nelson

Data Source: CH2MHill report of the same name, March 2008.

Effective Storage Area: 1000 ac (see pg. 28 in report).

WQ Benefits: Calculated as 99 cfs times an estimated load reduction of 0.50 mg/L for TN and 0.10 mg/L for TP. The report does not give an estimate for load reduction, so these numbers are estimated as approximately 30% and 50%, respectively for TN and TP, of the average load concentration expected for FW Caloosahatchee Southeast (from the current WMM/FDEP/TMDL modeling). Reductions of this magnitude are considered reasonable. Also, the resulting output concentrations would be approximately 1.0 and 0.10 mg/L, which approach the target concentrations of 0.8 and 0.08. The total load reductions would be 97500 lb/yr for TN, which is very close to the number that would be calculated using the SWFFS reduction for a "MAPS" (100 lb/ac/yr or 100000 lb/yr).

Further benefit for removal of land from existing citrus grove, calculated as 1320 ac of citrus times an estimated net source-load reduction of 6.10 lb/ac/yr for TN and 0.62 lb/ac/yr for TP in converting citrus to wetland, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 105500 lb/yr for TN and 20300 lb/yr for TP.

Further note: The report gives a total wetted area of 1000 ac, but only one third of that would be in floating-aquatic vegetation (FAV) cells, which would remove most of the TN. The residence time and flow rate (8 days and 99 cfs) were calculated using one-third area (333 ac) at 4.5 ft depth. The SWFFS estimate is based on the full area of1000 ac at 100 lb/ac/yr for a typical managed aquatic plant system (MAPS). For FAV cells themselves, the TN reduction might be on the order of 300 lb/ac/yr, but the report did not recommend that the project should be composed only of FAV cells.

CRE 11

Northern Everglades – Potential Management Measure

Project: Caloosahatchee Ecoscape Water Quality Treatment Area

Level: 4

Description: This project consists of a constructed wetland designed for optimal nitrogen removal from water diverted to the facility from the Caloosahatchee River and/or water from the Freshwater Caloosahatchee SouthWest sub-basin. The downstream estuary is generally limited by nitrogen, and therefore the treatment feature will be designed for optimal nitrogen removal. The assumption has been made that a feature targeting nitrogen removal will also successfully reduce concentrations of both phosphorus and suspended solids.

Purpose: The purpose of this project is to reduce nutrient concentrations within the Caloosahatchee River and nutrient pollutant loading to the downstream estuary. This feature, in conjunction with others within the basin, are designed to have the cumulative effect of reducing nutrient concentrations and loads significantly enough to meet water quality targets within the Caloosahatchee Estuary.
Note: This project is one of many developed by the SWFFS WQ sub-team to address the nutrient enrichment issues of the Caloosahatchee Basin. The strategy of this effort was to formulate both structural and non-structural features that, once implemented, will collectively lead to restoration through pollutant load reductions (primarily nutrients). The cumulative effect of these pollutant reductions are to achieve water quality targets set forth by the SWFFS WQ sub-team (based either on an ecological resource, historical conditions, or reference conditions).

Location/Size/Capacity:

- Sub-basin: Freshwater Caloosahatchee SouthWest
- Location: Caloosahatchee Ecoscape (see BAT ID BC84)
- Size and Capacity: The facility will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits:

- Nutrient load reduction to Caloosahatchee River and Estuary. The specific water quality benefits will be dependent upon the size of the feature, the effectiveness of the design and operation for removal of nitrogen (as well as other constituents), and on the concentration of pollutants in the inflow water to the feature (Caloosahatchee River and/or sub-basin runoff)

- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Constructed wetlands have been shown to be effective phosphorus removal features. Applying methods/technologies to target nitrogen is assumed to be able to increase N removal efficiencies. This sub-basin has been determined to be an appropriate place for a water quality treatment feature due to its location within the basin.

Estimate of Water Quantity Benefits:

- Water quantity benefits may be achieved through the water storage capabilities of the feature (reducing peak flows or providing flows to downstream estuary depending upon season/conditions). Any potential water quantity benefits should be considered incidental because the feature's main purpose is water quality treatment and should be operated as such.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- It is assumed that the Caloosahatchee River and/or sub-basin sources will be able to adequately supply this feature with the water necessary for effective operation. It should be noted that during times of drought, competing water uses may have an impact on the operation of this feature and/or the water use of this feature may impact other water uses (e.g. MFL at S-79)

Level of Certainty: Level 4- implementation certainty unknown; conceptual idea; may have rough order of magnitude cost and/or general basin location

Contact: Jennifer Nelson

Source: Management Measure description

Effective Storage Area: 1000 ac

WQ Benefits: Calculated using SWFFS reductions for "STA" (currently 100 lb/ac/yr for TN and 25 lb/ac/yr for TP).

Further benefit for removal of land from existing improved pasture, calculated as 1060 ac of improved pasture times an estimated net source-load reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting pasture to water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 110000 lb/yr for TN and 26400 lb/yr for TP.

CRE 13

Northern Everglades – Potential Management Measure

Project: West Caloosahatchee Water Quality Treatment Area

Level: 3

Description: This project consists of a constructed wetland in association with the C-43 West Basin Storage Reservoir (formerly Berry Groves property) in Hendry County. The feature will be designed to treat water from the reservoir for nutrient removal (focused on nitrogen). The downstream estuary is generally limited by nitrogen, and therefore the treatment feature will be designed for optimal nitrogen removal. The assumption has been made that a feature targeting nitrogen removal will also successfully reduce concentrations of both phosphorus and suspended solids.

Purpose: The general purpose of this project is to reduce nutrient concentrations within the Caloosahatchee River and nutrient pollutant loading to the downstream estuary. The reservoir is an opportunity to utilize its infrastructure to collect water from the River, store it, and provide water to the constructed wetland for treatment. This feature, in conjunction with others within the basin, are designed to have the cumulative effect of reducing nutrient concentrations and loads significantly enough to meet water quality targets within the Caloosahatchee Estuary.
Note: This project is one of many developed by the SWFFS WQ sub-team to address the nutrient enrichment issues of the Caloosahatchee Basin. The strategy of this effort was to formulate both structural and non-structural features that, once implemented, will collectively lead to restoration through pollutant load reductions (primarily nutrients). The cumulative effect of these pollutant reductions are to achieve water quality targets set forth by the SWFFS WQ sub-team (based either on an ecological resource, historical conditions, or reference conditions).

Location/Size/Capacity:

- Sub-basin: Freshwater Caloosahatchee SouthWest
- Location: Associated with C-43 West Storage Basin Reservoir
- Size and Capacity: The facility will be sized in order to achieve maximum concentration and load reductions of nitrogen, under the constraints of property size, and other applicable constraints.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits:

- Nutrient load reduction to Caloosahatchee River and Estuary. The specific water quality benefits will be dependent upon the size of the feature, the effectiveness of the design and operation for removal of nitrogen (as well as other constituents), and on the concentration of pollutants in the inflow water to the feature (Reservoir water)

- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Constructed wetlands have been shown to be effective phosphorus removal features. Applying methods/technologies to target nitrogen is assumed to be able to increase N removal efficiencies. This sub-basin has been determined to be an appropriate place for a water quality treatment feature due to its location within the basin.

Estimate of Water Quantity Benefits:

- Water quantity benefits may be achieved through the water storage capabilities of the feature (reducing peak flows or providing flows to downstream estuary depending upon season/conditions). Any potential water quantity benefits should be considered incidental because the feature's main purpose is water quality treatment and should be operated as such.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- It is assumed that the Caloosahatchee River and/or sub-basin sources will be able to adequately supply this feature with the water necessary for effective operation. It should be noted that during times of drought, competing water uses may have an impact on the operation of this feature and/or the water use of this feature may impact other water uses (e.g. MFL at S-79)

Level of Certainty: Level 3- Implementation Certainly unknown; Conceptual level of design/activity development complete; Location defined

Contact: Jennifer Nelson

Source: Management Measure description

Effective Storage Area: 1200 ac

WQ Benefits: Calculated using SWFFS reductions for "STA" (currently 100 lb/ac/yr for TN and 25 lb/ac/yr for TP).

Further benefit for removal of land from existing citrus grove, calculated as 1300 ac of citrus times an estimated net source-load reduction of 9.75 lb/ac/yr for TN and 1.32 lb/ac/yr for TP in converting pasture to water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 129000 lb/yr for TN and 30700 lb/yr for TP.

CRE 18

Northern Everglades – Potential Management Measure

Project: Harns Marsh Improvements, Phase I Construction - ECWCD

Level: 1

Description: Lehigh Acres is located within the service area of the East County Water Control District. East County Water Control District (ECWCD) was created on May 5, 1958. It encompasses over 63,000 acres of land and approximately 311 miles of canals. ECWCD is a political sub-division of the State of Florida and is funded through the collection of an acreage tax. ECWCD is requesting a state appropriation in the form of a member project. The Harns Marsh Restoration project is a result of a comprehensive hydrologic study of the area to identify problems and solutions. Harns Marsh is a 578-acre-flood detention facility within ECWCD boundaries.

An analysis of the hydrology and hydraulics for the entire District was conducted to provide both the policy and decision makers with the necessary information to properly dedicate resources toward those critical water management facilities that have the greatest impact for the least cost.

The following problems and solutions were identified:

- The control weir at the South Marsh will be rebuilt to accept flows at a lower elevation.
- The existing marsh inlet structures will be equipped with automated staff and rainfall gauges and drawdown gates.
- The drawdown gates will only be opened when large storms such as hurricanes are expected and will release water to provide additional flood protection. Normally, these gates will be closed to provide maximum dry season storage.

Purpose: Lowering the intake point for the South Marsh will expand the storage by 230 acres. This will provide a potential to store 1,450 acre-feet of water. Construction of a control weir at the outlet of Harns Marsh into the Orange River which will raise water levels in Harns Marsh; restrict flows from Harns Marsh; and lower peak flow discharge into the Orange River at least 20 percent for the 25- year-design storm.

The control weirs in Able Canal which discharge into Harns Marsh will be repaired, modified, or replaced to allow flexible operation to provide maximum flood storage in the marsh. Separate wet and dry season control elevations will be maintained by ECWCD. A pump may also be added to lift water to the cypress head during dry periods. Higher water levels year round, due to these improvements, will provide the best management practices for the Marsh. Design and permitting is well under way for the first phase, which will include the replacement of the outlet structures (S-HM-2) and (S-HM-3) along with the addition of a controllable gate structure next to the existing inlet to the South Marsh structure (S-HM-1).The ECWCD is also working with the Lee County Parks and Recreation Department to allow limited, responsible civic groups access to enjoy the Marsh for recreational purposes.

Location/Size/Capacity: Harns Marsh is located in Sections 10, 14, & 15, within Township 44S, Range 26E, Lee County, Florida. It is entirely within the boundaries of East County Water Control District located south of State Route 80 and east of Buckingham Road.

Harns Marsh is a 578 acre flood detention facility. Lowering the intake point for the South Marsh will expand the storage by 230 acres. This will provide a potential to store 1,450 acre feet of water.

Initiative Status: Modeling has been completed, preliminary design and planning has been completed and final design / permitting for phase 1 has been started and should be completed in early 2008. Final design / permitting for Phase 2 should be started in early 2008. Construction will follow contingent on availability of state legislative funding to match East County Water Control District funds.

Cost: Total Estimated Project Cost for Phase I Construction: $1,750,000.00
Requested Funding: $875,000.00

Documentation:

Estimate of Water Quality Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume BMPs were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:

- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety
- Provide recreational opportunities
- Provide native wildlife habitat
- Provide native plant habitat free of exotic and invasive plants

Estimate of Water Quantity Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown

- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: This project is certainly at Level 2 and approaching Level 1.

- **Level 1-** already constructed/implemented or construction/implementation imminent
- **Level 2-** construction/implementation likely; detailed design/activity development ongoing; location well defined

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Data Source: Roger Copp, ADA consultant for ECWCD, email, 4/24/08.

Effective Storage Area: 808 ac as wetland (578 existing plus 230 new).

WQ Benefits: Reduction of 3345 lb/yr for TN and 535 lb/yr for TP. Roger estimated this as 25% reduction of total load for TN and 40% for TP.

CRE 19

Northern Everglades – Potential Management Measure

Project: Harns Marsh Improvements, Phase II Final Design - ECWCD

Level: 2

Description: Lehigh Acres is located within the service area of the East County Water Control District. East County Water Control District (ECWCD) was created on May 5, 1958. It encompasses over 63,000 acres of land and approximately 311 miles of canals. ECWCD is a political sub-division of the State of Florida and is funded through the collection of an acreage tax.

ECWCD is requesting a state appropriation in the form of a member project. The Harns Marsh Restoration project is a result of a comprehensive hydrologic study of the area to identify problems and solutions. Harns Marsh is a 578- acre flood detention facility within ECWCD boundaries.

An analysis of the hydrology and hydraulics for the entire District was conducted to provide both the policy and decision makers with the necessary information to properly dedicate resources toward those critical water management facilities that have the greatest impact for the least cost.

The following problems and solutions were identified:

- The control weir at the South Marsh will be rebuilt to accept flows at a lower elevation.
- The existing marsh inlet structures will be equipped with automated staff and rainfall gauges and drawdown gates.
- The drawdown gates will only be opened when large storms such as hurricanes are expected and will release water to provide additional flood protection. Normally, these gates will be closed to provide maximum dry season storage.

Purpose: Lowering the intake point for the South Marsh will expand the storage by 230 acres. This will provide a potential to store 1,450 acre- feet of water. Construction of a control weir at the outlet of Harns Marsh into the Orange River which will raise water levels in Harns Marsh; restrict flows from Harns Marsh; and lower peak flow discharge into the Orange River at least 20 percent for the 25-year-design storm.

The control weirs in Able Canal which discharge into Harns Marsh will be repaired, modified, or replaced to allow flexible operation to provide maximum flood storage in the Marsh. Separate wet and dry season control elevations will be maintained by ECWCD. A pump may also be added to lift water to the cypress head during dry periods. Higher water levels year round due to these improvements will provide the best management practices for the Marsh. Design and permitting is well under way for the first phase construction which will include the replacement of the outlet structures (S-HM-2) and (S-HM-3) along with the addition of a controllable gate structure next to the existing inlet to the south marsh structure (S-HM-1).

The second phase planning and preliminary design has been completed with the final design and permitting (this project) will follow in early 2008. The second phase will include the replacement of structure (S-OR-1) and (S-OR-1SE). The ECWCD is also working with the Lee County Parks and Recreation Department to allow limited, responsible civic groups access to enjoy the Marsh for recreational purposes.

Location/Size/Capacity: Harns Marsh is located in Sections 10, 14, & 15, within Township 44S, Range 26E, Lee County, Florida. It is entirely within the boundaries of ECWCD located south of State Route 80 and east of Buckingham Road.

Harns Marsh is a 578-acre-flood detention facility. Lowering the intake point for the south Marsh will expand the storage by 230 acres. This will provide a potential to store 1,450 acre feet of water.

Initiative Status: Modeling has been completed, preliminary design and planning has been completed and final design / permitting for Phase 1 has been started and should be completed in early 2008. Final design / permitting for Phase 2 should be started in early 2008. Construction will follow contingent on availability of funding to match ECWCD funds.

Cost: Total Estimated Project Cost for Phase II, Final Design: $227,820.00
Requested Funding: $113,910.00

Documentation: See attached copy of design contract and scope of engineering services.

Estimate of Water Quality Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does percent reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:

- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety
- Provide recreational opportunities
- Provide native wildlife habitat
- Provide native plant habitat free of exotic and invasive plants

Estimate of Water Quantity Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: This project is certainly at Level 3 and approaching Level 2.

- **Level 2-** construction/implementation likely; detailed design/activity development ongoing; location well defined
- **Level 3-** implementation certainty unknown; conceptual level of design/activity development complete; location defined

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Data Source: Roger Copp, ADA consultant for ECWCD, email, 4/24/08.

Effective Storage Area: None

WQ Benefits: Reduction of 1337 lb/yr for TN and 201 lb/yr for TP. Apparently Roger estimated the combined reduction for CRE 18 and CRE 19 as 35% of total load for TN and 55% for TP.

CRE 20

Northern Everglades – Potential Management Measure

Project: Yellowtail Structure Construction - ECWCD

Level: 2

Description: Lehigh Acres is located within the service area of the East County Water Control District. East County Water Control District (ECWCD) was created on May 5, 1958. It encompasses over 63,000 acres of land and approximately 311 miles of canals. ECWCD is a political sub-division of the State of Florida and is funded through the collection of an acreage tax.

The Yellowtail Structure will replace an old, failing broad- crest weir with a new sheet- pile weir with operable gates that will allow for better control of canal water, for water quality, and water recharge purposes. The proposed structure will have top-down gates that will enable the District to have more control (within the established permit levels) of releasing or containing water as needed.

Purpose: The existing 30-year-old structure leaks which allows the entire basin to drain during extended dry periods. This leaking structure also does not allow for adequate removal of sediment/nutrients from storm water runoff and it does not allow for groundwater recharge—which is becoming a serious problem within the District.

Location/Size/Capacity: The Yellowtail Structure is located in Section 31, within Township 44S, Range 27E, Lee County, Florida. It is within the boundaries of ECWCD and it is located south of Lee Boulevard, west of Homestead Road and just east of Anita Ave.

Initiative Status: Modeling has been completed, preliminary design and planning has been completed and final design / permitting should be completed in early 2008. Construction will follow contingent on availability of funding to match East County Water Control District funds.

Cost: Total Estimated Construction Cost: $500,000.00
Requested Funding: $250,000.00

Documentation:

Estimate of Water Quality Benefits:
- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume BMPs were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:

- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety

Estimate of Water Quantity Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: This project is certainly at Level 3 and approaching Level 2.

- **Level 2-** construction/implementation likely; detailed design/activity development ongoing; location well defined
- **Level 3-** implementation certainty unknown; conceptual level of design/activity development complete; location defined

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Data Source: Roger Copp, ADA consultant for ECWCD, email, 4/24/08.

Effective Storage Area: None

WQ Benefits: Reduction of 714 lb/yr for TN and 60 lb/yr for TP, estimated as 3% of total load for TN and 5% for TP.

CRE 21

Northern Everglades – Potential Management Measure

Project: Hendry County Storage

Level: 4

Description: East County Water Control District (ECWCD) is a Florida Statutes 298 Special District created in 1958 to build, operate, and maintain drainage facilities in eastern Lee County and western Hendry County. The boundaries of the ECWCD are essentially the same as that of unincorporated Lehigh Acres with the addition of three square miles of adjacent land in Hendry County. The District encompasses over 63,000 acres of land and approximately 311 miles of primary and secondary freshwater canals with numerous culverts, water control structures and bridges.

The ECWCD has three natural and one man-made outfall(s) that convey stormwater runoff to the C-43 Canal (Caloosahatchee River). The three natural outfalls, the Orange River, Hickeys Creek, and Bedman Creek are meandering water bodies that begin at various locations along the ECWCD boundary and flow into the C-43 Canal. The development of the ECWCD canal system modified the historic flow patterns of surface water that feed these natural outfalls. Prior to the establishment of the ECWCD, surface water entered the natural outfalls via overland sheet flow and natural tributaries. The construction of the ECWCD canal network reduced the storage capacity of the ECWCD headwaters area and changed the volume and intensity of storm water entering the Orange River, Hickeys Creek, and Bedman Creek.

The ECWCD system was designed when excess surface water was considered the "common enemy", and the intent was to significantly reduce water table levels so Lehigh Acres could be developed. No significant sized parcels of land were set aside for water detention or impoundment to reduce the surface water flow impacts on the three natural outfalls from the ECWCD. Given the current deficiency of available surface water storage areas within the ECWCD system, additional route(s) of stormwater discharge from the ECWCD along with basin interconnections and additional storage within the system are needed to reduce the impacts to the three natural outfalls.

The recently completed work under the ongoing Lehigh Headwaters Initiative Study is recommending that ECWCD proceed with increasing the amount of storage volume available for storm events, provide for additional water quality treatment in the canals and increase groundwater recharge. This proposed Hendry County Storage land purchase project will help to address all three of these needs in the Lehigh Acres area.

Purpose: To purchase land for additional storm water storage capacity and treatment during the rainy season and to provide base flows for the ECWCD's outfalls along with additional groundwater recharge in the dry season.

Location/Size/Capacity: The location is not finalized but negotiations have started with the owner of an entire section of land in western Hendry County on the ECWCD eastern border.

Preliminary efforts have focused on the western portions of Hendry County because of cheaper land prices and the availability of large tracts of property under single ownership. **The proposed size is roughly one section of land or 640 +/- acres.**
Initiative Status: Preliminary discussions with the property owners of some potential sites have taken place and some preliminary modeling and planning has been completed.

Cost: Estimated Project Cost: $10,000,000.00
Requested Funding: $5,000,000.00

Documentation:

Estimate of Water Quality Benefits:
- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:
- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety

Estimate of Water Quantity Benefits:
- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 4- implementation certainty unknown; conceptual idea; may have rough order of magnitude cost and/or general basin location

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Source: Management measure description.

Effective Storage Area: One section of about 640 ac, with approximately 80% as reservoir area.

WQ Benefits: Calculated using SWFFS reductions for "shallow reservoir" (currently 12 lb/ac/yr for TN and 3 lb/ac/yr for TP). Total load reduction is estimated as 6000 lb/yr for TN and 1500 lb/yr for TP.

CRE 22

Northern Everglades – Potential Management Measure

Project: Hendry Extension Canal Widening (Construction) - ECWCD

Level: 2

Description: East County Water Control District (ECWCD) is a Florida Statutes 298 Special District created in 1958 to build, operate, and maintain drainage facilities in eastern Lee County and western Hendry County. The boundaries of the ECWCD are essentially the same as that of unincorporated Lehigh Acres with the addition of three square miles of adjacent land in Hendry County. The District encompasses over 63,000 acres of land and approximately 311 miles of primary and secondary freshwater canals with numerous culverts, water control structures and bridges.

The ECWCD has three natural and one man-made outfall(s) that convey stormwater runoff to the C-43 Canal (Caloosahatchee River). The three natural outfalls, the Orange River, Hickeys Creek, and Bedman Creek are meandering water bodies that begin at various locations along the ECWCD boundary and flow into the C-43 Canal. The development of the ECWCD canal system modified the historic flow patterns of surface water that feed these natural outfalls. Prior to the establishment of the ECWCD, surface water entered the natural outfalls via overland sheet flow and natural tributaries. The construction of the ECWCD canal network reduced the storage capacity of the ECWCD headwaters area and changed the volume and intensity of storm water entering the Orange River, Hickeys Creek, and Bedman Creek.

The ECWCD system was designed when excess surface water was considered the "common enemy", and the intent was to significantly reduce water table levels so Lehigh Acres could be developed. No significant sized parcels of land were set aside for water detention or impoundment to reduce the surface water flow impacts on the three natural outfalls from the ECWCD. Given the current deficiency of available surface water storage areas within the ECWCD system, additional route(s) of stormwater discharge from the ECWCD along with basin interconnections and additional storage within the system are needed to reduce the impacts to the three natural outfalls.

The recently completed work under the ongoing Lehigh Headwaters Initiative Study is recommending that ECWCD proceed with increasing the amount of storage volume available for storm events, provide for additional water quality treatment in the canals and increase groundwater recharge. This proposed canal widening project will help to address all three of these needs in the Lehigh Acres area.

Purpose: To provide additional storm water storage capacity and water treatment in a 5.5 mile section of Hendry Extension Canal.

Location/Size/Capacity: The canal widening project starts at SR 82 along the Lee County/Hendry County Line and extends north approximately 5.5 miles to the northeast corner of Section 1, Township 45 S, Range 27 E (near structure S-H-3).

Initiative Status: Phase I (the southern 2 miles) is designed and just received SFWMD permit approval. Phase II (the northern 3.5 miles) is designed and SFWMD permit approval is expected anytime.

Cost: Estimated Construction Cost: $500,000.00

Documentation:

Estimate of Water Quality Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:

- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Provide public recreational opportunities with linear parks along the canal
- Protect public health and safety

Estimate of Water Quantity Benefits:

- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

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Source: Management measure description.

Effective Storage Area: Canal length of 5.5 miles.

WQ Benefits: None

Note: Changed to "None" on 5/2/08. Originally estimated WQ Benefits as: Estimated canal width at 30-ft, for total surface area of 20 ac. Load reduction calculated using

SWFFS reductions for "in-canal WQ treatment" (currently 20 lb/ac/yr for TN and 5 lb/ac/yr for TP). Total load reduction is estimated as 400 lb/yr for TN and 100 lb/yr for TP.

CRE 29

Northern Everglades – Potential Management Measure

Project: Lehigh Acres Wastewater Treatment and Stormwater Retrofit

Level: 3

Description: This project consists of the installation of stormwater treatment features in Lehigh Acres (e.g. wet detention ponds, bioretention areas, vegetated swales, riparian buffers, etc.). The project will update the current stormwater management system (which is minimal or non-existent) within the existing urban area of Lehigh Acres prior to build-out of the platted area.

This project also consists of the conversion of high-density septic tanks to centralized wastewater treatment in Lehigh Acres including additional installation of the infrastructure for a treated wastewater re-use system.

Purpose: The purpose of this project is to install structural components to slow and hold stormwater on the land to facilitate settling and nutrient uptake prior to discharge into canals and ditches that discharge to the Caloosahatchee River and to eliminate high-density septic systems as well as the use of private wells for irrigation. The replacement of septic systems increases the level of wastewater treatment significantly and eliminates the potential pollutant loading of high-density septic systems in an area with high water tables and sandy soils.

Location/Size/Capacity:

- Sub-basin: Hickey Creek
- Location: Lehigh Acres – particularly in the area between Greenbriar and Hickey Creek natural area.
- Size and Capacity: The size, capacity, and specific type of the stormwater features will be dependent upon the land availability within the area.

Initiative Status: Conceptual

Cost: TBD

Documentation: Southwest Florida Feasibility Study (SWFFS) Water Quality Sub-team: Water Quality Plan Formulation Document (work in progress)

Estimate of Water Quality Benefits:

- Nutrient and TSS load reduction to Caloosahatchee River and Estuary. The specific water quality benefits will be dependent upon the size of the area within Lehigh Acres that can be retrofitted with stormwater features, and the amount of stormwater that can be held by the cumulative system.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Constructed wetlands have been shown to be effective phosphorus removal features. Applying methods/technologies to target nitrogen is assumed to be able to increase N removal efficiencies. This sub-basin has been determined

to be an appropriate place for a water quality treatment feature due to its location within the basin. Eliminating septic tanks will also contribute to the reduction of nutrients and other pollutants to nearby surface waters and shallow groundwater.

Estimate of Water Quantity Benefits:

- Water quantity potential benefits include the reduction or dampening of "flashy" discharges to canals and the Caloosahatchee River by holding stormwater on the land for a longer period of time, and allowing some percolation into the surficial aquifer.
- Level of Certainty- Conceptual
- Assumptions leading to benefit estimate- Stormwater BMPs have been proven to be effective at removal of certain water quality constituents.

Level of Certainty: Level 3- implementation certainty unknown; conceptual level of design/activity development complete; location defined

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Source: Management Measure description

Effective Storage Area: 50000 ac (full footprint of Lehigh Acres within ECWCD)

WQ Benefits: Calculated using SWFFS reductions for "urban suite, i.e. "wastewater treatment and stormwater retrofit", (currently 3.0 lb/ac/yr for TN and 0.6 lb/ac/yr for TP). (This presumes that the entire area is fully built out with septic and will be fully replaced by the end of the planning horizon.)

CRE 30

Northern Everglades – Potential Management Measure

Project: Aquifer Benefit and Storage for Orange River Basin (ABSORB) - ECWCD

Level: 2

Description: The East County Water Control District. East County Water Control District (ECWCD) is a Florida Statutes 298 Special District created in 1958 to build, operate, and maintain drainage facilities in eastern Lee County and western Hendry County.

The ECWCD has three natural and one man-made outfall(s) that convey storm water runoff to the C-43 Canal (Caloosahatchee River). The three natural outfalls, the Orange River, Hickeys Creek, and Bedman Creek are meandering water bodies that begin at various locations along East County Water Control District's boundaries and flow into the C-43 Canal. The development of the ECWCD canal system modified the historic flow patterns of surface water that feed these natural outfalls. Prior to the ECWCD, surface water entered the natural outfalls via overland sheet flow and natural tributaries. The construction of the ECWCD canal network reduced the storage capacity of the ECWCD headwaters area and changed the volume and intensity of storm water entering the Orange River, Hickeys Creek, and Bedman Creek.

The ECWCD system was designed when excess surface water was considered the "common enemy", and the intent was to significantly reduce water table levels so Lehigh Acres could be developed. No significant sized parcels of land were set aside for water detention or impoundment to reduce the surface water flow impacts on the three natural outfalls from the ECWCD. Given the current deficiency of available surface water storage areas within the ECWCD system, additional route(s) of storm water discharge from the ECWCD along with basin interconnections and additional storage within the system are needed to reduce the impacts to the three natural outfalls. In addition to these objectives, it will also be beneficial to restore the historic headwaters area and re-establish historical flow patterns where possible.

The recently completed work under the ongoing Lehigh Headwaters Initiative Study is recommending that ECWCD proceed with increasing the amount of storage volume available for storm events, provide for additional water quality treatment in the canals and increase groundwater recharge in the SW Lehigh Acres area. The proposed A.B.S.O.R.B. project will help to address all three of these needs in the southwest Lehigh Acres area as well as to lessen the impact on the environment and the surrounding communities affected by the Caloosahatchee Watershed.

Purpose: The purpose of this project is to continue the restoration goals and watershed improvement projects that were started under the Caloosahatchee Watershed Initiative during the last few years. This project will be the final design phase for Alternative #3 that was recommended in the preliminary design report.

Location/Size/Capacity: The A.B.S.O.R.B. project is located in the southwest portion of Lehigh Acres, Lee County, Florida. It is referred to as drainage basin #7 and #10 located within

Township(s) 44S and 45S and Range(s) 25E and 26E of the East County Water Control District. Both basins combined include approximately 18.6 square miles and are generally located south of Buckingham Road, and east of State Route 82 and west of Yellowtail Canal.

Initiative Status: Modeling has been completed, preliminary design and planning has been completed and final design / permitting could start in early 2008 contingent on availability of funding to match East County Water Control District funds.

Cost: Total Estimated Final Design Cost: $150,000.00
Requested Funding: $75,000.00

Documentation: See attached copy of the preliminary Design Report.

Estimate of Water Quality Benefits:
- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:
- Flood attenuation
- Water quality improvements
- Enhancement of existing wetlands
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety

Estimate of Water Quantity Benefits:
- Minimum
- Maximum
- Most Likely
- Level of Certainty – conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: This project is at **Level 3** and ready to proceed to **Level 2** with the necessary funding in place.

Source: Roger Copp, ADA consultant for ECWCD, email, 4/25/08.

Effective Storage Area: 18.6 sq-mi residential area.

WQ Benefits: Reduction of 8200 lb/yr of TN and 820 lb/yr or TP, based on estimate from Roger Copp. (Note: This estimate should be reviewed.)

CRE 44

Northern Everglades – Potential Management Measure

Project: Spanish Creek / Four Corners Environmental Restoration

Level: 2

Description: Flowway Restoration Water Quality Improvement Attenuation

Purpose: Improve water quality. Restore flow ways, aquifer recharge

Location/Size/Capacity: 400 – 4,000 acres in Lee County near the intersection of Hendry, Glades,
Charlotte and Lee Counties

Initiative Status: *Preliminary Design*

Cost: $10,000,000 - $100,000,000

Estimate of Water Quality Benefits:
- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- *conceptual*
- Assumptions leading to benefit estimate- Modeled values for flow and assume 20% reduction due to settling in the basin

Estimate of Water Quantity Benefits:
- Minimum – *15,000 ac/ft*
- Maximum- *37,000 ac/ft*
- Most Likely- *20,000 ac/ft*
- Level of Certainty- *conceptual*
- Assumptions leading to benefit estimate- *(Calculated using modeled flow rates and assumed BMP efficiency)*

Level of Certainty: Level 3- Implementation Certainly unknown; Conceptual level of design/activity development complete; Location defined.

Contact: Clyde Dabbs – SFWMD

Source: Clyde Dabbs, SFWMD.

Effective Storage Area: 400 ac reservoir.

WQ Benefits: Calculated using SWFFS reductions for “deep reservoir” (currently 4 lb/ac/yr for TN and 1 lb/ac/yr for TP).

Further benefit for removal of land from existing citrus grove, calculated as 3200 ac of citrus times an estimated net source-load reduction of 6.10 lb/ac/yr for TN and 0.62 lb/ac/yr for TP in converting citrus to wetland, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 21100 lb/yr for TN and 2400 lb/yr for TP.

8-08-08

WQ Benefits: Estimated as 34 Mton/yr for TN and 5.9 Mton/yr for TP for constructed wetland, as modeled by WSI (written commun., 8/6/08).

Further benefit for removal of land from existing citrus grove, calculated as 3200 ac of citrus times an estimated net source-load reduction of 6.10 lb/ac/yr for TN and 0.62 lb/ac/yr for TP in converting citrus to wetland, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 95000 lb/yr for TN and 15000 lb/yr for TP.

CRE 45

Northern Everglades – Potential Management Measure

Project: Billy Creek Filter Marsh, Phase I & II

Level: 1

Description: The completed project will include the construction of a 56-acre filter marsh facility on an undeveloped parcel adjacent to Billy Creek. The project will install a water control structure within Billy Creek to divert flows into the filter marsh facility providing additional attenuation of stormwater flows within the channel itself. The filter marsh facility itself will consist of an 8 acre open water lake, 13 acre wetland marsh, and incorporate/restore an existing 12 acre cypress hammock.

Purpose: The lake will provide for removal of the suspended solids and sediments. The wetland marshes and cypress hammock will provide for the removal of nutrients such as nitrogen, phosphorus, and heavy metals.

Location/Size/Capacity: City of Fort Myers (Billy Creek)

Initiative Status: Listed in FY 09 Caloosahatchee Partners for Restoration (CPR) project is ready to begin

- Design Complete
- Permit issuance: March 2008
- Phase 1: March 2008; Phase 2: October 2008

Cost: $2 million - City of Fort Myers request SFWMD contribute $1 million

Documentation: see CPR FY09 report

Estimate of Water Quality Benefits (Tons/per 3-year Event):

- Minimum – 0.08 (N); 0.13 (P); 62 (TSS)
- Maximum – 0.16 (N); 0.45 (P); 74 (TSS)
- Most Likely – 0.20 (N); 0.29 (P); 86 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation
-

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow=outflow)):

- Minimum – 42 ac / 84 ac-ft / 4 cfs
- Maximum – 42 ac / 84 ac-ft / 12 cfs
- Most Likely – 42 ac / 84 ac-ft / 8 cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- operational assumptions

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

Contact: Judy Nothdurft – SFWMD; Molly Meadows – SFWMD

Source: City of Fort Myers Stormwater Master Plan Update, Chap. 12, Jan. 2008.

Effective Storage Area: Project footprint is 56 ac, with 8 ac in lake and 13 in marsh.

WQ Benefits: Reduction of 4511 lb/yr for TN and 1132 lb/yr for TP.

CRE 48

Northern Everglades – Potential Management Measure

Project: Manuel's Branch Silt Reduction Structure

Level: 2

Description: This project is located in the vicinity of Manuel's Drive, Cortez Boulevard, and Fort Myers High School.

Purpose: The project proposes to install siltation reduction measures within the existing channel section in the vicinity of the Cortez Boulevard crossing. The proposed project will reduce the siltation associated with the stream bank scour, erosion, and degradation. Funds will be used for the design and permitting of the structures.

Location/Size/Capacity: City of Fort Myers

Initiative Status:

- Final Design (90% complete)
- Permit submittal July 2008

Cost: $15,000 for design and permitting

Documentation:

Estimate of Water Quality Benefits (Tons/per 3-year Event):

- Minimum – 0.05 (N); 0.06 (P); 32 (TSS)
- Maximum – 0.30 (N); 0.90 (P); 42 (TSS)
- Most Likely – 0.15 (N); 0.12 (P); 37 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow=outflow)):

- Minimum – 2 ac / 1 ac-ft / 1 cfs
- Maximum – 2 ac / 1 ac-ft / 3 cfs
- Most Likely – 2 ac / 1 ac-ft / 2 cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- operational assumptions

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

Contact: Judy Nothdurft – SFWMD

Source: Management Measure description.

Effective Storage Area: None

WQ Benefits: City of Fort Myers estimated load reduction of 0.15 tons per 3-year event for TN and 0.12 tons for TP. In the absence of more suitable numbers, it was assumed that the 3-year event is roughly equivalent to the full load for an average year. While not exact, this is probably within 50% of what the engineer would calculate, as borne out by similar numbers for Manuel's Branch Weirs and Billy Creek.

Total load reduction is estimated as 300 lb/yr for TN and 240 lb/yr for TP.

CRE 49

Northern Everglades – Potential Management Measure

Project: Manuel's Branch East and West Weirs

Level: 2

Description: The project involves the installation of two weir/water control structures within existing canal sections.

Purpose: The purpose of the weir structures is to create a linear storage feature within the upstream reach of the existing canal to attenuate flows downstream and reduce peaking effects of past urbanization and storm sewering practices.

Location/Size/Capacity: City of Fort Myers

Initiative Status:

- Design and Permitting Complete
- Construction March 2008

Cost: $240,000 - Funds will be used for the design, permitting and construction of the structures.

Estimate of Water Quality Benefits (Tons/per 3-year Event):

- Minimum – 0.30 (N); 0.12 (P); 64 (TSS)
- Maximum – 0.60 (N); 0.24 (P); 84 (TSS)
- Most Likely – 0.45 (N); 0.12 (P); 74 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow=outflow)):

- Minimum – 5 ac / 15 ac-ft / 3 cfs
- Maximum – 5 ac / 15 ac-ft / 7 cfs
- Most Likely – 5 ac / 15 ac-ft / 5 cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- operational assumptions

Level of Certainty: Level 1- already constructed/implemented or construction/implementation imminent

Contact: Judy Nothdurft – SFWMD

Source: City of Fort Myers Stormwater Master Plan Update, Chap. 12, Jan. 2008.

Effective Storage Area: None

WQ Benefits: Reduction of 920 lb/yr for TN and 356 lb/yr for TP.

CRE 53

<u>Northern Everglades – Potential Management Measure</u>

Project: Caloosahatchee Creeks Preserve Hydrologic Restoration

Level: 2

Description: Lee County has hired a biologist/engineer to design and permit a hydrological restoration project on Caloosahatchee Creeks Preserve, a Conservation 20/20 preserve in Lee County. Planned hydrological restoration projects include plugging the ditches that currently occur on the property and providing culverts to flow under existing berms. One large ditch channels water north-south directly into the Caloosahatchee River and one east-west ditch channels water into a canal (Stroud Creek) and then into the Caloosahatchee River. The ditch plugs will slow the water and allow onsite wetlands to be rehydrated and filter the water before it enters the Caloosahatchee River.

Purpose: The purpose of the project is to reduce the amount of channelized water that enters the Caloosahatchee River and to rehydrate the wetlands on Caloosahatchee Creeks Preserve.

Location/Size/Capacity: The project will take place in management units 108-1 and 108-2 (211.2 acres) of a 1,325 acre Caloosahatchee Creeks Preserve on the northern shore of the Caloosahatchee River. The capacity has not yet been determined. Tom Odum, the consultant, expects to submit a permit application to the South Florida Water Management District in December 2007.

Initiative Status:

- Advance planning phase and associated field work
- Preliminary Plans and Specification (30% complete)
- Intermediate Design (60% complete) : Plans are underway and should be submitted to the South Florida Water Management District in December 2007.
- Pre-final Design (90% complete)
- Final Design
- Permit submittals

Cost: The construction cost is estimated to be $500,000. At this point, Lee County has secured $350, 000 from the Florida Department of Environmental Protection for the construction of the project. We are requesting the balance of the project ($150,000) to be funded by the South Florida Water Management District.

Documentation: Please see the attached documentation from the Florida Department of Environmental Protection.

Estimate of Water Quality Benefits:

- Minimum –
- Maximum-
- Most Likely-

- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)
- Quantitative water quality benefits are not available at this time, but will be available in December once the engineering design has been completed.

Estimate of Water Quantity Benefits:

- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)
- Quantitative water quantity benefits are not available at this time, but will be available in December once the engineering design has been completed.

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

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Source: Management Measure description.

Effective Storage Area: 1200 ac.

WQ Benefits: Calculated using SWFFS reductions for "restored wetland" (currently 40 lb/ac/yr for TN and 10 lb/ac/yr for TP).

CRE 57

Northern Everglades – Potential Management Measure

Project: Powell Creek Algal Turf Scrubber

Level: 2

Description: The project proposes to install and operate for one year a mobile unit of the Algal Turf Scrubber system. This project also contains funding for a large scale permanent installation of an Algal Turf Scrubber based on the results of the pilot project.

Purpose: The Algal Turf Scrubber is an alternative technology designed to optimize and create flow conditions that maximize the nutrient uptake at rates higher than constructed wetland systems. Installation of the product is estimated to remove of 200 - 1000 pounds of phosphorous and 500 - 8000 pounds of nitrogen for every acre of process area. Based upon the results of this pilot project, a large scale installation of the Algal Turf Scrubber system might be pursued.

Location/Size/Capacity: Adjacent to Powell Creek bypass and approximately 1500 feet north of the Caloosahatchee river. Treatment area is about 10,000 square feet.

Initiative Status:

- Advance planning phase and associated field work
- Preliminary Plans and Specification (30% complete)
- Intermediate Design (60% complete)
- Pre-final Design (90% complete)
- Final Design
- Permit submittals

Cost: $427,000 (Ad Valorem funding) The contract for this project (4600000978-A1) was amended to increase funding in the amount of $1,205,000 (Ad Valorem) for the design and construction of the permanent Algal Turf Scrubber.

Documentation:

Estimate of Water Quality Benefits:

- Minimum – 20% less than most likely
- Maximum- 20% more than most likely
- Most Likely- 125 pounds of N, 50 pounds of P, and 5,000 pounds of TSS annually.
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)

Estimate of Water Quantity Benefits:

- Minimum – 0
- Maximum- 20% more than most likely
- Most Likely- 2 cubic feet per second
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

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Source: Management Measure description.

Effective Storage Area: 10000 sq-ft facility on 11-ac site.

WQ Benefits: Reduction of 125 lb/yr for TN and 50 lb/yr of TP, for a treatment area of approximately one-quarter acre. This is consistent with the SWFFS reductions, and also matches the lower-end estimates that are claimed by the vendor (500 lb/ac/yr for TN). Note: The 2 cfs value reported in the MM is unrealistic for a feature of that size.

CRE 59

Northern Everglades – Potential Management Measure

Project Feature: North Fort Myers Surface Water Restoration

Level: 1

General Description/Background: Construction and Operation of a surface water management system to serve a 2400 acre Project know as North Fort Myers Surface Water Restoration Project to improve water discharge and water quality in North Fort Myers via the Gator Slough and Powell Creek systems.

Powell Creek (a channelized canal, overgrown with vegetation) begins at the south side of Del Prado, approx 3.2 miles east of the U.S. 41-Del Prado intersection and flows in a north south direction between Palermo development to the west and Sloanes Gate to the east, and eventually discharging into the Caloosahatchee River. The area is has been severely impacted by off road vehicles and erosion is common.

The historic flow in the area has been altered over time because of construction of roadways and residential development. As a result, the surface water is impounded north of Del Prado during intensive storms causing flooding impacts to the adjacent neighborhoods.

The proposed improvements include channel improvements, the construction of diversion weirs to accommodate offsite flows from Palermo (Golf and residential) as well as constructing an environmental weir at the location of the twin 60-inchRCPs,(to be removed) as well as an additional environmental weir upstream to provide for surface water storage and attenuation. The 125 foot wide conveyance is designed to meander about the centerline flanked by shallow littoral zones. These areas will be planted with shallow water emergent aquatic plants to facilitate longer contact time for nutrient uptake. The environmental weir will serve to capture sediment and to slow velocities.

The strategy for stormwater pollution reduction will focus on reduction of nutrients in the project watershed by increasing residence time of surface waters in areas of North Fort Myers to increase nutrient uptake by wetland plants and allow increased percolation for groundwater recharge by slowing the overland flow and increasing the system capacity.
In conclusion the project will incorporate filter marsh like plantings and to regulate storm events runoff to more mimic historical patterns.

Purpose: Flowway Restoration Water Quality Improvement Attenuation

Location/Size/Capacity: 20 acres in Lee County south of Del Prado Blvd. and north of the Alliance for the Arts school.

- Initiative Status:
- Construction Plans 95%
- Lee County Development Order DOS2007-00268 approved.

- South Florida Water Management District Permit 36-05574-P approved
- United States Army Corp of Engineers Permit SAJ-2001-6929- (IP-MJD) approved
- Construction Contract Documentation
- Prequalification of Contractors underway.

Cost: $ 1,200,000

Documentation: Natural Resources CIP Budget Guide, Lee County Surface Water Management Plan.

Estimate of Water Quality Benefit:

ESTIMATED POLLUTANT LOAD REDUCTION:

BMPs Installed		**TSS kg/yr**	**TP kg/yr**	**TN kg/yr**	**Sediment kg/yr**	**BOD kg/yr**	**Other kg/yr**	**Other kg/yr**
Filter Marsh Treatment Train								
Pollutant Loads	Pre-Project	21,370	140	2,671		3,860		
	Post-Project	11,224	79	1,986		3,553		
	Load Reduction	10,146	61	685		307		
	% Reduction	47%	43	26		8		

Level of Certainty: **Level 2-** Construction/implementation likely; detailed design/activity development ongoing; location well defined.

Contact:
Anura Karuna-Muni
1500 Monroe St, 3rd Floor, Fort Myers, FL 33901. Phone: 239-533-8131 Fax: 239-485-8408
Akaruna-muni@leegov.com

Source: Management Measure description.

Effective Storage Area: 20 ac max.

WQ Benefits: Reported as 685 kb/yr for TN and 61 kg/yr for TP, or 1510 lb/yr for TN and 135 lb/yr for TP

CRE 64

Northern Everglades – Potential Management Measure

Project Feature: Yellow Fever Creek/Gator Slough Transfer Facility (#208509)

Level: 1

General Description/Background: Construct an operable interconnection facility between the Gator Slough Canal and Yellow Fever Creek in North Fort Myers/Northeast Cape Coral. The project would transfer surface waters during periods of high flows from Gator Slough canal system located just north of Del Prado Blvd (S22-T43-R24) to the Yellow Fever Creek near Littleton Rd through a control facility. The project will utilize existing rights of way.

Purpose: This project will improve the area's overall water quality by reducing and balancing the fresh water peak inflows to Matlacha Pass and Charlotte Harbor. By transferring these excess surface water flows to the Caloosahatchee, the overall system will mimic the historical flow patterns and hydrologic distribution.

Location/Size/Capacity: Yellow Fever Creek (S22-T43-R24)

Initiative Status: Ongoing

Cost: $600,000.

Documentation: Lee County Natural Resources CIP Budget Guide

Estimate of Water Quality Benefit: unknown

- Minimum:
- Maximum:
- Most Likely:
- Level of Certainty:
- Assumptions:

Estimate of Water Quantity Benefit: NA

- Minimum:
- Maximum:
- Most Likely:
- Level of Certainty:
- Assumptions: This project will improve the area's overall water quality by reducing and balancing the fresh water peak inflows to Matlacha Pass and Charlotte Harbor.

Level of Certainty: Level 1- Already constructed/implemented or construction/implementation imminent.

Contact: Roland Ottolini – 239-533-8127

Source: Management Measure description. Additional information from Anura Karuna-Muni, Lee County, by phone, 4/24/08.

Effective Storage Area: None

WQ Benefits: Water would be transferred from one basin to another, with no net change in loadings. Using 806 ac-ft/yr and an estimate of 1.27 mg/L for TN and 0.154 mg/L for TP, which is typical of runoff from the Yucca Pens area, the load is calculated as 2784 lb/yr for TN and 338 lb/yr for TP.

In the water-quality spreadsheet, these flows and loads will be subtracted from the North Coastal sub-region and added to the Tidal North sub-region. The spreadsheet will contain one line for each sub-region.

CRE 69

Northern Everglades – Potential Management Measure

Project: Cape Coral Wastewater Treatment and Stormwater Retrofit

Level: 2

Description: The City of Cape Coral is implementing the utility expansion program to changeover from septic systems to gravity sewers. About ¼ of the city already has sewer systems, and this project is being done in phases, currently in the southwestern portion of the city.
This project also involves the replacement of older stormwater inlets with newer inlets designed to assist with stormwater management.

Purpose: The new inlets facilitate the filtration of nutrients and pollutants and reduce the effects of "first flush" by retaining this water within the City's swale system. As such, the new inlet structures will reduce residential pollutant loads including fertilizers and pesticides and road run off containing oils and heavy metals and to reduce the nutrient load to the city's canal system and ultimately the Caloosahatchee River, Matlacha Pass and surrounding waters. Funds will be used for the purchase and installation of the inlets.

Location/Size/Capacity: The project is being done in phases, Southwest 5, 6 and 7 are currently being started. They encompass about 1/8 of the city

Initiative Status:
- Advance planning phase and associated field work
- Preliminary Plans and Specification (30% complete)
- Intermediate Design (60% complete)
- Pre-final Design (90% complete)
- Final Design
- Permit submittals

Cost: $893,500

Documentation: City of Cape Coral's Utility Expansion Plan

Estimate of Water Quality Benefits:
- Minimum –
- Maximum -
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)

Estimate of Water Quantity Benefits:

- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 2- construction/implementation likely; detailed design/activity development ongoing; location well defined

Contact: Connie Jarvis, City of Cape Coral, 239.574.0745; Molly Meadows – SFWMD

Source: Management Measure description

Effective Storage Area: Approx. 1500 ac in Cape Coral east and 18000 ac in Cape Coral west, according to current expansion plan out to about 2015.

WQ Benefits: Calculated using SWFFS reductions for “urban suite” (currently 3.0 lb/ac/yr for TN and 0.6 lb/ac/yr for TP). (This presumes that the entire area is fully built out with septic.)

CRE 77

Northern Everglades – Potential Management Measure

Project: Cape Coral Canal Stormwater Recovery by ASR

Level: 1

Description: At present the City of Cape Coral experiences a shortfall of water during the dry season and freshwater resources are lost to tidally influence estuaries and waterways during the rainy season. During this rainy season approximately 200 Million gallons per day of freshwater is lost impacting these areas.

By capturing and storing surface flows using planned ASR wells, the volume of fresh water escaping the canals at weirs and locks is reduced. This reduces, and in some cases may eliminate, point source discharge to riparian areas and estuaries in the watershed. ASR will also reduce the potential threat of saltwater intrusion by eliminating over-pumping of irrigation water from the Mid Hawthorne Aquifer.

Development of ASR wells provides a feasible solution to reduce or eliminate point source discharge and the growing water storage concern. This project is being implemented as a phased project, which has funding identified in the City's Capital Improvement Plan for the next eight years.

Funding requested will be used for construction of conveyance and/or surface water treatment necessary under Florida Statue for ASR.

Purpose: In addition to prevention of saltwater intrusion and creation of more reliable water resource availability, anticipated benefits to the Caloosahatchee River watershed include:

- Flood attenuation
- Water quality improvements to an impaired waterbody
- Protection of existing wetlands
- Reduction of sediment and nutrient loading

Location/Size/Capacity:

Initiative Status:

- Advance planning phase and associated field work — TBD
- Preliminary Plans and Specification (30% complete) — TBD
- Intermediate Design (60% complete) — TBD
- Pre-final Design (90% complete) — TBD
- Final Design — TBD
- Permit submittals — TBD

Cost: Total Construction Costs: $15 million - Requested Funding: $500,000

Documentation:

Estimate of Water Quality Benefits:

- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)

Estimate of Water Quantity Benefits:

- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 1- already constructed/implemented or construction/implementation imminent. Planning, system modeling and preliminary design have been completed. Engineering and construction is currently on-going with three ASR wells being drilled during 2007-2008 and three wells being permitted for construction during 2008-2009. Conveyance and water quality treatment systems will be constructed during the same timeframes in a phased manner.

Source: Management Measure description, with updated info obtained by Clyde Dabbs.

Effective Storage Area: None

WQ Benefits: Assumed for 30 percent reduction, estimated at net reduction of 0.5 mg/L for TN and 0.10 mg/L for TP.

CRE 121

Northern Everglades – Potential Management Measure

Project: City of Labelle Stormwater Master Plan Implementation

Level: 2

Description: The City of LaBelle is located in Hendry County, southwest of Lake Okeechobee in the SFWMD West Caloosahatchee Basin. Much of the LaBelle water management system was constructed many years ago without an overall plan, and years of non-coordinated modifications and lack of maintenance has resulted in periodic flooding problems within the city limits. Additionally, only minimal water quality storage is provided to the stormwater runoff before the ultimate discharge into the Caloosahatchee River.

The LaBelle Stormwater Quality Improvement Project is intended to implement stormwater conveyance and water quality storage improvements within the City of LaBelle. This Project will implement a portion of the previously performed "Identification of Storm Water Issues and Recommended Improvements Report" (Report) for the City of LaBelle, previously funded by the SFWMD in 2004. The goal of the improvements will be to provide increased water quality storage and reduce local road flooding within the LaBelle Drainage Basin previously identified as Basin C-5 in the Report. The proposed improvements will be designed to attenuate surface water runoff within Road Rights-of-Way and other City-owned lands, within Basin C-5, to improve water quality, and reduce peak flood stages. The Project will address both existing and projected storm water conditions and will improve the conveyance of storm water during storm events and reduce pollutant loadings discharging directly into the Caloosahatchee River.

Purpose: To implement (Design, Permit, and Construct) stormwater conveyance and water quality storage improvements within the City of Labelle. The project will provide increased water quality storage, reduced sediment and nutrient loadings, and reduce local road flooding within the LaBelle Drainage Basin previously identified as Basin C-5 in the previously performed "Identification of Storm Water Issues and Recommended Improvements Report".

Location/Size/Capacity: This project will include stormwater conveyance and water quality storage improvements within Basin C-5, which consists of approximately 149 acres of urban/residential lands Basin C-5 is generally described as State Road 80 South to Seminole Avenue, and Oak Street East to Grant Street, within the City Limits of LaBelle, Florida. The Project Design will recommend proposed swale grades and typical sections, new and replacement culvert locations, sizes, and inverts, and any proposed detention areas on City owned property.

Initiative Status: *Advance planning phase and associated field wor*k
In 2004, an "Identification of Storm Water Issues and Recommended Improvements Report" was initiated for the City of LaBelle. This report was funded and coordinated with the SFWMD Watershed Initiative Program. This report addressed several items including:

- Delineated drainage basins within the City of LaBelle;

- Identified general deficiencies (flooding) within the basins;
- Prioritized basins in need of improvements
- Performed preliminary hydraulic modeling of design storm events;
- General recommendations for stormwater quality, quantity, and conveyance improvements;
- Target land for acquisition for stormwater storage and treatment areas;
- Address permitting and public interest issues;
- Preliminary Construction Cost Estimates

This report identified Basin C-5 as the first priority in which to proceed with the Design and Permitting of the stormwater improvements. Topographic survey of the existing ditches, drainage ways, and stormwater conveyance system has already been collected as part of the previous work. Design, Permitting, and Construction of the improvements in Basin C-5 will be performed under this project.

Cost: Opinion of Probable Cost for the Design Permitting, and Construction of the stormwater improvements within Basin C-5 is $350,000.

Documentation:

Estimate of Water Quality Benefits:
- Minimum –
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown
- Assumptions leading to benefit estimate- (e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities- location/sub-watershed where activity will apply; what does % reduction apply to-which land uses, only new development, etc.)

The anticipated water quality benefits to the Caloosahatchee River include:
- Increased volume for water quality storage in improved roadside swale system and new common detention areas;
- Increased volume for water quality storage with the installation of new control structures;
- Reduction of sediment and nutrient loadings to the estuary through increased water quality storage volume and time duration;
- Improved water quality through vegetated swales (grass) and the possible incorporation of littoral planting components in improved stormwater detention areas;

Estimate of Water Quantity Benefits:
- Minimum
- Maximum-
- Most Likely-
- Level of Certainty- conceptual/final/unknown

- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

The anticipated water quantity benefits to the Caloosahatchee River include:

- Reduction in peak discharge from Project Area from increase storage volume in system;
- Reduction in peak discharge from Project Area from installation of control structures;
- Help to protect public health and safety by reducing local flooding in Basin C-5 during various storm events;
- Improve conveyance and reduce local flooding in Basin C-5 through improved interconnectivity between drainage swales along local streets;

Level of Certainty: Level 3 considering the work previously performed.

Source: City of LaBelle Stormwater Plan and Recommended Improvements, May 2004.

Effective Storage Area: Stormwater retrofit for 2556 ac.

WQ Benefits: Calculated using SWFFS reductions for "urban stormwater" (currently 30 lb/ac/yr for TN and 5 lb/ac/yr for TP).

Total load reduction is estimated as 76700 lb/yr for TN and 12800 lb/yr for TP

CRE 122

Northern Everglades – Potential Management Measure

Project: Rehydrate Lee County Well Fields

Level: 3

Description: East County Water Control District (ECWCD) is a Florida Statutes 298 Special District created in 1958 to build, operate, and maintain drainage facilities in eastern Lee County and western Hendry County. The boundaries of the ECWCD are essentially the same as that of unincorporated Lehigh Acres with the addition of three square miles of adjacent land in Hendry County. The District encompasses over 63,000 acres of land and approximately 311 miles of primary and secondary freshwater canals with numerous culverts, water control structures and bridges.

The ECWCD has three natural and one man-made outfall(s) that convey stormwater runoff to the C-43 Canal (Caloosahatchee River). The three natural outfalls, the Orange River, Hickeys Creek, and Bedman Creek are meandering water bodies that begin at various locations along the ECWCD boundary and flow into the C-43 Canal. The development of the ECWCD canal system modified the historic flow patterns of surface water that feed these natural outfalls. Prior to the establishment of the ECWCD, surface water entered the natural outfalls via overland sheet flow and natural tributaries. The construction of the ECWCD canal network reduced the storage capacity of the ECWCD headwaters area and changed the volume and intensity of storm water entering the Orange River, Hickeys Creek, and Bedman Creek.

The ECWCD system was designed when excess surface water was considered the "common enemy", and the intent was to significantly reduce water table levels so Lehigh Acres could be developed. No significant sized parcels of land were set aside for water detention or impoundment to reduce the surface water flow impacts on the three natural outfalls from the ECWCD. Given the current deficiency of available surface water storage areas within the ECWCD system, additional route(s) of stormwater discharge from the ECWCD along with basin interconnections and additional storage within the system are needed to reduce the impacts to the three natural outfalls.

The recently completed work under the ongoing Lehigh Headwaters Initiative Study is recommending that ECWCD proceed with increasing the amount of storage volume available for storm events, provide for additional water quality treatment in the canals and increase groundwater recharge. This proposed project could help ECWCD address all three of these needs in the Lehigh Acres area if it determined that the project is feasible.

Purpose: To reconnect and rehydrate the area south (well fields) of SR 82. Historically the southern portion of the District drained to the south of SR 82 but the existing canal system drains everything to the north. This project would try to restore the historic conditions and divert more water to the south which could help recharge groundwater in the Lee County "DR/GR" area. By sending stormwater to drained wetlands outside of the Caloosahatchee estuary watershed, this project will reduce nutrient loads to the estuary while providing appropriate treatment in drained wetlands of the Estero and Imperial River watersheds.

Location/Size/Capacity: This project would involve the area along the southern boundary of the District on both sides of SR 82 between the Hendry County Line and Gunnery Road. The current request is for diversion of runoff from southern ECWCD lands (In the vicinity of Mirror Lakes) to Lee County Port Authority mitigation lands and ultimately to the Green Meadows well fields.

Initiative Status: This project has been preliminarily discussed in the Lehigh Headwaters Initiative Meetings and should be studied further to determine its feasibility. ECWCD has positive discussions with Lee County Port Authority, Lee County Natural Resources, and Lee County Utilities.

Cost: Estimated Study and Preliminary Design Cost: $100,000.00

Documentation:

Estimate of Water Quality Benefits:

- Minimum: 0 pounds TN/year
- Maximum: 5,600 pounds TN/yr (assumes 25% TN removal)
- Most Likely: 2,800 pounds TN/yr
- Level of Certainty – conceptual
- Assumptions leading to benefit estimate-(e.g. for features- sub-watershed; period of record; inflow concentration/load; did you assume bmps were implemented or not) (e.g. for activities – location/sub-watershed where activity will apply; what does % reduction apply to which land uses, only new development, etc.)

The anticipated benefits to the Caloosahatchee River include:

- Flood attenuation
- Water quality improvements
- Rehydration of existing wetlands
- Rehydration of existing well fields
- Reduction of sediment and nutrient loading to the estuary
- Provide aquifer recharge
- Protect public health and safety

Estimate of Water Quantity Benefits:

- Minimum: 0 acre feet/yr, 0 cfs peak flow
- Maximum: 8,000 acre-feet/yr, 70 cfs peak flow
- Most Likely: 4,000 acre-feet/yr, 35 cfs peak flow
- Level of Certainty – conceptual
- Assumptions leading to benefit estimate- (e.g., sub-watershed; period of record; flow/volume; operational assumptions)

Level of Certainty: Level 3- Implementation Certainly unknown; Conceptual level of design/activity development complete; Location defined.

Source: Management Measure description.

Effective Storage Area: None

WQ Benefits: Estimated at 2800 lb/yr for TN from MM. No input for TP, but assumed 500 lb/yr as reasonable in comparison to TN.

CRE 123

Northern Everglades – Potential Management Measure

Project: North Ten Mile Canal Stormwater Treatment System

Level: 2

Description: This project is located in the vicinity of Ten Mile Canal from Canal Street to Carrell Road and borders along the westerly boundary of the CSX/Seminole Gulf railroad and proposes to create a large scale detention storage/treatment area for those portions of the watersheds encompassing the Fowler commercial corridor and easterly industrial areas. This project will also work in conjunction with the proposed easterly weir/control structures for Manuel's Branch and Carrell Canal near Royal Palm Avenue.

Purpose: By constructing this project, the storm water runoff can better mimic a pre-developed hydrologic response condition(s). This, in turn, will attenuate peaking flows, decrease the degree of flooding in the downstream portions of the watershed, and decrease the pollutant constituency concentrations for enhanced water quality within the Manuel's Branch and Carrell Canal waterways and the outfalling stormwater flows to the Caloosahatchee.

Location/Size/Capacity: City of Fort Myers

Initiative Status:
- Design (60% complete)
- Permit submittal March 2008

Cost: $600,000

Estimate of Water Quality Benefits (Tons/per 3-year Event):
- Minimum – 0.60 (N); 0.24 (P); 12 (TSS)
- Maximum – 1.20 (N); 0.48 (P); 168 (TSS)
- Most Likely – 0.90 (N); 0.36 (P); 148 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation.

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow - outflow)):
- Minimum – 12 ac / 50 ac-ft / (24 - 6) cfs
- Maximum – 12 ac / 50 ac-ft / (72 - 18) cfs
- Most Likely – 12 ac / 50 ac-ft / (48 - 12) cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- operational assumptions.

Source: Management Measure description

Effective Storage Area: 12 ac

WQ Benefits: Estimated at 1800 lb/yr for TN and 720 lb/yr for TP for 3-year event.

CRE 124

Northern Everglades – Potential Management Measure

Project: Carrell Canal (FMCC) Water Quality Improvements

Level: 2

Description: This project is located between McGregor Boulevard and US 41 within that area known as the Fort Myers Country Club (FMCC) and proposes to create a Stormwater Treatment Area (STA) via diversion structures, quiescent settling ponds, and constructed marshes within the "non-play" areas (5.5 acres ±) of the existing golf course facility.

Purpose: The proposed project will reduce the characteristic pollutants of nutrients, suspended solids, and sediments associated with the contributory land uses. This facility will also work collectively with a number of other individual stormwater treatment projects currently being considered or implemented in order to improve the overall water quality of Carrell Canal and the stormwater discharges to the Caloosahatchee River.

Location/Size/Capacity: City of Fort Myers

Initiative Status:
- Design Complete
- Permit Complete (36-06607-P)

Cost: $500,000

Documentation:

Estimate of Water Quality Benefits (Tons/per 3-year Event):
- Minimum – 0.30 (N); 0.12 (P); 64 (TSS)
- Maximum – 0.60 (N); 0.24 (P); 84 (TSS)
- Most Likely – 0.45 (N); 0.12 (P); 74 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow=outflow)):
- Minimum – 5 ac / 10 ac-ft / 3 cfs
- Maximum – 5 ac / 10 ac-ft / 7 cfs
- Most Likely – 5 ac / 10 ac-ft / 5 cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate - operational assumptions

Level of Certainty: Level 2- Construction/implementation likely; detailed design/activity development ongoing; location well defined.

Source: Management Measure description and City of Ft. Myers Stormwater Master Plan Update

Effective Storage Area: 5 ac

WQ Benefits: Estimated at 924 lb/yr for TN and 296 lb/yr for TP.

CRE 125

Northern Everglades – Potential Management Measure

Project: Shoemaker-Zapato Canal Stormwater Treatment

Level: 2

Description: The project proposes to install weir/control structures upstream of Michigan Avenue to improve the function and operations of the interconnection along the southerly boundary of the Vo-Tech facility between the Shoemaker and Zapato Canals. The project will provide for peak flow attenuation through increased channel storage and the "balancing" of outfalling stormwater volumes between the two canal systems so as to improve the water quality and reduce erosion and siltation into Billy Creek.

Purpose: This facility will also work collectively with a number of other individual stormwater treatment areas along Billy Creek and its tributaries currently being considered or implemented in order to improve the overall water quality of Billy Creek and the stormwater discharges to the Caloosahatchee River. The proposed project will reduce the characteristic pollutants of nutrients, suspended solids, and sediments associated with the contributory land uses.

Location/Size/Capacity: City of Fort Myers (Billy Creek)

Initiative Status:
- Planning Phase (Master Plan)

Cost: $375,000

Documentation:

Estimate of Water Quality Benefits (Tons/per 3-year Event):
- Minimum – 0.30 (N); 0.13 (P); 31 (TSS)
- Maximum – 0.90 (N); 0.17 (P); 37 (TSS)
- Most Likely – 0.60 (N); 0.15 (P); 34 (TSS)
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- BMP implementation

Estimate of Water Quantity Benefits (acre / acre-feet / cfs (inflow=outflow)):
- Minimum – 6 ac / 9 ac-ft / 3 cfs
- Maximum – 6 ac / 9 ac-ft / 7 cfs
- Most Likely – 6 ac / 9 ac-ft / 5 cfs
- Level of Certainty- conceptual
- Assumptions leading to benefit estimate- operational assumptions

Level of Certainty: Level 2- Construction/implementation likely; detailed design/activity development ongoing; location well defined.

Source: Management Measure description

Effective Storage Area: None

WQ Benefits: Estimated at 1200 lb/yr for TN and 300 lb/yr for TP

CRE 126

Northern Everglades – Potential Management Measure

Project: Fort Myers-Cape Coral Reclaimed Water Interconnect

Level: 5

Description: This proposed project plans a 20-inch diameter transmission line between the Fort Myers South Wastewater Treatment Plant and the Cape Coral Everest Reclamation Plant. The pipeline will be installed underneath the Caloosahatchee River using directional bore drilling techniques. The Everest plant has recently been upgraded to store more reclaimed water. Fort Myers is required by a FDEP permit condition to upgrade the South Plant to meet reclaimed water standards, and the design has been completed. However, the City has no reclaimed water customers in the South Plant service area, so is required by FDEP to construct an injection well for disposal rather than discharging to the Caloosahatchee River. An interconnect with Cape Coral and an agreement to take all the effluent from the South Plant will eliminate the need for an injection well. Cape Coral does need additional water and has an expanding distribution system of irrigation lines.

Purpose: The project will eliminate the City of Fort Myers' wastewater discharge from entering the Caloosahatchee Estuary, eliminate the need for the City to construct an injection well for dispose of high quality reclaimed water, and will provide reclaimed water to the City of Cape Coral which has infrastructure in place to distribute the water.

Location/Size/Capacity:
- Sub-basin: Cape Coral
- Location: near Mid-Point Bridge between Cape Coral and Fort Myers
- Size and Capacity: 20-inch diameter transmission line to pass 9 MGD of reclaimed water

Initiative Status: Conceptual

Cost: Roughly $12 - 15 million

Documentation: Cape Coral public Works feasibility study in progress

Estimate of Water Quality Benefits:
- Nutrient load reduction to Caloosahatchee River and Estuary
- Level of Certainty- If cost effective, construction of pipeline will eliminate 6 to 11 MGD of wastewater discharge
- Assumptions of benefit estimate- none, project will eliminate nutrient loads

Estimate of Water Quantity Benefits:
- Route wastewater flow into the Cape Coral reclaimed water system
- Level of Certainty- will add 6 to 11 MGD of irrigation water

- Assumptions of benefit estimate- none

Level of Certainty: Level 5- Implementation certainty unknown-Conceptual idea with limited information.

Contact Person: Terry Bengtsson, SFWMD 239-229-1822
Saeed Kazemi, City of Fort Myers, 239-332-6830
George Reilly, City of Cape Coral, 239-524-0709

Source: Management Measure description

Effective Storage Area: None

WQ Benefits: Calculated using 9 MGD at concentrations reported for Ft. Myers wastewater discharges (2.77 mg/L for TN and 0.19 mg/L for TP).

8-08-08

Effective Storage Area: None

WQ Benefits: No load reductions are currently presumed. Formerly calculated using 9 MGD at concentrations reported for Ft. Myers wastewater discharges (2.77 mg/L for TN and 0.19 mg/L for TP).

CRE 128

Northern Everglades – Potential Management Measure

Project Feature/Activity: East Caloosahatchee Storage

Level: 4

General Description/Background: The East Caloosahatchee Storage Project is located on approximately 7500 acres which is currently in private ownership. This project comprises a series of distributed reservoirs located in the East Caloosahatchee basin. This project could potentially create 100,000 ac-ft of above ground storage.

Purpose: The project objectives are to provide additional storage in the East Caloosahatchee Basin to meet unmet demands. The distributed reservoirs would be smaller localized reservoirs to supply irrigation demands.

Location/Size/Capacity: The project is located in the East Caloosahatchee Basin. A series of potential reservoir sites have been located with a total are of approximately 8,000 acres. The distributed reservoirs will provide above ground storage to meet unmet demand in the basin:

Initiative Status:

• Advance planning phase and associated field work	TBD
• PIR/BODR	TBD
• Preliminary Plans and specifications	TBD
• Intermediate Design for the PS and Reservoir	TBD
• Pre-final Design	TBD

Cost: Not yet determined

Documentation: For more information, please see CWMP Planning document.

Estimate of Water Quality Benefits
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: It is assumed that there will be some level of water quality treatment by simply holding water for a period of time before releasing in to the river. Level of treatment is unknown at this time.

Estimate of Water Quantity Benefits
- Minimum: 50,000 ac-ft of above ground storage
- Maximum: 100,000 ac-ft of above ground storage
- Most Likely: 70,000 ac-ft
- Level of Certainty: Conceptual
- Assumptions: Acquisition of approximately 8,000 acres in the East Caloosahatchee Basin

Screening Criteria
- Proof of Concept: 0
- Other Impacts: 1

Level of Certainty: Level 4- Implementation certainty unknown-Conceptual idea; May have rough order of magnitude cost and/or general basin location.

Contact: Clyde Dabbs; SFWMD; 239-338-2929 *7759

Source: Management Measure description.

Effective Storage Area: Current configuration is one large reservoir with an effective area of 8000 ac and capacity of 70000 ac-ft.

WQ Benefits: Calculated using SWFFS reductions for "deep reservoir" (currently 4 lb/ac/yr for TN and 1 lb/ac/yr for TP).

Further benefit for removal of land from existing citrus grove, calculated as 5000 ac of citrus times an estimated net source-load reduction of 6.89 lb/ac/yr for TN and 0.56 lb/ac/yr for TP in converting citrus to open water, and as 2700 ac of sugar cane times an estimated net source-load reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 83000 lb/yr for TN and 11700 lb/yr for TP.

08-08-08

Effective Storage Area: Current configuration is one large reservoir with an effective area of 8000 ac and capacity of 70000 ac-ft.

WQ Benefits: Estimated as 46 Mton/yr for TN and 3.5 Mton/yr for TP for reservoir, as modeled by WSI (written commun. 8/6/08).

Further benefit for removal of land from existing citrus grove, calculated as 5000 ac of citrus times an estimated net source-load reduction of 6.89 lb/ac/yr for TN and 0.56 lb/ac/yr for TP in converting citrus to open water, and as 2700 ac of sugar cane times an estimated net source-load reduction of 6.13 lb/ac/yr for TN and 0.31 lb/ac/yr for TP in converting sugar cane to open water, as supplied by Del Bottcher (SWET, draft report, 5/8/08).

Total load reduction is estimated as 152000 lb/yr for TN and 11400 lb/yr for TP.

CRE 128a

Northern Everglades – Potential Management Measure

Project Feature/Activity: Caloosahatchee Storage - Additional

Level: 4

General Description/Background: The Caloosahatchee Storage - Additional Project is to be located in the Freshwater Basins of the Caloosahatchee River. This project could potentially create 50,000 ac-ft of above ground storage.

Purpose: The project objectives are to provide additional storage in the East Caloosahatchee Basin to meet unmet demands.

Location/Size/Capacity: The project is located in the Freshwater Caloosahatchee Basins. The distributed reservoirs will provide above ground storage to meet unmet demand in the basin.

Initiative Status:

- Advance planning phase and associated field work TBD
- PIR/BODR TBD
- Preliminary Plans and specifications TBD
- Intermediate Design for the PS and Reservoir TBD
- Pre-final Design TBD

Cost: Not yet determined

Documentation: For more information, please see CWMP Planning document.

Estimate of Water Quality Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: It is assumed that there will be some level of water quality treatment by simply holding water for a period of time before releasing in to the river. Level of treatment is unknown at this time.

Estimate of Water Quantity Benefits

- Minimum: 50,000 ac-ft of above ground storage
- Maximum: 50,000 ac-ft of above ground storage
- Most Likely: 50,000 ac-ft
- Level of Certainty: Conceptual
- Assumptions: Acquisition of approximately 3,500 acres in the Freshwater Caloosahatchee Basins

Screening Criteria

- Proof of Concept: 0
- Other Impacts: 1

Contact: Clyde Dabbs; SFWMD; 239-338-2929 *7759

Source: Management Measure description.

Effective Storage Area: Current configuration is one large reservoir with an effective area of 6250 ac and capacity of 50000 ac-ft. No location, general or otherwise, has been designated for this feature.

WQ Benefits: Calculated using SWFFS reductions for "deep reservoir" (currently 4 lb/ac/yr for TN and 1 lb/ac/yr for TP).

August 8, 2008

Description / Purpose: Deep storage reservoir to capture excess flow.

Source: Management Measure description.

Effective Storage Area: Current configuration is one large reservoir with an effective area of 6250 ac and capacity of 50000 ac-ft. No location, general or otherwise, has been designated for this feature.

WQ Benefits: Estimated as 58 Mton/yr for TN and 4.3 Mton/yr for TP for reservoir, as modeled by WSI (written commun., 8/6/08).

CRE 129

Northern Everglades – Potential Management Measure

Project: Wastewater Treatment Plant Upgrade and Reuse Opportunities

Level: 5

Description: Evaluate opportunities to 1) upgrade existing wastewater treatment plants within the watershed; 2) construct future planned plants to higher treatment levels; and 3) beneficially distribute reclaimed water. A comprehensive evaluation of existing wastewater treatment plants within the watershed will be conducted as part of the TMDL allocation and BMAP process. This process will evaluate existing levels of treatment for both point and non-point sources and will determine responsibilities and obligations for each source. The process has very clear steps to ensure that all point sources are achieving Best Available Technology Economically Achievable (BAT) requirements at a minimum and that any additional reductions necessary to achieve the TMDL are allocated to all sources. The allocation process also provides credits for reducing pollutant loading through reuse. This process will likely result in more stringent requirements for some point sources in balance with the requirements imposed on non-point sources. The allocation process is structured to assign reduction obligations between point and non-point sources in a fair and equitable manner. Because point sources, like WWTPs, have well established technologies for achieving reliable and predictable nutrient reductions they should be considered a priority for achieving nutrient reductions. However, it is important to hold all sources accountable for their pollutant loads and reduction responsibilities. Because non-point source nutrient reductions are more costly with less predictable performance, consideration should be given to maximizing point source reductions and offsetting non-point source reduction through water quality credit trading.

Once the allocation process is completed and the required treatment levels/allocations for these wastewater treatment plants are determined, future RWPP updates will incorporate a quantification of benefits resulting from more stringent treatment levels.

Purpose: The project will address treatment of wastewater discharge entering the Caloosahatchee Estuary. The project will also address the disposal of high quality reclaimed water by providing credits for beneficial reuse and identifying opportunities for and infrastructure necessary to maximize beneficial reuse.

Location/Size/Capacity: Treatment plants are located in five of the subregions.

Initiative Status:

- Advance planning phase and associated field work- Will be evaluated as part of the Caloosahatchee TMDL Allocation and BMAP process
- Preliminary Plans and Specifications
- Intermediate Design
- Pre-final Design
- Final Design
- Permit submittals

Cost:

Documentation:

Estimate of Water Quality Benefits:
- Minimum – TBD
- Maximum- TBD
- Most Likely- TBD
- Level of Certainty- unknown
- Assumptions leading to benefit estimate- Nutrient loading potential from this management measure is large. Achieving reductions from Wastewater Treatment Plans is very controllable and predictable which makes it an attractive target for achieving nutrient reductions. . Level of treatment and hence quantification of benefits will be determined through the TMDL allocation and BMAP process and is unknown at this time.

Estimate of Water Quantity Benefits:
- Minimum – TBD
- Maximum- TBD
- Most Likely-TBD
- Level of Certainty- unknown
- Assumptions leading to benefit estimate- Beneficial reuse should result in water quantity benefits, however it is not possible to quantify at this time.

Level of Certainty: Level 5

Contact: Janet Starnes

This Management Measure is consistent with the Southwest Florida Regional Planning Council Wastewater Resolution recommendation Section 3 on wastewater treatment.

Upgrade and Reclaimed Water

CRE 129 – Alt 4, Local

Source: Management Measure description. List of wastewater treatment plants, with operating capacity and effluent concentrations from Table 3-14 of CDM report to SFWMD, Nutrient Load Assessment – Estero Bay and Caloosahatchee River Watershed, Jan. 2007.

Effective Storage Area: None

WQ Benefits: Calculated using existing operating capacity and effluent concentrations, with assumption that concentration will be reduced to some minimum attainable level (currently estimated as 0.40 mg/L for TN and 0.04 mg/L for TP). Total potential reductions for all facilities in the 5 subregions are 175000 lb/yr for TN and 28000 lb/yr for TP.

08-08-08

Description / Purpose: Upgrade 17 existing wastewater treatment plants to reduce the effluent loadings. Includes the potential for distribution as reclaimed water. Also designates two future plants, East Fort Myers (Lehigh) and North Cape Coral, for additional treatment. Treatment plants are located in five of the subregions.

Source: Management Measure description. List of wastewater treatment plants, with operating capacity and effluent concentrations from Table 3-14 of CDM report to SFWMD, Nutrient Load Assessment – Estero Bay and Caloosahatchee River Watershed, Jan. 2007.

Effective Storage Area: None

WQ Benefits: No load reductions are currently presumed. Formerly calculated using existing operating capacity and effluent concentrations, with assumption that concentration would be reduced to some minimum attainable level (estimated as 0.40 mg/L for TN and 0.04 mg/L for TP), giving total potential reductions for all facilities in the 5 subregions as 175000 lb/yr for TN and 28000 lb/yr for TP.

CRE 130

Northern Everglades – Potential Management Measure

Project Feature/Activity: Animal Manure Application Rule

Level: 1

General Description/Background: In February 2008, FDACS initiated rule development (5M-10 Florida Administrative Code) to control the land application of animal wastes in the Caloosahatchee River Watershed. The proposed rule includes minimum application setbacks from wetlands and all surface waters. Landowners who apply more than one ton per acre of manure must develop conservation plans, approved by the US Department of Agriculture/National Resource Conservation Service (USDA/NRC), that specifically address the application of animal wastes and include soil testing to demonstrate the need for manure application. All use of animal manure must be recorded and included in the operation's overall nutrient management plan. FDACS expects to complete rule making for this effort by the fall of 2008.

Purpose: Improve water quality by reducing nutrient runoff and leaching resulting from the land application of manure.

Location/Size/Capacity: Statewide for one acre applications or greater.

Initiative Status:

Cost: Not applicable

Documentation: (Insert Rule Name and citation)

Estimate of Water Quality Benefits
- Minimum:
- Maximum:
- Most Likely:
- Level of Certainty:
- Assumptions:

Estimate of Water Quantity Benefits
- Minimum: N/A
- Maximum: N/A
- Most Likely: N/A
- Level of Certainty: N/A
- Assumptions: N/A

Level of Certainty: Level 1

Screening Criteria
- Proof of Concept: N/A
- Other Impacts: N/A

Contact: Rich Budell; FDACS; 850-617-1704

Final Water Quality Method and Summary: N/A
Final Water Quantity Method and Summary: N/A

Note: FDACS has adopted by administrative rule, agricultural Best Management Practices addressing containerized nursery, vegetable and agronomic crop and citrus land uses in the Caloosahatchee River Watershed. FDACS is currently developing and will be adopting BMP programs for cow/calf, sod and equine operations. BMP's for all agricultural land uses are expected to be adopted by early 2009.

CRE 131

Northern Everglades – Potential Management Measure

Project Feature/Activity: Septage Disposal Requirements

Level: 1

General Description/Background: In response to the new provisions of Section 373.4592(4)(a)2.f. and (b)2.f., F.S., regarding application of septage in the Caloosahatchee and St. Lucie rivers, respectively, FDOH has notified all county permitting authorities in the watersheds of another requirement regarding septage disposal. Entities disposing of septage within the watersheds must develop and submit to DOH an agricultural use plan that limits applications, based upon nutrient loading. At this time, there are no known septage application sites in these watersheds. Once SFWMD or FDEP has promulgated nutrient concentration limits for runoff from sites in these watersheds, through the SFWMD's 40E-61 Regulatory Nutrient Source Program or another validly adopted rule, FDOH will notify all county permitting authorities in the watersheds that nutrient concentrations originating from these application sites may not exceed the established limits.

Purpose: Improve water quality by reducing nutrient runoff and leaching resulting from the land application of septage within the Caloosahatchee watershed.

Location/Size/Capacity: Caloosahatchee River Watershed

Initiative Status:

Cost: Not applicable

Documentation: (Insert Rule Name and citation)

Estimate of Water Quality Benefits
- Minimum:
- Maximum:
- Most Likely:
- Level of Certainty:
- Assumptions:

Estimate of Water Quantity Benefits
- Minimum: N/A
- Maximum: N/A
- Most Likely: N/A
- Level of Certainty: N/A
- Assumptions: N/A

Level of Certainty: Level 1

Screening Criteria

- Proof of Concept: N/A
- Other Impacts: N/A

Contact:

Final Water Quality Method and Summary: N/A
Final Water Quantity Method and Summary: N/A

APPENDIX C

NORTHERN EVERGLADES REGIONAL SIMULATION MODEL

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C1.0 NORTHERN EVERGLADES REGIONAL SIMULATION MODEL

A customized modeling tool, the Northern Everglades Regional Simulation Model (NERSM), was used to guide the formulation and evaluation of alternative plans during the River Watershed Protection Plan (RWPP) process. Key information about the model, model simulations, and application of simulation output was previously presented in Section 6; additional details from the modeling exercise are presented in this Appendix. This appendix is an update to Appendix B of the Lake Okeechobee Watershed Construction Project Phase II Technical Plan (LOP2TP) report (SFWMD, 2008).

South Florida is a unique environment requiring specialized models to simulate regional operations. South Florida has a complex regional hydrologic system that includes thousands of miles of primary and secondary networked canals, nearly 300 man-made flow-regulation structures, thousands of square miles of nearly flat terrain much of which are wetlands, and permeable surficial soils that enhance groundwater-surface water interactions. Hydrologic and hydraulic analyses of this complex system require a computational model that can run quickly, offer flexibility, and generate output that can be clearly interpreted. Because of the region's highly variable hydrology (extreme rain events and periods of extended droughts), it is imperative that models be capable of running regional simulations of decades covering wet, dry and average rainfall conditions. Finally, land use changes and water demands for this extended period of time requires the user to easily modify input data sets, as well as an ability to use generalized data sets to optimize performance.

The Regional Simulation Model (RSM) was developed by the South Florida Water Management District (SFWMD) to overcome these limitations. RSM provides the computational framework for developing more complete and numerically sound integrated surface water and groundwater models where both components receive equal attention.

The RSM uses advanced computational techniques such as efficient sparse matrix solver and a finite volume method to simulate 2-D surface water and groundwater flow (SFWMD, 2005b). In addition, the RSM model uses an object oriented programming approach which allows new objects to be inserted or existing objects to be removed from the model without compromising the functionality of existing modules.

When used in a meshed system, RSM has two principal components, the Hydrologic Simulation Engine (HSE) and the Management Simulation Engine (MSE). The HSE simulates natural hydrology, water conveyance systems such as canals and natural bodies of water. The HSE component solves the governing equations of water movement through both the natural hydrologic system and the man-made structures. The MSE component consists of a multi-level hierarchical control scheme, which includes both the local and regional control of hydraulic structures. These two components work seamlessly to conduct the long term modeling necessary for this complex region.

RSM can be used as a node-link model when implemented in a study area that can be conceptualized as a lumped system, as in the case of NERSM. RSM produces complete water budgets given appropriate boundary conditions and simplified operating rules. Initial usage of NERSM was in the LOP2TP process. A refined version of the NERSM was utilized during the

RWPP planning process. More advanced capabilities of RSM such as 1-D canal flow routing and 2-D overland flow/groundwater flow calculations were not used in NERSM.

In summary, to support both the LOP2TP and the RWPP planning processes, RSM was applied to create NERSM, a customized hydrologic model. This model is used to simulate hydrologic conditions in the Northern Everglades Technical Plan study area (**Figure C-1**) under varying scenarios such as Current Base, Future Base, and alternative plans. It should be noted that the recommended plan from the LOP2TP project became the basis for the RWPP Future Base (RWPPB). In other words, the RWPP assumes that the LOP2TP is implemented and all RWPP alternatives build upon the improved conditions resulting from LOP2TP implementation. Comparison of the Current Base and the RWPPB is provided in Section 6.2 of the RWPP, while comparison of the RWPPB and the RWPP alternatives is given in Section 6.5. Subsequent reference to a Future Base in this Appendix corresponds to RWPPB.

C1.1 Spatial Representation

The model area covers the Lake Okeechobee Watershed, Caloosahatchee River Watershed, and the St. Lucie River Watershed. The Lake Okeechobee Watershed consists of five sub-watersheds north of the lake: the Upper Kissimmee Basin (KUB), Lower Kissimmee Basin (LKB), Taylor Creek / Nubbin Slough (TCNS), Lake Istokpoga (LI), and Fisheating Creek (FEC).The model also represents the Water Supply and Environment (WSE) Regulation Schedule for regulatory releases to the Caloosahatchee (C-43) Estuary through S-77 and the St. Lucie (C-44) Estuary via S-308. The Caloosahatchee River Watershed consists of the East Caloosahatchee (ECAL) and West Caloosahatchee (WCAL) sub-watersheds, while the St. Lucie River Watershed consists of the C-23, C-24, C-44, Ten Mile Creek and Tidal sub-watersheds.

The study area is represented in NERSM by a series of links and nodes (**Figure C-2**). Each node represents a distinct drainage basin or hydrologic feature for which a water balance is simulated. Links represent the processes that convey water from one node to another. The combined link-node diagram illustrates the spatial distribution and movement of water as it is conveyed within a sub-watershed and between sub-watersheds. Larger, more complex sub-watersheds like the KUB and LKB are represented using multiple links and nodes. Others, TCNS, LI, and FEC are represented by a single node linked to Lake Okeechobee. Although Lake Okeechobee is represented as a single node, its water balance is influenced by links to each of the tributary watersheds and the inter-basin transfers of water (**Figure C-2**).

The model uses an object-oriented approach, which allows new objects (i.e. software modules) to be added without the need to edit the previous code or functionality of existing modules. For example, the addition and operation of a new reservoir would be simulated as a discrete “object” – there would be no need to modify the coding for other elements of the water management system. In this application, NERSM receives boundary conditions from two existing models – Upper Kissimmee Chain of Lakes Routing Model (UKISS) and the South Florida Water Management Model (SFWMM). NERSM uses some output from the UKISS as input to the model representing the LKB Sub-watershed.

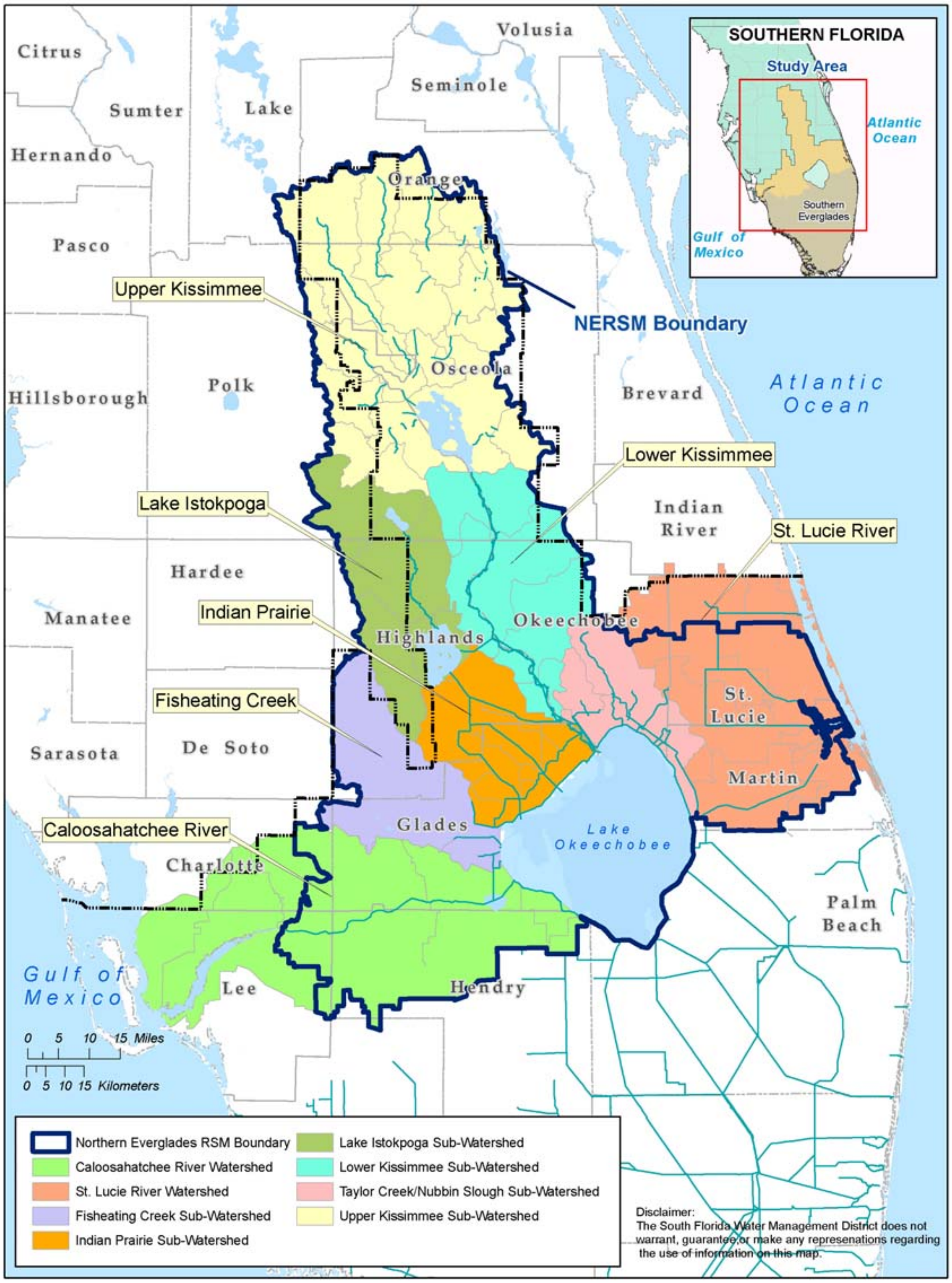


Figure C-1. Watersheds modeled in the NERSM

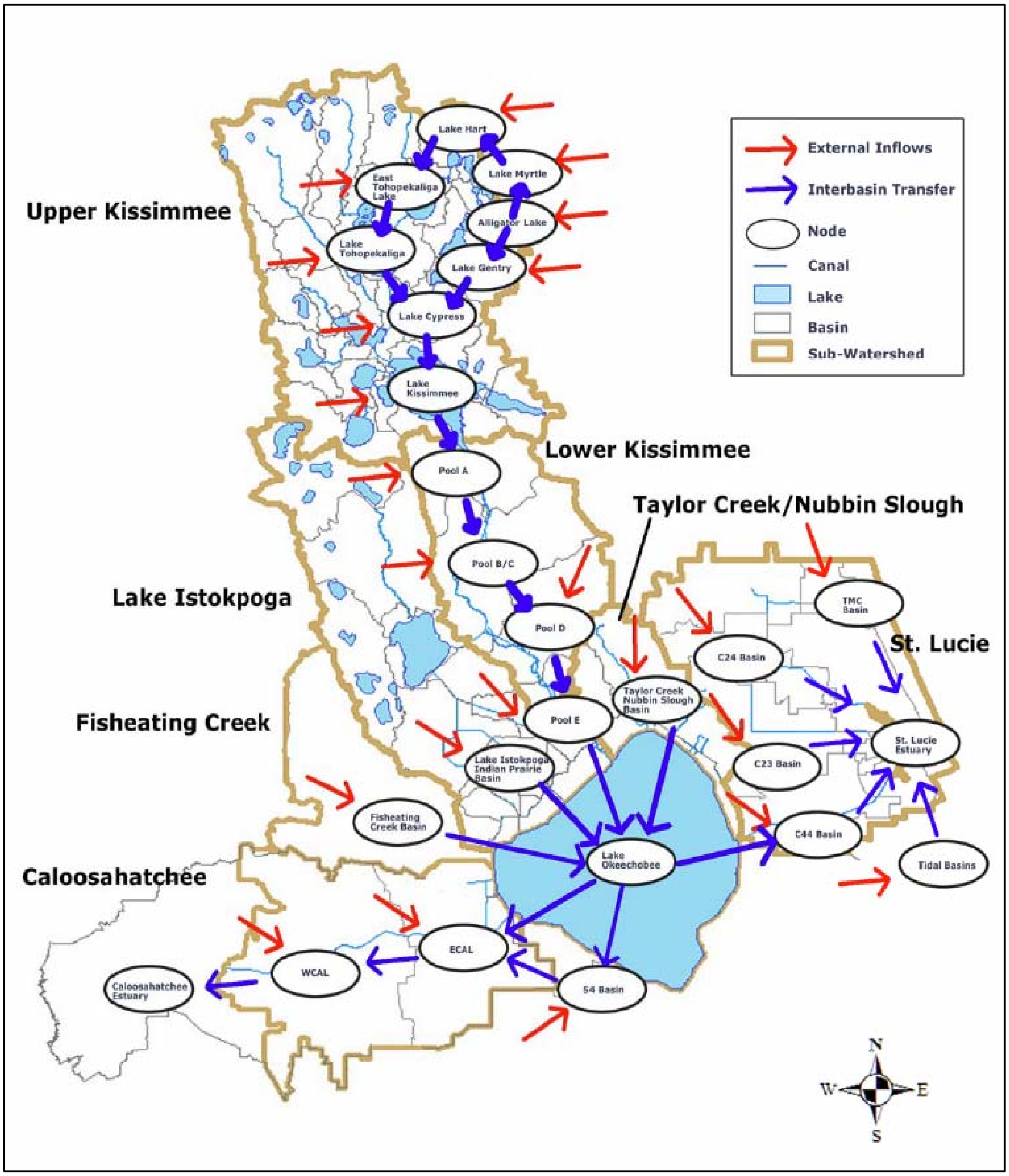


Figure C-2. Node-link diagram representation of NERSM

C1.2 Simulation Period

NERSM is a transient model that calculates a water balance for each node on a time interval of one day. A simulation period spanning 36 years from January 1, 1970 through December 31, 2005 was selected for evaluating various water management scenarios. All management scenarios evaluated using NERSM are based on the same 36-year simulation period.

The simulation period selected for the NERSM is slightly different from the 36-year period typically used by SFWMM (1965 to 2000). For the NERSM simulation, the inclusion of the last five years (2001-2005) was driven by the desire to include extreme events such as Hurricanes Charlie, Frances, and Jeanne in 2004, and Hurricane Wilma in 2005.

C1.3 Theoretical Assumptions and Limitations

Major assumptions and limitations of NERSM are as follows:

- The simulation period is sufficiently long, such that the hydrologic conditions in existence during this period and used as model input varied sufficiently to adequately characterize the performance measures considered in the evaluation of RWPP management alternatives.

- Water is routed through storage features assuming a level pool with negligible slope in the water surface. The assumption is valid as long as the volume entering a storage feature during the one-day time step is small relative to the volume of water in storage.

    - The model simulates the management of the system according to a set of operational criteria referred to as management rules. These rules are expressed in regulation schedules, gate-operation criteria, and established rules governing the operation of the structures. It is assumed that the management rules prescribed for the various simulation scenarios are reasonable for the variety of hydrologic conditions represented by the period of simulation. Under unusual conditions, the actual operation may differ from the established rules and can lead to differences between calculated and observed conditions.

- A daily time step is assumed to be adequate for planning purposes and the evaluation of RWPP performance measures. Most measures are expressed in terms of annual, monthly, and weekly statistics. A possible exception is the extreme low and high stages calculated for Lake Okeechobee. This assumption should be valid because the difference between an instantaneous minimum (or maximum) and the model-calculated daily value is small compared to the year-to-year variability in range of extreme stages calculated for a daily simulation spanning 36 years.

- Historical inflows to TCNS, LI, and FEC, based on monitoring, are assumed to produce historical outflows from these sub-watersheds into Lake Okeechobee. Referred to as the "flow pass-through method," this eliminates the need to develop stage-volume relationships for existing storage features within the sub-watersheds or to simulate the rainfall-runoff process for the sub-watershed.

- It is assumed that a change in management rules will not change the historical hydrologic variables.

- Sub-watershed areas are reduced in size for proposed future management measures (MMs) such as reservoirs and stormwater treatment areas (STAs). It is assumed that the historical sub-watershed inflow discharged to Lake Okeechobee can be reduced in proportion to the ratio of the effective footprint "taken" by the management measure relative to the overall area of the sub-watershed.

- Other than the footprint associated with MMs considered in the Future Base and alternative scenarios, it is assumed that changes in land use or land cover within the study area, e.g. conversion to natural lands, will require some runoff modification in order to account for increased evapotranspiration (ET) and attenuation.

- No flow-regulation structures exist in the Fisheating Creek Sub-watershed. The creek has an open connection with Lake Okeechobee. The link between the sub-watershed and Lake Okeechobee is simulated by an assumed "dummy" structure that has a very high flow conveyance capacity.

- The lower Kissimmee River and floodplain between consecutive water control structures is assumed to be hydrologically similar to a level-pool reservoir with a unique stage-volume relationship. Lock operations are not simulated.

- It is assumed there is no connection between Lake Istokpoga and the Kissimmee River. Structure G-85 is simulated as being closed.

- The Caloosahatchee Estuary target is the ecologically-based EST05 time series which establishes the desired temporal distribution of surface water discharges via S-79 into the estuary. Lake Okeechobee is used to meet this target.

- The St. Lucie Estuary target was established using an updated version of the optimization model (OPTI) used to size reservoir and establish optimal operations as recommended in the IRL-South project (SFWMD, 2004). NERSM attempted to mimic the OPTI-6 generated flows into the St. Lucie Estuary in order to mimic the performance of the IRL-S PIR. The option to explicitly make Lake Okeechobee releases to meet these operational targets is turned off in all RWPP scenarios.

- Elevations are referenced to the National Geodetic Vertical Datum of 1929 (NGVD). Units of measure for input, output and calculations are from the English Customary System which includes measures such as inches, feet, miles, gallons, and acres.

C1.4 Model Input

The following types of data are provided as input to NERSM.

- **Hydrologic boundary conditions**: These are system "state variables" used to describe inflow to and discharge from the sub-watersheds. Boundary conditions are based on daily time series of historical flow records collected at control structures and hydrometeorologic data. Boundary conditions for watersheds simulated using the flow pass-through method are based on daily historical flow records obtained from the SFWMD's DBHYDRO database for the 36 year simulation period. The water balance for other sub-watersheds is based on daily records of rainfall, pan evaporation, and other hydrometeorologic data compiled from a variety of data sources.

- **Watershed and system characteristics:** Models such as UKISS, SFWMM and WaSh - which consider discrete components of the hydrologic cycle such as ET, surface runoff, and groundwater seepage - require additional input for watershed characteristics such as soil porosity, direct runoff-routing coefficients, channel roughness, etc. and parameters used to calculate ET, such as leaf area index. Stage-volume relationships are used to represent the storage of water within the surficial aquifer; water bodies such as lakes, reservoirs, and STAs; and other storage systems, such as aquifer storage and recovery (ASR) wells.

- **Hydraulic variables:** The flow of water through open channels, gated hydraulic structures, and pumps is governed by empirical equations called “ratings” that relate flow to system state variables. Some examples of state variables are stage (the water level in a canal, stream, lake or reservoir), and physical characteristics, such as channel and gate geometry, pump diameter, and pump operating speed. Model input includes site-specific parameters for the equations associated with the specific hydraulic controls that are being simulated.

- **Management variables:** Regulation schedules represent the management aspect of the system aimed at multiple objects, such as optimizing flood control, water conservation, and environmental enhancement. A regulation schedule contains zones of time within which flow releases are prescribed depending on the “state” the system is in. Regulation schedules for existing structures have evolved over time in response to hydrologic conditions, such as the recent hurricanes and alterations in flow-management objectives.

C1.5 Model Output

Although NERSM can be set up to output a variety of information, the primary variable of interest are calculated stages and flows at specific structures, and sub-watershed water balances. Output can be recorded at user-selected time intervals, although daily output is the most common. Post-simulation processing algorithms are used to aggregate the daily output into summary formats such as the average annual sub-watershed volumes of rainfall, tributary inflow, ET, and flow releases. Post processing is used to generate information for quantifying specific performance measures designated for the various project MMs (**Table C-1)**.

C1.6 Model Validation

To ensure that the NERSM was performing as intended, Current Base and Future Base conditions were also simulated using the SFWMM and the Upper Kissimmee Model. Consistent input series were used for all model simulations.

NERSM output for Lake Okeechobee and the two estuaries were compared to SFWMM output for the same regions. NERSM output for the Lower Kissimmee sub-watershed was compared to UKISSWIN output.

C1.6.1 South Florida Water Management Model (SFWMM)

The SFWMM has been extensively used in previous SFWM modeling efforts. The major operational components of Lake Okeechobee that are common to both SFWMM and NERSM are the WSE schedule and Lake Okeechobee Service Area (LOSA) water supply procedure. For both sets of operations, outlet flows from individual structures were compared to the results from the equivalent SFWMM run in order to validate the operational methodology in the NERSM simulations. In both cases, the comparison showed good correlation in terms of the timing and magnitude of the flows in the two models.

Table C-1. Performance Measures Used to Evaluate Current and Future Base Conditions and Alternatives

Sub-Watershed	Performance Measure
Lake Okeechobee	Total surface P Loading to Lake Okeechobee
	Extreme high lake stage > 17 ft
	Extreme low lake stage < 10 ft
	Lake stage envelope – weeks below
	Lake stage envelope – weeks above
	Number of times proposed min water level & duration – criteria exceeded
Caloosahatchee Estuary	Number of times salinity envelope criteria NOT met
	Number of times estuary high discharge criteria exceeded (between 2,800 and 4,500 cfs)
	Number of times estuary high discharge criteria exceeded (>4,500 cfs)
	Target Flow distribution based on EST05 time series established for S-79
St. Lucie Estuary	Number of times estuary high discharge criteria exceeded (between 2,000 & 3,000 cfs)
	Number of times estuary high discharge criteria exceeded (>4,500 cfs)
	Number of times salinity envelope criteria NOT met
Water Supply	LOSA demand cutback volumes for 7 yrs with largest cutbacks
	Mean annual EAA/LOSA supplemental irrigation demands not met

C1.6.2 UKISSWIN Model

The UKISSWIN model was developed by the SFWMD to simulate the operation of the lake system in the Upper Kissimmee River Basin. UKISSWIN was used to supply boundary conditions to NERSM. The UKISSWIN model area covers the following lakes: Alligator, Myrtle, Hart, and Mary Jane, Gentry, East Tohopekaliga, and Tohopekaliga, Cypress, Hatchineha, and Kissimmee. The model is capable of simulating both the hydrology and management of the lake system in three modes: simulation, calibration, and forecasting. The model is well calibrated and undergoes continuous updates. It is routinely used to forecast the monthly lake stages, using rainfall as the conditional independent variable.

NERSM treated the simulation of the lake system in the Upper Kissimmee Sub-watershed the same way UKISSWIN did, using the same routing scheme, identical rainfall data, and same ET model. NERSM used watershed inflow data from UKISSWIN output as one of its boundary conditions. The major differences between the two models are the stage-area and stage-volume relationships. NERSM adopted the most updated data available (developed as part of the Kissimmee Basin Modeling and Operations Study (KBMOS). In general, the modeling results are very similar between the NERSM and UKISSWIN models.

C1.6.3 Validation Results

NERSM performance was shown to match SFWMM (2X2) (**Figure C-3)** and UKISSWIN (**Figures C-4** and **C-5**). The NERSM was therefore considered suitable for making planning level decisions.

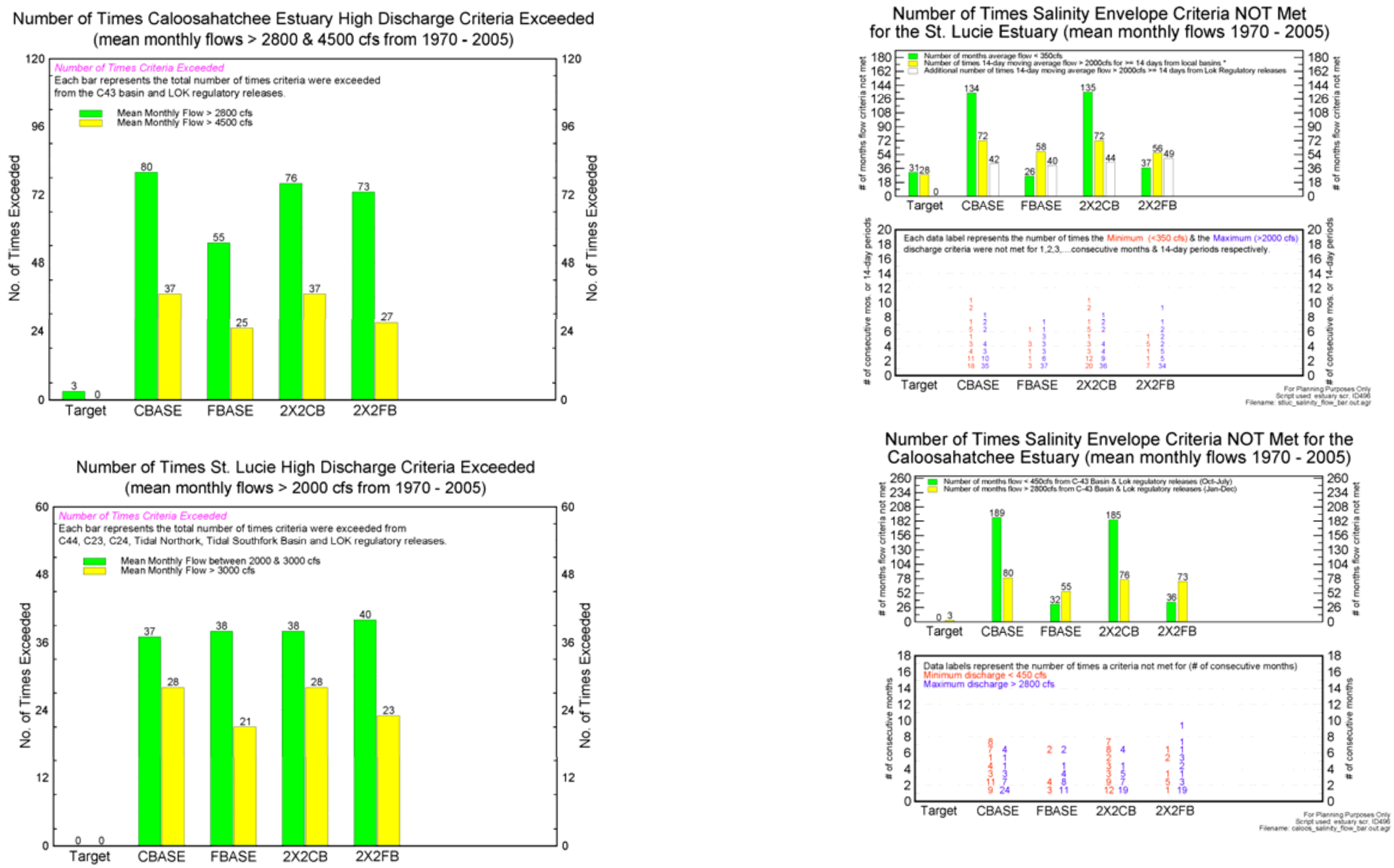
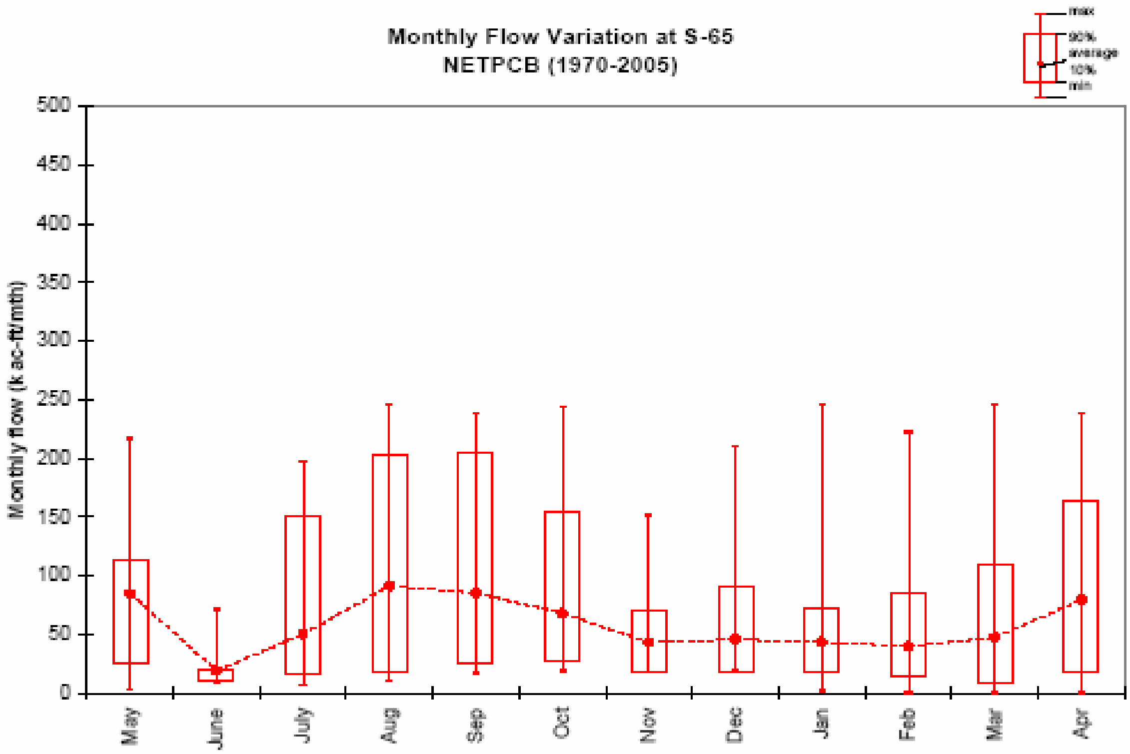


Figure C-3. Comparison of NERSM and SFWMM (2x2) Model outputs for selected performance measures



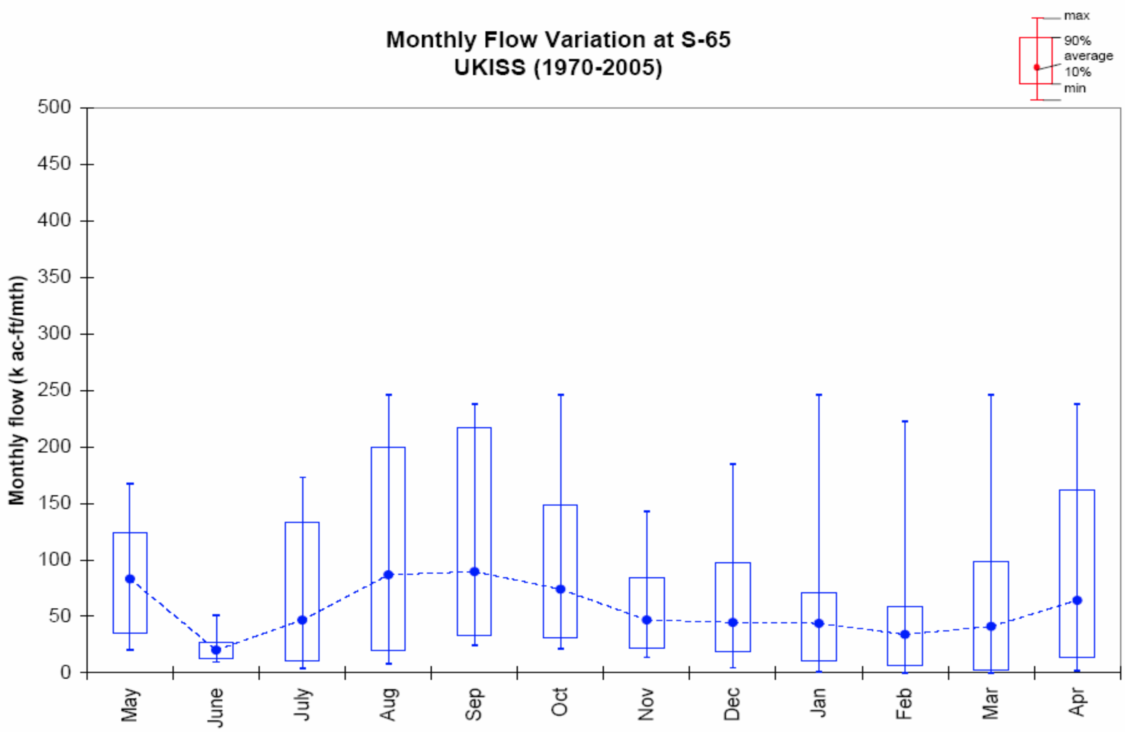
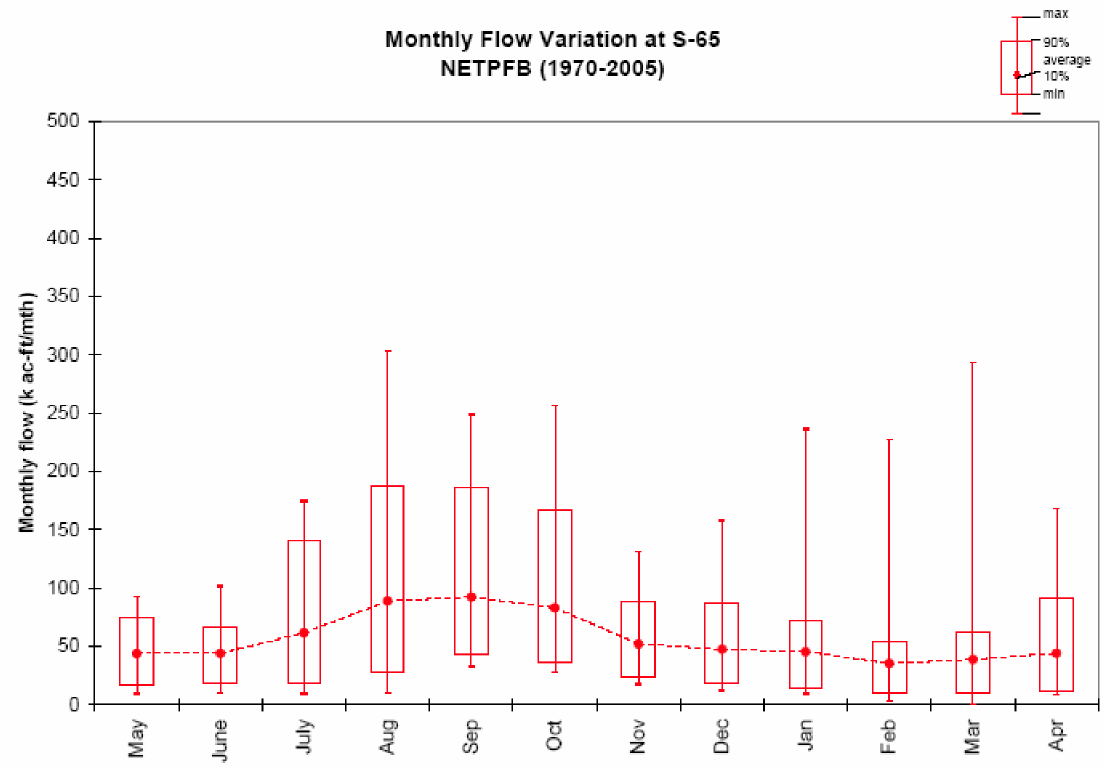


Figure C-4a and b. Monthly flow variation at S-65 in NERSM and UKISSWIN models for Current Base



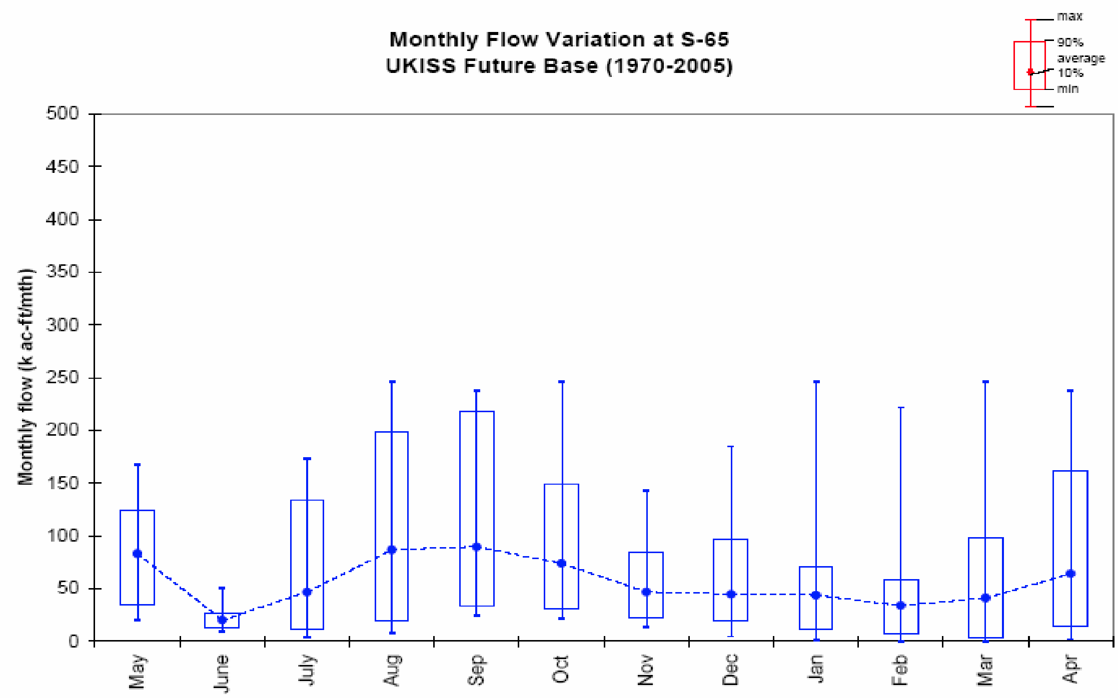


Figure C-5a and b. Monthly flow variation at S-65 in NERSM and UKISSWIN models for Future Base

C2.0 NERSM APPLICATION

C2.1 Modeling Scenarios

The following scenarios were evaluated using the NERSM:

- **Current Base** – This scenario represents sub-watershed and management conditions that existed in the Lake Okeechobee Watershed in 2005. The condition assumes that no CERP projects had been implemented for a sufficient time to reflect impacts of implementation. The more recent records of historical flow used for the Lower Kissimmee Basin (LKB) Sub-watershed model reflect to some degree the effects of incremental restoration associated with Phase I of the Kissimmee River Restoration (KRR) through 2005. In addition, the effects of STAs constructed recently prior to 2005 in the TCNS Sub-watershed have not been demonstrated because of dry conditions and a lack of data to characterize performance. Regulatory (flood control) releases from Lake Okeechobee to the estuaries and to the Water Conservation Areas (WCAs) are simulated based on the WSE Regulation Schedule consistent with the SFWMM 2005 base run.

- **RWPP Future Base (RWPPB)** – This scenario represents the Current Base scenario plus planned conditions likely to exist in the Lake Okeechobee Watershed following the implementation of three Acceler8 projects; two Kissimmee River water resources projects and recommendations from the LOP2TP project (note: this scenario should not be confused with the LOP2TP Future Base). The following projects were included in the RWPPB scenario:

  - **Acceler8 Projects**: C-43 Caloosahatchee River Reservoir, C-44 St. Lucie Canal Reservoir and STA, and A-1 Everglades Agricultural Area Reservoir.

  - **Kissimmee Projects**: KRR Project and the Kissimmee River Headwaters Revitalization

  - **LOP2TP Recommended Projects**: Combined Reservoir storage, STA storage and ASR capacity equal to 914,000 acre-feet, 54,000 acre-feet and 66 million gallons per day (MGD), respectively. Additional details can be found in the LOP2TP Technical Plan (SFWMD, FDEP, and FDACS, 2008).

  - **Ten Mile Creek Reservoir Project**

  The same sub-watershed inflow time series used in the Current Base simulation are used in the Future Base simulation. Pools B, C, and D in the Current Base simulation are combined to form pool BCD in the Future Base simulation. Regulatory (flood control) releases from Lake Okeechobee to the estuaries and to the WCAs are simulated based on the WSE Regulation Schedule, consistent with the SFWMM 2010A8 run.

  – This scenario is essentially the same as the LOP2TP Future Base plus LOP2TP recommended MMs, and enhancements to the Caloosahatchee River and St. Lucie River watershed simulation. The NERSM version used in LOP2TP treated several hydrologic variables in both river watersheds as boundary conditions, e.g. C-44 Reservoir operations, backflow to Lake Okeechobee, etc. This version also lumped the contribution of the basins that comprise each watershed. The version of NERSM used in the RWPPs, on the other hand, treats the basins upstream of S-79: East Caloosahatchee, West Caloosahatchee and S-4 as separate computational nodes with different associated demand and runoff characteristics. Likewise, St. Lucie River Watershed basins outside the C-44 Basin were treated separately in order to simulate the different water quantity and quality features during alternative plan development and analysis phase of the project. A summary of the MMs recommended during the LOP2TP planning process is shown in **Table C-2**. Management measure numbers correspond to those in the LOP2TP Technical Plan (SFWMD, FDEP, and FDACS, 2008).

- **RWPP Alternative Plans (ALTs 1 through 4) –** The RWPP planning process formulated and evaluated four alternative plans for achieving project goals and objectives. Each scenario represents the RWPPB scenario, plus a variety of MMs from three general categories – reservoir storage, water quality treatment, and wetland/natural land restoration. MMs meeting the following criteria were selected to be included in the model:

  1. The MM should have water quantity benefits to the regional system. Some MMs, like on-site treatment, are too small to make an imprint on the regional performance measures and, thus, were not included in the model.
  2. A conceptual design should exist for the MM. If none exists, sufficient documentation should exist where the purpose, relative storage capacity and reasonable linkage to the regional system can be roughly established.

  The combinations of specific MMs are summarized in **Tables C-3** and **C-4** for the Caloosahatchee River and St. Lucie River watersheds, respectively. These combinations are also described in other sections of the report. The alternative plans are summarized as follows:

  Alternative 1 – This alternative is defined as the "common elements" that are included in all subsequent alternatives. It includes (MMs) that were either already constructed/implemented or their construction/implementation was imminent, or MMs, in the opinion of the working team, with construction/implementation imminent, pending resolution of certain issues. The MMs in Alternative 1 range from Level 1 to Level 4. (Refer to Section 6.1.1 for a description of the MM levels). For the Caloosahatchee River Watershed, the MMs in Alternative 1, as simulated by NERSM, are as follows: C-43 Water Quality Treatment and Demonstration Project (BOMA property), C-43 Distributed Reservoirs, and Clewiston STA. For the St. Lucie River Watershed, the MMs in Alternative 1, as simulated by NERSM, are as follows: C23/24 Reservoir (North and South), C23/C24 STA, and natural lands in CERP IRL-S Project.

  The water quantity benefits of Alternative 1 are quantified by the combined capacities of reservoir storage and STA storage at 47,913 acre-feet for Caloosahatchee River Watershed and 95,946 acre-feet for St. Lucie River Watershed.

Alternative 2 –The primary objective of this alternative is to maximize the storage capacity. In addition to MMs included in Alternative 1, Alternative 2 provides a substantial increase in acreage for additional and enlarged reservoirs in the ECAL sub-watershed. The MMs in ECAL could potentially create an additional 100,000 acre-feet of above ground storage from a series of distributed reservoirs, and another 21,490 acre-feet can be realized using a proposed reservoir and stormwater treatment area in the vicinity of Lake Hicpochee. No new MMs were proposed for the other sub-watersheds in the study area.

Alternative 3 – The primary objective of this alternative is to maximize nutrient load reductions in the Caloosahatchee River Watershed. Using Alternative 1 as the basis, new MMs were added for further nutrient load reduction. Three MMs were incorporated in NERSM to simulate this alternative. The West Caloosahatchee Water Quality Treatment Area consists of a constructed wetland designed to treat water from the reservoir to reduce nutrient concentrations from the Caloosahatchee River and nutrient loading to the downstream estuary. The Caloosahatchee Ecoscape Water Quality Treatment Area consists of a constructed wetland designed for optimal removal of nitrogen from the Caloosahatchee River. The Caloosahatchee Area Lakes Restoration (Lake Hicpochee) involves restoring the historical lake bed of Lake Hicpochee that could be used to treat runoff from agricultural canals that currently flow into Lake Hicpochee and the Caloosahatchee River.

Approximately 7,500 acres of land would be involved in above three MMs. No additional MMs were included in the St. Lucie River Watershed.

Alternative 4 – Alternative 4 is a hybrid of Alternative Plans 2 and 3, thus increasing the storage and nutrient load reduction potential relative to all previous alternatives. The East Caloosahatchee storage is increased to 150,000 acre-feet, a 50,000 acre-feet increase from Alternative 2. The basis for this increase was partially determined by performing a sensitivity analysis of the storage capacity in Alternative 2. Section C6.0 of this appendix provides the results of the sensitivity analysis. All treatment facilities in Alternative 3 are included in Alternative 4.

Table C-2. Summary of Management Measures Simulated in NERSM RWPPB

Sub-Watershed	Management Measure		Reservoir			STA			ASR / Deep Well Injection
	MM ID #	MM ID	Effective Area (acre)	Capacity (ac-ft)	Inflow / outflow Capacity (cfs)	Effective Area (acre)	Capacity (ac-ft)	Inflow / Outflow Capacity (cfs)	Inflow / Outflow Capacity (MGD)
TCNS	16 24 17 99 100	Lakeside Ranch STA[a], Brady Ranch STA[a], Lemkin Creek STA[a], Taylor Creek Critical Project STA (CP) [a], Nubbin Slough Critical Project STA (CP) [a]				**5,096** (2400, 1600, 205, 118, 773)	**7,863** (3240, 2430, 500, 147, 1546)	**744 / ~744[b]** (300, 200, 100, 24, 120)	
	113	Taylor Creek STA				1,800	2,700	300 & 300[d] / ~600[b]	
	19	Taylor Creek ASR							6/6
LKB	26	Paradise Run ASR							50/50
	29	Kissimmee Reservoir	10,079	161,263	1,500 / 1,500				
	93	Kissimmee River ASR Pilot							5/5
	107	Kissimmee Reservoir East	12,500	200,000	1,000 / 300[f] & 2,500[g]				
	114	Istokpoga/Kissimmee RASTA	8,100	129,600	1,000 & 1,500[c] / 1,500[h] & 2,500[g]				
LI	18	Seminole Brighton Reservation ASR							5/5
	30	Istokpoga Reservoir	4,973	79,560	500 / 2,500				
	31	Istokpoga STA				7,240	10,860	2,000 / ~2,000[b]	
	111	S-68 STA				2,400	3,240	250 / ~250[b]	
	114	Istokpoga/Kissimmee RASTA: Reservoir	9,000	144,000	750 & 750[c] / 1,500				
	114	Istokpoga/Kissimmee RASTA: STA				7,200	10,800	1,500 & 1,500[e] / ~3,000[b]	
FEC	 61 77 115	Reservoirs: FEC RASTA I, FEC RASTA II, Nicodemus Slough RASTA	13,815	199,980	2,450 & 1,500[c] / 1,100				

	 61 77 115	STAs: FEC RASTA I, FEC RASTA II, Nicodemus Slough RASTA				14,355	21,533	1,100 / ~1,100[b]	

Notes:

[a] – Combined into a single STA

[b] – Assumed passive weir

[c] – Receives inflow (second priority) from Lake Okeechobee in addition to watershed inflow

[d] – Receives inflow from Kissimmee East reservoir

[e] – Receives inflow from Istokpoga/Kissimmee reservoirs

[f] – Sends outflow (first priority) to Taylor Creek Reservoir converted to STA

[g] – Sends outflow (second priority) back to Kissimmee River

[h] – Sends outflow (first priority) to Istokpoga Canal RASTA: STA

Table C-3. Summary of Management Measures Simulated in NERSM for CRWPP

Mgmt Measure Number	Sub-Watershed	Description	Model Implementation	Specifications				
				Footprint (acre)	Effective Area (acre)	Capacity (ac-ft)	Operating Depth (ft)	Inflow/outflow (cfs)
RWPPB								
	FSW	C-43 Reservoir	reservoir storage	varies	varies	178600	20-42 ft NGVD	1500/1200
Alternative 1		add-ons to RWPPB						
CRE10	FSE	C-43 Water Quality Treatment Demonstration Project (BOMA Property)	water quality treatment	1335	1000	4500	4.50	99/99
CRE-LO 41	FSE, FNE	C-43 Distributed Reservoirs	reservoir storage; ALT1 MM adopted from LO Plan	6600	5280	42400	8.03	500/500
CRE-LO 92	S-4	Clewiston STA	water quality treatment; post-processing analysis only	766	700	1013	n/a; see description	40/40
Alternative 2		add-ons to Alternative 1						
CRE 128	FSE	East Caloosahatchee Storage	reservoir storage; combined with CRE-LO 41	8,800	7,040	100,000	see description	750/750
CRE-LO 40	FNE	West Lake Hicpochee Project	reservoir storage; ALT2 MM adopted from LO Plan, combined with CRE-LO 41	7,500	6,000	21,490	see description	250/250
Alternative 3		add-ons to Alternative 1						
CRE 04	FNE	Caloosahatchee Area Lakes Restoration	restoration; runoff adjustment in ECAL	5,300	5,300	10,600	n/a; see description	103/103

Mgmt Measure Number	Sub-Watershed	Description	Model Implementation	Specifications				
				Footprint (acre)	Effective Area (acre)	Capacity (ac-ft)	Operating Depth (ft)	Inflow/outflow (cfs)
		Project (Lake Hicpochee)						
CRE 11	FSW	Caloosahatchee Ecoscape Water Quality Treatment Area	water quality; combined with CRE 13	1,220	1,000	4,000	see description	99/99
CRE 13	FSW	West Caloosahatchee Water Quality Treatment Area	water quality; combined with CRE 11	1,530	1,200	4,800	see description	99/99
Alternative 4		add-ons to Alternative 1						
CRE 12a	FSE	Caloosahatchee Storage - Additional	reservoir storage; combined with CRE-LO 41	11,719	9,375	150,000	see description	500/500
CRE-LO 40	FNE	West Lake Hicpochee Project	reservoir storage; ALT2 MM adopted from LO Plan, combined with CRE-LO 41	7,500	6,000	21,490	see description	250/250
CRE 04	FNE	Caloosahatchee Area Lakes Restoration	restoration; runoff adjustment in ECAL	5,300	5,300	10,600	n/a; see description	103/103
CRE 11	FSW	Caloosahatchee Ecoscape Water Quality Treatment Area	water quality; combined with CRE 13	1,220	1,000	4,000	see description	99/99
CRE 13	FSW	West Caloosahatchee Water Quality Treatment Area	water quality; combined with CRE 11	1,530	1,200	4,800	see description	99/99

Sub-Watersheds:

S-4 - S-4 sub-basin
FNE - Caloosahatchee River Freshwater Northeast of S-78
FSE - Caloosahatchee River Freshwater Southeast of S-78
FNW - Caloosahatchee River Freshwater Northwest of S-78
FSW - Caloosahatchee River Freshwater Southwest of S-78

Table C-4. Summary of Management Measures Simulated in NERSM for SLRWPP

Mgmt Measure Number	Sub-Watershed	Description	Model Implementation	Specifications				
				Footprint (acre)	Effective Area (acre)	Capacity (ac-ft)	Operating Depth (ft)	Inflow/outflow (cfs)
RWPPB								
LO14	C44	C-44 Reservoir/STA	combined reservoir and STA		9,700	50,246	5.18	1060 / 550
	Ten-Mile Creek	TMC Reservoir/STA	combined reservoir and STA		656	7,078	10.79	360 / 200
Alternatives								
SLE09	C23/C24/C44	Natural Lands in CERP IRL-S Project	runoff adjustment					
SLE24	C24	C23/24 STA	stormwater treatment area		2,568	3,852	1.50	200 / 200
SLE24	C24	C-23/24 Reservoir (North & South)	reservoir storage; combined with C23		6,940	92,094	13.27	900 / 800
SLE40	C23/C44	C-23/44 Interconnection	via 250 cfs pump					

C2.2 Model Setup

The following sub-sections explain how the different sub-watersheds were conceptualized and the input requirements of the model. Additional discussions are provided, specific to how the RWPPB and alternative scenarios were created.

C2.2.1 Upper Kissimmee Basin Sub-watershed

The Upper Kissimmee (KUB) Sub-watershed model covers nine interconnected lakes (Alligator, Myrtle, Hart, Gentry, East Tohopekaliga, Tohopekaliga, Cypress, Hatchineha and Kissimmee) or Lake Management Areas (LMAs), as shown in **Figure C-6**. The lakes are interconnected with canals and flow is strictly regulated using water control structures at the outlet of each lake. The NERSM model for the KUB area is based on the Upper Chain of Lakes Routing Model (KROUTE) developed by SFWMD (Fan, 1986) to simulate the operations of the lake system in the Upper Kissimmee River Basin.

In the nine-lake system, Alligator Lake is the uppermost lake, with no clearly defined surface water inflow. The outflow from Lake Alligator to the north is through a chain of small lakes to East Lake Tohopekaliga, and to the south through Lake Gentry to Lake Cypress. East Lake Tohopekaliga discharges south to Lake Tohopekaliga, which discharges into Lake Cypress. The lower three lakes - Lake Cypress, Lake Hatchineha and Lake Kissimmee tend to equalize in stage, since there are no hydraulic structures in the canals connecting the three lakes. The natural creeks Boggy, Shingle, Reedy and Catfish provide tributary flows to East Lake Tohopekaliga, Lake Tohopekaliga, Lake Cypress and Lake Hatchineha (**Figure C-6)**. The lakes are shallow and range in depth from 8 feet in Lake Kissimmee to 13 feet in Lake Alligator. The lakes cut into the surficial aquifer, which has a thickness ranging from 50 to 100 feet. The permeability of the aquifer is estimated to be low; hence, seepage is normally small as compared to the surface inflows.

The KUB lakes are assumed in the NERSM model to be level pools, and storage routing based on mass balance is performed on a daily time step, starting from the uppermost lake (Lake Alligator) to the lowermost lake (Lake Kissimmee). The water control structures which interconnect the lakes include six spillways (S-60, S-62, S-59, S-61, S-63 and S-65), two culverts (S-57 and S-58) and two open channel connections (C-36 and C-37). The flows through the gated spillway water control structures were computed using the daily headwater and tailwater values and gate openings modeled at the water control structure, as defined by the spillway and culvert equations used in the KROUTE model, and are similar to SFWMD's FLOW program (Ansar, 2003).

The maximum allowable gate openings for a set of headwater and tailwater conditions at the spillway were computed using the "Riprap Control" criteria, established by the U. S. Army Corps of Engineers (C&SF Project, Master Water Control Manual, 1994) to protect the structures from high velocity flow, resulting in downstream erosion. The two gated culvert structures S-57 and S-58 do not have any gate operation criteria. However the discharge capacities of the two culvert structures are relatively small as compared to the spillways, and the S-58 culvert has seldom been used during the period of record. The flow through the open channel canals C-36 and C-37 connecting lakes Cypress and Hatchineha, and lakes Hatchineha and Kissimmee is modeled using a variation of the Manning's equation, using stage and water surface slope as independent variables, and is outlined in the KROUTE model.

Figure C-6. Chain of lakes and control structures in Upper Kissimmee Sub-watershed

Watershed inflows to the lakes, which include direct runoff and base flows, were based on data sets that came out of the calibration effort for the UKISSWIN model (PBS&J, Christ et al., 2001). These were imposed as flow boundary conditions for the nine lakes. Historical flows obtained from U.S. Geological Survey (USGS) for Shingle, Boggy, Reedy and Catfish creeks were also imposed as boundary conditions for the lakes Toho, East Toho, Cypress and Hatchineha. For Shingle Creek, the flow split was assumed to be 70 percent into Lake Hatchineha and 30 percent into Lake Cypress. Rainfall and ET data derived from the time series developed for the SFWMM for the climatic period of record 1970-2005, was used as model boundary conditions, with open water evaporation assumed for the nine lakes.

The KUB lakes are regulated by tight management schedules, and the regulation schedules are aimed at optimizing flood control, water supply and environmental enhancement. Though the trend of the regulation schedules is to attain the maximum and minimum stage at the beginning and end of the wet season, the schedules themselves have been frequently modified in the past based on real time water management needs. In the NERSM model, the actual lake regulation schedules for the simulation time period are entered as rule curves. The model simulates the management of the KUB lakes and canal system with a set of management rules. These rules are implemented in the model as regulation schedules, gate operation criteria, and rules of operation of the water control structures.

C2.2.2 Lower Kissimmee Basin Sub-watershed

The Current Base setup for the LKB Sub-watershed reflects conditions post-Phase I of the KRR project. The sub-watershed is partitioned into 4 major basins separated by water control structures. **Figure C-7** illustrates the node-link diagram for the LKB Sub-watershed in the Current Base NERSM scenario. In NERSM, the C-38 canal, Kissimmee River and floodplain portions of the Pools A, BC, D, and E are simulated as level-pools linked by water control structures. Only the major gated spillway structures in place post-Phase I of the KRR are simulated: S-65A, S-65C, S-65D, and S-65E. Auxiliary culverts and overflow weirs next to the major spillways are not modeled since flow through these is expected only under extreme conditions, the simulation of which is beyond the scope of this project. Weirs 1, 2, 3, though still in place in 2005, are not modeled. Locks at these structures are also not modeled.

Stage-volume and stage-area relationships for the canal/river/floodplain were developed as part of the KBMOS project. For the restored portion of the Kissimmee River (Pool BC), these relationships were further manipulated and defined in terms of average heads at the upstream and downstream ends of the pool. To be consistent with the SFWMM methodology for translating S-65 into S-65E flows, sub-watershed inflows (runoff) into the C-38 canal, the Kissimmee River, and floodplain were estimated based on historical flow data at LKB Sub-watershed boundary structures (i.e. S-65E – S-65 flows). Runoff was prorated based on each basin area and the resulting time series was imposed as the boundary condition to each level-pool.

For the Future Base and alternative scenarios, S-65C is removed as part of the full KRR (phases I-IV) and only three level-pools are simulated: Pools A, BCD, and E. Stage-volume and stage-area relationships were developed for Pool BCD as part of this modeling effort (EarthTech, 2007a). The capacity of S-65D is also increased. The modeled structure operations for S-65D are based on the current level of understanding of the fully restored system (EarthTech, 2007b).

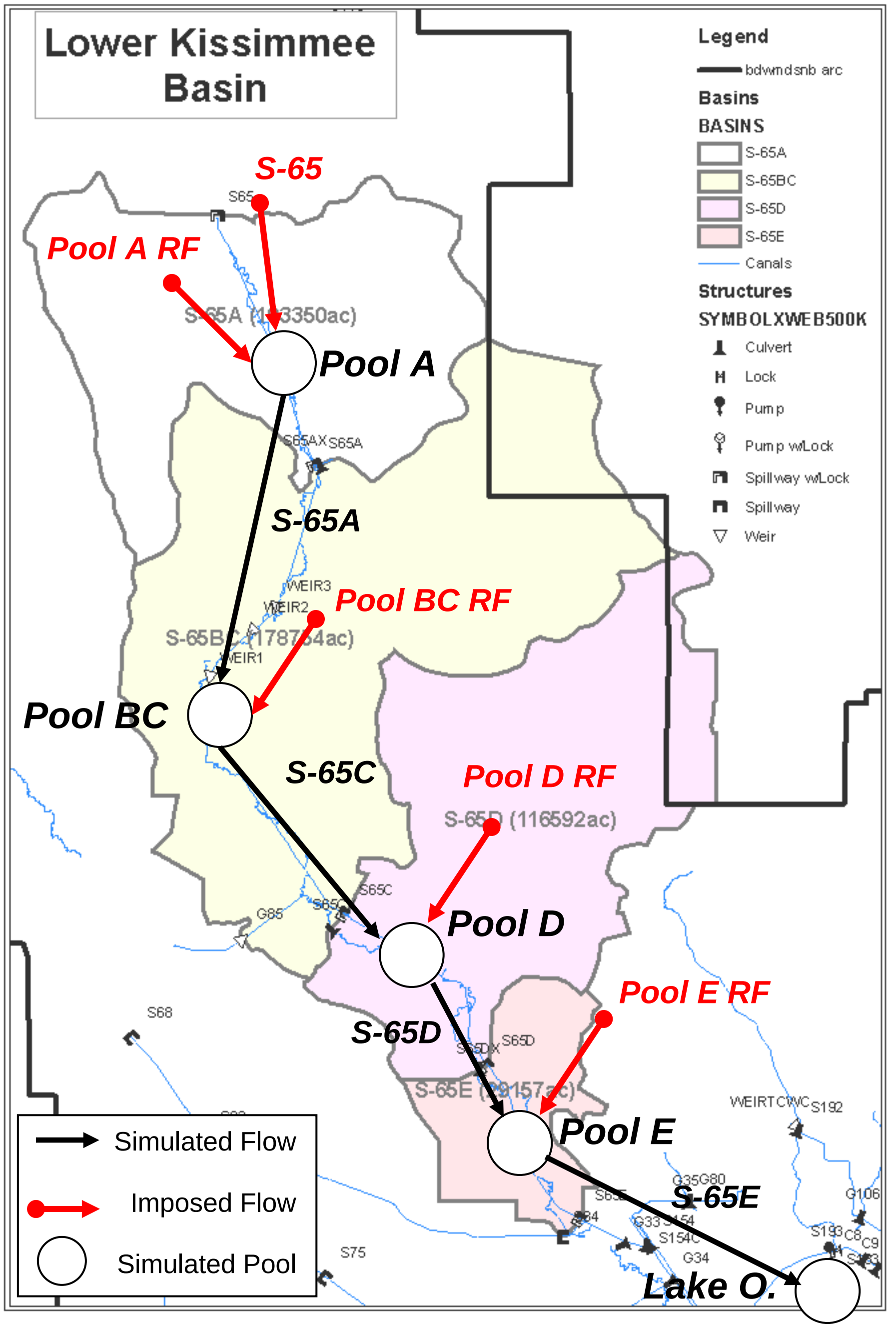


Figure C-7. Node-link diagram representation of Current Base condition for Lower Kissimmee Sub-watershed in NERSM

C2.2.2.1 Lower Kissimmee Sub-watershed Configuration for RWPPB

Figure C-8 is a schematic showing how MMs in the Lower Kissimmee Sub-watershed were simulated in RWPPB. Descriptions of how Lower Kissimmee MMs and basin flows were simulated for RWPPB are provided below:

Pool E

- 3 outlet structures: 1) Structure to Kissimmee Reservoir East; 2) Structure to Paradise Run ASR; and 3) S-65E
- When Lake Okeechobee is above the high envelope stage and Pool E has excess (i.e. Pool E is above its optimum of 21.0 feet as defined in the Future Base simulation), water will be sent to Kissimmee Reservoir East first (subject to capacity and available storage below maximum depth), then to Paradise Run ASR (subject to capacity), and any remaining excess will be sent downstream thru S-65E (subject to capacity).
- When Lake Okeechobee is below the low envelope stage, water will be sent from Kissimmee Reservoir East to Lake Okeechobee through Taylor Creek STA (subject to capacity) as first priority, and back to Pool E as second priority (subject to capacity). When Lake Okeechobee is below the low envelope stage, water will be sent from Paradise Run ASR to Pool E (subject to capacity). From Pool E water will be discharged by S-65E (subject to capacity) once Pool E exceeds its optimum of 21.0 feet.
- An emergency flood control operation is added to discharge water from Kissimmee Reservoir East, regardless of the Lake Okeechobee stage, to ensure that the reservoir depth does not exceed 16.5 feet (which corresponds to its maximum depth, plus a buffer).
- During times when Lake Okeechobee is within the stage envelope, S-65E will move local excess plus any inflows coming from upstream (subject to capacity).

Dummy Node

- Four outlet structures: (1) Structure to Kissimmee Reservoir, (2) Structure to Istokpoga/ Kissimmee Reservoir, (3) Structure to Kissimmee River ASR Pilot, and (4) Bypass to Lake Okeechobee
- When Lake Okeechobee is above the high envelope stage, water will be sent from the dummy node to Kissimmee Reservoir first (subject to capacity and available storage below maximum depth), then to Istokpoga/Kissimmee Reservoir (subject to capacity and available storage below maximum depth), then to Kissimmee River ASR Pilot (subject to capacity), and any remaining water will be sent downstream to Lake Okeechobee.
- When Lake Okeechobee is above the high envelope stage, water may also be sent directly from Lake Okeechobee into the Istokpoga/Kissimmee Reservoir. Flows from Lake Okeechobee are subject to capacity and available storage below maximum depth, once inflows from Lower Kissimmee into these reservoirs are considered (i.e. basin water has priority over Lake Okeechobee water).
- When Lake Okeechobee is below the low envelope stage, water will be sent from the Istokpoga/Kissimmee Reservoir to Istokpoga STA (subject to capacity) as first priority, and downstream to Lake Okeechobee as second priority (subject to capacity). When Lake Okeechobee is below the low envelope stage, water will be sent from the Kissimmee

Reservoir and the Kissimmee River ASR Pilot (subject to capacity) downstream to Lake Okeechobee.

- An emergency flood control operation is added to discharge water from the Kissimmee and the Istokpoga/Kissimmee Reservoirs, regardless of the Lake Okeechobee stage, to ensure that the reservoirs do not exceed a depth of 16.5 feet (which corresponds to its maximum depth, plus a buffer). Note that inflows to both reservoirs are cutoff once it reaches its maximum depth of 16 feet; however, rainfall may bring it above 16 feet.
- Regardless of the Lake Okeechobee stage, any water remaining in the dummy node that is not diverted to either project feature will be sent directly to Lake Okeechobee

#26: 10 Well ASR System (Paradise Run ASR)

- Inlet: capacity: 50 MGD (77.5 cubic feet per second (cfs)), source: C-38 Pool E
- Outlet: capacity: 50 MGD (77.5 cfs), destination: C-38 Pool E
- Efficiency loss: 30 percent (70 percent recovery rate)

#107: Kissimmee Reservoir East

- Location: Lower Kissimmee Basin Pool E
- Storage capacity: 200,000 acre-feet
- Footprint: 14,000 acres
- Effective storage area: 12,500 acres = 200,000 acre-feet / 16 feet
- Maximum depth: 16 feet
- Emergency discharge when depth reaches 16.5 feet
- Inlet: capacity: 1,000 cfs pump, source: Upstream of S-65E (Pool E) (1st source priority for discharge)
- Outlet: capacity: 300 cfs pump, destination: Taylor Creek STA (1st source priority for discharge, 2nd destination priority for discharge)
- Outlet: capacity: 2,500 cfs pump, destination: Upstream of S-65E (Pool E) (2nd source priority for discharge)
- Will receive ET & rainfall representative of Pool E
- No seepage loss assumed

#29: Kissimmee Reservoir

- Location: Indian Prairie/Istokpoga Sub-watershed
- Storage capacity: 161,263 acre-feet
- Footprint: 10,281 acres
- Effective storage area: 10,079 acres = 161,263 acre-feet / 16 feet
- Approximate bottom elevation: 33 feet NGVD29
- Maximum depth: 16 feet (49 feet NGVD29)
- Emergency discharge when depth reaches 16.5 feet
- Inlet: capacity: 1,500 cfs pump, source: Downstream of S-65E
- Outlet: Modeled as a 1,500 cfs pump.
- Will receive ET & rainfall representative of Indian Prairie/Istokpoga Sub-watershed

- No seepage loss assumed

#108: Istokpoga/Kissimmee Reservoir

- Location: Indian Prairie/Istokpoga Sub-watershed
- Storage capacity: 129,600 acre-feet
- Footprint: 9,000 acres
- Effective storage area: 8,100 acres = 129,600 acre-feet / 16 feet
- Maximum depth: 16 feet
- Emergency discharge when depth reaches 16.5 feet
- Inlet: capacity: 1,000 cfs pump, source: Downstream of S-65E (1st source priority for inflow into Istokpoga/Kissimmee Reservoir, 1st destination priority)
- Inlet: capacity: 1,500 cfs pump, source: Lake Okeechobee (2nd destination priority for inflow into Istokpoga/Kissimmee Reservoir)
- Outlet: capacity: 1,500 cfs pump, destination: Istokpoga STA (1st source priority for discharge, 2nd destination priority for discharge)
- Outlet: capacity: 2,500 cfs pump, destination: Downstream of S-65E (2nd source priority for discharge)
- Will receive ET & rainfall representative of Indian Prairie/Istokpoga Sub-watershed
- No seepage loss assumed

#93: Kissimmee River ASR

- Inlet: capacity: 5 MGD (7.75 cfs), source: Downstream of S-65E
- Outlet: capacity: 5 MGD (7.75 cfs), source: Downstream of S-65E
- Efficiency loss: 30 percent (70 percent recovery rate)

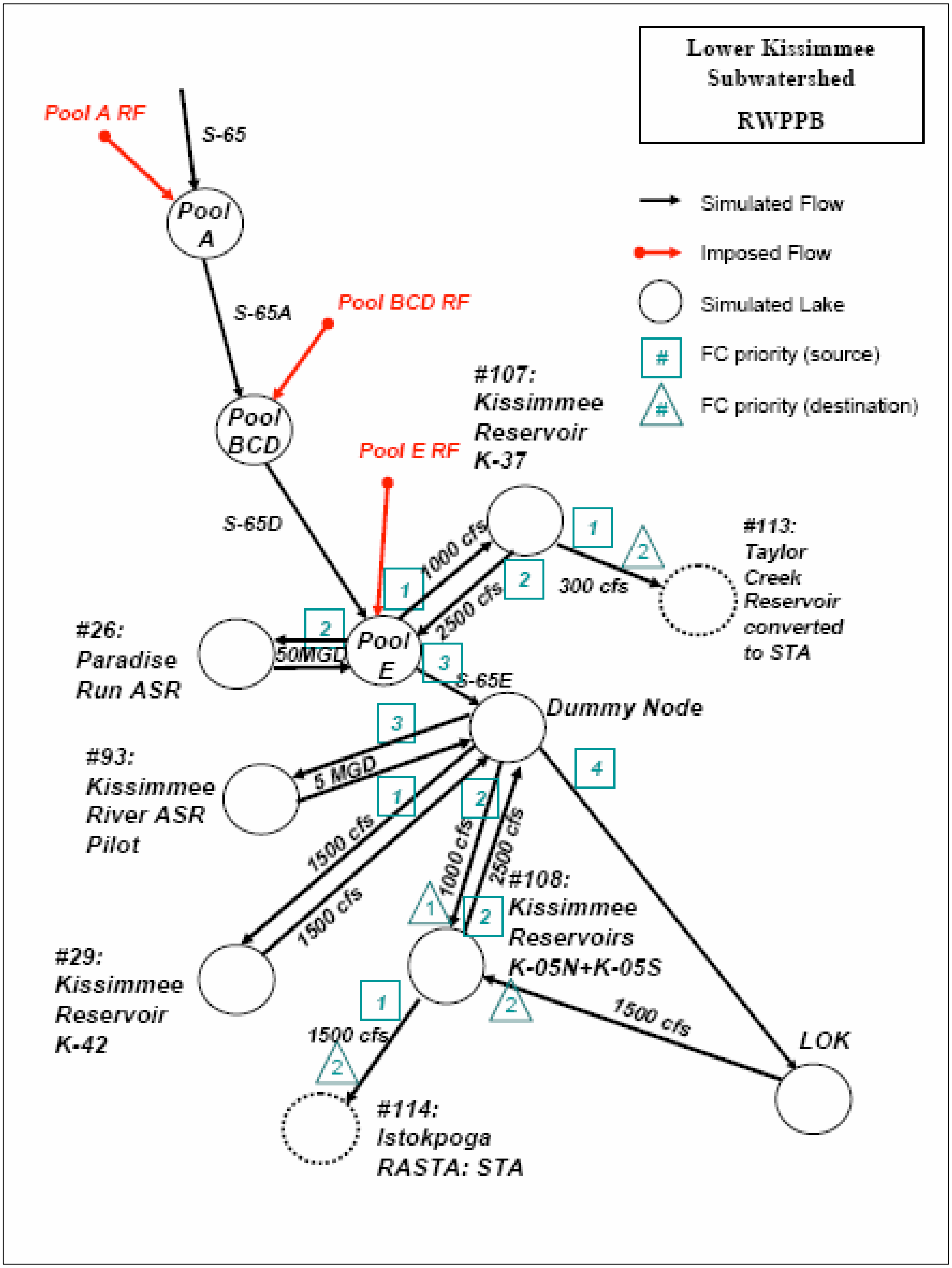


Figure C-8. Lower Kissimmee Sub-watershed simulation configuration for RWPPB.

C2.2.2.2 Taylor Creek/Nubbin Slough Sub-watershed

It is assumed that the runoff from Taylor Creek/Nubbin Slough (TCNS) Sub-watershed is equal to the total historical outflow from the sub-basins in this region. Hence, historical flow from S-191 Basin and S-133 Basin (TCNSQ in DBHYDRO), S-135 Basin (S135 in DBHYDRO) and S-154 Basin (S154 in DBHYDRO) are imposed as boundary conditions to TCNS Sub-watershed. This is the total outflow from TCNS basin to Lake Okeechobee in Current and Future Base scenarios.

Management measures such as reservoirs, STAs and ASRs are modeled as level pools. A portion of the total outflow from the TCNS Sub-watershed would be intercepted by these MMs before reaching Lake Okeechobee. Rainfall and ET are simulated for each management measure. Inflow and outflow through structures (pump stations, weir or spillways) are simulated according to operating rules that control movement of water among these MMs and Lake Okeechobee.

C2.2.2.3 Taylor Creek/Nubbin Slough Sub-watershed Configuration for RWPPB

Figure C-9 is a schematic showing how MMs in the TCNS Sub-watershed were simulated in RWPPB. Descriptions of how TCNS MMs and basin flows were simulated in RWPPB are provided below:

#113: Taylor Creek STA

- Location: TCNS Sub-watershed (North of City of Okeechobee)
- Trigger: Lake Okeechobee stage envelope.
- Storage capacity: 24,00 acre-feet
- Footprint: 1600 acres
- Approximate bottom elevation: 35.5 feet NGVD29
- Maximum depth: 15 feet (50.5 feet NGVD29)
- Inlet 1: capacity: 300 cfs pump, source: TCNS Basin;
- Inlet 2: capacity: 300 cfs pump, source: Kissimmee Reservoir East
- Outlet: weir width 200 feet, starts releasing at 1.5 feet depth; destination: Lake Okeechobee.
- Operation:
  - When Lake Okeechobee is above the high envelope stage, water will be sent from the TCNS basin to Tailor Creek Reservoir first (subject to capacity)
  - When Lake Okeechobee is below the low envelope stage (in dry period), water will be sent from Tailor Creek Reservoir to Lakeside Ranch STA (subject to capacity) for treatment before sending to Lake Okeechobee
- Will receive ET & rainfall representative of TCNS Sub-watershed
- Seepage loss: 1 cfs (deep cutoff wall in place).

#16: Lakeside Ranch, #24 Brady Ranch STA; #99: Taylor Creek Critical Project STA; #100: Nubbin Slough Critical Project STA; #17: Lemkin Creek STA

- Location: TCNS Sub-watershed

- Brady Ranch STA in western Martin County, between the Beeline Highway and Lake Okeechobee, immediately east of Lakeside Ranch; 2430 acre-feet; 1800 acres; 1.5 feet
- Taylor Creek STA in Grassy Island Ranch; 147 acre-feet; 118 acres; 1.25 feet; 29.1feet NGVD29
- Nubbin Slough STA in New Palm/Newcomer Dairy; 1546 acre-feet; 773 acres; 2 feet; 21.9 feet NGVD29
- Lemkin Creek STA in Southwest of the city of Okeechobee. 500 acre-feet; 240 acres; 3 feet
- Storage capacity: 3240 + 2,430 +147+1546+500 = 7863 acre-feet
- Footprint: 1,600 (1,800 acres in one pager) 2160 + 1600 + 118+773+205 (240 acres in one pager)=4856 acres
- Approximate bottom elevation: 24.0 feet NGVD29
- Maximum depth: 4 feet At 2.5 feet, stops getting inflow; at 1.5 feet, start outflow
- Inlet: capacity: 300 + 200 +24+120+100 =744 cfs pump, source: TCNS Sub-watershed
- Outlet: weir width 250 feet, weir height 1.5 feet, crest elevation at 25.5 feet NGVD29 (starts releasing at 1.5 feet) destination: Lake Okeechobee – seepage will be sent to Lake Okeechobee via special water mover
- Will receive ET & rainfall representative of TCNS Sub-watershed
- seepage loss: [{ (4856-205)/ 2160 }* 7] =15.1 cfs (to Lake Okeechobee)

#19: Taylor Creek ASR

- Location: TCNS Sub-watershed (adjacent to L63N canal in Okeechobee)
- Inlet: capacity: 6 MGD (9.3 cfs), source: Dummy node1
- Outlet: capacity: 6 MGD (9.3 cfs), destination: Lake Okeechobee
- Operation:
  - When Lake Okeechobee is above the low envelope stage, 100 percent water will be sent to recharge Floridian aquifer well
  - When Lake Okeechobee is below the low envelope stage, 70 percent of water will be sent from the Tailor creek ASR to Lake Okeechobee
- Efficiency loss: 30 percent (70 percent recovery rate)

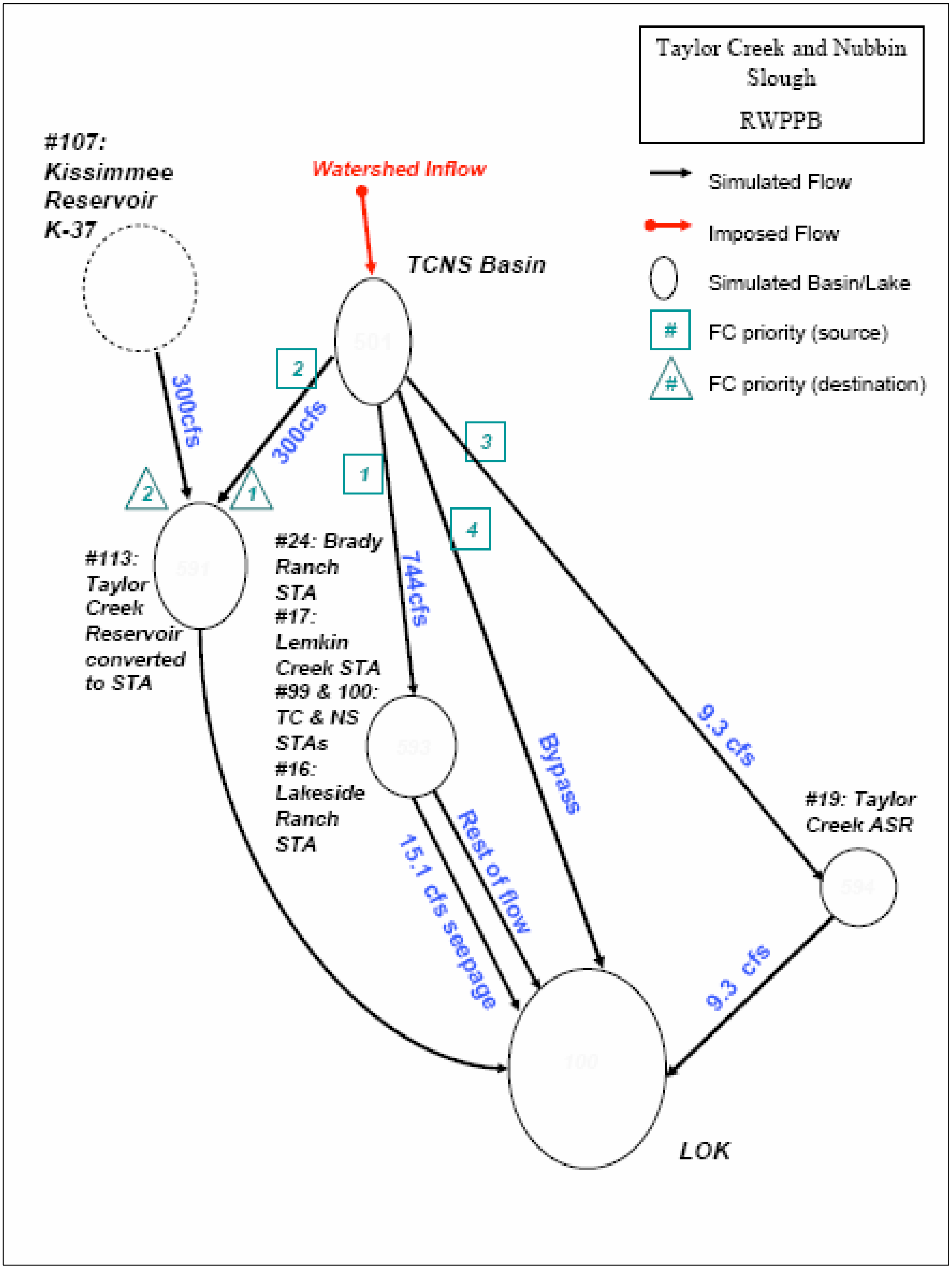


Figure C-9. Taylor Creek/Nubbin Slough Sub-watershed simulation configuration for RWPPB.

C2.2.3 Lake Istokpoga Sub-watershed

The Lake Istokpoga (LI) Sub-watershed was modeled in the NERSM as a flow pass through basin. The flows imposed as boundary conditions include the sum of the flows through SFWMD outflow structures S71, S72, S84, S127, S129 and S131 into Lake Okeechobee. The historical flow data for these structures were obtained from DBHYDRO for the time period 1970-2005.

Since the sub-watershed is modeled as a flow pass through basin, no other boundary conditions were imposed in the model. For simulating MMs such as reservoirs, STAs and ASRs in the alternative scenarios, the outflow (runoff) to Lake Okeechobee was reduced in proportion to the ratio of the effective footprint taken by the management measure to the total area of the sub-watershed. An inherent assumption in this approach is that open waterbodies exhibit the same amount of net rainfall as the corresponding runoff generated during pre-management measure.

C2.2.3.1 Lake Istokpoga Sub-watershed Configuration for RWPPB

Figure C-10 is a schematic showing how MMs in the LI Sub-watershed were simulated in RWPPB. Below are descriptions of how LI MMs and basin flows were simulated in RWPPB.

Istokpoga Flows

- The total Istokpoga flows will pass through the MMs with the following priorities 1) S-68 STA, 2) Istokpoga reservoir, 3) Istokpoga/Kissimmee RASTA 4) Istokpoga STA, and 5) Seminole Brighton Reservation ASR, subject to feature capacity and Lake Okeechobee stage envelope.
- The downstream Istokpoga RASTA: STA will receive flows from the Istokpoga/Kissimmee RASTA, and the Istokpoga/Kissimmee Reservoir as a secondary source.
- If Lake Okeechobee is above the high envelope stage and there is capacity in the Istokpoga Reservoir Complex, water from Lake Okeechobee will be back pumped into the Istokpoga/Kissimmee RASTA.
- Flows not utilized by the MMs will by bypass to Lake Okeechobee as last priority irrespective of the lake stage.

#18: Seminole Brighton Reservation ASR

- Inlet: capacity: 5 MGD (7.75 cfs), source: C-41 canal
- Outlet: capacity: 5 MGD (7.75 cfs), destination: C-41 canal
- Efficiency loss: 30 percent (70 percent recovery rate)

#30: Istokpoga Reservoir

- Location: LI Sub-watershed (C-40A/C-41A basins)
- Storage capacity: 79,560 acre-feet
- Effective area: 5,416 acres
- Approximate bottom elevation: 29 feet NGVD29
- Maximum depth: 16 feet

- Inlet: capacity: 500 cfs pump, source: C-41A canal downstream of S-83
- Outlet: Pump with outflow capacity of 2500 cfs
- No seepage loss assumed

#31: Istokpoga STA

- Location: LI Sub-watershed (L-49 basins)
- Storage capacity: 10,860 acre-feet
- Effective area: 7,240 acres
- Approximate bottom elevation: 17 feet NGVD29
- Maximum depth: 1.5 feet
- Inlet: capacity: 2000 cfs pump, source: C-41 canal downstream of S-71
- Outlet: Two weirs with outflow capacity of 1000 cfs each, invert elevation 18.5 feet NGVD
- No seepage loss assumed

#111: S68 STA

- Location: LI Sub-watershed (L-49 basins)
- Storage capacity: 3,240 acre-feet
- Effective area: 2,400 acres
- Approximate bottom elevation: 17 feet NGVD29
- Maximum depth: 1.35 feet
- Inlet: capacity: 250 cfs pump, source: C-41 canal downstream of S-68
- Outlet: One weir with outflow capacity of 250 cfs each, invert elevation 18.35 feet NGVD
- No seepage loss assumed

#114: Istokpoga/Kissimmee RASTA: Reservoir

- Location: Indian Prairie/LI Sub-watershed
- Storage capacity: 144,000 acre-feet
- Footprint: 10,000 acres
- Effective area: 9,000 (90 percent of 10,000)
- Maximum depth: 16 feet
- Inlet 1: capacity: 750 cfs pump, source: C-41A canal downstream of S-83
- Inlet 2: capacity: 750 cfs pump, source: Lake Okeechobee (2nd priority for inflow)
- Outlet: Pump with outflow capacity of 1,500 cfs into Istokpoga/Kissimmee RASTA: STA
- No seepage loss assumed

#114: Istokpoga/Kissimmee RASTA: STA

- Location: LI Sub-watershed
- Storage capacity: 10,800 acre-feet
- Effective area: 7,200 acres
- Approximate bottom elevation: 17 feet NGVD29

- Maximum depth: 1.5 feet
- Inlet 1: capacity: 1500 cfs pump, source: Istokpoga/Kissimmee RASTA
- Inlet 2: capacity 1500 cfs pump, source: Istokpoga/Kissimmee RASTA
- Outlet: Three weirs with outflow capacity of 1000 cfs each, invert elevation 18.5 feet NGVD
- No seepage loss assumed

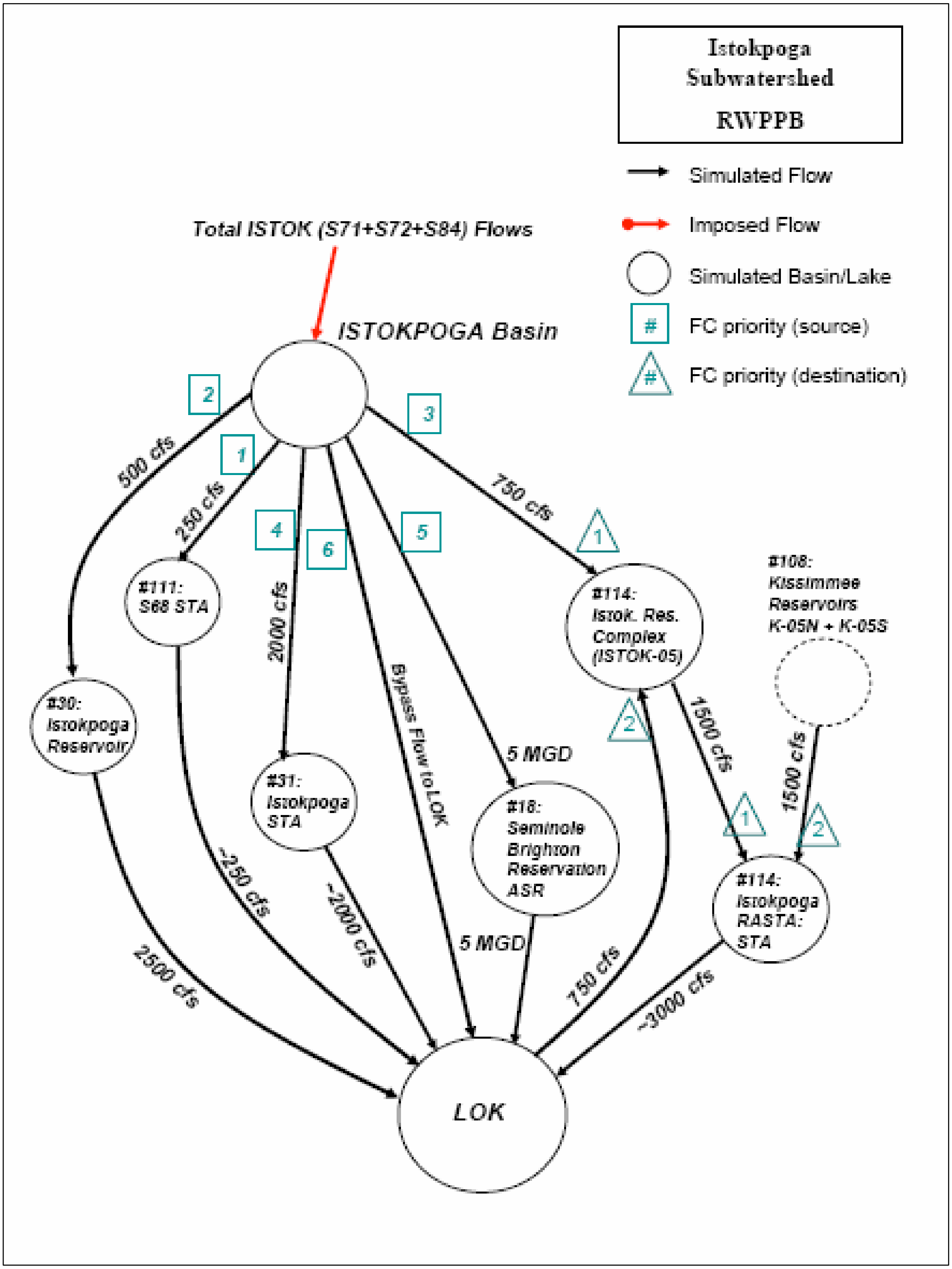


Figure C-10. Istokpoga Sub-watershed simulation configuration for RWPPB

C2.2.4 Fisheating Creek Sub-watershed

The Fisheating Creek (FEC) Sub-watershed has a total area of approximately 315,007 acres, with a substantial variation in elevation from upstream to downstream. Flows from the basin represent the "natural" inflow to Lake Okeechobee by gravity. The FEC Basin has not been greatly altered by water management projects, such as lake regulation schedules, channelization, and impoundments. The creek flows are extremely flashy in nature. The sub-watershed contains large areas of high quality habitat for fish and wildlife.

This basin is modeled as a flow pass through, which means the watershed outflow time series is imposed as the inflow boundary conditions. Since there are no flow-monitoring sites close to Lake Okeechobee, the inflow time series is developed based on historical data at the Palmdale station. This station is the most downstream "natural" station, which is located on the upper FEC Basin, several miles upstream of the confluence of the creek to Lake Okeechobee. The assumption is the Lake Okeechobee inflows downstream of Palmdale are included in the modified-delta-storage (MDS) term.

C2.2.4.1 Fisheating Creek Sub-watershed Configuration for RWPPB

Figure C-11 is a schematic showing how MMs in the FEC Sub-watershed were simulated in RWPPB. Descriptions are provided below of how FEC Basin flows and MMs are simulated in RWPPB:

#61: FEC RASTA I, #77: FEC RASTA II, Nicodemus Slough RASTA: Reservoirs

- Location: FEC Sub-watershed
- Storage capacity: 27,000 + 14,580 + 158,400 = 199,980 acre-feet
- Footprint: 3000 + 1350 + 11,000 =15,350 acres (90 percent of footprint =13,815 acres)
- Maximum depth: [10 feet (F-05); 12 feet (I-33); 16 feet [F-01]] , 199,980 / 13,815 = 14.5 feet; (Bottom Elevation + 14.5 feet) NGVD29
- Emergency discharge when depth reaches. Bottom Elevation + 14.5 + 0.5 feet NGVD29
- Inlets:
  450+200+1800 = 2450 cfs pump for first source: FEC Basin; and
  1,500 cfs pump from second source: Lake Okeechobee
- Outlet: capacity: 500+100+500 = 1100 cfs pump, destination: STA
- Operation:
  - When Lake Okeechobee is above high envelope stage, water is sent from FEC basin to the reservoir (subject to capacity and available storage below maximum depth), and any remaining excess will be sent to Lake Okeechobee through bypass – first priority
  - When Lake Okeechobee is above high envelope stage, water is sent from Lake Okeechobee to the reservoir (subject to capacity and available storage below maximum depth) – second priority
  - When Lake Okeechobee is below high envelope stage, water is sent directly from FEC basin to Lake Okeechobee through bypass.
  - When Lake Okeechobee is below the low envelope stage, water is sent from reservoir to the STA (subject to capacity and available storage below 2.5 feet maximum depth).

- Receives ET & rainfall representative of FEC Sub-watershed
- No seepage loss assumed

#61: FEC RASTA I, #77: FEC RASTA II, Nicodemus Slough RASTA: STAs

- Location: FEC Sub-watershed
- Storage capacity: 12,150+608+ 8,775 = 21,533 acre-feet
- Footprint: 9000+450 +6,500 = 15,950 acres (90 percent of footprint = 14,355 acres)
- Maximum depth: 21,533 / 14,355 = 1.5 feet;
- Inlet: capacity: 500+100+500 = 1100 cfs pump, (2.5 feet + Bottom Elevation NGVD) when reservoir stops releasing, source: FEC RASTA I, #77: FEC RASTA II, Nicodemus Slough RASTA Reservoir
- Outlet: crest length (calculated based on inflow and 1foot head difference), crest elevation at (1.5 feet + Bottom Elevation) NGVD29; destination: Lake Okeechobee; Outflow occurs when STA water level is above outlet weir elevation.
- Receives ET & rainfall representative of FEC Sub-watershed
- No seepage loss assumed

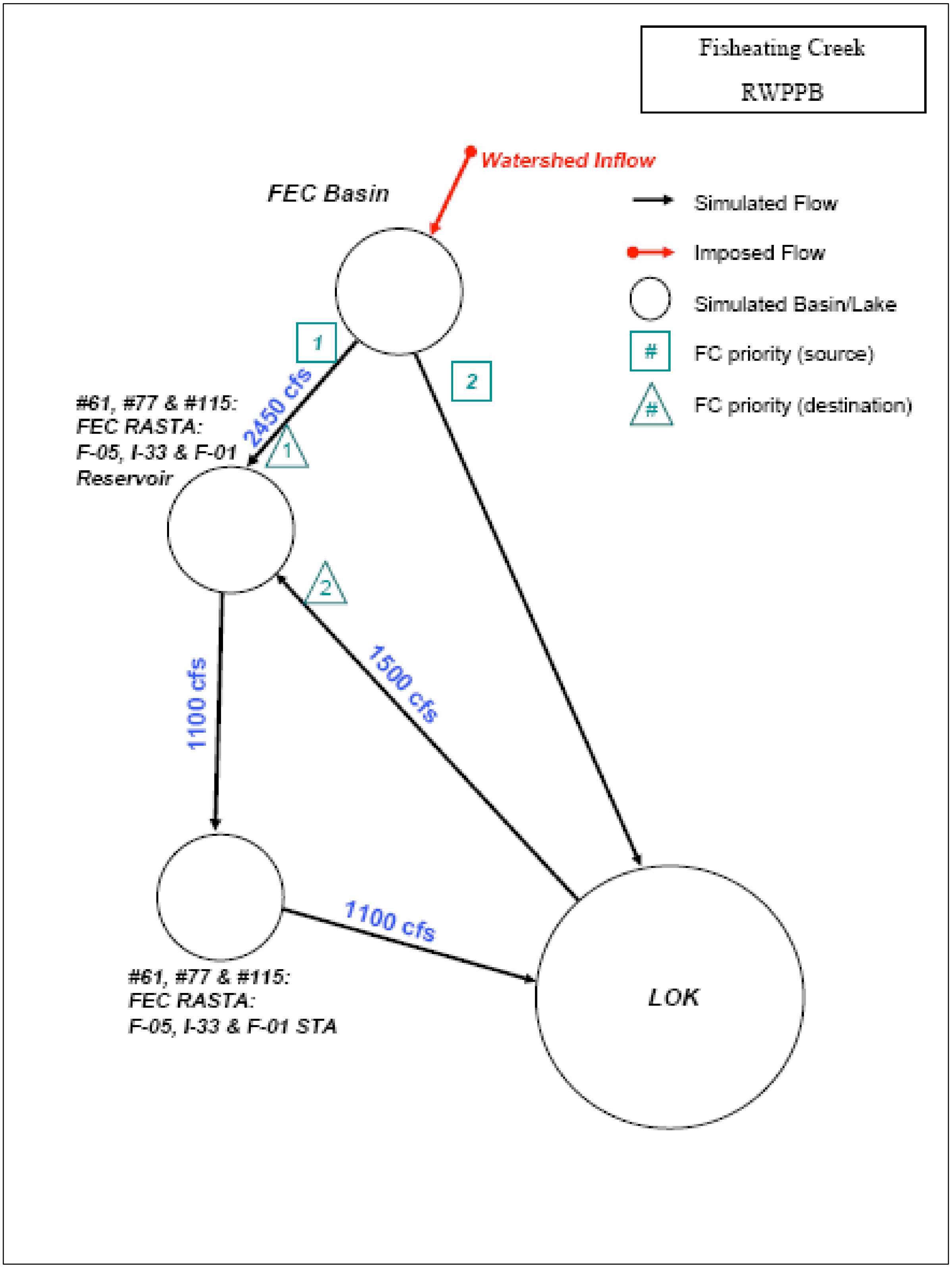


Figure C-11. Fisheating Creek Sub-watershed simulation configuration for RWPPB

C2.2.5 Caloosahatchee River Watershed

The Caloosahatchee River Watershed, as modeled in the NERSM, includes the non-tidal portion of the watershed that drains into the Caloosahatchee Estuary via S-79. The version of NERSM that was used in LOP2TP was based on a single node representation of all basins upstream of S-77. However, demand and runoff in the ECAL and WCAL basins can be very different in magnitude at times. Therefore, in order to better account for available water for capture by individual proposed water MMs in the RWPP these two sub-watersheds are modeled as separate nodes instead of a single node. In addition, the S-4 basin was included in the model domain in order to simulate direct interaction between S-4 Basin and East Caloosahatchee Basin, as well as S-4 Basin and Lake Okeechobee.

C2.2.5.1 River Watershed Protection Plan Base

The Caloosahatchee River Watershed is conceptualized as a series of interconnected nodes and links, as shown in **Figure C-12**. Model nodes represent water bodies such as basins, lakes, estuaries, reservoirs and STAs; while links represent water control structures (or components of structures) connecting model nodes. Water MMs, such as reservoirs and STAs, are simulated as storage nodes.

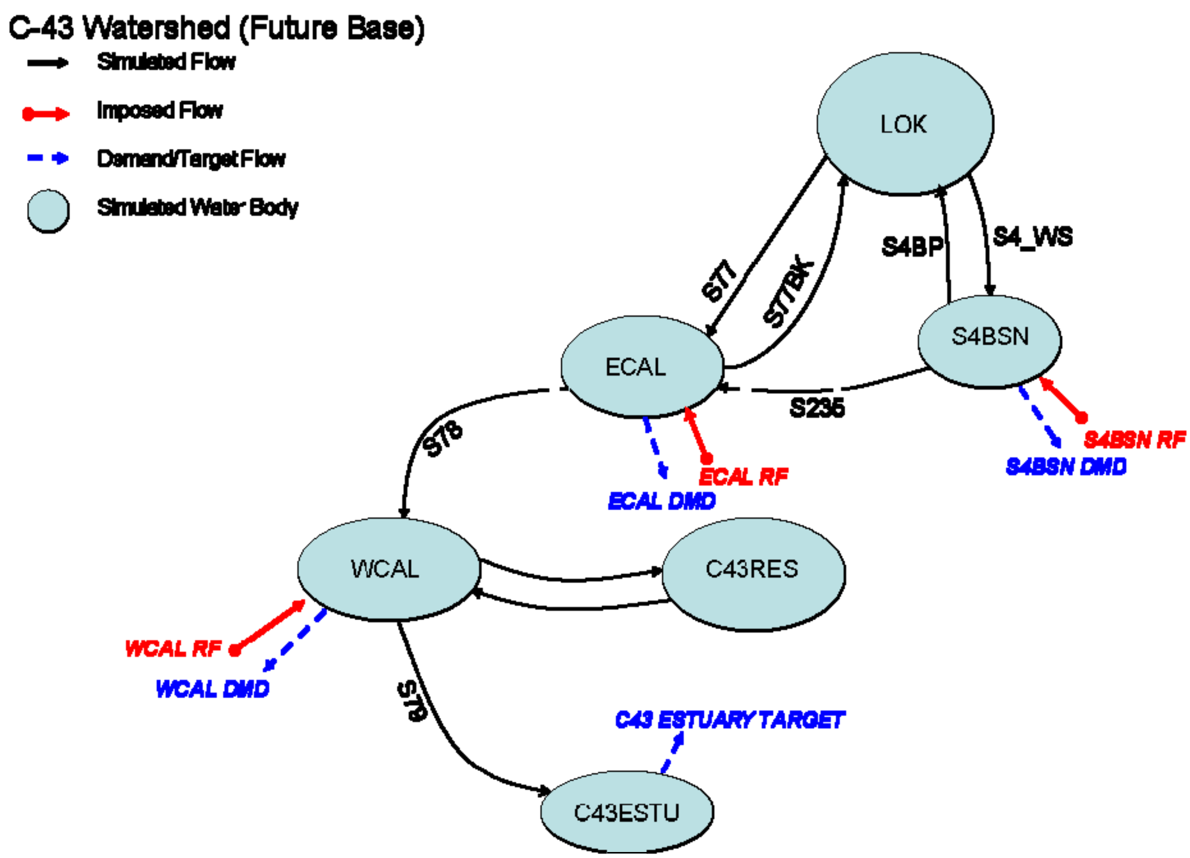


Figure C-12. Node-link diagram for the Caloosahatchee River Watershed as modeled in RWPP Future Base

Water control structure capacities are listed in **Table C-5**. Inflows into ECAL include the S-77 structure, which discharges from Lake Okeechobee for water supply, environmental, and regulatory purposes; and the S-235 structure, which discharges excess flows from the S-4 Basin. S-77 will also allow natural backflow into Lake Okeechobee when it is low (below 11.5 feet NGVD). This backflow component is modeled as a separate outflow structure from ECAL (S-77BK). ECAL and WCAL are connected through the S-78 structure, which discharges for water supply, environmental and flood control purposes. WCAL discharges to the C-43 Reservoir and into the Caloosahatchee Estuary through S-79 which handles both deliveries to meet estuary needs and upstream excess. The S-4 Basin gets its supplemental agricultural water supply from Lake Okeechobee (S-4WS) and can discharge to either the lake (S-4BP) or ECAL (S-235) for flood control.

Table C-5. Structure Capacities for the RWPPB Future Base Simulation

Structure	Capacity (cfs)
S-77	7800
S-77BK	7800
S-78	*
S-79	*
c43respumpin	1500
c43respumpout	1200
c43resoverflow	5000
S-4WS	*
S-4BP	2805
S-235	200

*Structure capacity is assumed to be limited only by available basin runoff.

Runoff generated on ECAL, WCAL and the S-4 Basin is applied directly to each corresponding basin node as a boundary condition. Runoff generated in the S-4 Basin is handled as follows: if the lake is below 13 feet NGVD, 100% of the excess in the S-4 Basin is sent to the lake; however, if the lake is above or equal to 13 feet NGVD, 83% of the excess is sent to ECAL through S-235, subject to capacity, and the remainder is sent to the lake.

Agricultural and public water supply demands in ECAL, WCAL, and the S-4 Basin, and environmental needs in the C-43 Estuary drive water supply and environmental deliveries in the model. Surface water demand (~10.2 MGD) from the Olga public water supply plant in Lee County is accounted for in the WCAL demand time series. Excess in upstream nodes is first used to meet water supply and environmental demands in downstream nodes before it is pushed or forced downstream. For example, ECAL excess and S-4 Basin discharges through S-235 are first used to meet downstream needs in the following order: (1) water supply needs in WCAL and (2) environmental needs in the C-43 Estuary. Excess in WCAL is first used to meet environmental needs in the C-43 Estuary. Any remaining water supply need in ECAL, WCAL and the S-4 Basin is to be met from Lake Okeechobee, subject to the Hybrid Lake Okeechobee Water Shortage Management (LOWSM) cutback scheme. It is assumed that basins farther downstream from the lake are cutback first, while delivering as much water supply as possible to those basins closer to the lake (i.e. WCAL is cutback before ECAL). Lake regulatory releases are not counted towards meeting water supply demands. Instead, the lake releases *additional* water beyond the regulatory release to meet water supply needs.

Starting from the RWPPB simulation, the C-43 Reservoir proposed as part of CERP is included in all alternatives. Stage-area and stage-volume relationships for the C-43 Reservoir are show in **Figure C-13**. The purpose of this reservoir is to store basin excess and Lake Okeechobee regulatory releases that exceed estuary demands, in order not to harm the estuary. Inflows into the reservoir are suspended when the reservoir reaches 41.7 feet NGVD. During times of low upstream excess and low lake regulatory releases, the C-43 Reservoir is used to meet estuary demands before any additional water is brought in from Lake Okeechobee for environmental purposes. This remaining environmental need may be met from Lake Okeechobee, as long as the lake stage is above 11.5 feet NGVD. The C-43 Reservoir may also overflow into WCAL for emergency purposes when its stage exceeds 41.8 feet NGVD.

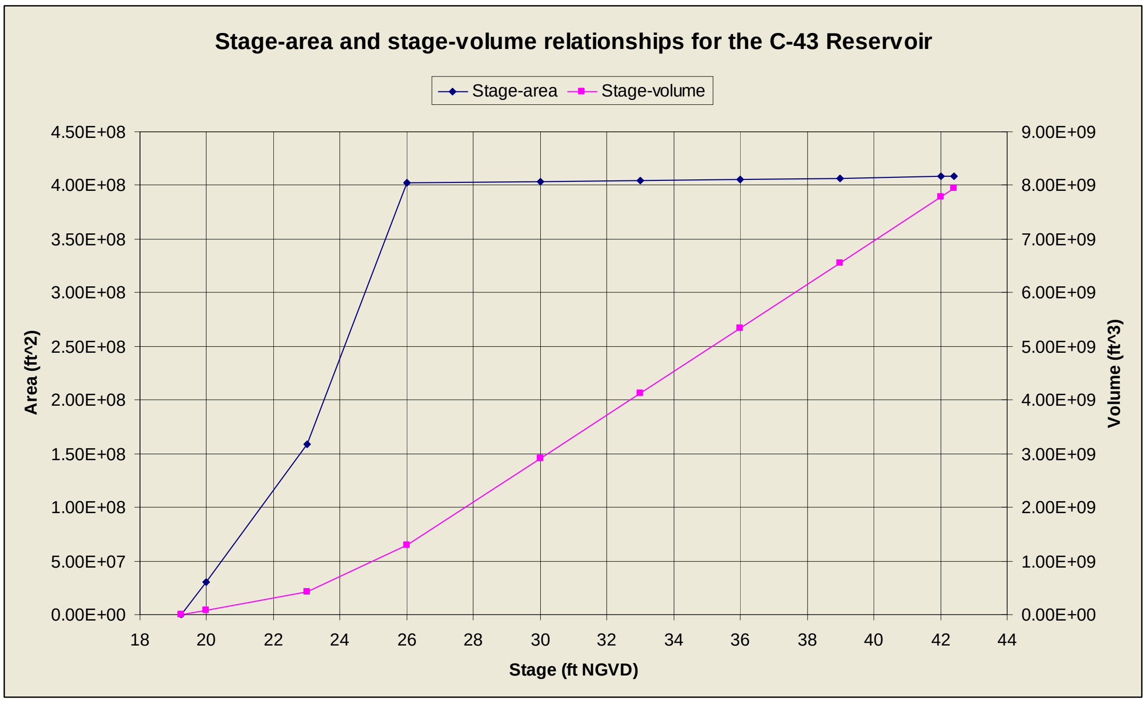


Figure C-13. Stage-area and stage-volume relationships for the C-43 Reservoir

C.2.2.5.2 Alternatives

All RWPP alternatives build upon the RWPPB simulation. Nodes are added to represent MMs and links represent structures linking the MMs to individual sub-watersheds or other MMs. Runoff time series applied to a sub-watershed are adjusted in each alternative in order to account for the footprint of proposed MMs (reservoirs and STAs) to be simulated as part of the alternative.

C.2.2.5.2.1 Caloosahatchee River Watershed Configuration for Alternative 1

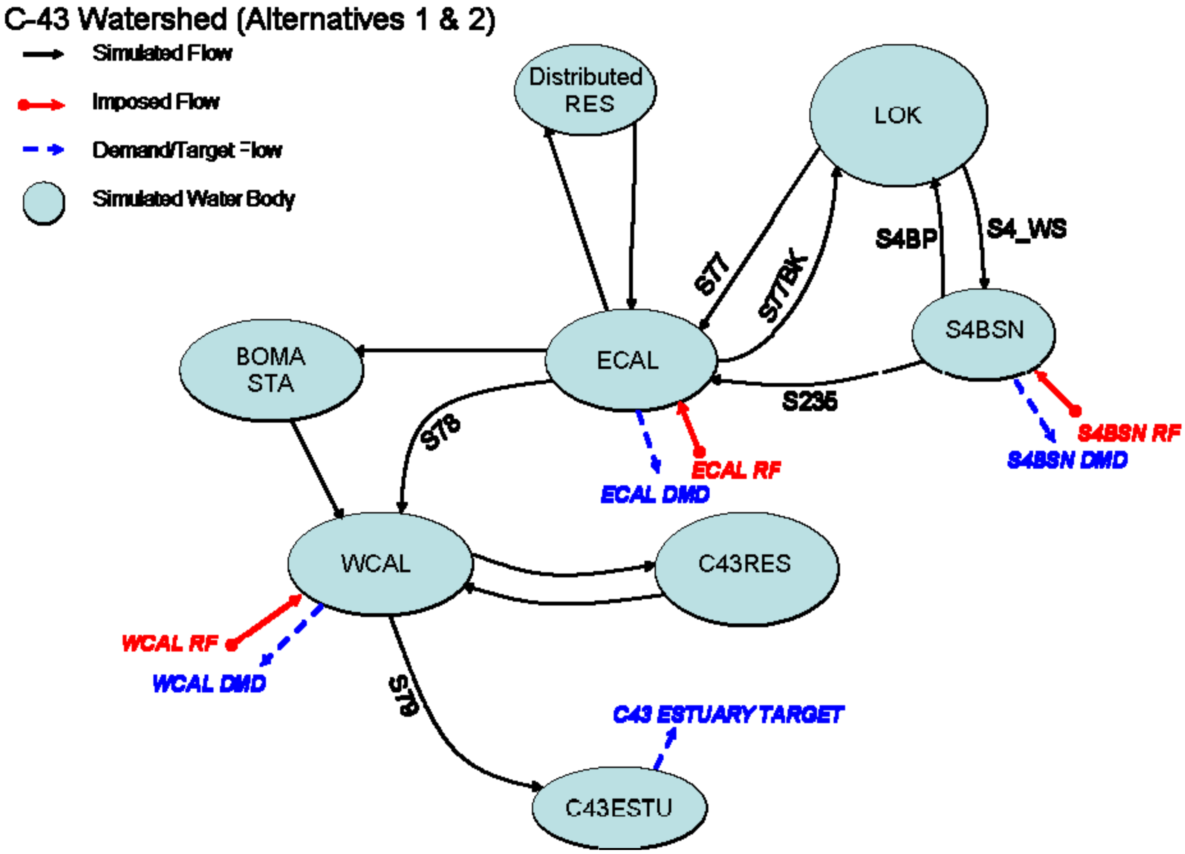


Figure C-14. Node-link diagram for the C-43 Watershed in RWPP Alternatives 1 & 2

Note: In Alternative 2, "Distributed RES" represents the combined storage of the C-43 Distributed Reservoirs, East Caloosahatchee Storage, and Lake Hicpochee MMs.

Figure C-14 shows the node-link representation of CRWPP for Alternative 1. The following are brief descriptions of the MMs included in this alternative:

- CRE-10: C-43 Water Quality Treatment and Demonstration Project (BOMA property)
  - Location: ECAL
  - Storage capacity: 4,500 acre-feet
  - Footprint: 1,335 acres
  - Effective storage area: 1,000 acres
  - Maximum depth: 4.5 feet (when outflow starts) = 4,500 acre-feet/1,000 acres
  - Inlet: capacity: 99 cfs, source: ECAL
  - Outlet: capacity: 99 cfs, destination: WCAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- CRE-LO-41: C-43 Distributed Reservoirs
  - Location: ECAL
  - Storage capacity: 42,400 acre-feet

- Footprint: 6,600 acres
- Effective storage area: 5,280 acres
- Maximum depth allowed for inflow: 8.03 feet = 42,400 acre-feet/5,280 acres
- Emergency discharge when depth reaches: 8.53 feet
- Inlet: capacity: 500 cfs, source: ECAL
- Outlet: capacity: 500 cfs, destination: ECAL
- Overflow: capacity: 500 cfs, destination: ECAL
- Receives ET & rainfall representative of ECAL sub-watershed
- No seepage loss assumed

The general modeling approach used in Alternative 1 can be summarized as follows:

- As a general rule, any excess at a particular node is first used to meet demands (both water supply and environmental) immediately downstream of the node, and then demands farther downstream are met from upstream to downstream. Once excess has been used to meet all downstream demands, then it is forced downstream as flood control.
- Excess in ECAL and S-4 Basin, and storage in the C-43 Distributed Reservoirs are first used to meet downstream needs in the following order of priority: (1) water supply needs in ECAL, (2) water supply needs in WCAL, and (3) environmental demands in the C-43 Estuary.
- Excess in WCAL, plus other leftover excesses from upstream (i.e. excess after WCAL water supply needs are met), are first used to meet environmental demands in the C-43 Estuary.
- Water supply deliveries from Lake Okeechobee to ECAL, WCAL, and the S-4 Basin are subject to the Hybrid LOWSM cutback scheme. During times when the Hybrid LOWSM scheme calls for cutbacks, WCAL is cutback before ECAL.
- S-77 backflow to the lake is first priority for excess discharge when the lake stage < 11.5 feet NGVD.
- When the lake stage >= 11.5 feet NGVD, any leftover excess at the ECAL node (i.e. excess after downstream needs are met) is sent to the C-43 Distributed Reservoir and then to BOMA, before it is sent downstream through S-78 as flood control. The C-43 Distributed Reservoir will only capture leftover excess from the S-4 Basin and ECAL, not lake regulatory releases.
- Excess from the S-4 Basin is handled the same way as in the Future Base simulation:
  - If the lake stage < 13 feet NGVD, 100% of remaining excess is sent to Lake Okeechobee.
  - If the lake stage >= 13 feet NGVD, 83% of remaining excess is sent to S-235 (subject to capacity), while 17% is sent to Lake Okeechobee.
- C-43 Estuary demands are to be met first from lake regulatory releases and excess from the S-4 Basin, WCAL, ECAL, BOMA STA and C-43 Distributed Reservoir outflows; secondly from the C-43 Reservoir; and thirdly as an explicit environmental delivery from the lake. The lake can send additional environmental water to the C-43 Estuary only when the lake is above 11.5 feet NGVD.
- Uncontrolled outflow from BOMA STA is treated like any other upstream excess. It is first used to meet water supply needs in WCAL. The remainder (i.e. BOMA outflow beyond WCAL needs) will then be treated as WCAL excess.

C.2.2.5.2.2 Caloosahatchee River Watershed Configuration for Alternative 2

Figure C-14 shows the node-link representation of CRWPP for Alternative 2. The following are brief descriptions of the MMs included in this alternative:

- CRE-10: C-43 Water Quality Treatment and Demonstration Project (BOMA property)
  - Location: ECAL
  - Storage capacity: 4,500 acre-feet
  - Footprint: 1,335 acres
  - Effective storage area: 1,000 acres
  - Maximum depth: 4.5 feet (when outflow starts) = 4,500 acre-feet/1,000 acres
  - Inlet: capacity: 99 cfs, source: ECAL
  - Outlet: capacity: 99 cfs, destination: WCAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- Simulated as a single reservoir: CRE-LO-41: C-43 Distributed Reservoirs; CRE-128: East Caloosahatchee Storage; CRE-LO-40: Lake Hicpochee
  - Location: ECAL
  - Storage capacity: 163,890 acre-feet
  - Footprint: 22,900 acres
  - Effective storage area: 18,320 acres
  - Maximum depth allowed for inflow: 8.95 feet = 163,890 acre-feet/18,320 acres
  - Emergency discharge when depth reaches: 9.45 feet
  - Inlet: capacity: 1,500 cfs, source: ECAL
  - Outlet: capacity: 1,500 cfs, destination: ECAL
  - Overflow: capacity: 1,500 cfs, destination: ECAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed

The modeling approach is identical to that of Alternative 1, with the exception that the C-43 Distributed Reservoir + Caloosahatchee Storage + Lake Hicpochee will now capture lake regulatory releases, as well as leftover excess from the S-4 Basin and ECAL.

C.2.2.5.2.3 Caloosahatchee River Watershed Configuration for Alternative 3

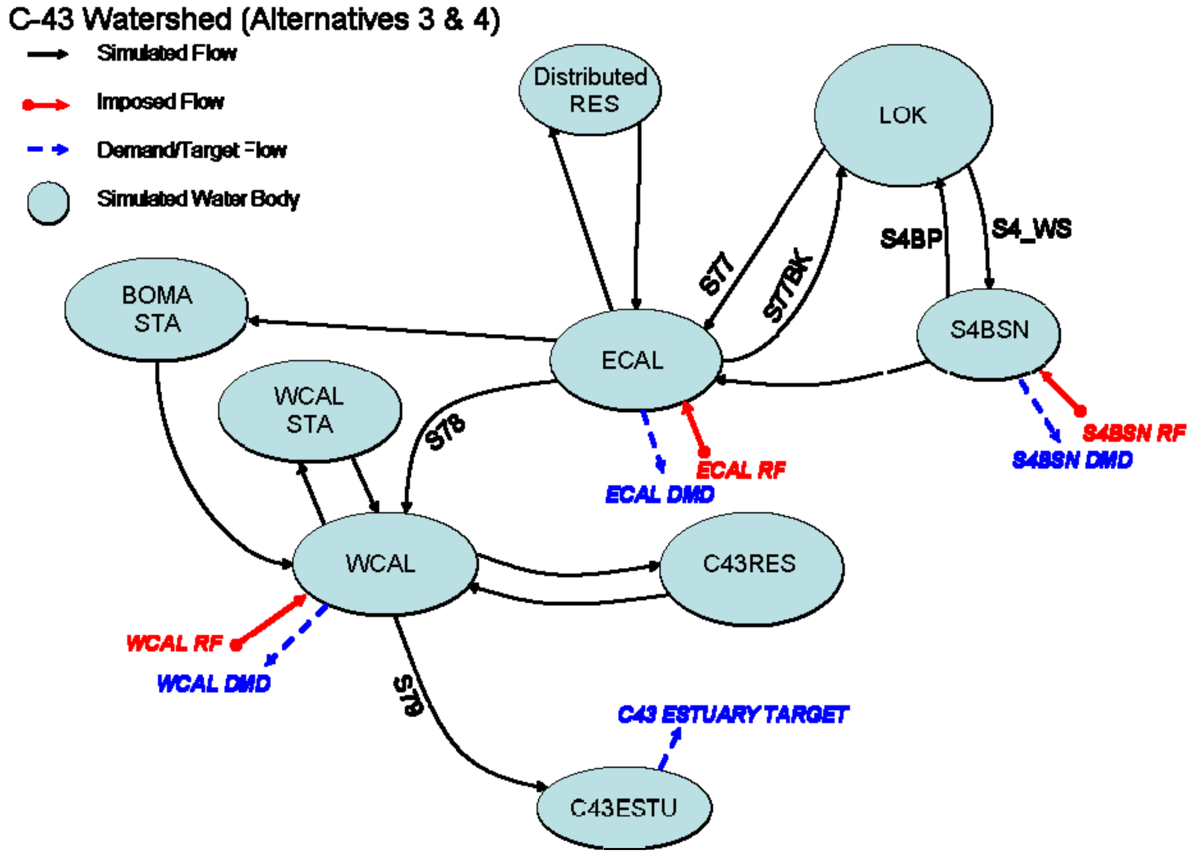


Figure C-15 - Node-link diagram for the C-43 Watershed in RWPP Alternatives 3 & 4

Notes: In Alternatives 3 & 4, "WCAL STA" represents the combined storage of Water Quality Treatment Areas Caloosahatchee Ecoscape and West Caloosahatchee. In Alternative 4, "Distributed RES" represents the combined storage of the C-43 Distributed Reservoirs, additional Caloosahatchee Storage, and Lake Hicpochee MMs.

Figure C-15 shows the node-link representation of CRWPP for Alternative 3. The following are brief descriptions of the MMs included in this alternative:

- CRE-04: Lake Hicpochee Restoration – Caloosa Lakes
  - Location: ECAL
  - Storage capacity: 10,600 acre-feet
  - Footprint: 5,300 acres
  - Maximum depth: N/A; this management measure was implemented by modifying the ECAL basin runoff/demand time series.
  - Inlet: 103 cfs
  - Outlet: 103 cfs
- CRE-10: C-43 Water Quality Treatment and Demonstration Project (BOMA property)
  - Location: ECAL
  - Storage capacity: 4,500 acre-feet
  - Footprint: 1,335 acres

  - Effective storage area: 1,000 acres
  - Maximum depth: 4.5 feet (when outflow starts) = 4,500 acre-feet/1,000 acres
  - Inlet: capacity: 99 cfs, source: ECAL
  - Outlet: capacity: 99 cfs, destination: WCAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- CRE-LO-41: C-43 Distributed Reservoirs
  - Location: ECAL
  - Storage capacity: 42,400 acre-feet
  - Footprint: 6,600 acres
  - Effective storage area: 5,280 acres
  - Maximum depth allowed for inflow: 8.03 feet = 42,400 acre-feet/5,280 acres
  - Emergency discharge when depth reaches: 8.53 feet
  - Inlet: capacity: 500 cfs, source: ECAL
  - Outlet: capacity: 500 cfs, destination: ECAL
  - Overflow: capacity: 500 cfs, destination: ECAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- Simulated as a single STA: CRE-11: Water Quality Treatment Area – Caloosahatchee Ecoscape; CRE-13: Water Quality Treatment Area – West Caloosahatchee
  - Location: WCAL
  - Storage capacity: 8,800 acre-feet
  - Footprint: 2,750 acres
  - Effective storage area: 2,200 acres
  - Maximum depth: 4.0 feet (when outflow starts) = 8,800 acre-feet/2,200 acres
  - Inlet: capacity: 198 cfs, source: WCAL
  - Outlet: capacity: 198 cfs, destination: WCAL
  - Receives ET & rainfall representative of WCAL sub-watershed
  - No seepage loss assumed

The modeling approach is identical to that of Alternative 1, with the exception that the Ecoscape and West Caloosahatchee Water Quality Treatment Areas now capture WCAL runoff as first priority before any other routing is performed in the model.

C.2.2.5.2.4 Caloosahatchee River Watershed Configuration for Alternative 4

Figure C-15 shows the node-link representation of CRWPP for Alternative 4. The following are brief descriptions of the MMs included in this alternative:

- CRE-04: Lake Hicpochee Restoration – Caloosa Lakes
  - Location: ECAL
  - Storage capacity: 10,600 acre-feet
  - Footprint: 5,300 acres
  - Maximum depth: N/A; this management measure was implemented by modifying the ECAL basin runoff/demand time series.
  - Inlet: 103 cfs

  - Outlet: 103 cfs
- CRE-10: C-43 Water Quality Treatment and Demonstration Project (BOMA property)
  - Location: ECAL
  - Storage capacity: 4,500 acre-feet
  - Footprint: 1,335 acres
  - Effective storage area: 1,000 acres
  - Maximum depth: 4.5 feet (when outflow starts) = 4,500 acre-feet/1,000 acres
  - Inlet: capacity: 99 cfs, source: ECAL
  - Outlet: capacity: 99 cfs, destination: WCAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- Simulated as a single reservoir: CRE-LO-41: C-43 Distributed Reservoirs; CRE-128a: Caloosahatchee Storage – Additional; CRE-LO-40: Lake Hicpochee
  - Location: ECAL
  - Storage capacity: 213,890 acre-feet
  - Footprint: 25,819 acres
  - Effective storage area: 20,655 acres
  - Maximum depth allowed for inflow: 10.36 feet = 213,890 acre-feet/20,655 acres
  - Emergency discharge when depth reaches: 10.86 feet
  - Inlet: capacity: 1250 cfs, source: ECAL
  - Outlet: capacity: 1250 cfs, destination: ECAL
  - Overflow: capacity: 1250 cfs, destination: ECAL
  - Receives ET & rainfall representative of ECAL sub-watershed
  - No seepage loss assumed
- Simulated as a single STA: CRE-11: Water Quality Treatment Area – Caloosahatchee Ecoscape; CRE-13: Water Quality Treatment Area – West Caloosahatchee
  - Location: WCAL
  - Storage capacity: 8,800 acre-feet
  - Footprint: 2,750 acres
  - Effective storage area: 2,200 acres
  - Maximum depth: 4.0 feet (when outflow starts) = 8,800 acre-feet/2,200 acres
  - Inlet: capacity: 198 cfs, source: WCAL
  - Outlet: capacity: 198 cfs, destination: WCAL
  - Receives ET & rainfall representative of WCAL sub-watershed
  - No seepage loss assumed

The modeling approach is identical to that of Alternative 1, with the following exceptions:

- The Ecoscape and West Caloosahatchee Water Quality Treatment Areas now capture WCAL runoff as first priority before any other routing is performed in the model.
- The C-43 Distributed Reservoir + Additional Caloosahatchee Storage + Lake Hicpochee will now capture lake regulatory releases, as well as leftover excess from the S-4 Basin and ECAL.

C2.2.6 St. Lucie River Watershed

The St. Lucie River Watershed, as modeled in the NERSM, includes the portion of the Indian River Lagoon South that discharges excess runoff into the St. Lucie Estuary. The watershed is comprised of a number of basins that flow controlled (non-tidal) or uncontrolled (tidal) into the St. Lucie Estuary. The non-tidal basins C-23, C24, Ten-Mile Creek (TMC) and C-44 are controlled by S-48, S49, the TMC structure and S-80, respectively. A total of four nodes represent these non-tidal basins. The remainder of the watershed (portion of North Fork outside the Ten-Mile Creek Basin, South Fork, and Basins 4, 5 and 6) was lumped into a single-node representation.

The watershed is connected to Lake Okeechobee only via C-44 Basin. S-308 serves as conduit for Lake Okeechobee water to the basin (to meet supplemental irrigation needs) and to the estuary (via S80) to release regulatory discharge. The other basins in St. Lucie River Watershed are independent of Lake Okeechobee in terms of meeting their supplemental irrigation needs and, thus, are not part of the Lake Okeechobee Service Area.

The version of NERSM that was used in the LOP2TP conceptualized the St. Lucie River Watershed as two nodes: C-44 and non-C44. C-44 was provided runoff and demand time series obtained from an offline AFSIRS/WATBAL modeling effort (Wilcox et al., 2003). Non-C44, a lumped representation of C-23, C-24, North fork (including Ten-Mile Creek), South Fork, and Basins 4, 5 and 6, was considered to provide boundary flows to the estuary. The time series of such discharges were based on a previous WaSh modeling exercise (Wan et al, 2003).

The current version of NERSM, as used in the RWPP, treated the non-C44 basins separately, thus allowing for the inter-basin transfer to occur between C23 and C44 Reservoir/STA, C23/C24 STA and TMC Sub-watershed, C23 Basin and C23/24 reservoir, C24 Basin and C23/24 Reservoir, and C23/24 Reservoir and C23/24 STA, as specified in the IRL preferred alternative project. The St. Lucie Estuary target time series was defined for each of the five-node representation of the St. Lucie River Watershed discharging directly into the St. Lucie Estuary. The corresponding time series were obtained using OPTI-6, the hydrologic optimization model used in IRL project (Wan et al., 2006).

C2.2.6.1 St. Lucie River Watershed Configuration for River Watershed Protection Plan Base

Figure C-16 is a schematic showing how MMs in the St. Lucie River Watershed were simulated in RWPPB. Preferred priority is listed for releases from basins, reservoirs, and STAs, but can be changed from within the model. North Fork, South Fork, and B456 basins have been combined into one sub-watershed (NF-SF-B456) for RWPPB. A summary of the sub-watersheds and reservoir and STA features, as simulated in NERSM, are as follows.

C23, C24, and NF-SF-B456 Sub-watersheds

- Three outlet structures discharge from each of the basins into the St. Lucie Estuary. Structure capacity is assumed to be limited only by available basin runoff.
- Runoff from each basin is first used to meet St. Lucie Estuary demands.

- Demands in each basin represent supplemental irrigation needs from surface water sources only.

Ten Mile Creek Sub-Watershed

- One outlet structure discharges into the St. Lucie Estuary. Structure capacity is assumed to be limited only by available basin runoff. Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, the remaining runoff is sent to the TMC Reservoir/STA.
- TMC Sub-watershed demands represent supplemental irrigation needs from surface water sources only. The TMC Reservoir/STA is the priority source for these needs.
- An emergency flood control pump of 200 cfs is added to discharge water from TMC Reservoir/STA to the TMC Sub-watershed to ensure that the reservoir does not exceed 11.29 feet (which corresponds to its maximum depth plus a buffer). Note that inflows to the TMC Reservoir/STA are cutoff once it reaches its maximum depth of 10.79 feet; however, rainfall may bring it above 10.79 feet.

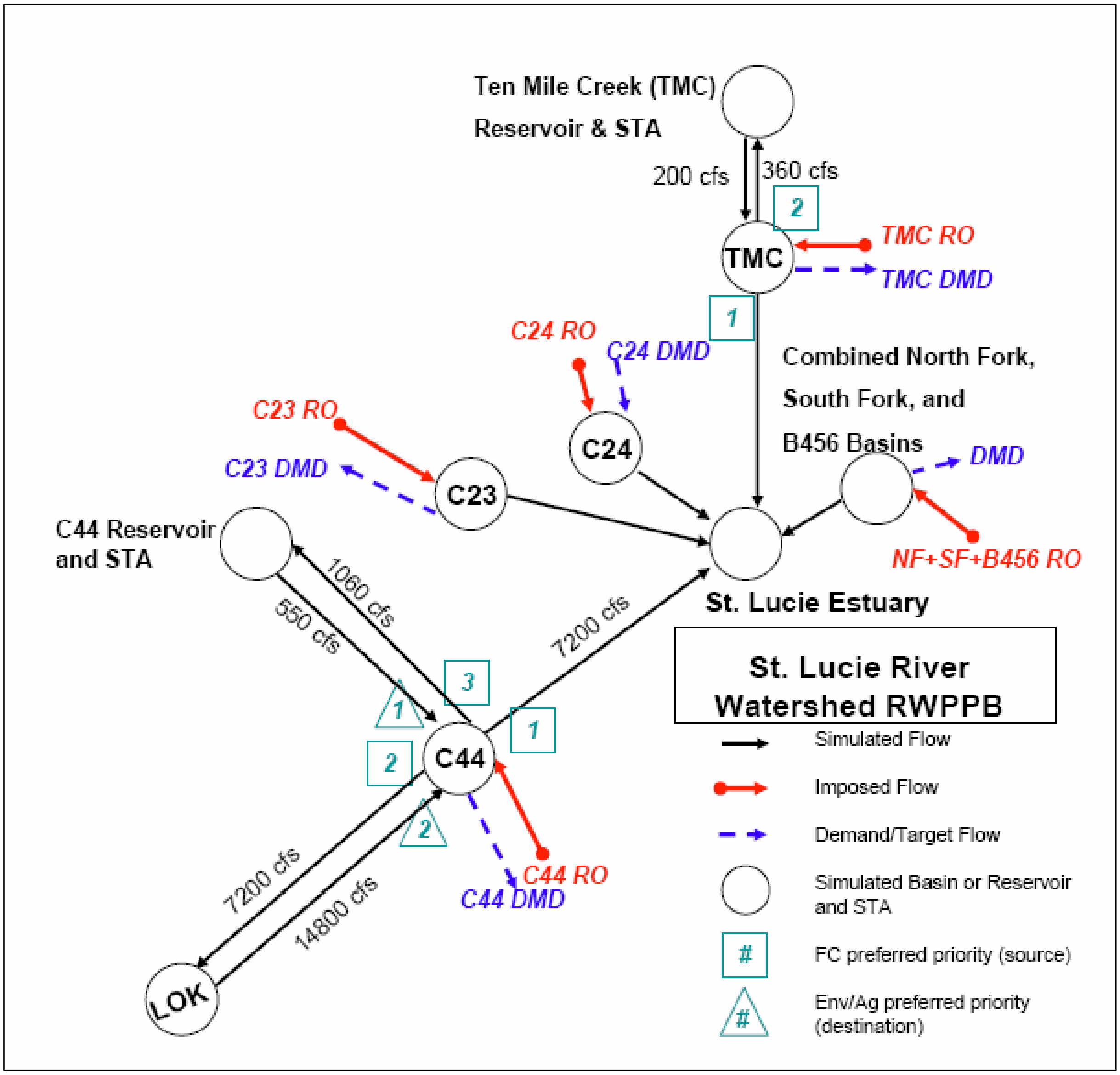


Figure C-16. St. Lucie River Watershed simulation configuration for RWPPB

Ten Mile Creek Reservoir and STA

- Location: TMC Sub-watershed
- Storage capacity: 656 acres * 10.79 feet = 7078 acre-feet
- Footprint: 820 acres (assumed 656 acres/80%)
- Effective storage area: 656 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)
- Maximum depth: 10.79 feet
- Emergency discharge when depth reaches: 11.29 feet
- Inlet: 360 cfs capacity, modeled as pump. Source: TMC Sub-watershed
- Outlet: 200 cfs capacity, modeled as pump. Destination: TMC Sub-watershed
- Will receive rainfall representative of North Fork basin.
- Will receive ET representative of St. Lucie basins (per input file)

- No seepage loss assumed

C44 Basin

- One outlet structure (S-80) discharges into the St. Estuary, with a capacity of 7200 cfs.
- Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, then the remaining runoff is sent to the C44 Reservoir/STA.
- Runoff from C44 Basin flows into Lake Okeechobee when Lake Okeechobee stage is below 14.5 feet NGVD. This condition overrides previous statement that remaining runoff is diverted to the C44 Reservoir/STA.
- C44 Basin demands are met first by C44 Reservoir/STA, then by Lake Okeechobee.
- St Lucie Estuary at S80, demands to be met in this priority order: (1) C44 runoff, (2) C44 Reservoir & STA releases, and (3) Lake Okeechobee explicit delivery, if desired.
- An emergency flood control pump of 1063 cfs is added to discharge water from C44 Reservoir/STA to the C44 Basin to ensure that the reservoir does not exceed 5.68 feet (which corresponds to its maximum depth plus a buffer). Note that inflows to the C44 Reservoir/STA are cutoff once it reaches its maximum depth of 5.18 feet; however, rainfall may bring it above 5.18 feet.

C44 Reservoir and STA

- Location: C44 Basin
- Storage capacity: 9700 acres * 5.18 feet = 50,246 acre-feet
- Footprint: 12,125 acres (assumed 9700 acres/80%)
- Effective storage area: 9700 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)
- Maximum depth: 5.18 feet
- Emergency discharge when depth reaches: 5.68 feet
- Inlet: 1060 cfs capacity, modeled as pump source: C44 Basin
- Outlet: 550 cfs capacity, modeled as pump destination: C44 Basin
- Will receive ET and rainfall representative of C44 Basin.
- No seepage loss assumed.

C2.2.6.2 St. Lucie River Watershed Configuration for Alternative 1 (ALT1)

Figure C-17 shows how Alternative 1 was simulated in NERSM. The node representation of the basins in Alternative 1 is essentially the same as in RWPPB. The C-23/C-24 Reservoir and the C-23/C-24 STA are additional managements for Alternative 1.

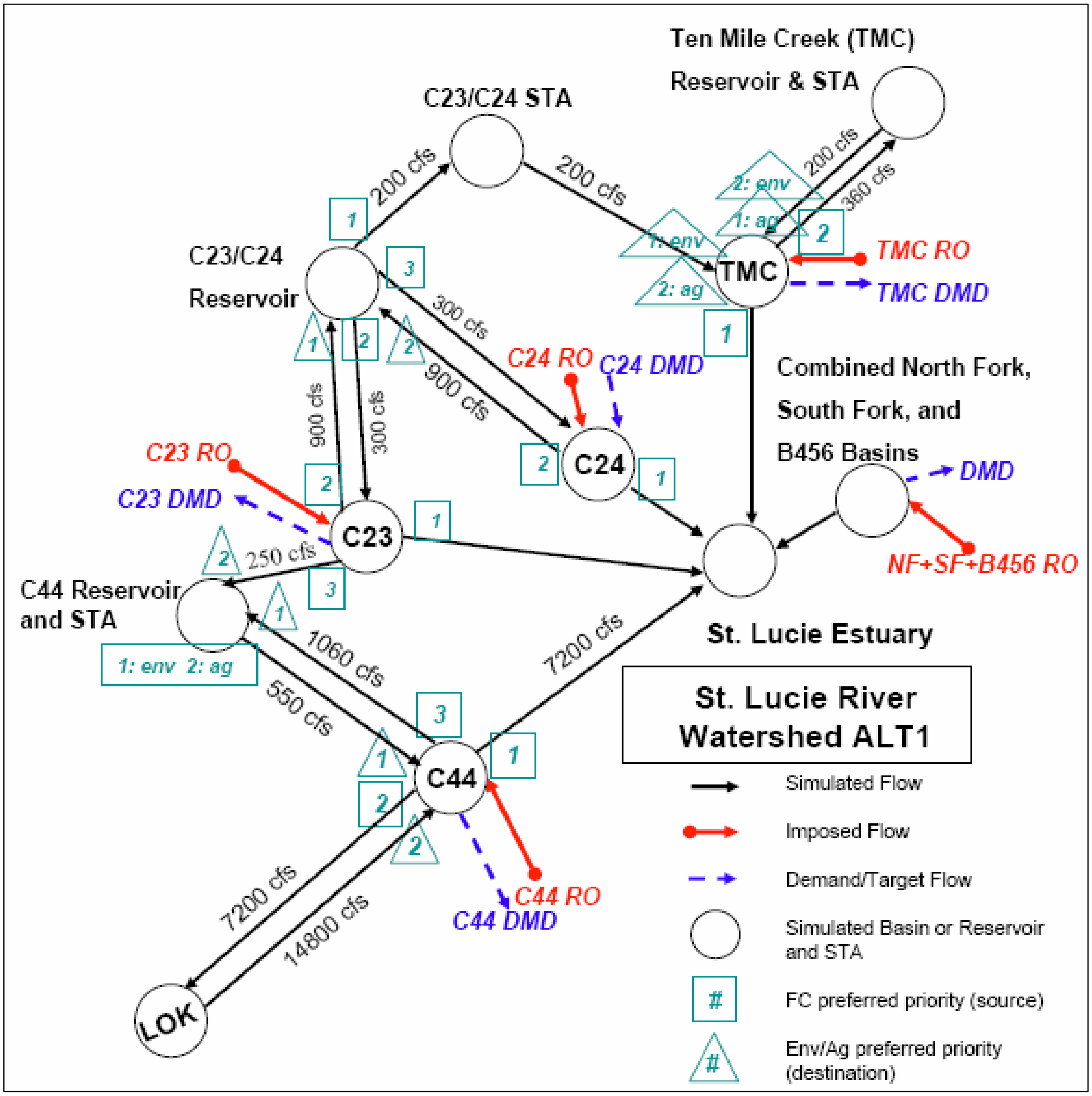


Figure C-17. St. Lucie River Watershed simulation configuration for Alternative 1

NF-SF-B456 Basins

- One outlet structure discharges into the St. Lucie Estuary.
- Basin runoff is first used to meet St. Lucie Estuary demands.
- Demands in each basin represent supplemental irrigation needs from surface water sources only.

C23 Basin

- One outlet structure discharges into the St. Lucie Estuary. Structure capacity is assumed to be limited only by available basin runoff. Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, then the remaining runoff is sent in this priority order: (1) to the C23/C24 Reservoir and (2) to C44 Reservoir/STA to meet agricultural and environmental demands.

C24 Basin

- One outlet structure discharges into the St. Lucie Estuary. Structure capacity is assumed to be limited only by available basin runoff. Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, then the remaining runoff is sent to the C23/C24 Reservoir.
- When water is available in the C23/C24 Reservoir, it will make releases to the basin to meet agricultural demands (third priority).

C23/C24 Reservoir and C23/C24 STA

- When water is available in the C23/C24 Reservoir, it will make 200 cfs release to the C23/24 STA when TMC estuary demand is greater than 200 cfs.
- When water is available in the C23/C24 Reservoir, it will make releases in this priority: (1) C23/C24 STA (above), (2) C23 Basin, and (3) C24 Basin.

C23/24 Reservoir

This reservoir is a combination of the C23 North Reservoir in C24 Basin and the C23/C24 South Reservoir in C23 and C24 basins.

- Location: C23 and C24 basins
- Storage capacity: 6940 acres * 13.27 feet = 92,094 acre-feet
- Footprint: 8675 acres (assumed 6940 acres/80 percent)
- Effective storage area: 6940 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)
- Maximum depth: 13.27 feet
- Emergency discharge when depth reaches: 13.77 feet
- Inlet: 900 cfs capacity, modeled as pump source: C23 Basin
- Inlet: 900 cfs capacity, modeled as pump source: C24 Basin
- Outlet: 300 cfs capacity, modeled as pump destination: C23 Basin
- Outlet: 300 cfs capacity, modeled as pump destination: C24 Basin
- Outlet: 200 cfs capacity, modeled as pump destination: C23/C24 STA
- Will receive rainfall representative of C24 Basin.
- Will receive ET and rainfall representative of St Lucie basins.
- No seepage loss assumed

C23/C24 STA Addition for ALT 1

This STA is physically located in TMC Sub-watershed.

- Location: C23 and C24 basins
- Storage capacity: 2568 acres * 1.5 feet = 3852 acre-feet
- Footprint: 3323 acres (assumed 2568 acres/ 80%)
- Effective storage area: 2568 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)

- Maximum depth: 1.5 feet
- Emergency discharge when depth reaches: 1.5 feet
- Inlet: 200 cfs capacity, modeled as pump source: C23/C24 Reservoir
- Outlet: 200 cfs capacity, modeled as pump destination: C23/C24 STA
- Will receive rainfall representative of North Folk Basin.
- Will receive ET and rainfall representative of St Lucie basins.
- No seepage loss assumed

Ten Mile Creek Basin

- One outlet structure discharges into the St. Lucie Estuary. Structure capacity is assumed to be limited only by available basin runoff. Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, then the remaining runoff is sent to the TMC Reservoir/STA.
- TMC Sub-watershed demands are met first by the TMC Reservoir/STA, and then represent supplemental irrigation needs from surface water sources only.
- An emergency flood control pump of 200 cfs is added to discharge water from TMC Reservoir/STA to the TMC Sub-watershed to ensure that the reservoir does not exceed 11.29 feet (which corresponds to its maximum depth plus a buffer). Note that inflows to the TMC Reservoir/STA are cutoff once it reaches its maximum depth of 10.79 feet; however, rainfall may bring it above 10.79 feet.
- When St. Lucie Estuary demand at TMC is greater than 200 cfs, a 200 cfs release is made from the C23/24 STA to TMC Sub-watershed.

Ten Mile Creek Reservoir and STA

- Location: TMC Sub-watershed
- Storage capacity: 656 acres * 10.79 feet = 7078 acre-feet
- Footprint: 820 acres (assumed 656 acres/80 percent)
- Effective storage area: 656 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)
- Maximum depth: 10.79 feet
- Emergency discharge when depth reaches: 11.29 feet
- Inlet: 360 cfs capacity, modeled as pump source: TMC Sub-watershed
- Outlet: 200 cfs capacity, modeled as pump. TMC Sub-watershed
- Will receive rainfall representative of North Folk Basin.
- Will receive ET representative of St. Lucie basins (per input file).
- No seepage loss assumed

C44 Basin

- One outlet structure (S-80) discharges into the St. Estuary with a capacity of 7200 cfs.
- Basin runoff is first used to meet St. Lucie Estuary demands. If remaining runoff still exists, then the remaining runoff is sent to the C44 Reservoir/STA.
- Runoff from C44 Basin flows into Lake Okeechobee when Lake Okeechobee stage is below 14.5 feet NGVD. This condition overrides previous statement that states that remaining runoff is diverted to the C44 Reservoir/STA.
- C44 Basin demands are met first by C44 Reservoir & STA, then by Lake Okeechobee.

- St Lucie Estuary at S80, demands to be met in this priority order: (1) C44 runoff, (2) C44 Reservoir & STA releases, and (3) Lake Okeechobee explicit delivery, if desired.
- An emergency flood control pump of 1063 cfs is added to discharge water from C44 Reservoir/STA to the C44 Basin to ensure that the reservoir does not exceed 5.68 feet (which corresponds to its maximum depth plus a buffer). Note that inflows to the C44 Reservoir/STA are cutoff once it reaches its maximum depth of 5.18 feet; however, rainfall may bring it above 5.18 feet.
- C44 Reservoir/STA receives 250 cfs from the C23 basin to meet agricultural and estuary demands.

C44 Reservoir and STA

- Location: C44 Basin
- Storage capacity: 9700 acres * 5.18 feet = 50,246 acre-feet
- Footprint: 12,125 acres (assumed 9700 acres/80 percent)
- Effective storage area: 9700 acres
- Approximate bottom elevation: 20.0 feet (assumed datum for depth calculations only)
- Maximum depth: 5.18 feet
- Emergency discharge when depth reaches: 5.68 feet
- Inlet: 1060 cfs capacity, modeled as pump source: C44 Basin
- Inlet: 250 cfs capacity, modeled as pump source: C23 Basin
- Outlet: 550 cfs capacity, modeled as pump destination: C44 Basin
- Will receive ET and rainfall representative of C44 Basin.
- No seepage loss assumed

C2.2.7 Lake Okeechobee Sub-watershed

Several features from NERSM were developed or adopted from SFWMM in order to meet the modeling requirements established during the alternative formulation and analysis phase of the project. Primary components that comprise the Lake Okeechobee water balance and computational algorithms incorporated in the model are described briefly below.

Lake Okeechobee is modeled as a lake, using established stage-area and stage-volume relationships established in the SFWMM. Rainfall during the period 1970 to 2005 is used to calculate the volume of water that falls directly on the lake surface. ET is calculated using the same methodology as implemented in the SFWMM.

Historical flows are applied for the TCNS, LI, and FEC Sub-watersheds in all of the scenarios. Historical sub-watershed flows are adjusted in select alternative scenarios, as needed, to account for the “footprint” of MMs considered in a particular scenario. NERSM calculated flows from the LKB Sub-watershed are another tributary inflow to Lake Okeechobee.

Backflows coming from the Everglades Agricultural Area (EAA) in areas south of Lake Okeechobee as simulated in SFWMM are input as a boundary condition for the NERSM.

In the RWPPB and alternative scenarios, the C-43 Reservoir is modeled in the NERSM with the sole purpose of meeting the environmental needs of the Caloosahatchee Estuary. The performance of C-43 Reservoir and its ability to meet C-43 Estuary demands are affected by Lake Okeechobee stages and its interaction with other MMs during the RWPP alternatives formulation process. The footprint for the C-43 Reservoir was obtained from modeling in support of the Project Implementation Report (PIR) phase of CERP developed by Wilcox (email communications, 2007). Rainfall and reference ET datasets for the reservoir were also obtained from the PIR model. The storage area and volume relationships for the reservoir were developed by Stanley Consultants (email 2007).

The C-44 Reservoir/STA receives water only from local basin runoff. However, local basin demand can be met primarily from the reservoir and from Lake Okeechobee as a back-up source. Hence, it is not explicitly simulated in NERSM. The C44 Reservoir/STA is also used to treat runoff prior to discharge into the estuary.

C2.2.8 Lake Okeechobee Operations

The WSE Regulation Schedule is implemented in NERSM for Lake Okeechobee regulatory releases. The regulatory releases are based on lake stage (compared to calendar based trigger lines) and climatic influences (both local and global). Lake water levels are checked against operational zones A, B, C, D1, D2 and D3, and then additional criteria in a decision tree (Tributary Hydrologic Conditions and Climatic and Meteorological Outlooks) are checked to guide the amount of release. Similar to the SFWMM model, seasonal forecasts are assumed in place of short-term meteorological forecasts, due to difficulty in deriving these data.

Regulatory releases to the Caloosahatchee and St. Lucie estuaries are simulated in the Current Base scenario based on the WSE Regulation Schedule as implemented in the SFWMM 2005 base run. Releases for the same purpose are simulated in the Future Base and alternative scenarios based on the WSE Regulation Schedule as implemented in the SFWMM 2010A8 run.

Discharges to the Caloosahatchee River (C-43) through S-77 and discharges to the St Lucie Canal (C-44) through S-308 are simulated based on the WSE Regulation Schedule. Simulated discharges to conservation areas include Lake Okeechobee to WCA 1 (S-352 to West Palm Beach canal), to WCA 2A (S-351 to Hillsboro canal), and to WCA 3A (S-351 to North New River canal and S-354 to Miami Canal).

Instead of meeting local basin demand and estuarine demands, as in the PIR model, the C-43 Reservoir operating rule in NERSM is designed to meet only estuarine demands. This change in functionality is more in line with the original intent of the C-43 Reservoir. The C-43 Reservoir simulation is capable of simulating the following operations for multiple purposes:

- Flood Control: releases expected at S-79 from either the Caloosahatchee Basin runoff or Lake Okeechobee regulatory releases through S-77. A check is made of the S-79 Caloosahatchee Estuary targets. Flows in excess of this target should be directed to the C-43 Reservoir, provided there is capacity in the reservoir.
- Water Supply: If the Caloosahatchee Basin runoff and S-77 regulatory releases are less than the Caloosahatchee Estuary target, releases should be made from the C-43 Reservoir to meet the deficit, subject to the available reservoir capacity.

Explicit Lake Okeechobee discharges to meet minimum flow requirements in the St. Lucie Estuary are not simulated in RWPPB and the alternatives. However, NERSM-calculated Lake Okeechobee regulatory releases are combined with the C-44 Basin and Reservoir/STA releases to evaluate the total impact on St. Lucie Estuary.

In the Current Base scenario, regulatory releases through C-10A are simulated consistent with SWFMM 2005. In the RWPPB and alternative scenarios, regulatory releases south are zero, except through C-10A.

Non-regulatory releases are sent to areas of the system for a variety of purposes, including irrigation, saltwater intrusion control, domestic water supply and environmental enhancement.

In the NERSM, environmental releases to the estuaries and water supply releases to LOSA are the only simulated non-regulatory flows out of Lake Okeechobee. Individual LOSA demands are input as boundary conditions in NERSM for all simulation scenarios. EAA conveyance cutbacks are not simulated in any of the simulated scenarios, but instead are fixed based on appropriate SFWMM output. In the Future Base and Alternative Plans scenarios, the Hybrid LOWSM methodology described below is implemented in NERSM.

All other non-regulatory releases such as environmental water supply releases to the WCAs and Everglades National Park, urban water supply releases to the Lower East Coast and discharges to the EAA reservoir were obtained from the SFWMM and input as boundary condition flows. In future versions of NERSM, Lake Okeechobee discharges will be made to the proposed above-ground reservoirs to be constructed in the EAA, based on operating rules built into the model.

C2.2.9 MDS and LOWSM Algorithms

The MDS term represents the arithmetic sum of all lake historical water budget components that: (1) are not accounted for in another simulated term on Lake Okeechobee, and (2) are assumed not to change from what happened historically. The calculation begins with the historical water budget definition for the lake (excluding seepage and regional groundwater movement):

$$delS_{hist} = RF_{hist} + qin_{hist} - qout_{hist} – Et_{hist}$$

where:
q = total structural flow aggregated over the current time step
RF = rainfall volume over the current time step
delS = $S_{t+1} - S_t$ = change in storage from the current to the next time step
ET = evapotranspiration volume over the current time step

This is expanded to form the following equation, in which some components will not change for any anticipated management/operational scenario to be evaluated in the future (subscript *NC*), and some components will change given the same scenario (subscript *C*):

$$(delS_{hist})_C = [(qin_{hist})_{NC} + (qin_{hist})_C + (RF_{hist})_{NC}] - [(qout_{hist})_{NC} + (qout_{hist})_C + (Et_{hist})_C]$$

Rearranging this equation gives the MDS term to be used in the model simulations:

$$(delS_{hist} - qin_{hist} + qout_{hist} + ET_{hist})_C = (RF_{hist} + qin_{hist} - qout_{hist})_{NC}$$

Note that the equation above illustrates the ability to calculate the MDS term using an aggregation of historically observed lake storage change, structure flow for stations that will be simulated (subscript *C*) and historical ET measurement. All of these terms can be easily obtained or estimated.

LOWSM methodology is used for allocation of Lake Okeechobee water to agricultural users during drought conditions. The methodology incorporates calendar-based water shortage trigger lines in a phased-cutback approach along with a set of weekly LOSA demands to be met. The weekly demands, based on a one-in-ten-year drought condition, were obtained from SFWMM.

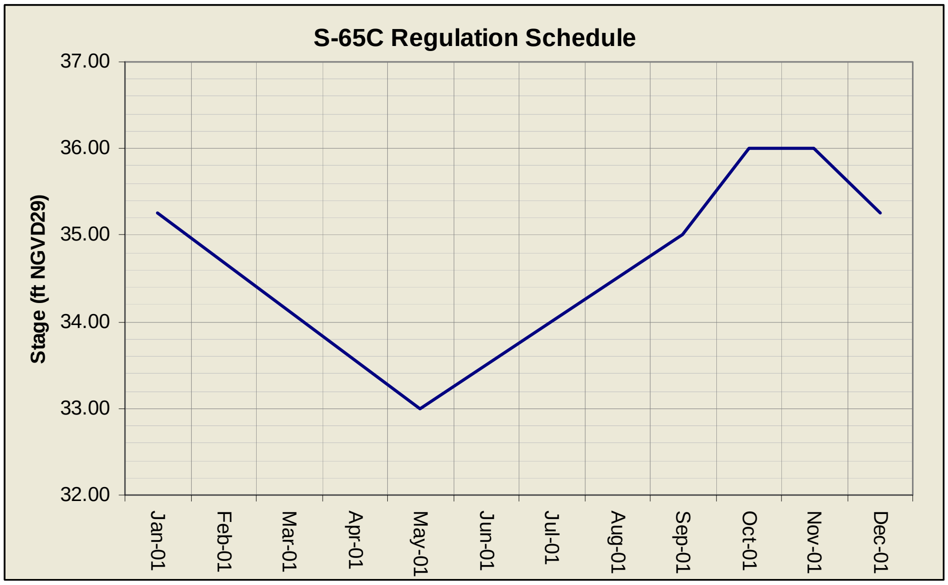
C2.3 Sub-watershed Specific Assumptions and Specifications

C2.3.1 Current Base (2005) Assumptions

Table C-6. Summary of Primary Characteristics of Current Base Condition Model

Feature	Entire Model Domain
General	• Model should reflect conditions around the year 2005, except when otherwise indicated. • Period of simulation is 1970 to 2005. • Model time step is daily. • All elevations are in feet, NGVD 29.
	Upper Kissimmee Sub-watershed (KUB)
General	• Model consists of nine interconnected lakes with flows imposed for the lakes with natural creeks. The outflows from the lakes are heavily regulated.
Climate	• Climate period of record is 1970-2005. Rainfall and ET data derived from the time series developed for the SFWMM, with open water evaporation assumed for the nine lakes.
Model Setup	• The Upper Kissimmee Sub-watershed model setup consists of nine lakes or Lake Management Areas (LMAs). The lakes are Alligator, Myrtle, Hart, Gentry, East Toho, Toho, Cypress, Hatchineha and Kissimmee. The lakes are interconnected with canals and water control structures which are tightly regulated.
Stage-Volume-Area Relationships	• Stage-volume and stage-area relationships for the nine lake management areas are those developed as part of the KBMOS effort.
Sub-watershed Inflows	• Sub-watershed flows developed as a part of the calibration of the UKISSWIN model (PBS&J, Christ et al. 2001) were imposed as flow boundary conditions for the nine lakes. Historical flows obtained from USGS for Shingle, Boggy, Reedy and Catfish creeks were also imposed as boundary conditions for Lakes Toho, East Toho, Cypress and Hatchineha. For Shingle Creek, the flow split was assumed to be 70 percent into Lake Hatchineha and 30 percent into Lake Cypress.
Structure Capacity	• The water control structures, which interconnect the lakes, include six spillways (S-60, S-62, S-59, S-61, S-63 and S-65), two culverts (S-57 and S-58) and two open channel connections (C36 and C37). The design capacities of the structures are given below: S-60 – 450 cfs S-62 – 500 cfs S-59 – 700 cfs S-61 – 2000 cfs S-63 – 700 cfs S-65 – 4000 cfs S-57 – 150 cfs S-58 – 130 cfs Locks used for navigation at the structures are not modeled.
Operations	The lakes and water control structures are regulated by rigid schedules, as defined in the Kissimmee Basin Water Supply Plan (SFWMD, 2000). An exception is Lake Kissimmee, which is simulated in the model using the Interim Regulation Schedule, as implemented in Phase I of the KRR Project. The flow through all structures in KUB were modeled using the daily headwater/tailwater and gate openings at the structure, as defined in the UKISS package in the SFWMD Technical Publication 86-5, and are similar to the SFWMD's Flow Program. The maximum allowable gate openings for a set of headwater/tailwater conditions at the spillway were computed using the "Riprap Control" criteria mentioned in the technical publication. The flow

Feature	Entire Model Domain
	through the open channel canals C-36 and C-37 connecting lakes Cypress and Hatchineha, and lakes Hatchineha and Kissimmee is modeled with a variation of the Manning's equation using stage and water surface slope as outlined in the technical publication.
	Lower Kissimmee Sub-watershed (LKB)
General	• Model reflects conditions post-Phase I of the KRR around the year 2005. • It is assumed that there is no connection between Lake Istokpoga and the Kissimmee River (i.e. G-85 is assumed closed).
Climate	• The climatic period of record is 1970 to 2005. • Rainfall time series were obtained from the 1914-2005 rainfall binary developed for the SFWMM. Rainfall values for the SFWMM grid cells fully contained within the LKB Sub-watershed were averaged to obtain the average rainfall time series for each pool or basin. • Reference grass evapotranspiration (RET) time series (by Penman-Monteith) were obtained from the 1948-2005 binary file developed for the SFWMM. RET values for the SFWMM grid cells fully contained within each LKB basin were averaged to obtain average RET time series for each basin. In the model it is assumed that open water evaporation from the four C-38/Kissimmee River reaches is 85 percent of RET for consistency with average annual open water ET rates in the UKISS model.
Model Setup	• The Lower Kissimmee Sub-watershed is comprised of four major basins reflecting partial (Phase I) KRR: S-65A, S-65BC, S-65D and S-65E. Only the C-38 canal, the Kissimmee River and floodplain portions of these basins are simulated as level pools: Pools A, BCD, and E.
Stage-Volume-Area Relationships	• Stage-volume and stage-area relationships used for the four level pools are those developed for the KBMOS project. For Pool BC, these relationships were later manipulated to obtain stage-volume and stage-area curves for representative level-pool head.
Sub-watershed Inflows	• To be consistent with the SFWMM methodology for translating S-65 into S-65E flows, sub-watershed inflows (runoff) were estimated based on historical flow data at LKB boundary structures (S-65E – S-65 flows). Runoff was prorated based on the relative area of each LKB basin and the resulting time series was imposed as boundary condition to each level pool.
Structure Capacity	• Only the major gated spillway structures in place post-Phase I of the KRR are included: S-65A, S-65C, S-65D, and S-65E. Culverts and overflow weirs next to these structures are not modeled. Broad-crested weirs on the tieback levee of S-65A are not modeled. Locks at these structures are also not modeled. • S-65B is not included in the simulation, as it was removed as part of Phase I of the KRR. • WEIRS 1, 2, 3, though still in place in 2005, are not modeled. • Rating curves developed by Ansar, et al. (2005) based on dimensionless analysis were used in simulating these gated spillways (**Table C-7)**. • Gates are assumed to always be at the maximum allowable gate opening (MAGO) for the set of headwater/tailwater stages. MAGO curves for these structures were obtained from the C&SF System Operating Manual (Draft-December 2005) and input as two-dimensional lookup tables. • Maximum historical discharges are used to limit flow through these structures: S-65A: 13,100 cfs S-65C: 19,300 cfs S-65D: 24,000 cfs S-65E: 27,900 cfs
Operations	• The four gated spillways are operated for flood control. The regulation schedule presented in Appendix C of the 2000 KB Water Supply Plan was only implemented in real-life for S-65B (D. Anderson, pers. comm.), which was removed as part of Phase I of KRR. Therefore, a single flood control trigger stage equal to the optimum headwater stage at each structure is used to operate the structures in the model. The exception is S-65C, where the schedule is used in the model as it captures the overall intent of post-Phase I operations (D. Anderson, pers. comm.). During a time step, a structure will try to remove any volume of water stored above this flood control trigger stage, plus any basin inflow subject to the structure capacity and limited to its maximum capacity.

<table>
<tr><th>Feature</th><th>Entire Model Domain</th></tr>
<tr><td></td><td>Flood control trigger stage:
S-65A: 46.3 ft
S-65D: 26.8 ft S-65E: 21.0 ft
</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Taylor Creek/Nubbin Slough Sub-watershed (TCNS)</td></tr>
<tr><td>General</td><td>• A flow-pass-through method is implemented for this area. The historical flow from this area into Lake Okeechobee is imposed as flow boundary condition. Then the flow would pass through the sub-watershed and outlet directly into Lake Okeechobee.</td></tr>
<tr><td>Climate</td><td>• The climatic period of record is 1970 to 2005.
• For flow pass-through method, RF and ET are not needed in the simulation.</td></tr>
<tr><td>Model Setup</td><td>• The whole sub-watershed is divided into three basins: TCNS (S191+S133), S154 (S154+S154C), and S135. Outflows from these basins into Lake Okeechobee are: TCNSQ (S191+S133), S154, and S135 respectively.</td></tr>
<tr><td>Stage-Volume-Area Relationships</td><td>• For flow pass-through method, stage-volume relationships will not be used.</td></tr>
<tr><td>Sub-watershed Inflows</td><td>• The sub-watershed inflows are assumed to produce historical outflows from the sub-watershed into Lake Okeechobee which are imposed as flow boundary conditions. These flows: TCNSQ, S-154 and S-135 are from DBHYDRO database.</td></tr>
<tr><td>Structure Capacity</td><td>• Design capacity: S-191 (7,440 cfs); S-133 (625 cfs); S-154 (1,000 cfs); S-135 (500 cfs).
• Since flow pass-through method is implemented for this area, the design capacity does not impact the simulation.</td></tr>
<tr><td>Operations</td><td>• Historically, structure S-191 is operated on headwater elevation, and maximum gate opening. S-135 and S-133 are pump stations, operated according to headwater elevation.
• For flow pass-through method, the structures are assumed to have been operated as was done historically.</td></tr>
<tr><td></td><td></td></tr>
</table>

Feature	Entire Model Domain
	Lake Istokpoga Sub-watershed
General	• A flow pass-through method is implemented for this area. The historical flow from this area into Lake Okeechobee is imposed as flow boundary condition. Then the flow would pass through the sub-watershed and outlet, directly into Lake Okeechobee. The sub-watershed is assumed to be cut off from Lower Kissimmee with the structure G-85 closed all the time.
Climate	• The climatic period of record is 1970 to 2005. • For flow pass-through method, RF and ET are not needed in the simulation.
Model Setup	• The Istokpoga model is set up such that historical outflows are assumed to pass through the sub-watershed. Outflows into Lake Okeechobee (through S-71, S-72, S-84, S-127, S-129 and S-131) are assumed to be lumped into a single quantity.
Stage-Volume-Area Relationships	• For flow pass-through method, stage-volume relationships will not be used.
Sub-watershed Inflows	• The sub-watershed inflows are assumed to produce historical outflows from the sub-watershed into Lake Okeechobee, which are imposed as flow boundary conditions.
Structure Capacity	• From the structure books, the major gated spillway structures design capacities are shown in parenthesis: S-68 (3,000 cfs), S-70 (5,000 cfs), S-71 (6,000 cfs), S-72 (3,000 cfs), S-84 (6,000 cfs), S-127 (625 cfs), S-129 (375 cfs) and S-131 (375 cfs). • Since flow pass-through method is implemented for this area, the design capacities do not impact the simulation.
Operations	• For flow pass-through method, the structures are assumed to have been operated as was done historically.
	Fisheating Creek Sub-watershed
General	• This sub-watershed is modeled as a flow pass-through. The historical outflow from Fisheating Creek into Lake Okeechobee is imposed as an inflow to the sub-watershed as a boundary condition and allowed to flow into Lake Okeechobee.
Climate	• The climatic period of record is 1970 to 2005. • For flow pass-through method, RF and ET are not needed in the simulation.
Model Setup	• The entire Fisheating Creek area is modeled as a single basin.
Stage-Volume-Area Relationships	• For flow pass-through method, stage-volume relationships are not used.
Sub-watershed Inflows	• Since this sub-watershed is modeled as a flow pass-through, sub-watershed outflow time series is imposed as inflow boundary conditions. • Since there are no flow-monitoring sites close to Lake Okeechobee, the inflow time series is developed based on historical data at the Palmdale station. Palmdale station is the most downstream "natural" station. It is located on Fisheating Creek, several miles upstream of its confluence with Lake Okeechobee. The assumption is that the runoff to Lake Okeechobee from the Fisheating Creek drainage area downstream of Palmdale is included in MDS term.
Structure Capacity	• No structures exist in this sub-watershed. Fisheating Creek has an open connection with Lake Okeechobee. A dummy structure is assumed with very high capacity to allow passing the sub-watershed inflow to Lake Okeechobee.
Operations	• For flow pass-through method, the structures are assumed to have been operated to pass historical outflow.

Feature	Entire Model Domain
Lake Okeechobee Sub-watershed	
General	• Current base simulation, as in SFWMM 2005 base run
Climate	• The climatic period of record is 1970 to 2005.
Model Setup	• Lake Okeechobee modeled as a "lake" in the Regional Simulation model with established stage-area and stage-volume relationships. Rainfall is part of the MDS term. ET simulated using the same methodology as in the SFWMM.
Stage-Volume-Area Relationships	• Same as in SFWMM
Sub-watershed Inflows	• Historical flows are applied for the Fisheating Creek, Lake Istokpoga and Taylor Creek/Nubbin Slough Sub-watersheds. Backflows coming from the east, west and south of Lake Okeechobee, as simulated in the SFWMM, will be input as boundary conditions in RSM. S-65E flows into Lake Okeechobee will be simulated.
Structure Capacity	• Same as in SFWMM
Operations	• Regulatory releases to the estuaries and to the WCAs are simulated based on the WSE Regulation Schedule. Based on the SFWMM equivalent run, regulatory releases through S-352 and S-351 (Hillsboro Canal) are zero. Regulatory releases through C-10A are also simulated. • Individual LOSA basin demands are boundary conditions. Water management cutback scheme is simulated based on hybrid LOWSM operations. EAA conveyance cutbacks are not currently simulated, but fixed based on SFWMM output. • NETP Sub-watersheds, which are simulated in the model, establish inflows into Lake Okeechobee. • All other inflows and outflows are fixed boundary conditions.

Table C-7. Spillway Equations Used in NERSM for All Modeling Scenarios

Flow Condition	Equation	Restriction	Remarks
Controlled Submerged (CS)	$Q = L\sqrt{g y_c^{\ 3}}$ $y_c = aG_o\left(\frac{H-h}{G_o}\right)^b$ a = 1.04, b = 0.30	$\frac{h}{G_o} \geq 1.0$	Also known as submerged orifice
Controlled Free (CF)	$Q = L\sqrt{g y_c^{\ 3}}$ $y_c = aG_o\left(\frac{H}{G_o}\right)^b$ a = 0.86, b = 0.35	$\frac{h}{G_o} < 1.0 \,\&\, \frac{H}{G_o} \geq \frac{1}{K}$ $K = 2/3$	Also known as free orifice
Uncontrolled Submerged (US)	$Q = L\sqrt{g y_c^{\ 3}}$ $y_c = aH(1-\frac{h}{H})^b$ a = 0.838, b = 0.167	$\frac{h}{G_o} < 1.0, \frac{H}{G_o} < \frac{1}{K}, \& \frac{h}{H} \geq K$ $K = 2/3$	Also known as submerged weir
Uncontrolled Free (UF)	$Q = L\sqrt{g y_c^{\ 3}}$ $y_c = aH$ a = 0.7	$\frac{h}{G_o} < 1.0, \frac{H}{G_o} < \frac{1}{K}, \& \frac{h}{H} < K$ $K = 2/3$	Also known as free weir
Transitional Flow	No transition region		

Source: "Dimensionless Flow Ratings at Kissimmee River Gated Spillways", December 2005, Tech Pub SHDM report, Operations and Hydro Data Management Division, SFWMD (M. Ansar, Z. Cheng, J. A. Gonzalez & M. J. Chen)]

In the table, the flow equation coefficients for the Kissimmee River spillways are shown.

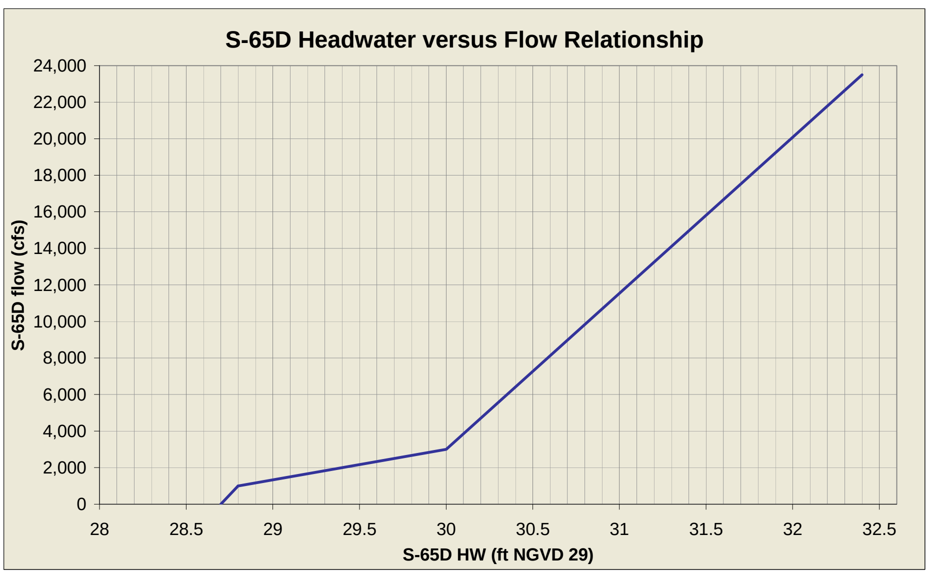
H: head water above CEL (feet) = HW-CEL;
h: tail water above CEL (feet) = TW-CEL;
g: gravitational acceleration, 32.2 ft/s^2;
G_o: gate opening (feet);
L: spillway width (feet);
y_c: critical depth (feet); and
Q: computed discharge (cfs).

Note: Coefficients a and b only apply to Kissimmee River gated spillways.

C2.3.2 Future Base (2015) Assumptions

Table C-8. Summary of Primary Characteristics of Future Base Condition

Feature	Entire Model Domain
General	• Model should reflect conditions around the year 2015, when all Acceler8 projects are in place. The future condition also assumes that the KRR and the Kissimmee River Headwaters Revitalization projects are in place. • Period of simulation is 1970 to 2005. • Model time step is daily. • All elevations are in feet NGVD 29.
	Upper Kissimmee Sub-watershed (KUB)
General	• Same as in Current Base.
Climate	• Same as in Current Base.
Model Setup	• Same as in Current Base.
Stage-Volume-Area Relationships	• Same as in Current Base.
Sub-watershed Inflows	• Same as in Current Base.
Structure Capacity	• Same as in Current Base.
Operations	• The lakes and water control structures are regulated by rigid schedules, as defined in the Kissimmee Basin Water Supply Plan (SFWMD, 2000). An exception is Lake Kissimmee, which is simulated in the model using the headwaters revitalization schedule.
	Lower Kissimmee Sub-watershed (LKB)
General	• Model reflects conditions after full KRR, around the year 2015. • It is assumed that there is no connection between Lake Istokpoga and the Kissimmee River (i.e. G-85 is assumed closed).
Climate	• Same as in Current Base.
Model Setup	• The Lower Kissimmee Sub-watershed is partitioned into three major basins reflecting full (Phases I-IV) KRR: S-65A, S-65BCD and S-65E. Only the C-38 Canal, the Kissimmee River, and floodplain portions of these basins are simulated as level pools: Pool A, BCD, D and E.
Stage-Volume-Area Relationships	• Stage-volume and stage-area relationships for the two channelized reaches are those developed as part of the KBMOS effort. Stage-volume and stage-area relationships have been recently developed for Pool BCD as part of this modeling effort.
Sub-watershed Inflows	• Same as in Current Base.
Structure Capacity	• Only the major gated spillway structures in place after full KRR are included: S-65A, S-65D, S-65E. Culverts and overflow weirs next to these structures are not modeled. Broad-crested weirs on the tieback levee of S-65A are not modeled. Locks at these structures are also not modeled. • S-65B, S-65C and WEIRS 1,2,3 are not included in the simulation as they were removed as part of KRR.

Feature	**Entire Model Domain**
	• U-shaped weir to be installed just upstream of S-65D, as part of the full KRR, is not modeled. • Rating curves developed by Ansar, et al. (2005) based on dimensionless analysis were used in simulating these gated spillways (**Table C-7**). • Gate openings are assumed to always be at the maximum allowable gate opening (MAGO) for the set of headwater/tail water stages. MAGO curves for these structures were obtained from the C&SF System Operating Manual (Draft-December 2005) and input as two-dimensional look-up tables. • Maximum historical discharges are used to limit flow through these structures, with the exception of S-65D, where limit reflects two additional gates that will be added as part of KRR: S-65A: 13,100 cfs S-65D: 28,000 cfs S-65E: 27,900 cfs
Operations	• S-65A and S-65E are operated for flood control based on a constant optimum headwater stage (flood control trigger level). S-65A: 46.3 ft S-65E: 21.0 ft • S-65D is operated for flood control based on the following headwater-flow relationship.  During a time step, a structure will try to remove any volume of water stored above this flood control trigger level, plus any basin inflows subject to the structure capacity and limited to its design capacity.
	Taylor Creek/Nubbin Slough Sub-watershed (TCNS)
General	• Same as in Current Base.
Climate	• Same as in Current Base.
Model Setup	• Same as in Current Base.
Stage-Volume-Area Relationships	• Same as in Current Base.

Feature	Entire Model Domain
Sub-watershed Inflows	• Same as in Current Base.
Structure Capacity	• Same as in Current Base.
Operations	• Same as in Current Base.
Lake Istokpoga Sub-watershed	
General	• Same as in Current Base.
Climate	• Same as in Current Base.
Model Setup	• Same as in Current Base.
Stage-Volume-Area Relationships	• Same as in Current Base.
Sub-watershed Inflows	• Same as in Current Base.
Structure Capacity	• Same as in Current Base.
Operations	• Same as in Current Base.
Fisheating Creek Sub-watershed	
General	• Same as in Current Base.
Climate	• Same as in Current Base.
Model Setup	• Same as in Current Base.
Stage-Volume-Area Relationships	• Same as in Current Base.
Sub-watershed Inflows	• Same as in Current Base.
Structure Capacity	• Same as in Current Base.
Operations	• Same as in Current Base.
Lake Okeechobee Sub-watershed	
General	• Future Base simulation based on SFWMM 2010A8 run
Climate	• Same as in Current Base.
Model Setup	• Lake Okeechobee modeled as a "lake" in the Regional Simulation model, with established stage-area and stage-volume relationships. Rainfall is part of the MDS term. ET simulated using the same methodology as in the SFWMM.
Stage-Volume-Area Relationships	• Same as in SFWMM
Sub-watershed Inflows	• Historical flows are applied for the Fisheating Creek, Lake Istokpoga and Taylor Creek/Nubbin Slough Sub-watersheds. Backflows coming from the east, west and south of Lake Okeechobee, as simulated in the SFWMM, will be input as boundary conditions in RSM. S-65E flows into Lake Okeechobee will be simulated.

Feature	Entire Model Domain
Structure Capacity	• Same as in SFWMM
Operations	• Regulatory releases to the estuaries are simulated based on the WSE Regulation Schedule. Based on the SFWMM equivalent run, regulatory releases south are zero. • Regulatory releases to the EAA reservoir will be fixed, based on the SFWMM simulation output. Likewise, EAA reservoir flows to meet EAA demand will also be fixed boundary conditions. • Lake Okeechobee serves as secondary source of irrigation water, subject to hybrid LOWSM for meeting C-43 Basin demand, as well as environmental deliveries to meet Caloosahatchee Estuary demands. In times of excess, lake regulatory discharges are also diverted into the C-43 Reservoir. • Lake Okeechobee serves as secondary source of irrigation water, subject to hybrid LOWSM for meeting C-44 Basin demand . Explicit Lake Okeechobee discharges to meet minimum flow requirements in the estuary are not simulated in all simulated scenarios for RWPP. However, lake regulatory discharges, as dictated by WSE Regulation Schedule, are still released into the St. Lucie Estuary. The C-44 Reservoir does not capture any Lake Okeechobee regulatory discharge. • Individual LOSA basin demands are boundary conditions. Water management cutback scheme is based on hybrid LOWSM operations. EAA conveyance cutbacks are not currently simulated but fixed, based on SFWMM output. • NETP Sub-watersheds: Same as in Current Base. • All other inflows and outflows are fixed boundary conditions.

C3.0 WATER BUDGET COMPONENTS

C3.1 Rainfall

South Florida is a sub-tropical region that is relatively wet, warm, and humid. On the average, the region receives about 53 inches of rain annually, 66 percent to 75 percent of which falls in the wet season (Shih, 1983). During the dry season, precipitation is governed by cold fronts that pass through the region approximately every seven days (Bradley, 1972). Rainfall from these fronts exhibit a more uniform distribution across the South Florida ecosystem compared to rainfall derived from the highly variable convection type thundershowers that occur during the wet season.

Rainfall distributions follow a bimodal pattern, with one peak in May or June and the other peak in September or October (Thomas, 1974). Annual rainfall over the past few decades has ranged from a low of 37 inches in 1961 to a high of 106 inches in 1947. Typically, annual values vary from 40 inches to 65 inches, with a mean annual rainfall over the Everglades of 51 inches (MacVicar and Lin, 1984).

Table C-9 shows average monthly and annual rainfall values for key individual sub-watersheds within the Lake Okeechobee Watershed. This data indicates that June and July are typically the wettest months and November, December, and January are the driest months. The Lake Okeechobee (Lake O) Sub-Watershed consists of lands that stretch from the west to the east coasts of Florida (Caloosahatchee, EAA, and St. Lucie drainage areas). Because of the extent of its geographic area, rainfall patterns in the sub-watershed are quite diverse. In **Table C-9**, rainfall values for the highest monthly and annual rainfalls (generally in the east coast portion of the sub-watershed (St Lucie drainage area)) and values for the smallest monthly and annual rainfalls (generally in the portion of the sub-watershed south of Lake Okeechobee (EAA drainage area)) are provided.

Table C-9. Average Monthly and Annual Rainfall Depths (inches) for Sub-watersheds as used in the NERSM (1970 – 2005)

Sub-Watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Dec	An-nual
Upper Kiss	2.2	2.63	3.09	2.42	3.75	7.35	7.53	6.95	6.48	3.36	1.82	2.04	49.62
Lower Kiss	1.97	2.3	2.82	2.49	3.81	7.43	7.02	6.7	6.56	3.78	1.67	1.59	48.14
TCNS	1.85	2.07	2.67	2.48	4.04	7.86	7.16	6.99	6.8	3.74	1.72	1.55	48.93
Istokpoga	1.97	2.3	2.82	2.49	3.81	7.43	7.02	6.7	6.56	3.78	1.67	1.59	48.14
FEC	1.87	2.09	2.53	2.35	4.03	8.46	7.71	7.53	7.13	3.69	1.58	1.55	50.52
Lake O	1.89	1.86	2.99	1.99	3.53	6.14	5.45	5.82	5.71	3.00	2.06	1.48	41.98
SLRW†	2.26	2.43	3.47	2.58	4.13	7.01	6.41	7.02	7.25	4.66	3.10	1.94	52.32
CRW‡	2.18	2.05	3.26	2.20	4.15	8.93	7.80	7.76	6.68	3.25	2.13	1.66	52.12

† Saint Lucie River Watershed
‡ Caloosahatchee River Watershed

C3.2 C3.2 Evapotranspiration

Evapotranspiration (ET) is the total evaporation plus transpiration by vegetation. Potential evapotranspiration (PET) is the water loss that would occur if soil moisture was always available, and all wetlands, streams, and lakes and impoundments always had standing water. If a marsh is only inundated for a portion of the year, actual ET will be less than PET.

District-wide average annual ET is estimated to be 51.2 inches (130.1 cm) although there is geographic variation. Temporal variation in annual PET in most of south Florida is small compared to annual variation in rainfall, which can be 50 percent less than, or greater than the average (Visher and Hughes, 1969). Greatest ET rates occur from April through August and the lowest rates occur in November, December, and January.

Average annual ET for Lake Okeechobee for the period of record from 1970 through 2005 was 55.36 inches. **Figure C-18** shows the variation in average monthly PET values for Lake Okeechobee.

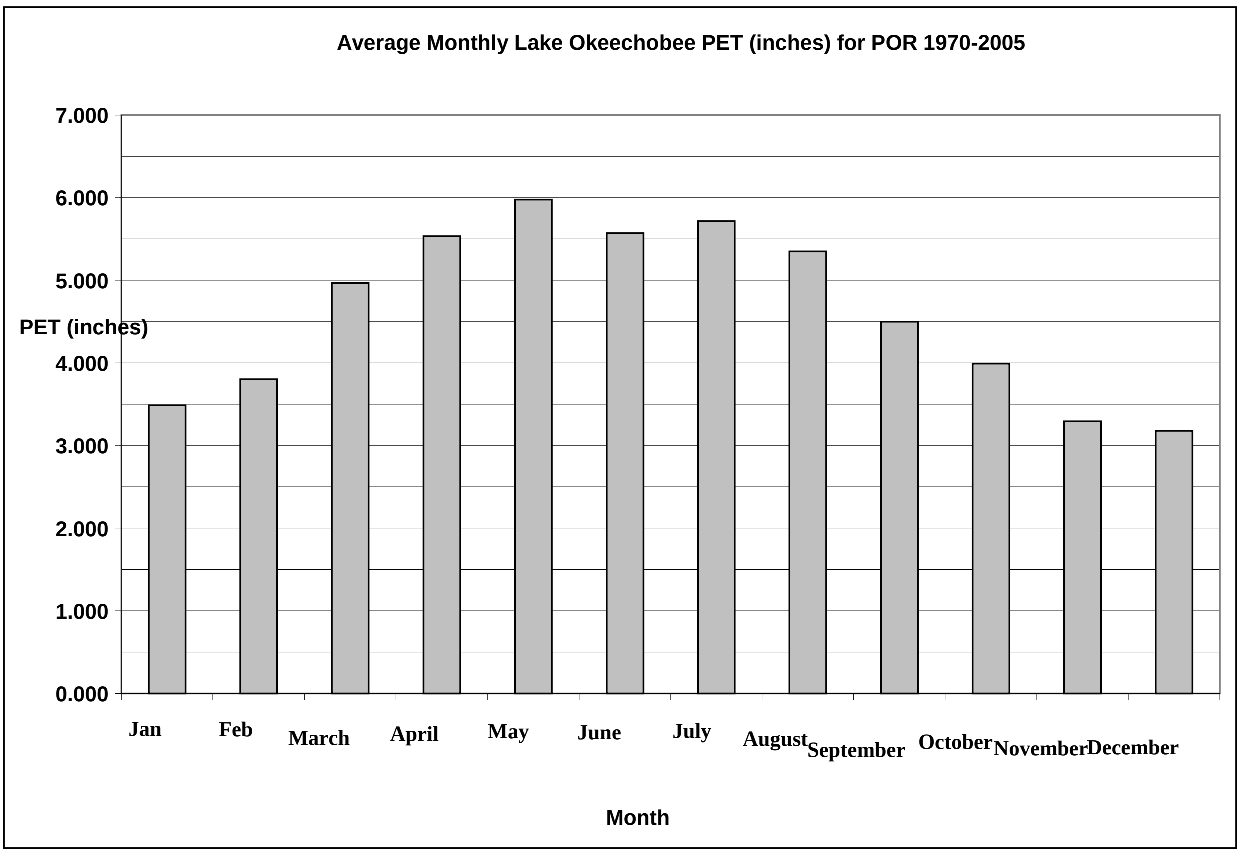


Figure C-18. Average monthly potential evapotranspiration rates at Lake Okeechobee as used in the NERSM (1970 through 2005)

C3.3 Flows

Flow characteristics, such as magnitude and timing of peak flows, seasonal variations in flows, and base flow conditions, are important considerations in the formulation, evaluation and comparison of alternative plans. Flow characteristics within the Lake Okeechobee Watershed vary considerably between sub-watersheds. In natural, unmanaged areas such as Fisheating Creek, flows are typically directly related to meteorological conditions. In heavily managed areas such as Taylor Creek/Nubbin Slough, magnitude and duration of peak flows is primarily controlled based on pre-determined water management objectives. Appendix B in the LOP2TP report describes the existing and Future Base flow conditions for the different sub-watersheds in the study area.

C4.0 ANNUAL AND SEASONAL SUB-WATERSHEDS WATER BUDGETS

During the course of creating the various models representing Current, Future Base and alternative scenarios, a simple graphic was developed to facilitate evaluating the reasonableness of model results. The graphic depicts the primary components of the hydrologic water budget calculated by NERSM for each sub-watershed for the period of simulation. The simulation-period average volumes of water associated with rainfall, ET, model-calculated flows, imposed flows (i.e. historical sub-watershed runoff, regulatory and non-regulatory releases, and change in Lake Okeechobee storage) are indicated on the graphics. Graphics were prepared for each modeling scenario, on an annual basis, for a wet season representing the period from June through October, and a dry season representing the period from November through May.

C4.1 Annual Sub-watershed Water Budget Components

Average annual volumes for primary sub-watershed water budget components are illustrated in **Figures C-19** through **C-24** for the six simulation scenarios. The net change in Lake Okeechobee storage in all scenarios is less than one percent of the total inflows or outflows from the lake. This important check of model integrity indicates that the various sinks and sources of water to Lake Okeechobee are being properly accounted for.

C4.2 Dry Season Sub-watershed Water Budget Components

Average dry season volumes for the primary sub-watershed water budget components are illustrated in **Figures B-25** through **B-30**. The negative value for Lake Okeechobee storage change indicates a net loss of water from storage in Lake Okeechobee during the seven-month dry period. A negative change in storage is associated with falling lake levels. The effects of MMs associated with the additional storage capacity considered in RWPPB and used in all alternatives are indicated by the arrows labeled "LOK withdrawals" that originate from Lake Okeechobee and go into the LI, TCNS and FEC sub-watersheds.

C4.3 Wet Season Sub-watershed Water Budget Components

Average wet season volumes for the primary sub-watershed water budget components are illustrated in **Figures B-31** through **B-36**. The positive value for Lake Okeechobee storage change indicates a net gain of water in Lake Okeechobee storage during the five- month wet period. A positive change in storage is associated with rising lake levels. Compared to the simulated volumes withdrawn during the dry season, the average volumes withdrawn from Lake Okeechobee for discharge in upland storage facilities is greater during the wet season.

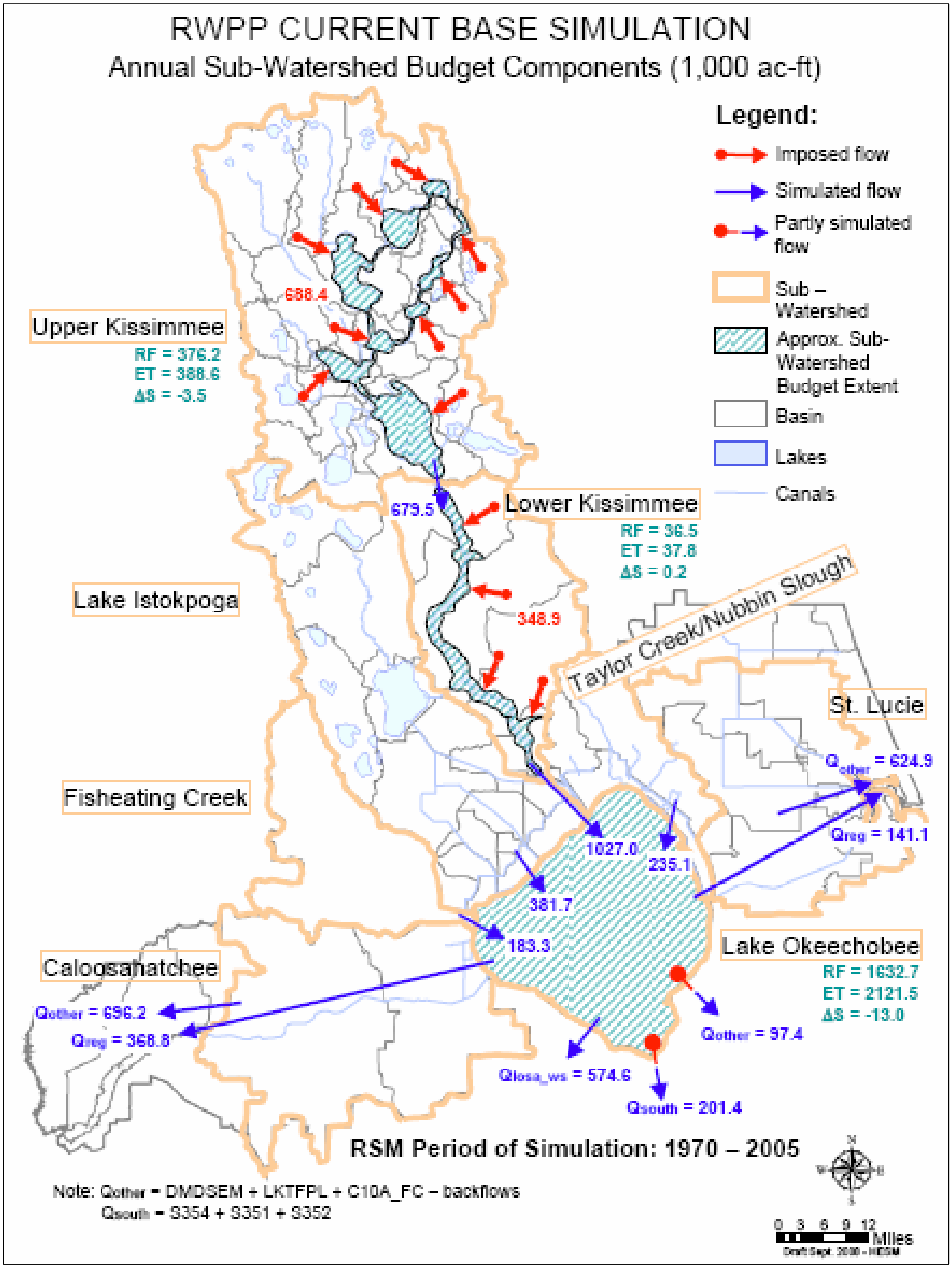


Figure C-19. NERSM calculated annual sub-watershed water budget components for Current Base

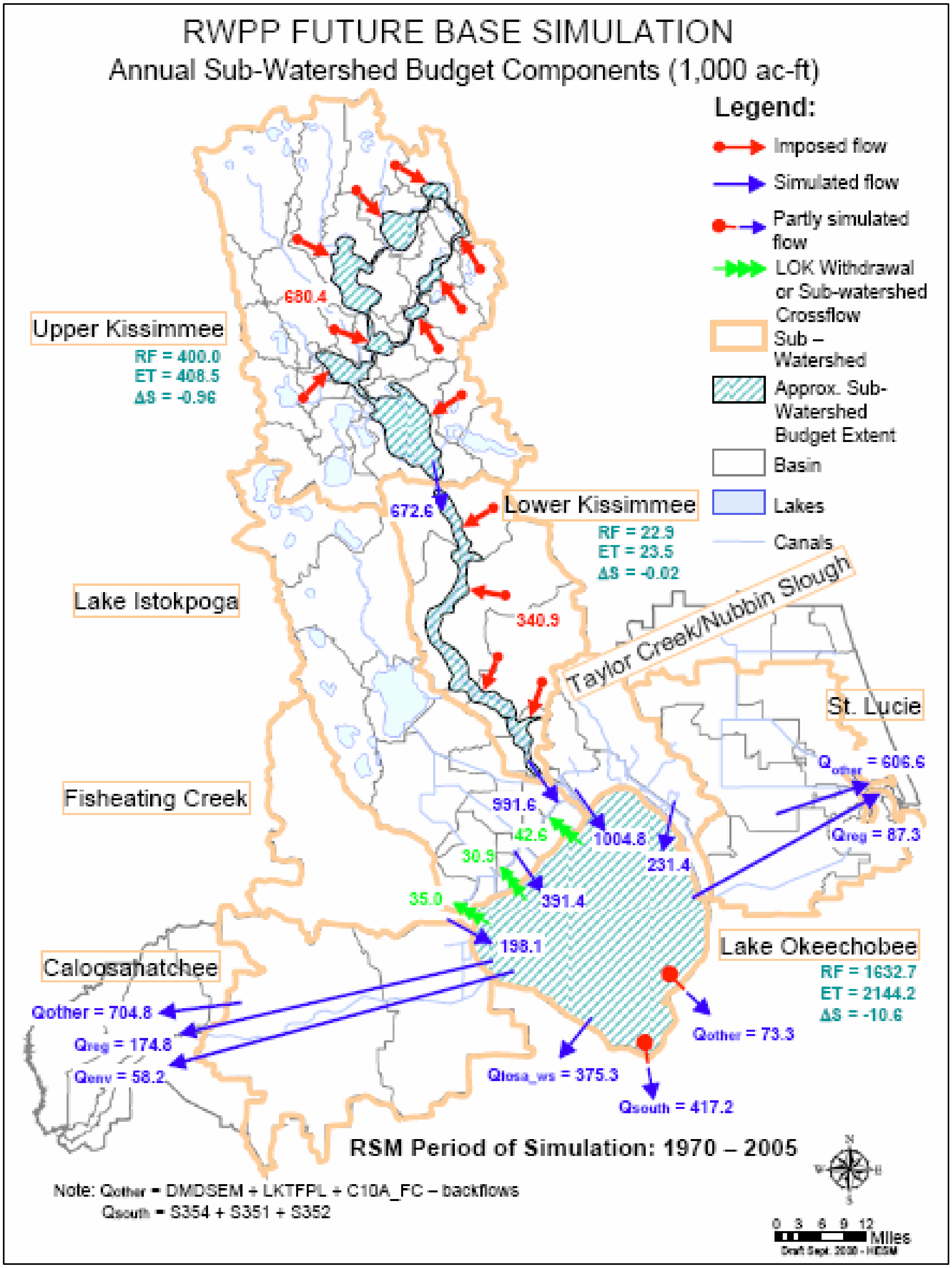


Figure C-20. NERSM calculated annual sub-watershed water budget components for RWPPB

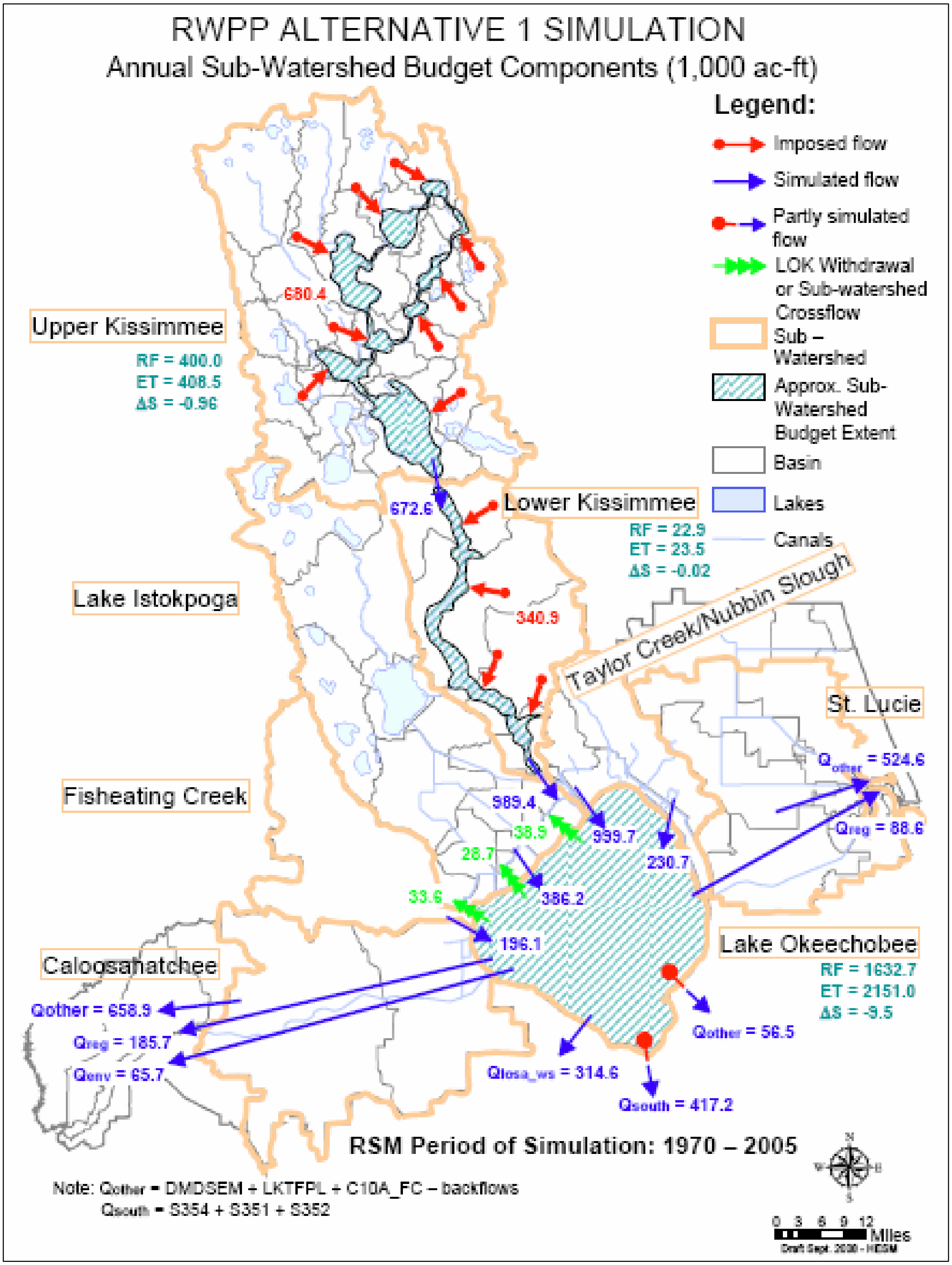


Figure C-21. NERSM calculated annual sub-watershed water budget components for Alternative 1

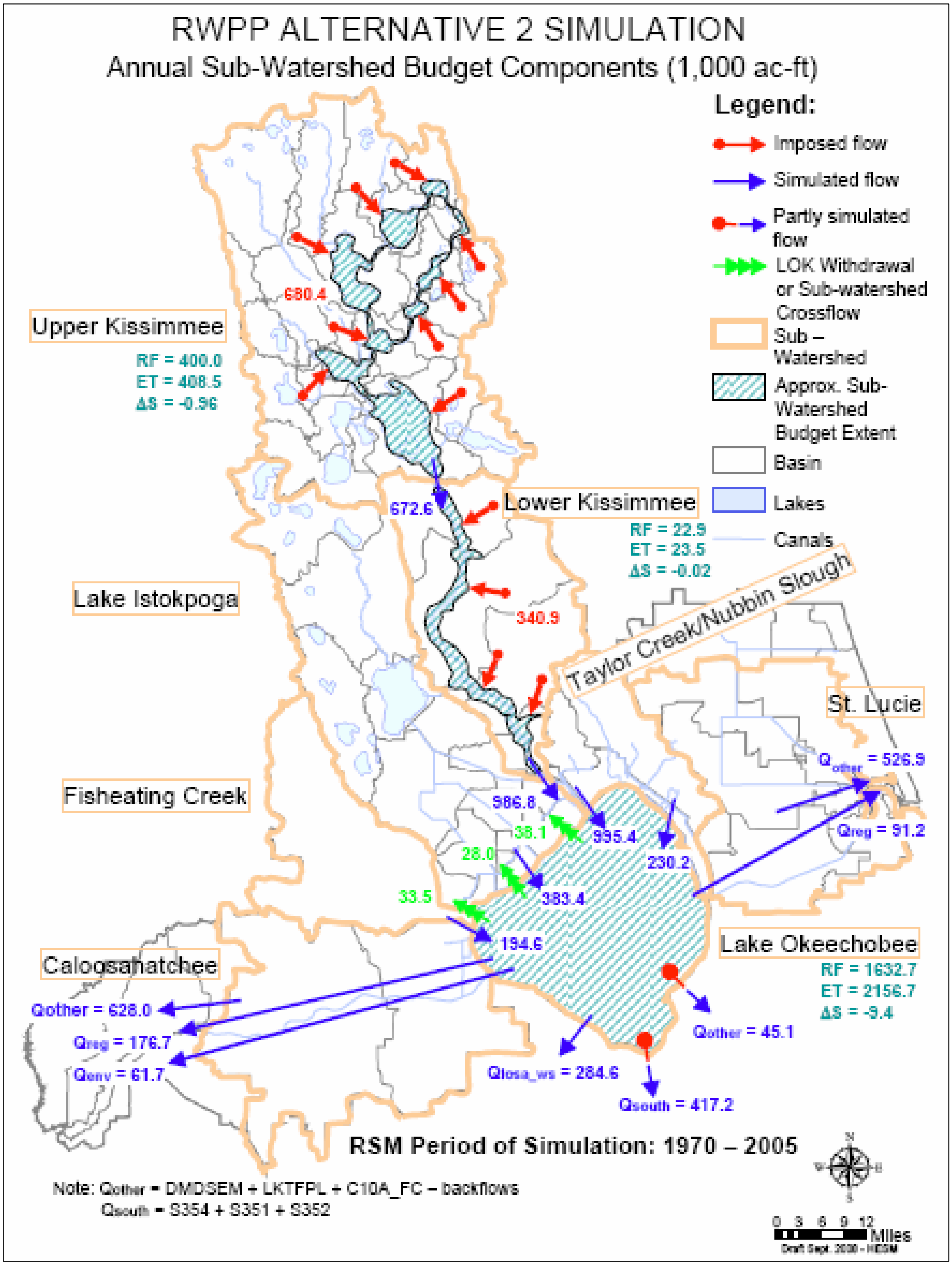


Figure C-22. NERSM calculated annual sub-watershed water budget components for Alternative 2

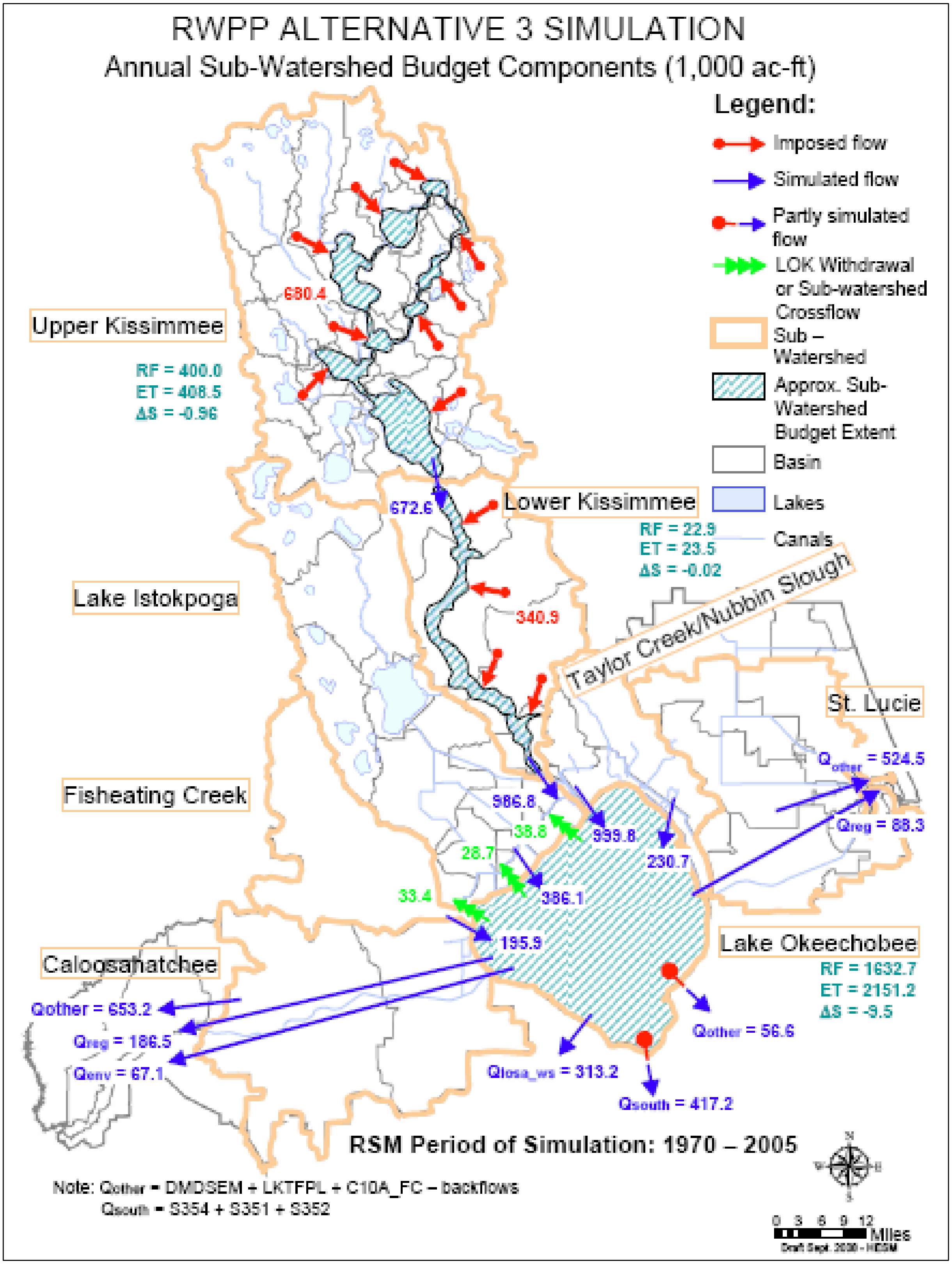


Figure C-23. NERSM calculated annual sub-watershed water budget components for Alternative 3

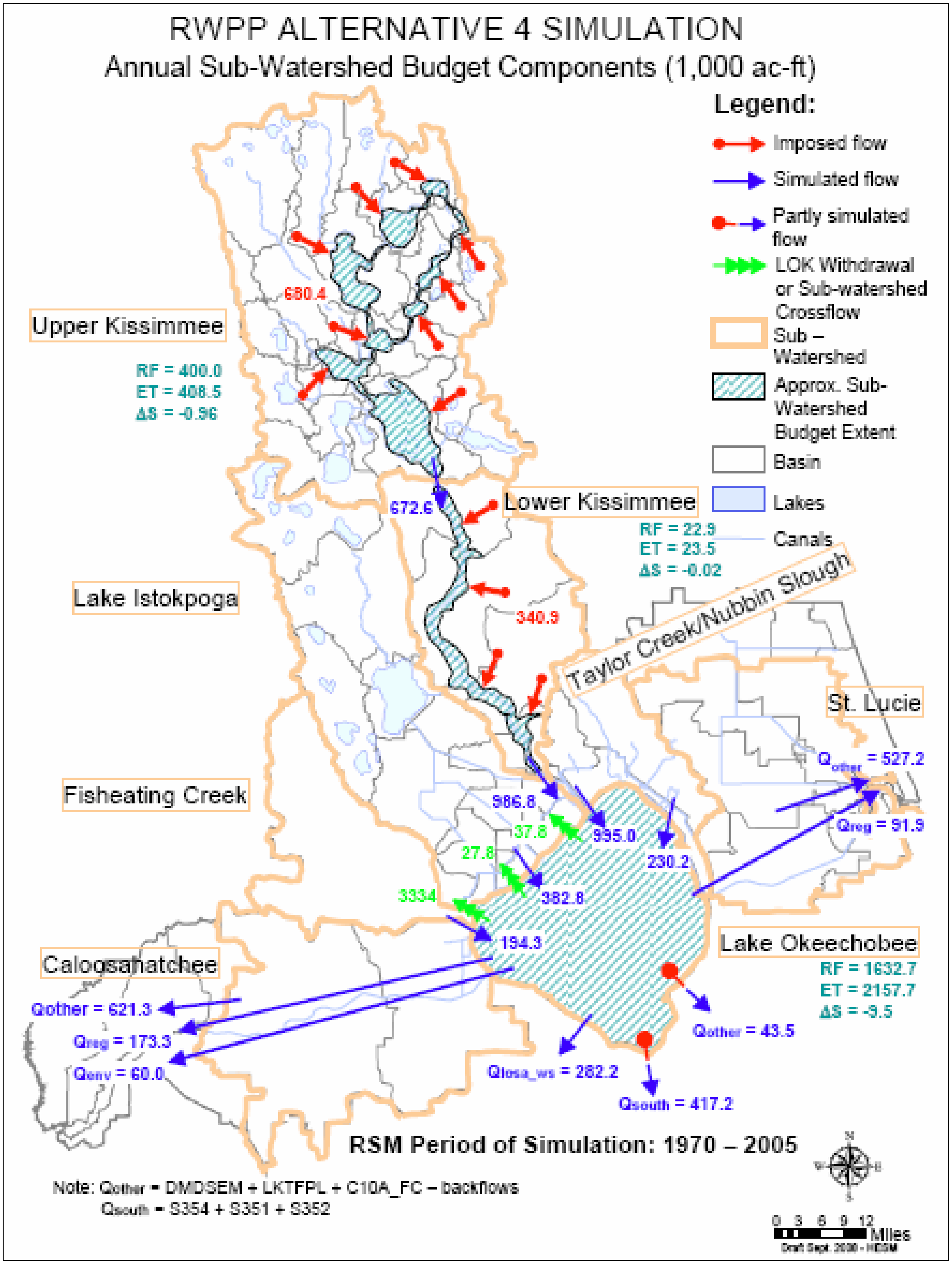


Figure C-24. NERSM calculated annual sub-watershed water budget components for Alternative 4

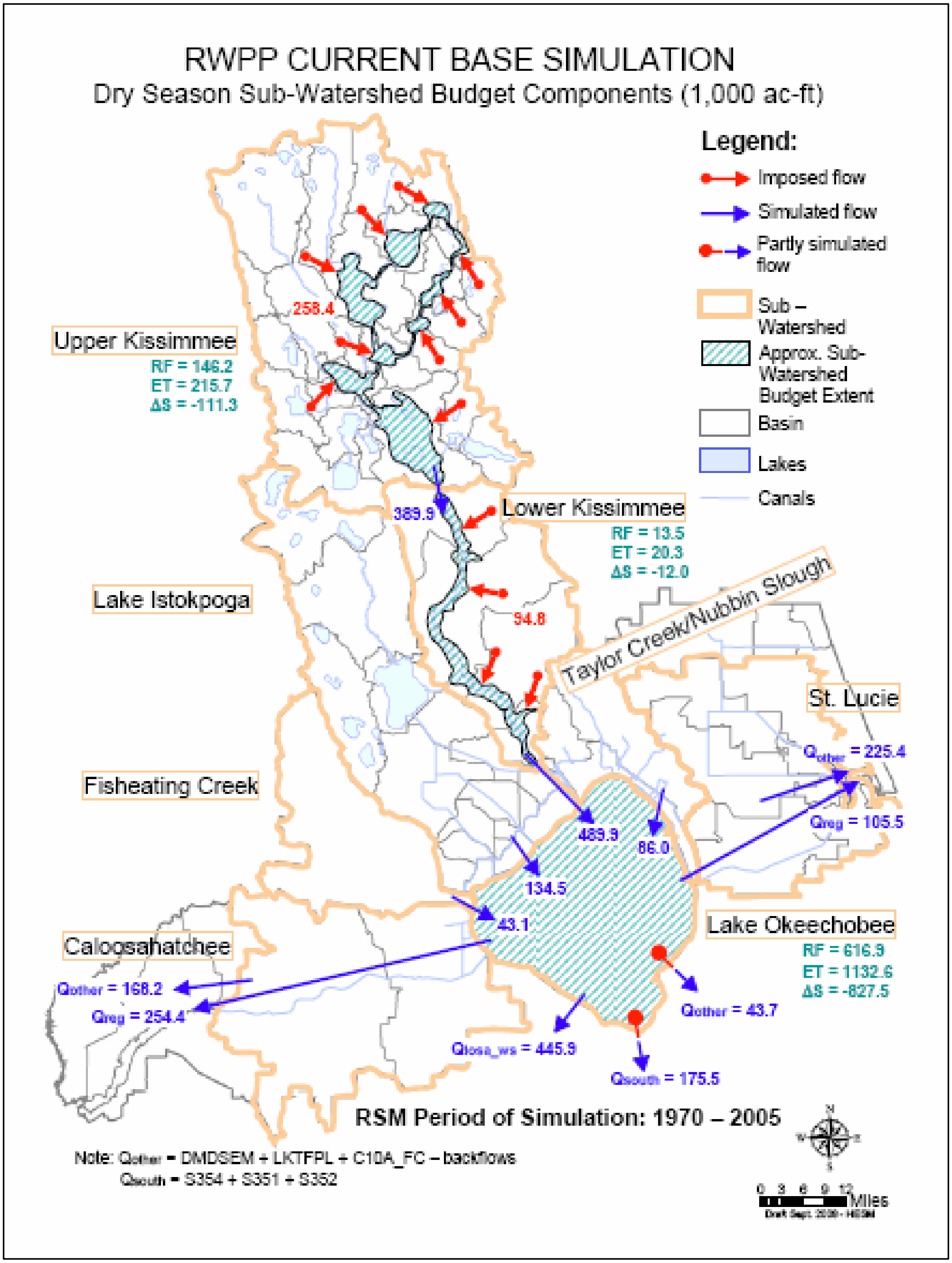


Figure C-25. NERSM calculated dry season sub-watershed water budget components for Current Base

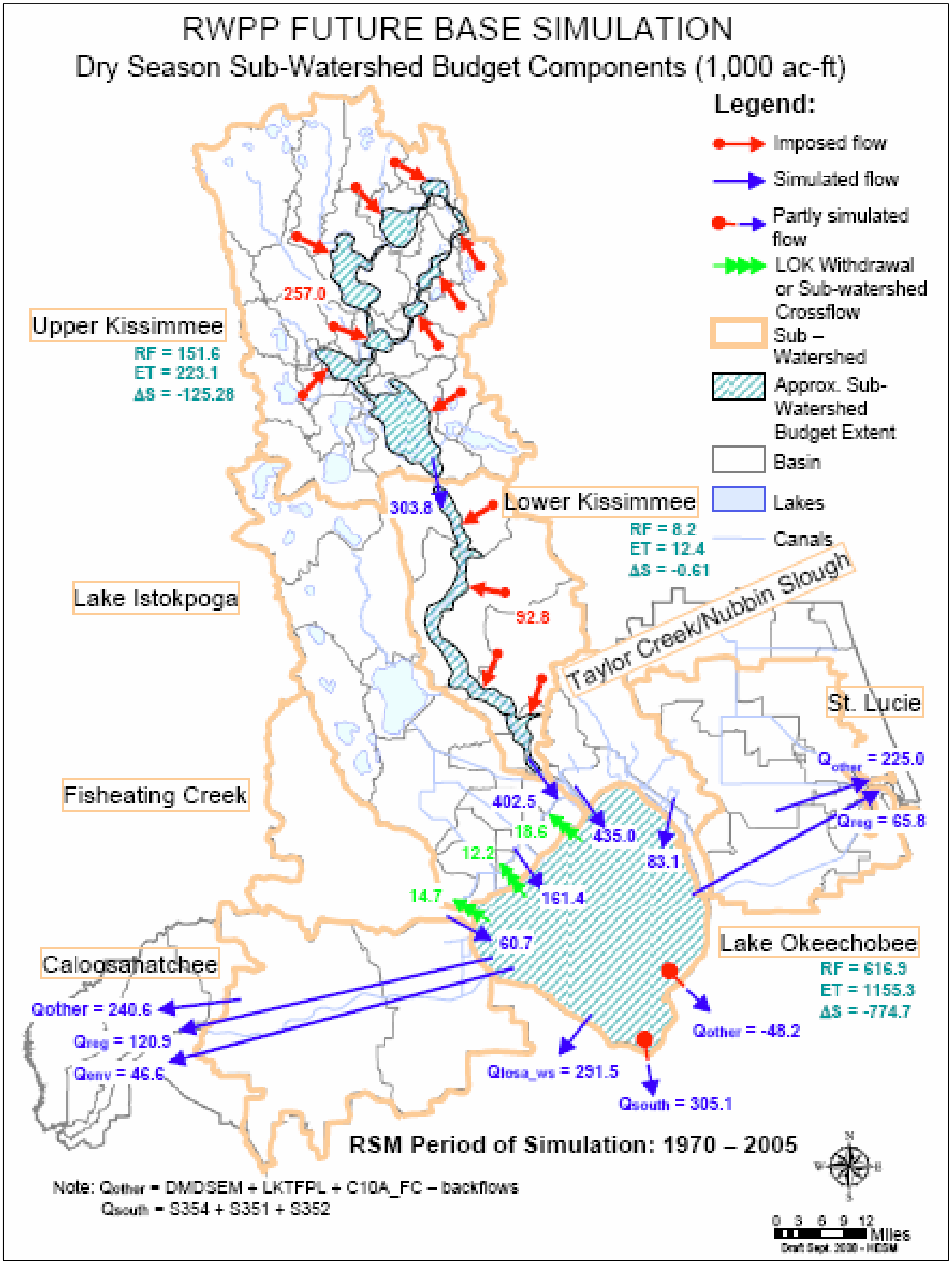


Figure C-26. NERSM calculated dry season sub-watershed water budget components for RWPPB

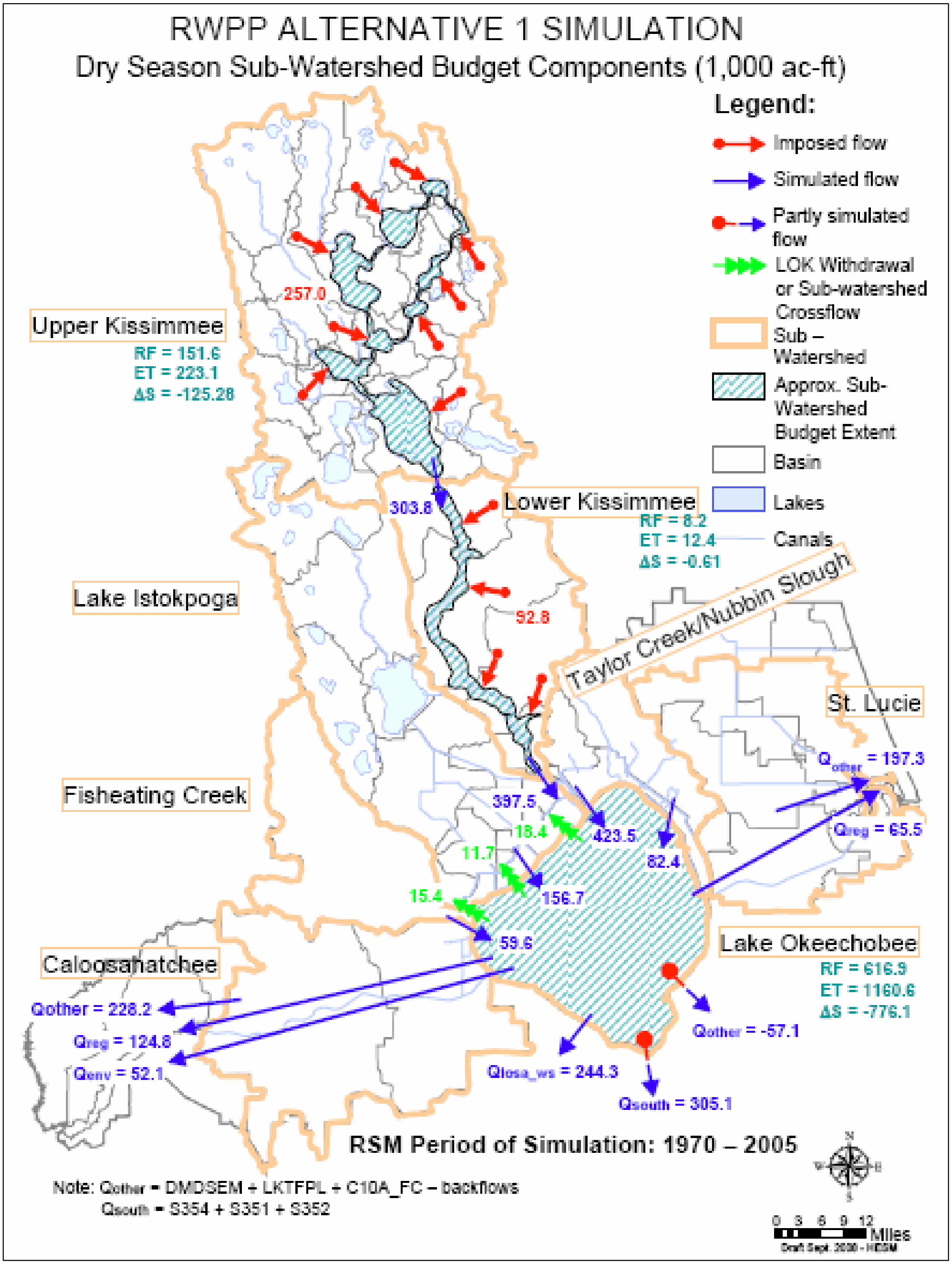


Figure C-27. NERSM calculated dry season sub-watershed water budget components for Alternative 1

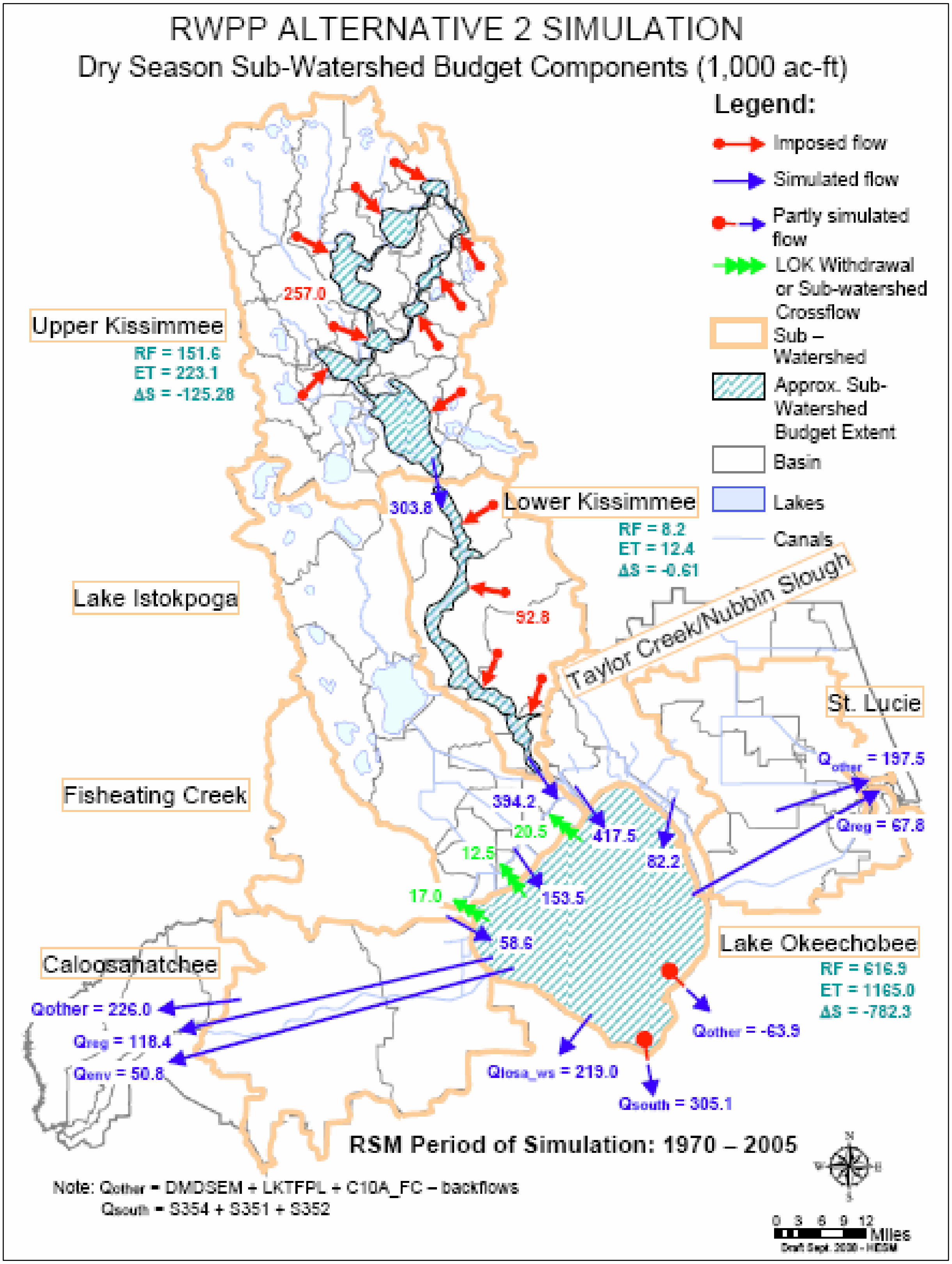


Figure C-28. NERSM calculated dry season sub-watershed water budget components for Alternative 2

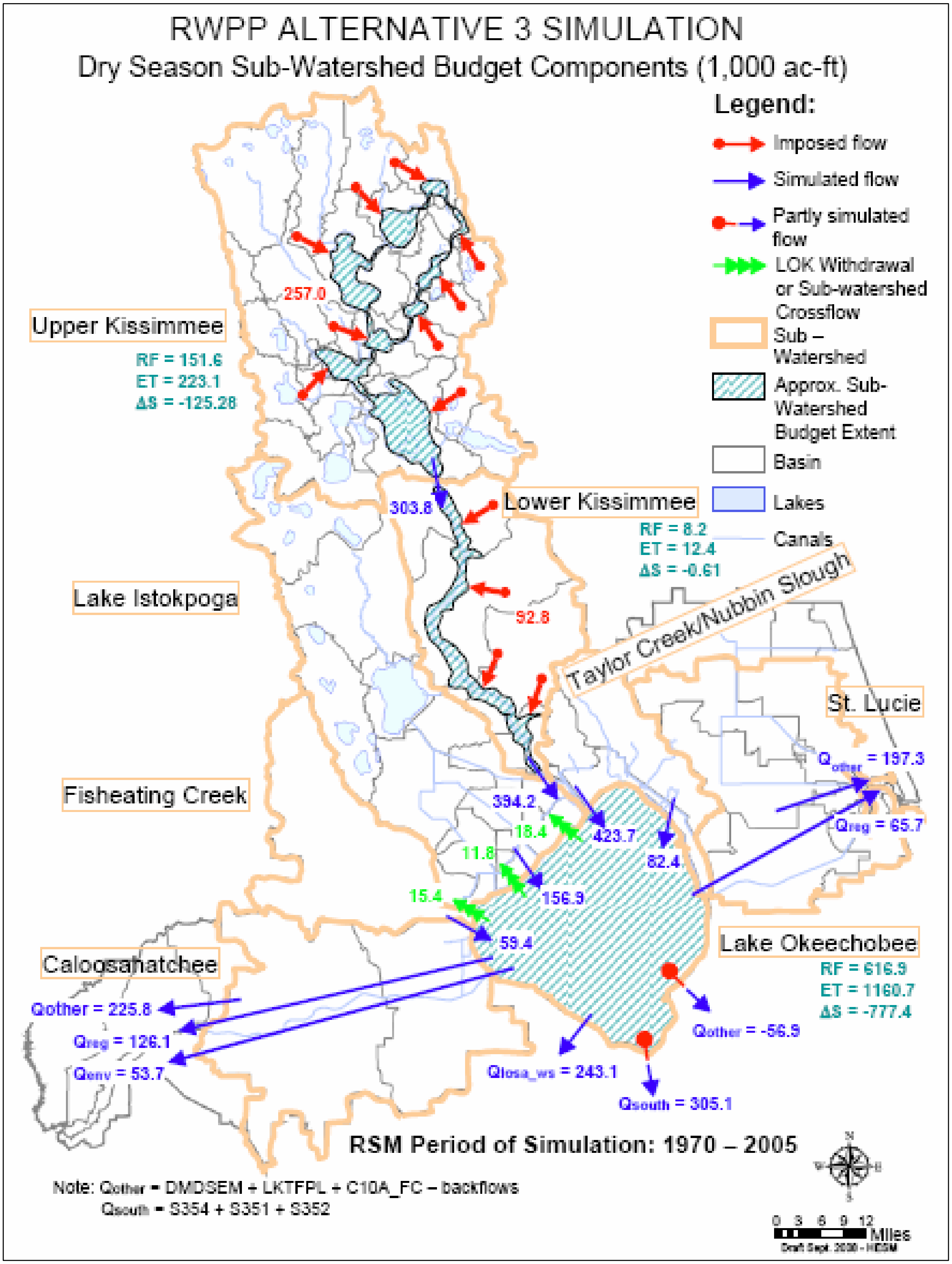


Figure C-29. NERSM calculated dry season sub-watershed water budget components for Alternative 3

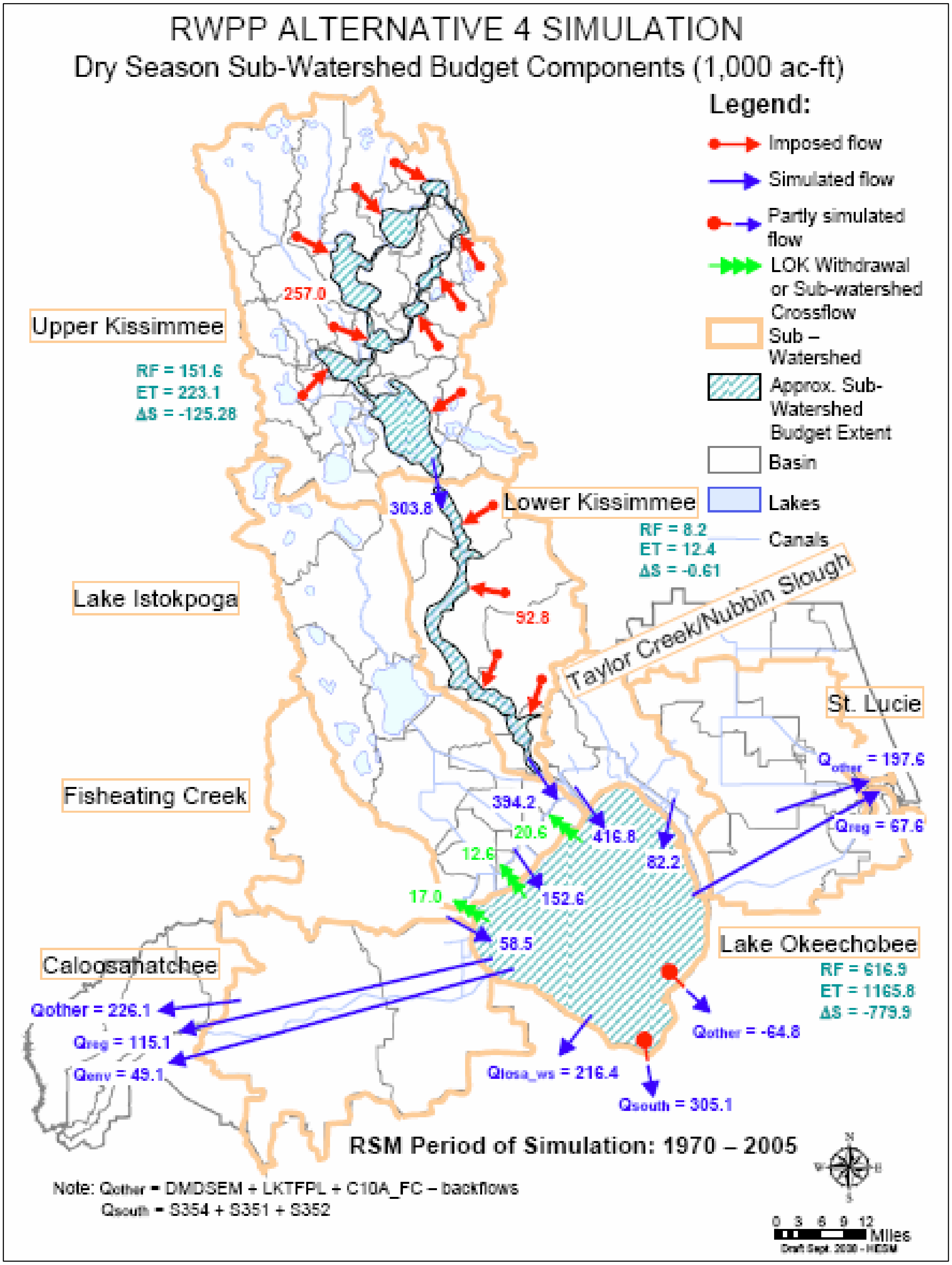


Figure C-30. NERSM calculated dry season sub-watershed water budget components for Alternative 4

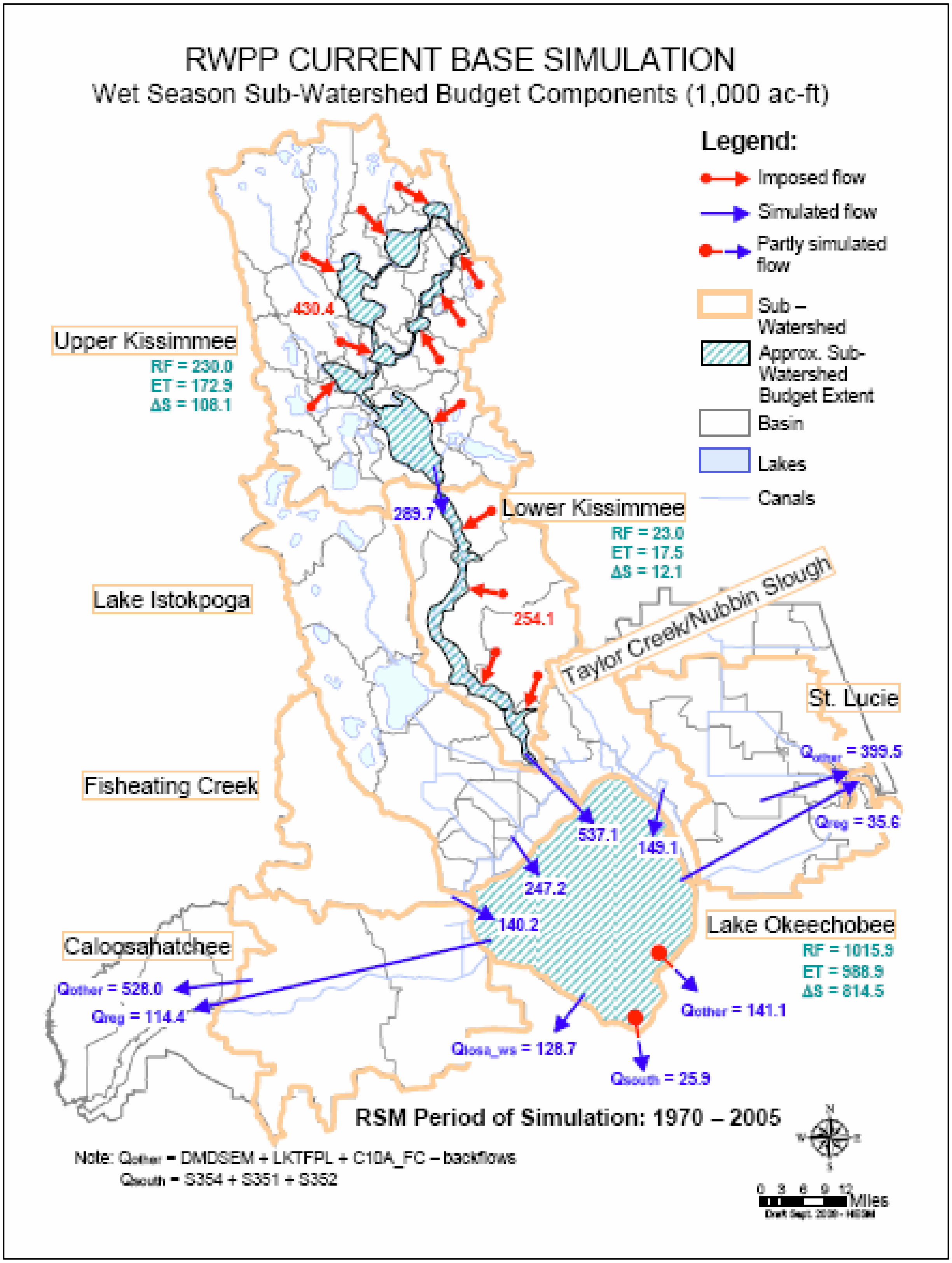


Figure C-31. NERSM calculated wet season sub-watershed water budget components for Current Base

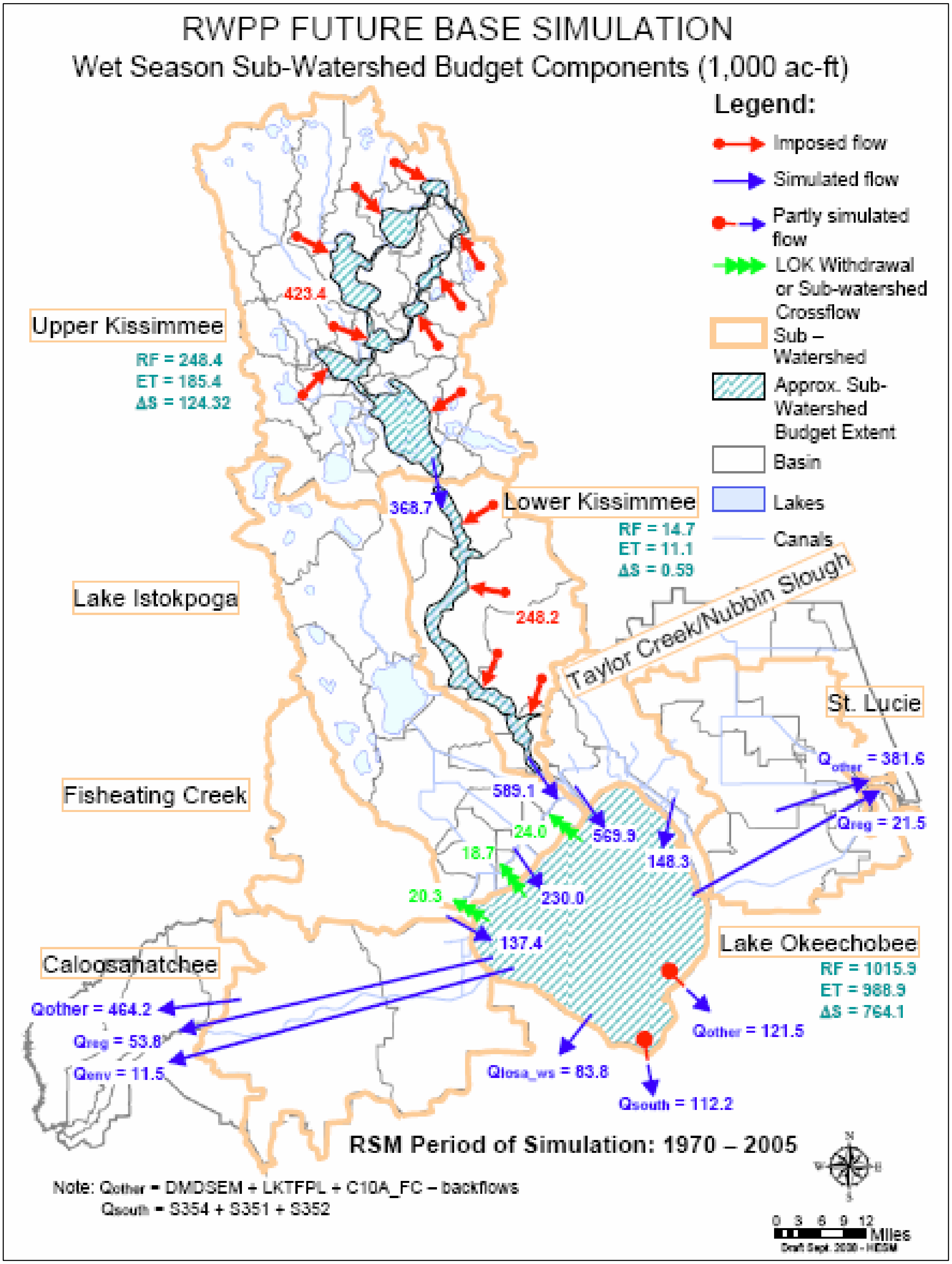


Figure C-32. NERSM calculated wet season sub-watershed water budget components for RWPPB

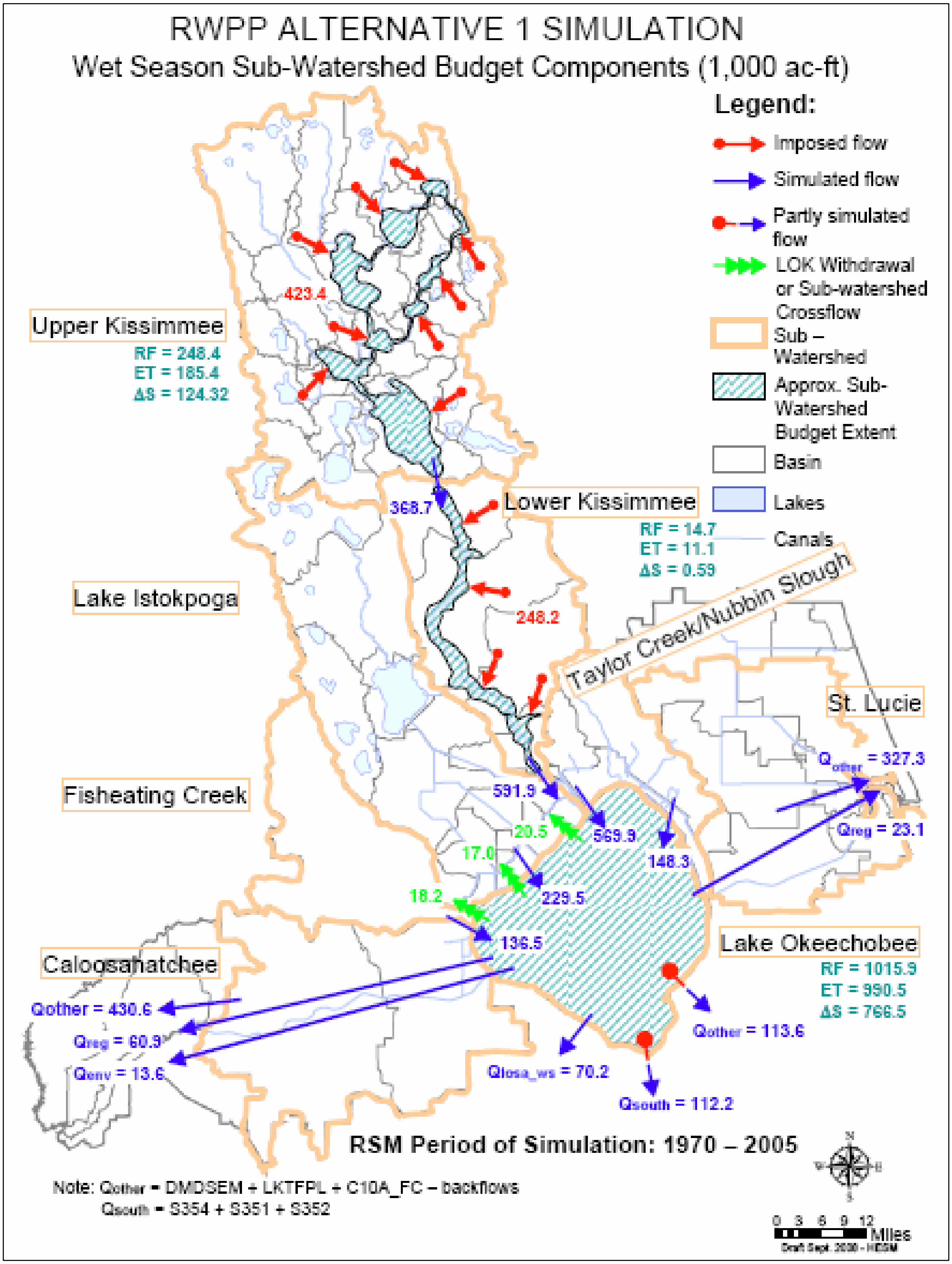


Figure C-33. NERSM calculated wet season sub-watershed water budget components for Alternative 1

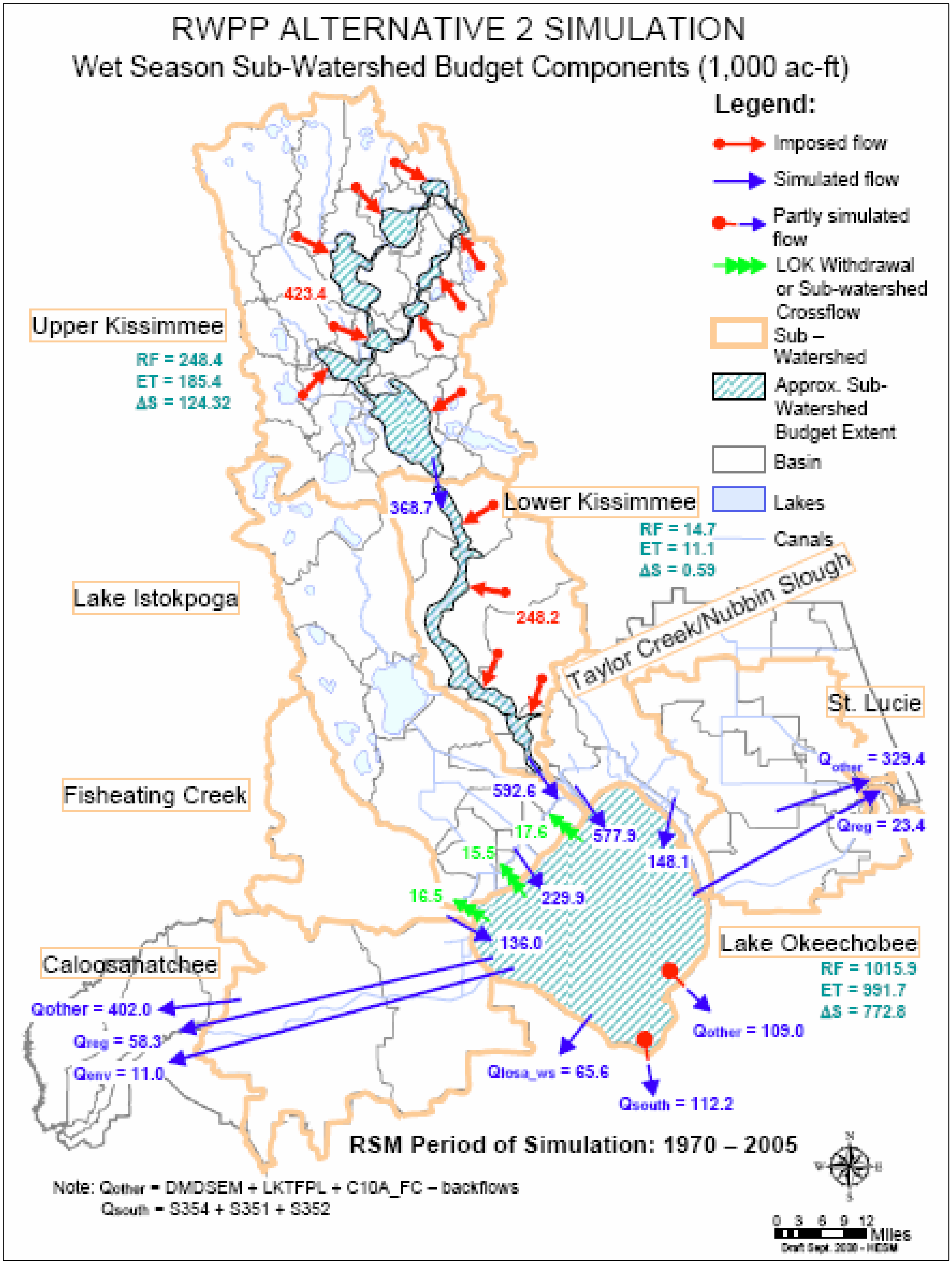


Figure C-34. NERSM calculated wet season sub-watershed water budget components for Alternative 2

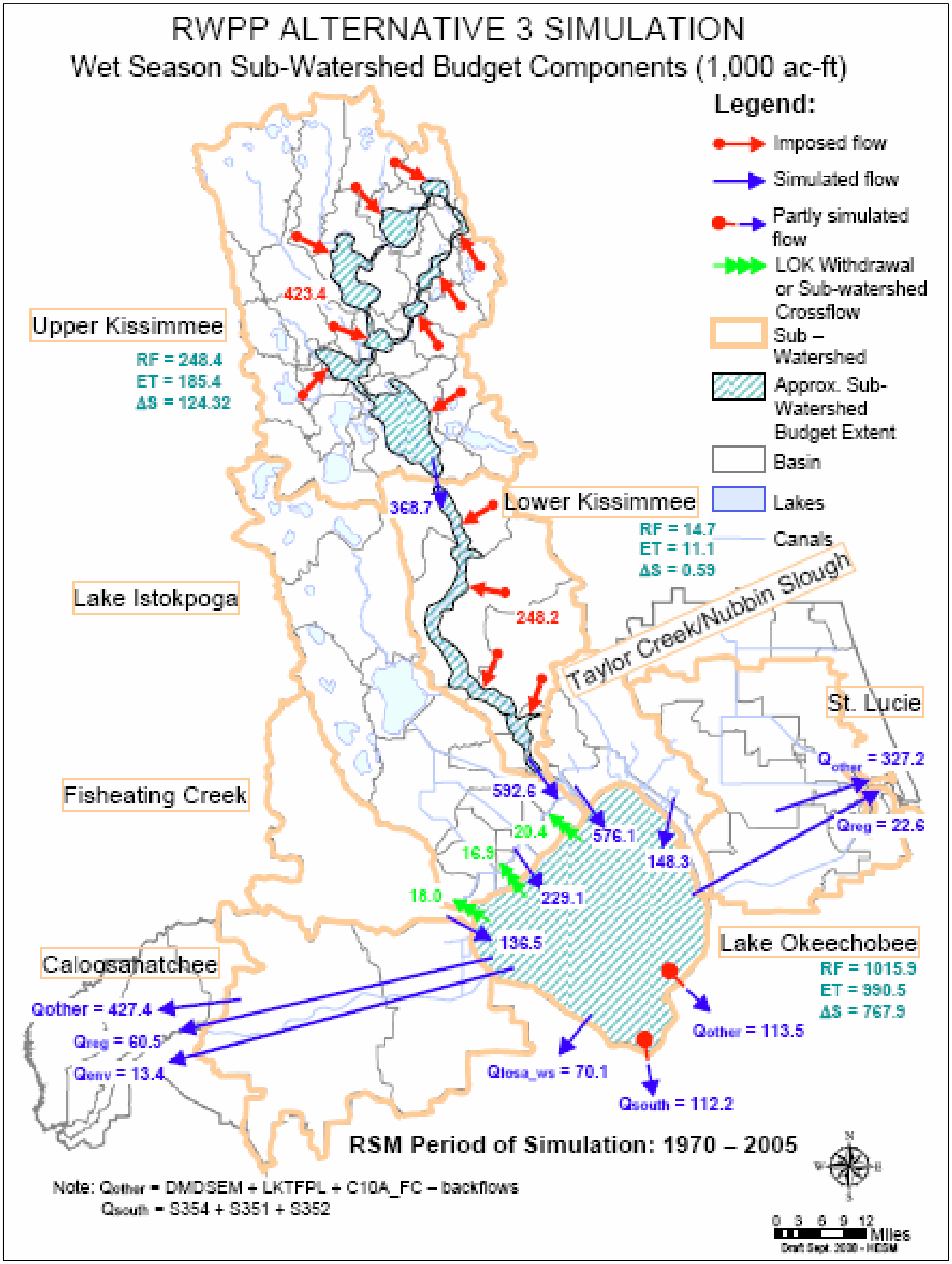


Figure C-35. NERSM calculated wet season sub-watershed water budget components for Alternative 3

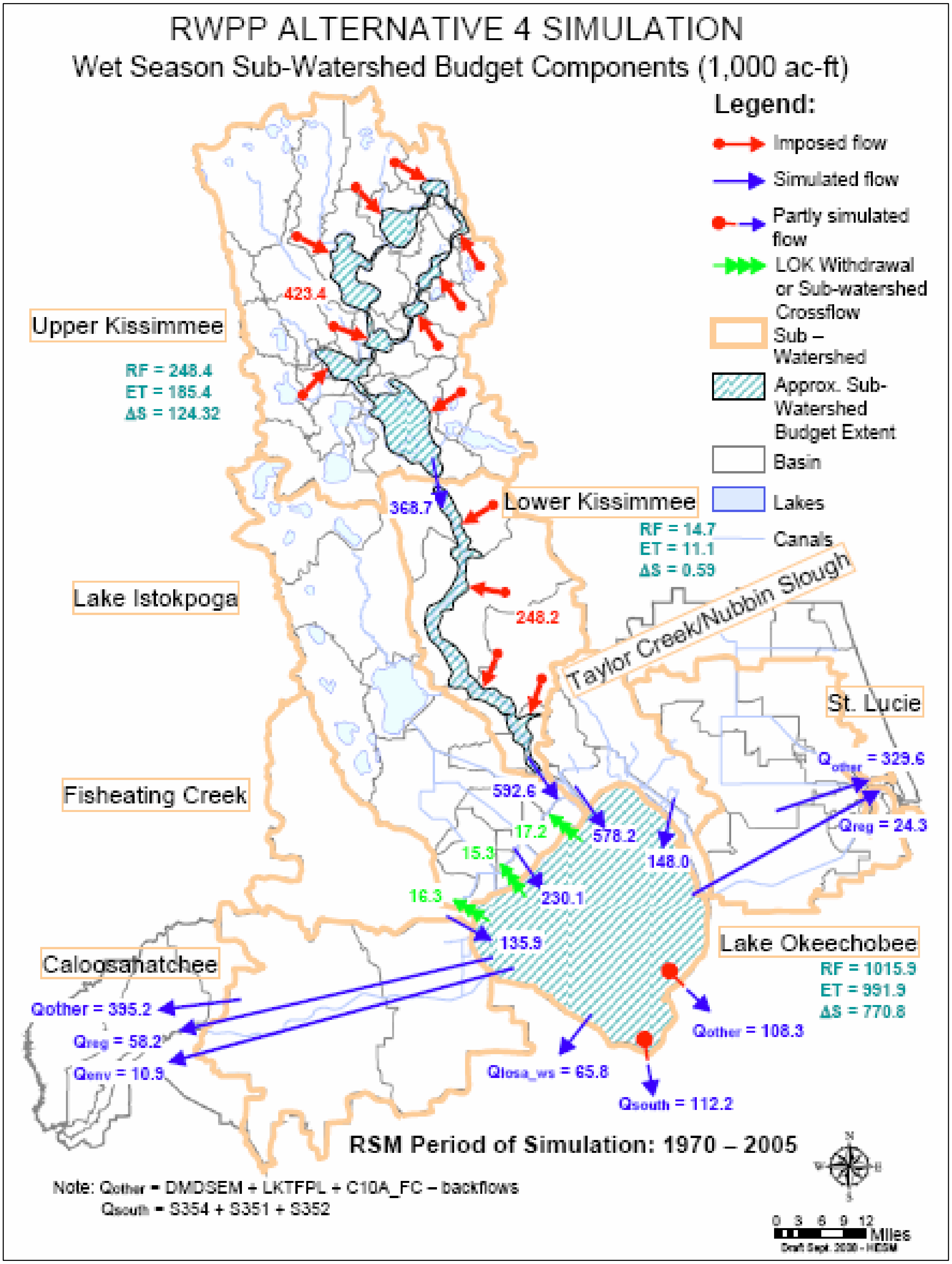


Figure C-36. NERSM calculated wet season sub-watershed water budget components for Alternative 4

C5.0 DETAILED WATER BUDGETS FOR THE CALOOSAHATCHEE AND ST. LUCIE RIVER WATERSHEDS

C5.1 Introduction

Additional annual water budget maps were developed for Caloosahatchee and St. Lucie River Watersheds and their interaction with Lake Okeechobee based on the Future Base conditions and alternative scenarios. Regional water budgets at this level of detail provide a useful means of comparing results from different model simulations and also to perform a quality check on the validity of the simulations.

Figure C-37 is a reference map showing the types of flows from sources to destinations to be summarized in this section. The accompanying **Table C-10** provides a description of all flow types as depicted in the selected water budget components maps corresponding to the modeling scenarios being compared. The number next to each description refers to the numbered arrow on the primary water budget component key.

Water budget maps (**Figures C-38** through **C-42**) are shown for the RWPP Future Base (RWPPB), Alternative 1 (ALT1), Alternative 2 (ALT2), Alternative 3 (ALT3) and Alternative 4 (ALT4). The key reflects the flow arrow on the water budget map, while each individual map reflects only those arrows relative to that particular simulation. The period of simulation is 1970-2005 and the flows shown are annual averages in 1000 acre-feet. In order to simplify the maps, flows are often lumped and represented by a single arrow. In the following discussion, the term "units" refers to 1000 acre-feet.

Table C-10. Description of Flow Types in the Selected Water Budget Components for RWPP

Key	Description
1.	Portion of S77 release from LOK to meet agricultural demands in CRW.
2.	LOK regulatory flow through S77.
3.	LOK environmental flows through S77 (can include LOK regulatory flows).
4.	Backflow to LOK from CRW.
5.	Agricultural water supply from C43 distributed reservoir.
6.	Portion of LOK regulatory release that goes to C43 reservoir.
7.	Portion of LOK regulatory release that goes to C43 distributed reservoir.
8.	Portion of LOK regulatory release that ends up in C43 estuary.
9.	Portion of LOK regulatory release that goes to BOMA.
10.	Flood control release from BOMA to C43 estuary.
11.	Environmental release from BOMA to C43 estuary.
12.	Environmental release from C43 distributed reservoir to C43 estuary.
13.	Portion of C43 runoff that bypasses WCAL Water Quality STA.
14.	Portion of C43 runoff that goes through WCAL Water Quality STA.
15.	Portion of C43 runoff that is treated through WCAL Water Quality STA.
16.	Portion of C43 runoff that goes to C43 distributed reservoir.
17.	Portion of C43 runoff that goes to BOMA.
18.	Portion of C43 runoff that ends up in C43 estuary.
19.	Portion of C43 runoff that is used for C43 estuary environmental demands.
20.	Environmental water supply from C43 reservoir.
21.	C43 runoff that ends up in C43 reservoir.
22.	C43 basin runoff.

Key	Description
23.	Runoff from EAA to LOK
24.	Agricultural water supply to EAA from LOK.
25.	Regulatory releases from LOK to EAA storage reservoir compartment 2.
26.	Backflows from C44 basin to LOK through S308.
27.	Agricultural water supply to C44 basin from LOK through S308.
28.	Regulatory releases from LOK to C44 estuary.
29.	Excess in C44 basin that goes to C44 estuary.
30.	Portion of excess runoff in C44 basin that meets environmental needs of St. Lucie estuary.
31.	Runoff from C44 basin that goes to C44 reservoir.
32.	Agricultural water supply to C44 basin from C44 reservoir.
33.	Environmental water supply to C44 estuary from C44 reservoir.
34.	Excess from non-C44 basins that goes to C44 estuary.
35.	Runoff from non-C44 basins that goes to C44 estuary.
36.	Environmental water supply from LOK to C44 estuary (already included in 27).
37.	C44 basin runoff.
38.	Actual environmental deliveries to C43 estuary from LOK and CRW.
39.	C43 estuary target flow.
40.	Actual environmental deliveries to C44 estuary from LOK and SLRW.
41.	C44 estuary target flow.

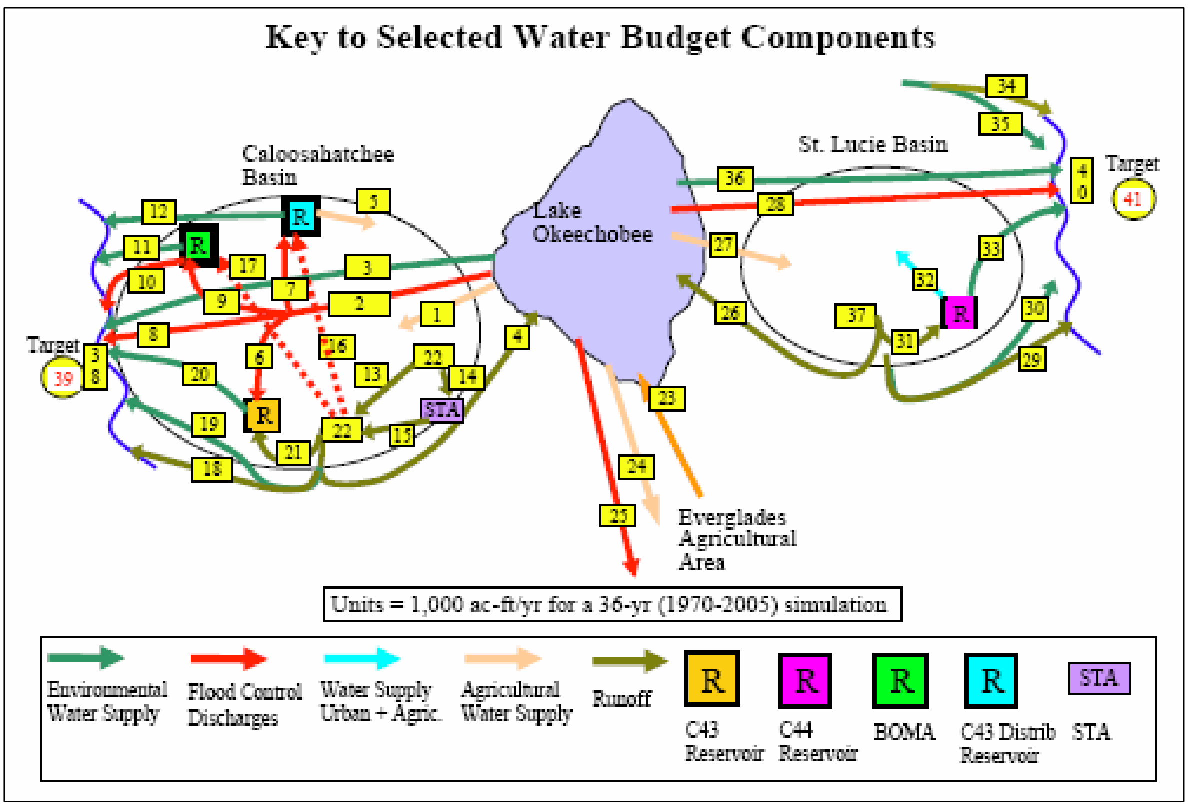


Figure C-37. Key to the selected water budget components for RWPP

C5.2 Annual Water Budget Components for River Watershed Protection Plan Base

Figure C-38 shows the annual average flows (1000 acre-feet) for the RWPP Future Base. For both Caloosahatchee River Watershed (CRW) and St. Lucie River Watershed (SLRW), the actual environmental deliveries to the estuary (530 and 460 units for CRW and SLRW, respectively) are close to the target (537 and 500 units for CRW and SLRW, respectively). The C43 Reservoir provides 31 percent of the environmental deliveries in CRW while the C44 Reservoir provides 3.5 percent of the environmental deliveries in SLRW. Non-C44 basins provide a major portion (82 percent) of the environmental deliveries to the estuary in SLRW. Backflow from the basin to the lake is a larger component in SLRW (53 units) than in CRW (6 units). Agricultural supply from the Lake Okeechobee to the basin is more in CRW (141 units) than in SLRW (21 units) due to higher agricultural demands.

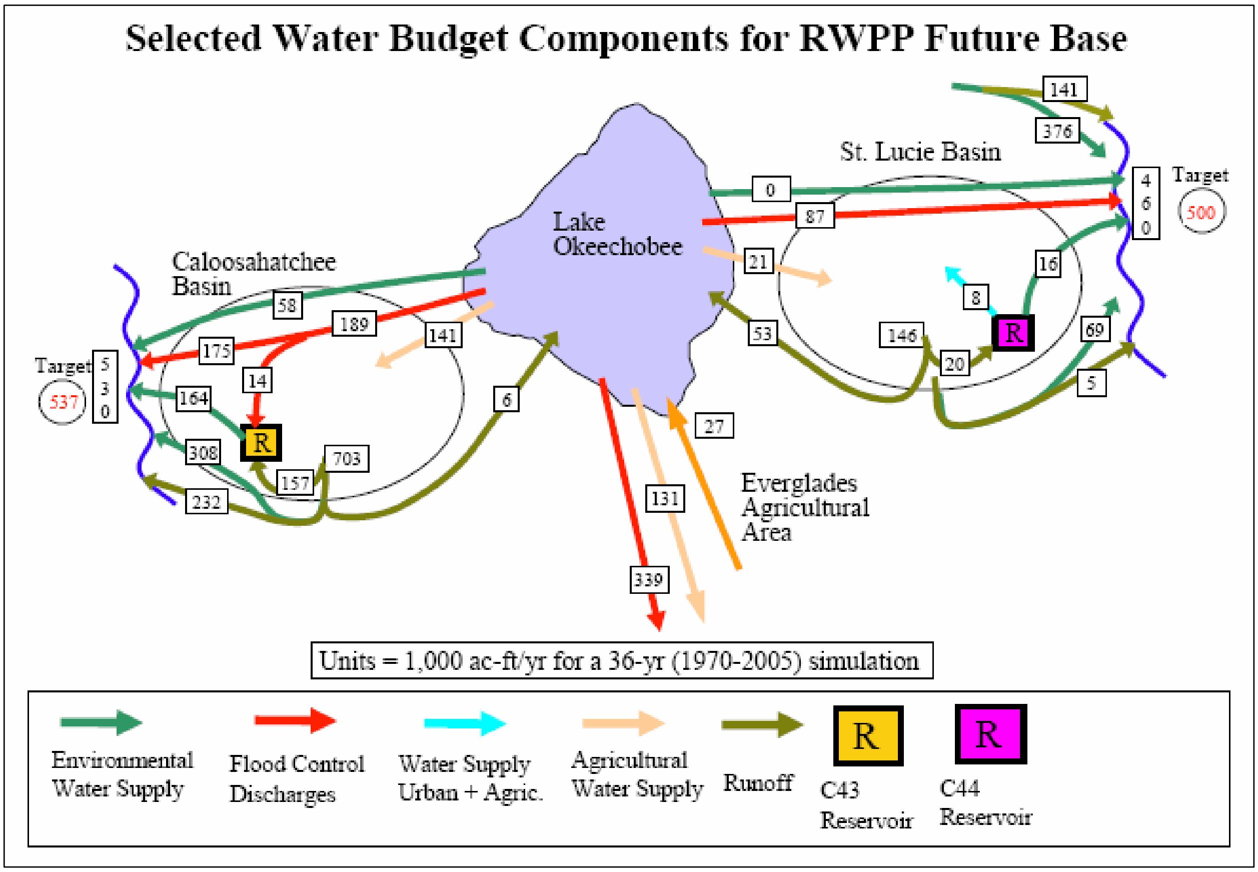


Figure C-38. Selected water budget components for RWPP Future Base

C5.3 Annual Water Budget Components for Alternative 1

Figure C-39 shows the annual average flows (1000 acre-feet) for Alternative 1. There is no new feature for SLRW and the only feature changes are in CRW. Alternative 1 includes the BOMA Reservoir and the C43 Distributed Reservoir in CRW. These two reservoirs aid in storing C43 Basin runoff (54 units in C43 Distributed Reservoir and 15 units in BOMA). The C43 Distributed Reservoir also helps in meeting CRW agricultural demands (54 units), which results in less demands on Lake Okeechobee (a reduction of 38 percent from the Future Base). Changes in SLRW are insignificant from the Future Base.

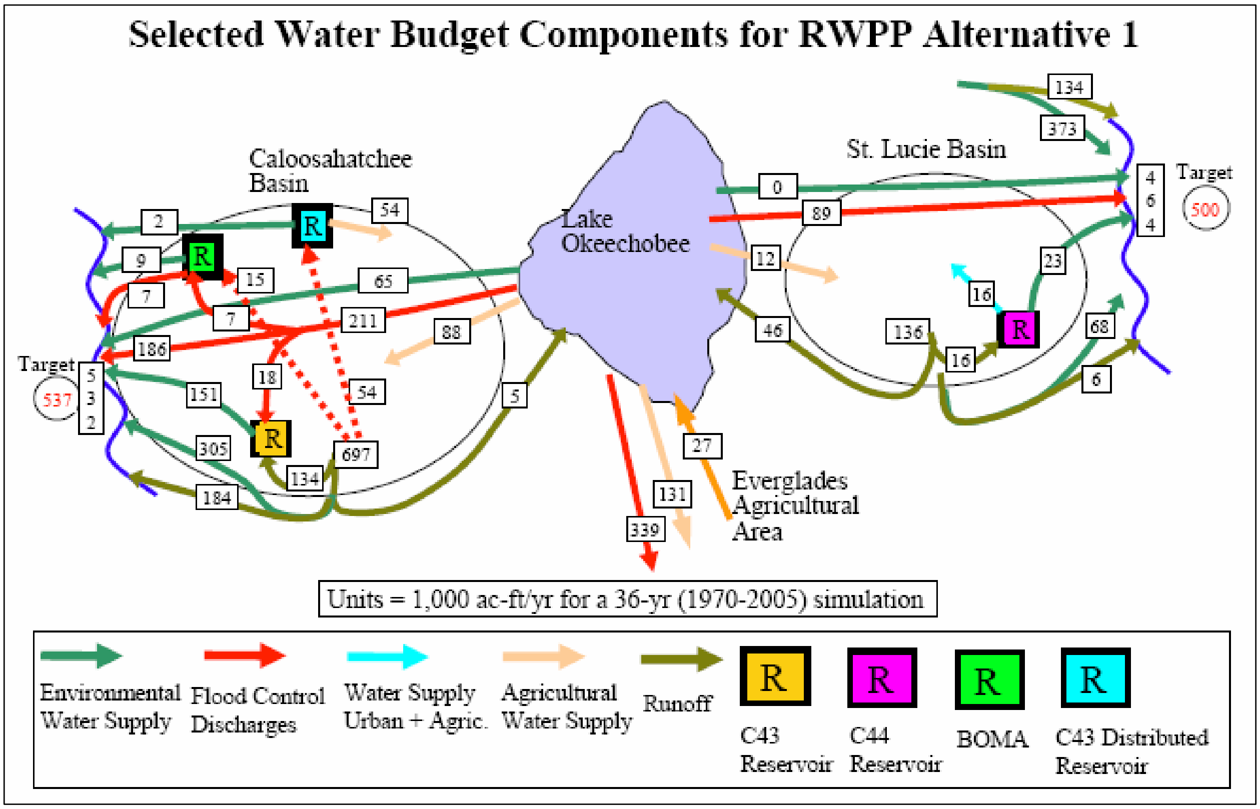


Figure C-39. Selected water budget components for RWPP Alternative 1

C5.4 Annual Water Budget Components for Alternative 2

Figure C-40 shows the annual average flows (1000 acre-feet) for management Alternative 2. There are no new features for SLRW. Additional storage due to East Caloosahatchee Storage and West Lake Hicpochee Project are combined with the C43 Distributed Reservoir to form a single storage node in NERSM for this alternative (designated as “C43 Distributed Reservoir”). Lake Okeechobee regulatory water is allowed to go to C43 Distributed Reservoir (15 units). Due to the increased size of the C43 Distributed Reservoir, it gets more water (114 units) than in ALT1 (54 units). As a result, the C43 Distributed Reservoir supplies more water for agricultural needs (85 units; an increase of 57 percent over alternative 1) and therefore there is less demand on Lake Okeechobee to provide for C43 Basin agricultural water needs (35 percent reduction over alternative 1).

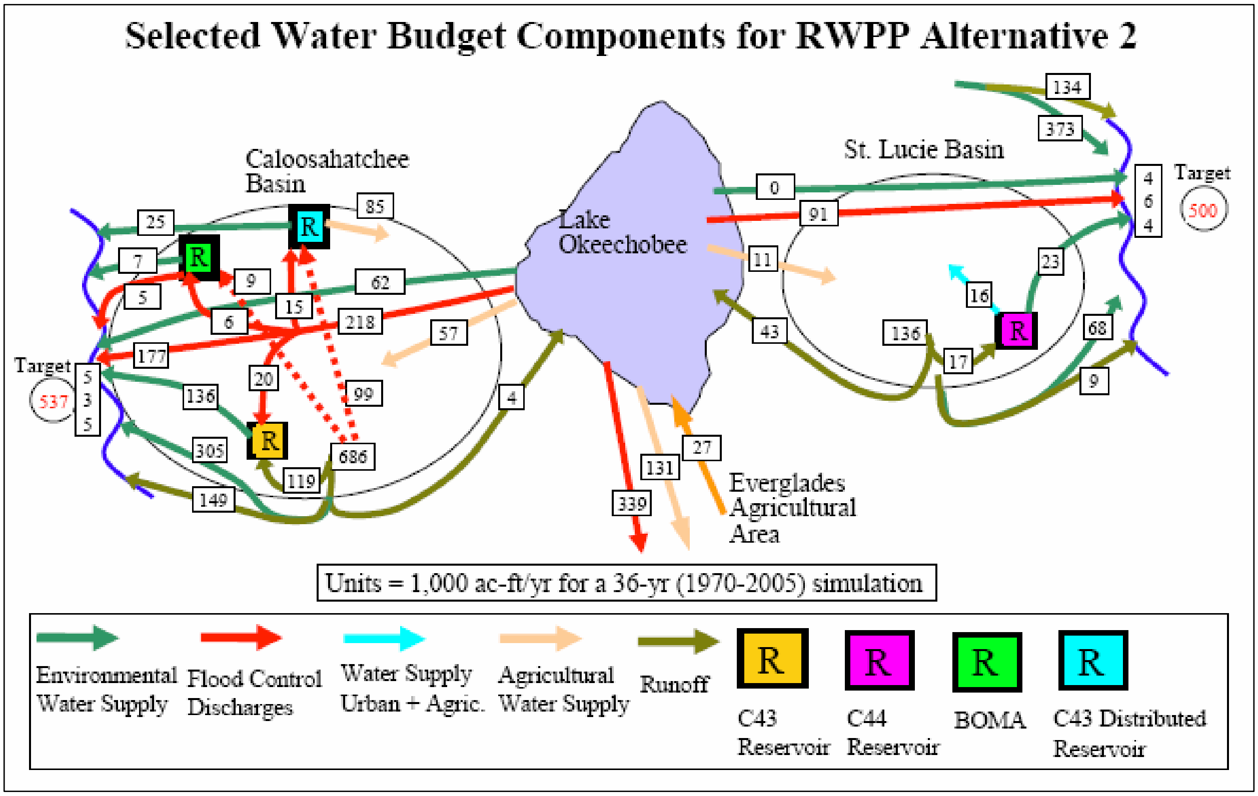


Figure C-40. Selected water budget components for RWPP Alternative 2

C5.5 Annual Water Budget Components for Alternative 3

Figure C-41 shows the annual average flows (1000 acre-feet) for Alternative 3. This management alternative includes a water quality storage node (designated as an STA) that represents the combination of Caloosahatchee Ecoscape Water Quality Treatment Area and the West Caloosahatchee Water Quality Treatment Area. The operation and size of the C43 Distributed Reservoir is the same as in Alternative 1. This management alternative performs very close to Alternative 1, except 10 percent of C43 Basin runoff (71 units out of 692 units) is treated through the water quality STA. Note that the total basin runoff is reduced in proportion to the STA footprint taken up by the management measure in consideration, e.g. 697 units in ALT1 and 692 units in ALT2.

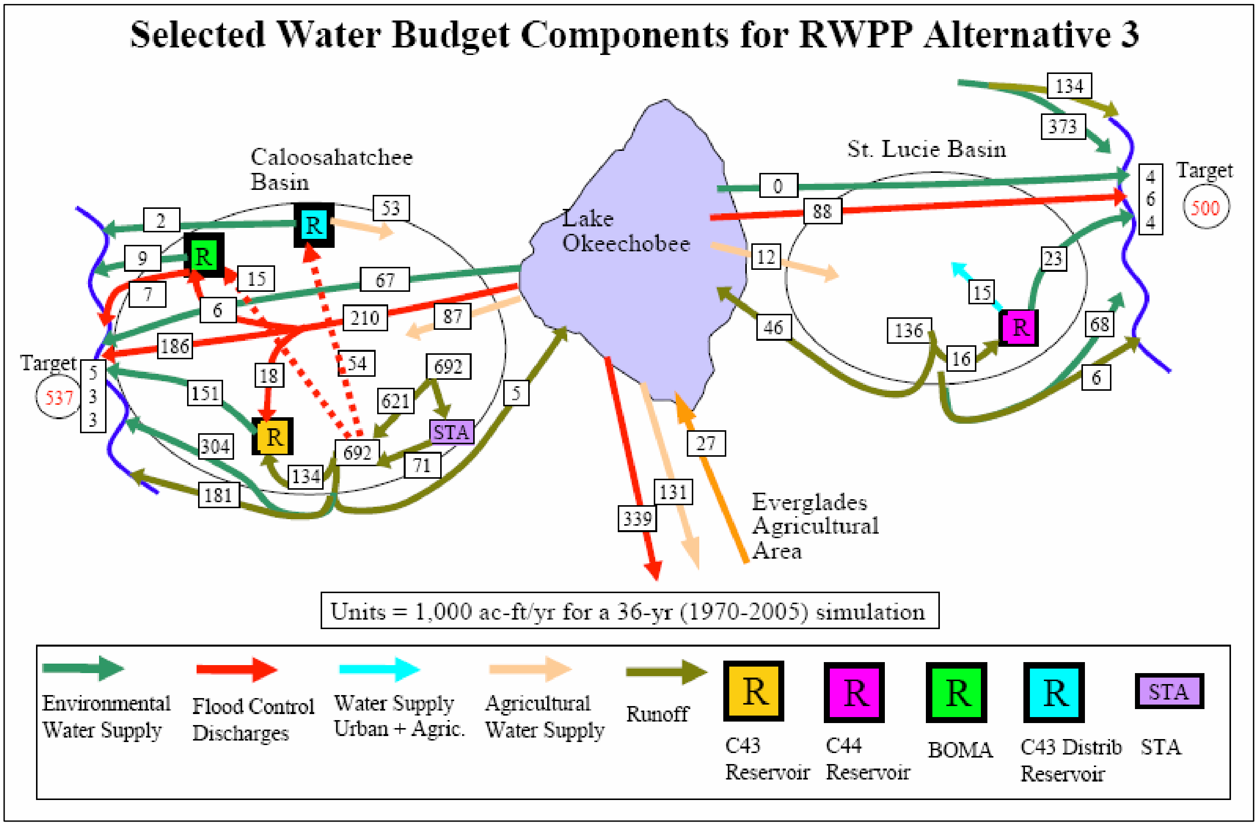


Figure C-41. Selected water budget components for RWPP Alternative 3

C5.6 Annual Water Budget Components for Alternative 4

Figure C-42 shows the annual average flows (1000 acre-feet) for Alternative 4. This management alternative combines the water quality MMs from Alternative 3 and the operation and increased storage facilities based on scenario runs built off of Alternative 2 (Section C6.0). This management alternative performs similar to Alternative 2, in terms of the standard set of performance measure graphics. In addition, 10 percent of C43 Basin runoff (71 units out of 695 units) is treated through the water quality MMs as in Alternative 3.

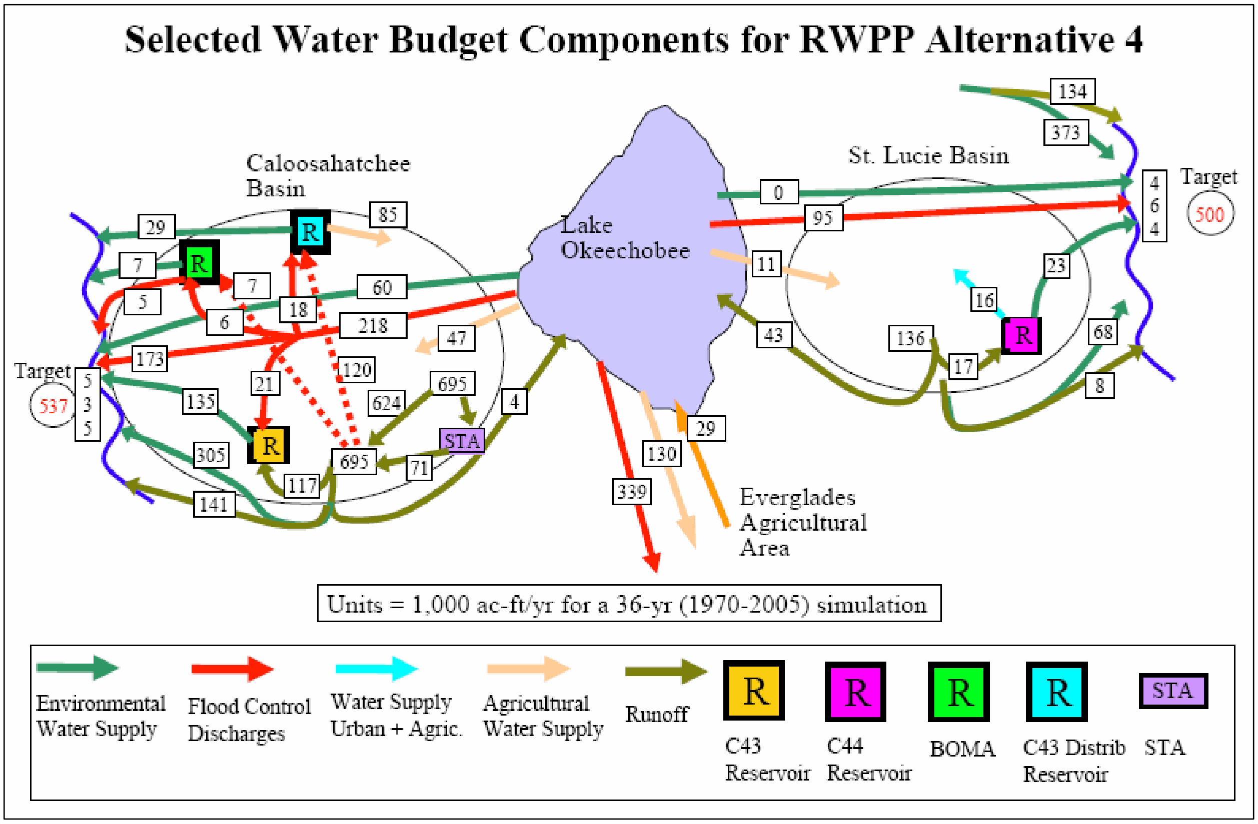


Figure C-42. Selected water budget components for RWPP Alternative 4

C6.0 SENSITIVITY ANALYSES FOR STORAGE CAPACITY SCENARIOS IN THE CALOOSAHATCHE RIVER WATERSHED

C6.1 Methodology

A sensitivity analysis on the impact of storage capacity in the Caloosahatchee Basin was conducted on Alternative 2, to evaluate the potential benefits from incrementally larger storage capacities. The added storage capacities located in the East Caloosahatchee Basin, ranging from 163,890 acre-feet for ALT2 to 563,890 acre-feet for ALT2D. The analyses are focused on the performance of Lake Okeechobee, the estuaries, and water supply. Implementation issues such as cost, real estate availability, etc. were not considered.

C6.2 Scenario Runs: Alternatives 2, 2A, 2B, 2C and 2D

Four scenario runs were performed by increasing the total storage capacity (including C43 Reservoir in the West Caloosahatchee Basin) in Alternative 2, as shown in **Table C-11**.

Table C-11. Storage Capacities (in acre-feet) of Alternative 2 Scenario Simulations in Caloosahatchee River Watershed

Scenario Run	ALT2	ALT2A	ALT2B	ALT2C	ALT2D
Storage Capacity (ac-ft)	342,490	392,490	492,490	642,490	742,490

C6.3 Performance Measures

The storage capacity scenarios were simulated over a 36-yr period of record from 1970 to 2005. Performances of each scenario were evaluated using the same set of RECOVER performance measures that were used in the evaluation of the RWPP Future Base and the original set of alternatives (Section 6.5).

C6.3.1 Lake Okeechobee

As can be seen in the Lake Okeechobee stage duration curve (**Figure C-43**), the change of storage capacity in Caloosahatchee has very small impact on lake stage.

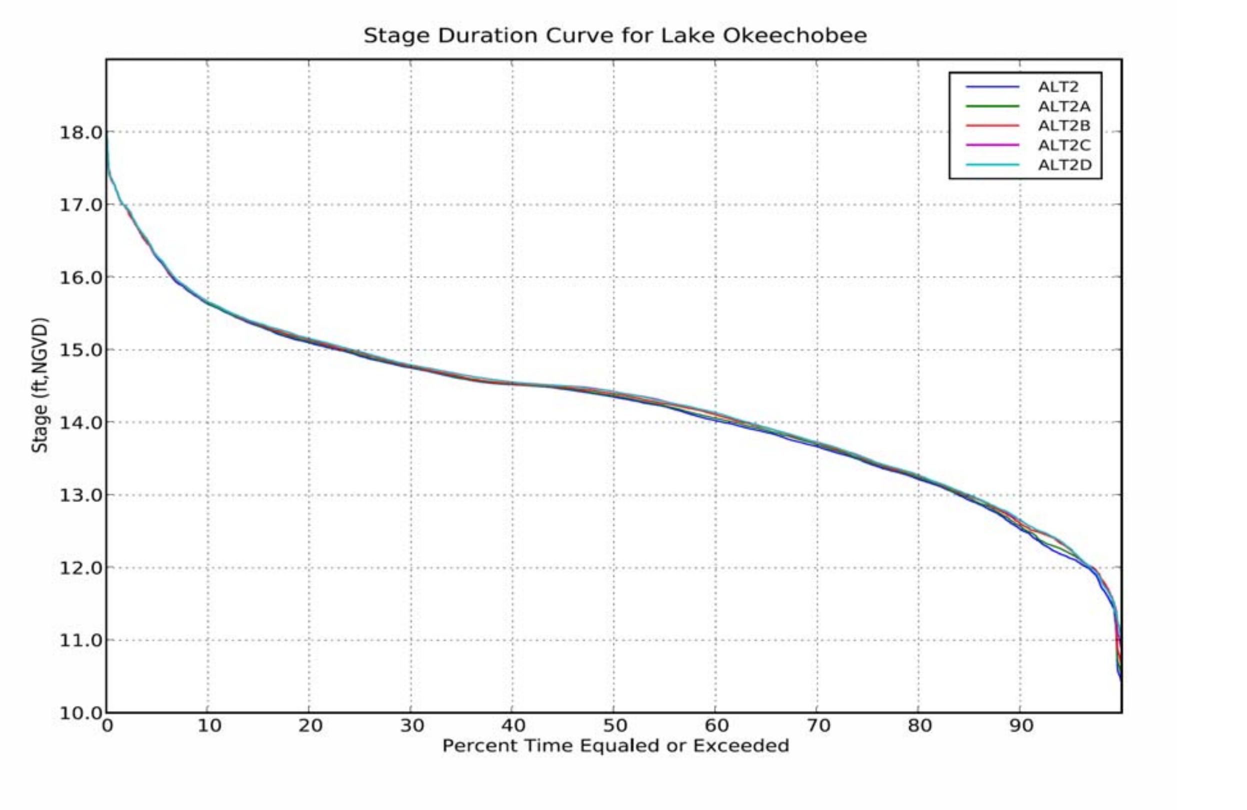


Figure C-43. Lake Okeechobee stage exceedance curves for scenario runs

C6.3.2 Estuaries

As shown in **Figure C-44**, the number of times that mean monthly estuary flow is greater than 2,800 cfs decreases with increases in storage capacity: from 47 times in ALT 2 to 38 times in ALT 2D. The number of times that mean monthly flow is over 4,500 cfs also dropped from 17 times in ALT 2 to 14 times in ALT 2D. The increase of storage capacity benefits the high estuary flow criteria to a limited extent. From **Figure C-45**, there is no significant change in the number of low flow occurrences (mean monthly flow less than 450 cfs), except from ALT2 to ALT2A when it decreased by 50 percent: from six to three occurrences.

Since the storage capacity changes were made in the Caloosahatchee Basin only, the performance of St. Lucie Estuary was only slightly affected. **Figure C-46** shows that the number of times mean monthly estuary flow is between 2,000 cfs and 3,000 cfs increases from 24 to 26 times from ALT2 to ALT2A; and stays the same (26) for the remaining scenario runs. In general, the performance of the scenario runs moved further away from the target (21). **Figure C-47** shows that the influence of storage capacity changes in the Caloosahatchee Basin has very little impact on the St. Lucie Estuary salinity envelope criteria, if at all.

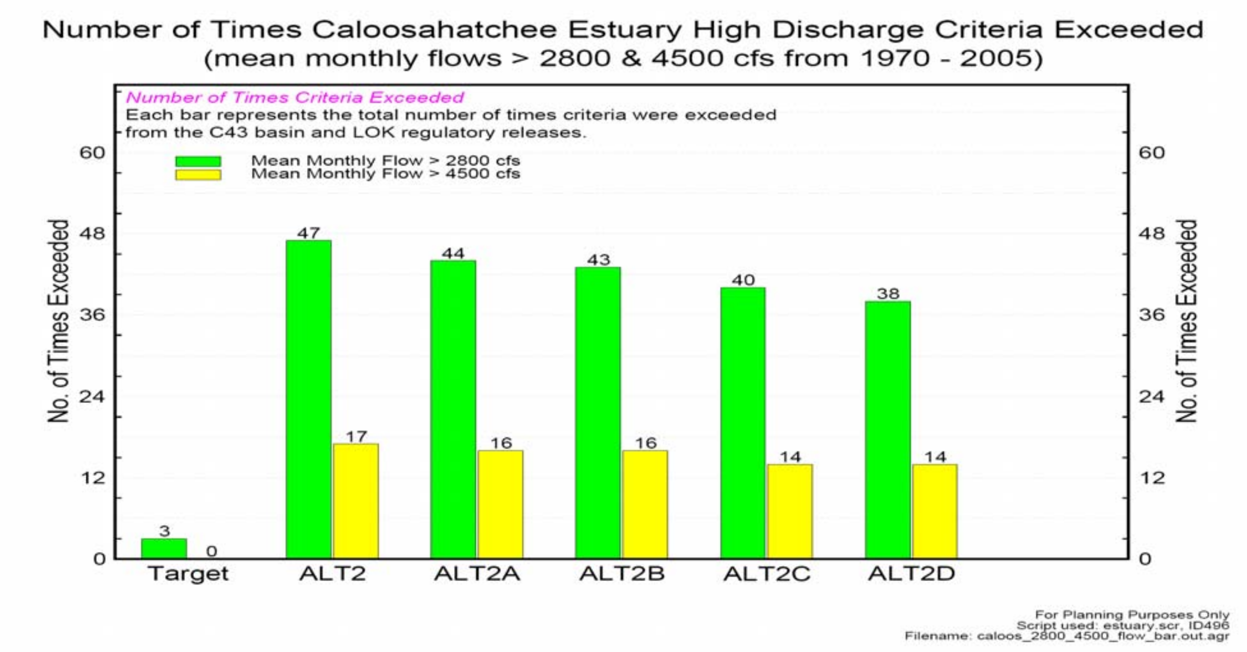


Figure C-44. Number of times Caloosahatchee Estuary high discharge criteria exceeded

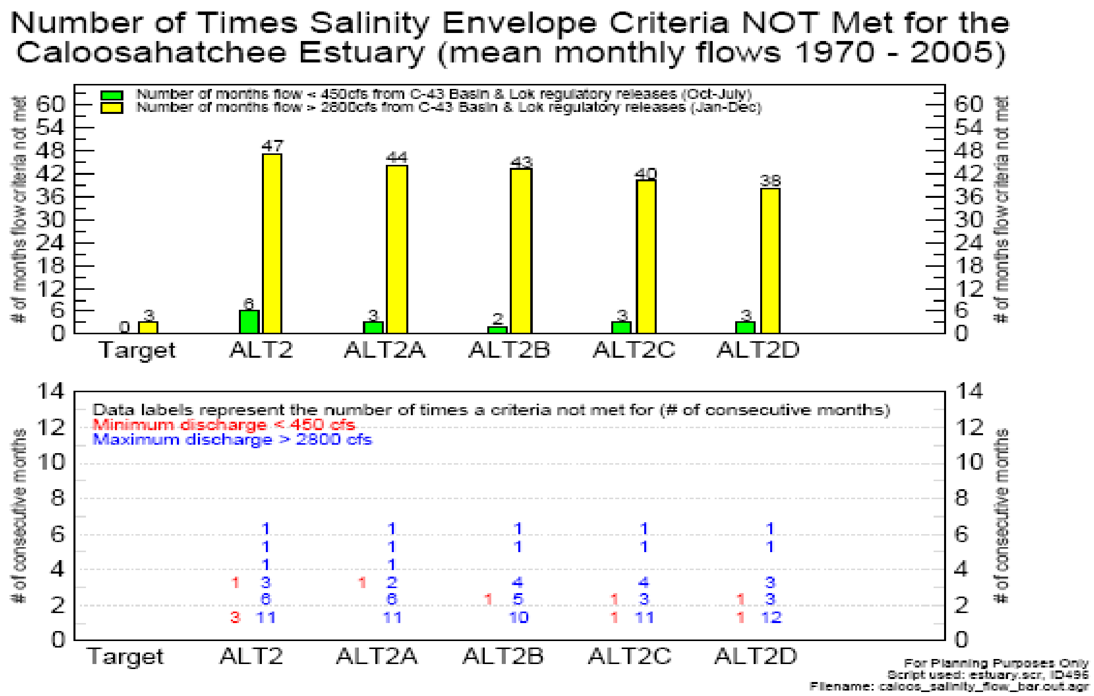


Figure C-45. Number of times salinity envelope criteria not met for the Caloosahatchee Estuary

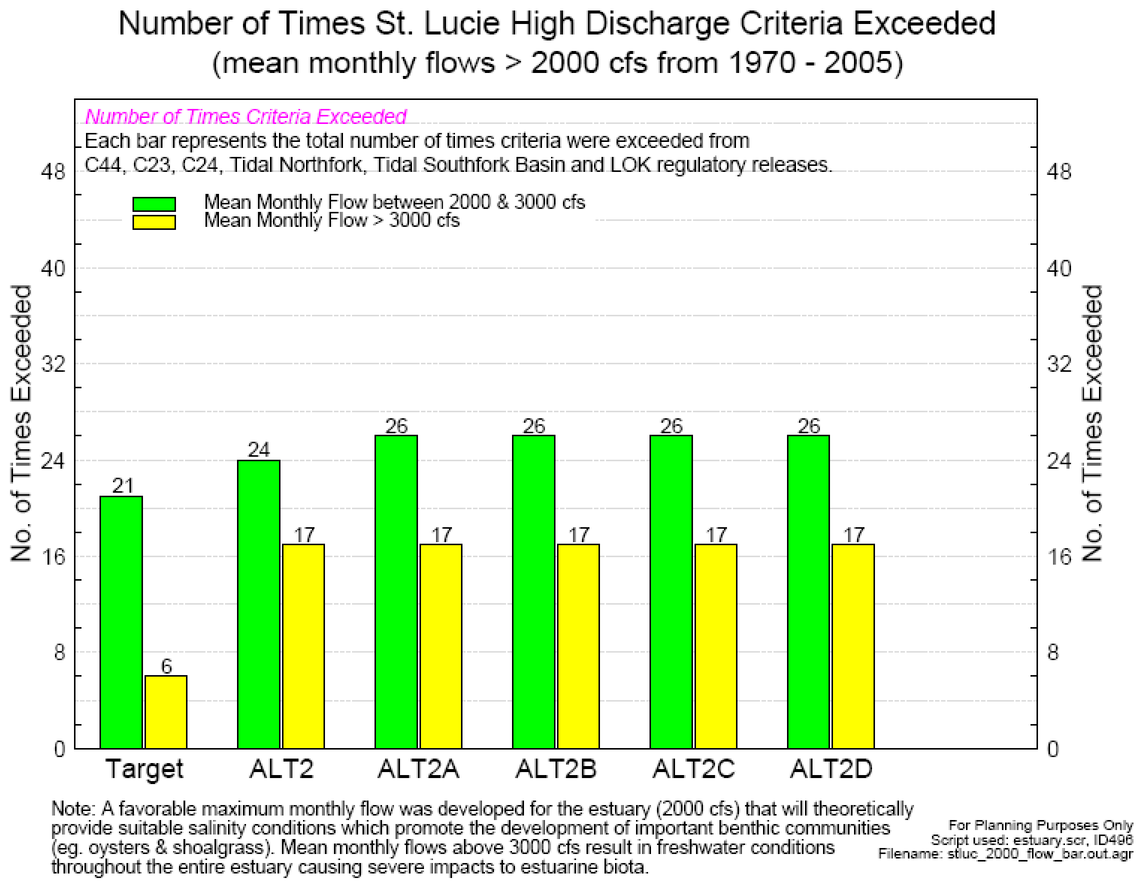


Figure C-46. Number of times St. Lucie Estuary high discharge criteria exceeded

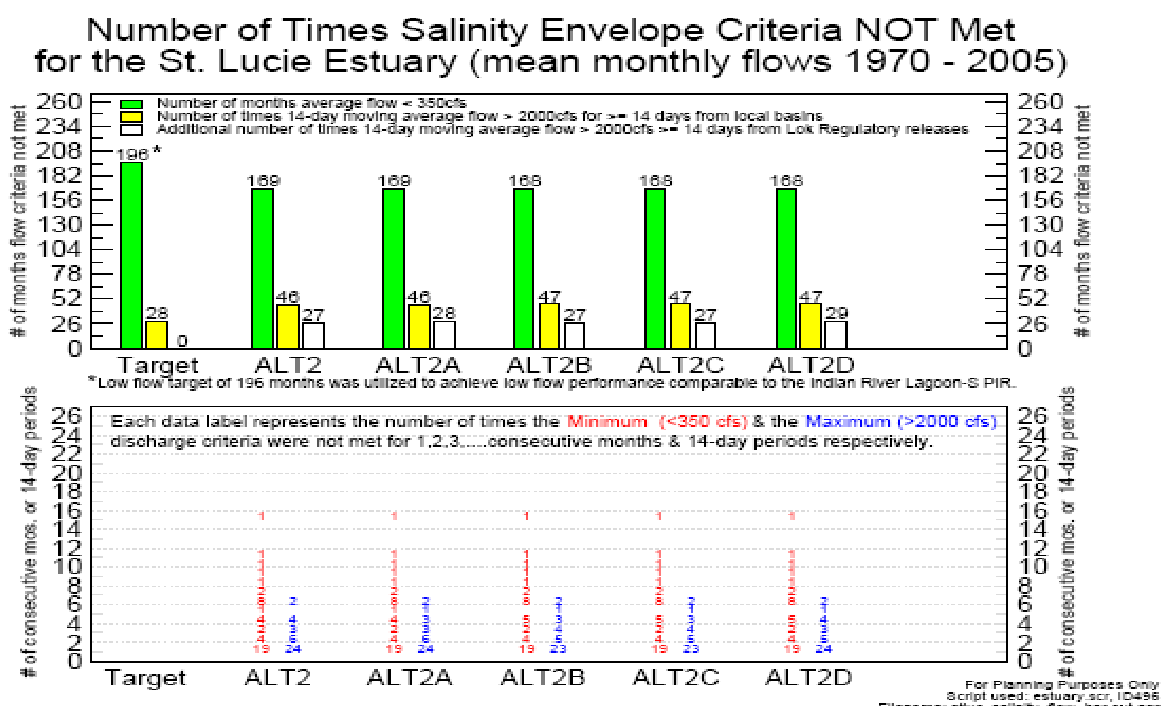


Figure C-47. Number of times salinity envelope criteria not met for the St. Lucie Estuary

C6.3.3 Lake Okeechobee Service Area

Figure C-48 shows the demand cutback volumes for the seven years within the simulation period with the largest cutbacks. The figure shows that LOSA demand cutback volumes decrease with increasing storage capacity, with the maximum reduction in 2001.

The annual EAA/LOSA supplemental irrigation plots (**Figure C-49**) show no significant difference among different storage capacity runs.

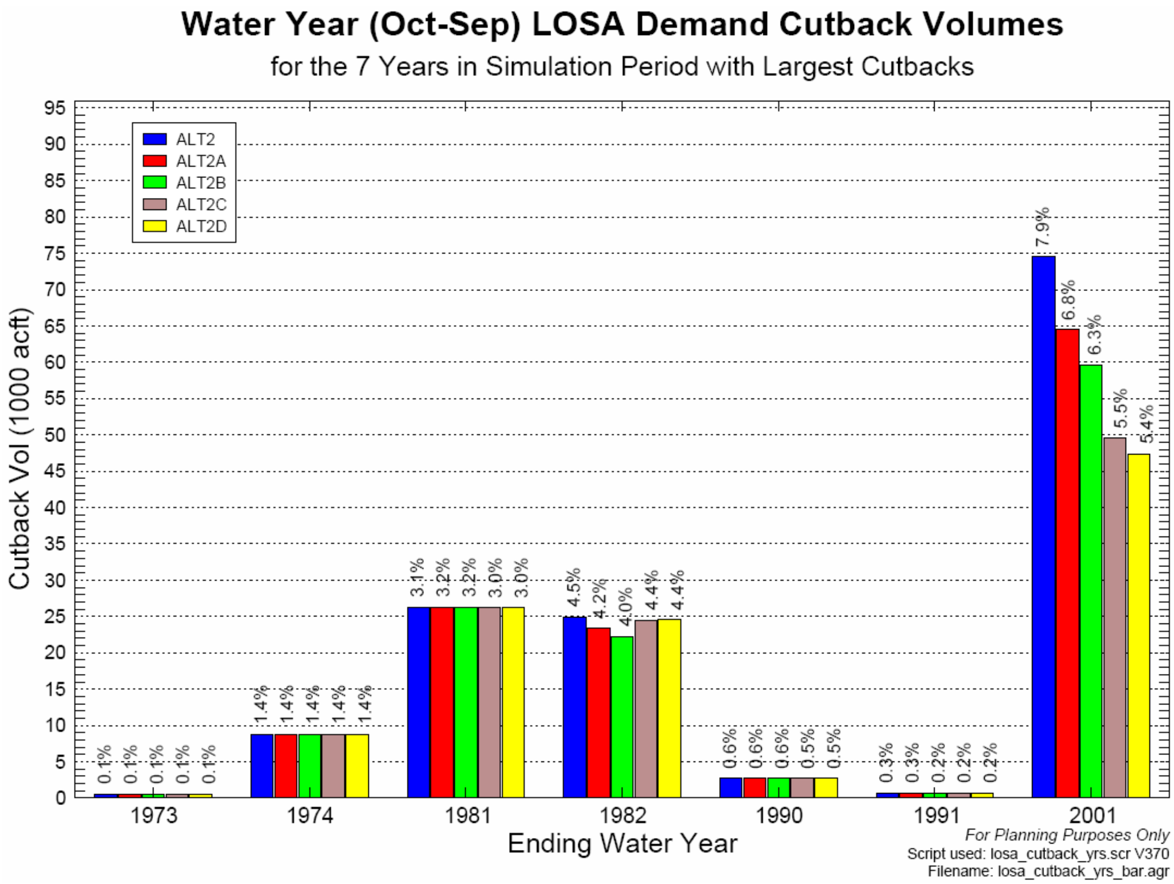


Figure C-48. Water year LOSA demand cutback volumes

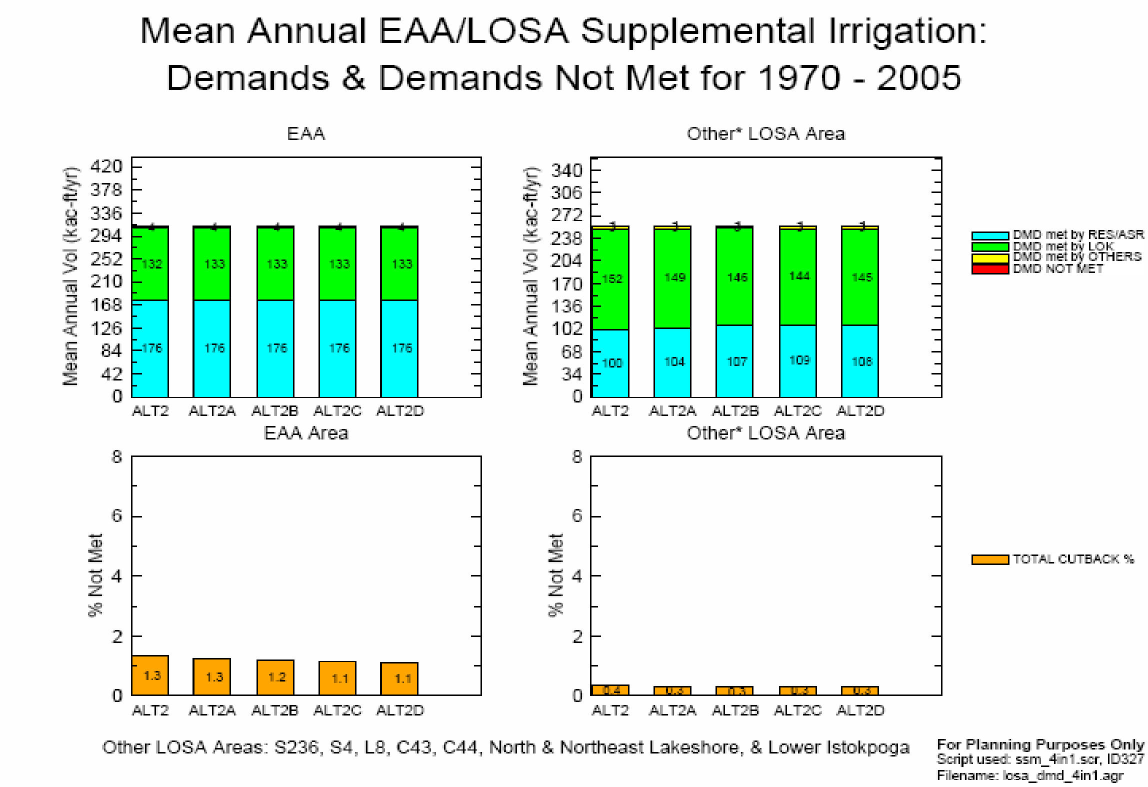


Figure C-49. Mean annual EAA/LOSA supplemental irrigation

C6.4 Conclusion

Based on a comparison of scenario runs with increasing storage capacities in the Caloosahatchee Basin, the follow conclusions could be drawn:

- Lake Okeechobee: Increase in storage capacity in Caloosahatchee Basin from 342,490 acre-feet to 742,490 acre-feet showed no significant impact on the Lake Okeechobee stage.
- Estuary: The Caloosahatchee Estuary high discharge performance measure showed limited improvement, with an increase in storage capacity. The impact on the estuary low flow was generally minimal, although a significant improvement can be demonstrated going from ALT2 to ALT2A. The storage capacity changes in Caloosahatchee Basin had a slight impact on St. Lucie Estuary performance.
- Water Supply: LOSA cutback volumes decreased the most (in terms of volume and percentage volume) in the worst year (water year 2001). EAA/LOSA water irrigation is not impacted.

Therefore, increases in storage capacities in the Caloosahatchee Basin would benefit the Caloosahatchee Estuary performance, both in the high discharge criteria (greater than 2,000 cfs) and low flow criteria (less than 450 cfs). The improvement was most pronounced from ALT2 to ALT2A. Likewise, the LOSA water supply performance, in terms of reduction in cutback and demand-not-met, would also improve. The benefits are quite limited because relatively large amounts of storage capacity increases beyond ALT2A did not show improvements in the other LOSA areas.

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APPENDIX D

Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies

Final Report

Tasks 1, 2, and 3

For Project Entitled

Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies

Prepared for

South Florida Water Management District

by

Soil and Water Engineering Technology, Inc.

July 14, 2008

INTRODUCTION

The South Florida Water Management District (SFWMD), in cooperation with the Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumer Services (FDACS), is developing the protection plans for both Caloosahatchee River and St. Lucie River watersheds as required by the Northern Everglades and Estuaries Protection Program (Section 373.4595, F.S). The plans will be developed partially based on a nutrient reduction spreadsheet approach detailing how nitrogen (N) and phosphorus (P) reductions will be achieved. The spreadsheet provides load reduction estimates resulting from Best Management Practices (BMPs), as well as local and regional projects. The letter report titled "Phosphorus Reduction Performance and Implementation Costs under BMPs and Technologies in the Lake Okeechobee Protection Plan Area" provides only part of the input data needed for the BMP spreadsheet for these additional watersheds. Therefore, the overall objectives of this project are to: 1) develop nutrient (nitrogen and phosphorus) loading rates, BMP reduction factors and implementation costs for both watersheds; and 2) conduct a detailed literature review and data analysis to quantify the BMP effectiveness for each commodity and soil type statewide.

METHODOLOGY AND RESULTS

The approach taken for developing the nutrient reduction spreadsheets for Caloosahatchee River and St. Lucie River watersheds was to update the previously developed spreadsheets for the Lake Okeechobee watershed using the additional literature data, land use data, observed flow and nutrient load data, and information from the watershed modeling project for the two watersheds. The SFWMD provided the land use breakdown for the two watersheds for twenty major land use categories, which included the six new land use categories (low density residential, medium density residential, high density residential, horse farms, transportation, and utilities). The following section describes how these data were used to develop the final unit nutrient load and BMP reduction spreadsheets. Though the methodology was very similar for both the Caloosahatchee and the St. Lucie watersheds, they are both included in order to highlight data sources and verification differences.

St. Lucie River Watershed

Figure 1 shows the basins within the St. Lucie River watershed. The 2004 land use distribution for this watershed was provided by SFWMD and is presented in Table 1. As can be seen, the table provides additional land use breakdowns beyond the twenty primary land use categories required for the project. These additional data were used during the development of the unit loads, but were integrated within the twenty categories for the final tables to prevent confusion. Measured data were provided by the SFWMD as presented in Table 2, which compared to data obtained from the Comprehensive Everglades Restoration Plan (CERP) System-wide Performance Measure Documentation Sheet (April 5, 2007).

The initial estimates of the unit nutrient loads were developed from the Lake Okeechobee Basin data provided in the BMP Letter Report (SWET, 2006b), general Florida estimates by Harper and Baker (2003 and 2007), and data collected within the basin by Graves, et al (2004). The final N and P unit loads for the watershed presented in Table 3 were developed as an iterative process starting with the initial unit loads estimates linked to a basin spreadsheet where the accumulative N and P loads from each basin could be calculated by multiplying the land use acreage by the unit loads. The net N and P loads were then compared to the measured basin and basin loads to verify if the net loads were at least in the ballpark and how the calculated and measured N and P loads for each of the basins compared. It was clear that the dominant land uses in the western basins were improved pasture and citrus while the eastern basins were much more residential and urban. Using this cross information, it was possible to estimate the relative importance of the various land uses and adjustments were made accordingly to obtain a reasonable agreement of runoff and nutrient loads and concentrations for each of the basins. However, it was observed that there was a potential problem using the measured flow data for net load estimates because of the high runoff variability between basins as seen in Table 2 for the annual runoff in terms of inches per year. Therefore, the cross basin comparisons focused more on matching the concentrations because they would be less influenced by any flow errors that might be the result of unmeasured inter-basin transfers. Since the unit loads are a function of both concentration and flow, it was first necessary to establish reasonable runoff coefficients for the various land uses (Harper and Baker, 2007). The resulting annual average runoff for the various land uses are provided in Table 3. Table 3 also provides the resulting N and P unit loads and concentrations from the iterative process of adjusting individual land use unit loads, which multiplied by the acreage of each land use within the basins (Table 4) to obtain reasonable basin runoff (Table 5), P loads (Table 6), and N loads (Table 7) comparison to observed data. The P unit load factors were adjusted individually. The N unit loads were also initially adjusted individually, but then a global multiplier factor was used to obtain reasonable matches to observed data. The verification for the N and P concentrations is also provided in Tables 6 and 7, respectively at the bottom of the tables. Note that the net calculated loads are slightly higher than observed data because these represent net source loads which do not reflect the additional assimilation that is expected in the stream and canals before reaching the basin outlets. Stream assimilation rates have been evaluated and new algorithms developed and upgraded by SWET (2001 and 2006a), where they found that P assimilation (20% to 50%) occurs mostly in the upland overland flow and small streams. Major sloughs/wetland systems were also found to have P assimilation rates in a similar range, while P assimilation rates in the canals and larger stream conveyances had much lower rates of 2% to 20%. Since the predominant flow features, below where the unit P source loads are, being estimated are canals and larger stream, the additional P assimilation was estimated to be in the order of 10%. Due to denitrification processes, N assimilation was estimated to be 50% larger than P, but very little data are available to verify the N values.

The next step was to establish BMP N and P reduction estimates for the St. Lucie watershed. This task was done by starting with the BMP reduction spreadsheets developed by SWET (2006b). These spreadsheets were expanded to include six additional land use categories and N responses. The BMP effectiveness values are based on the review and the author’s involvement in numerous studies and modeling projects around Florida. Typically, the studies provided more information on crop responses to water and fertility management than water quality responses. Where water quality responses were available, they were limited to specific crop management and soil conditions. There are no specific reports that provided BMP effectiveness values for the basin; therefore, the values for the St. Lucie watershed had to be estimated based on best professional judgment utilizing models that simulate the primary processes within the soil-plant environment based on results from numerous field and laboratory studies.

A complete description of the BMP information used in developing the BMP effectiveness values will be provided in the Task 4 report of this project, and therefore will only be briefly summarized here. The primary sources of agricultural BMP information were research and extension reports completed by Institute of Food and Agriculture Sciences, University of Florida (IFAS, UF) in association with various state agencies and grower groups, while urban BMP information was primarily from summary reports by Environmental Research and Design, Inc. and University of Central Florida. For citrus, the studies by Brian Bowman and David Calvert at the Indian River Research and Education Center and Ashok Alva and S. Paramasivam at the Citrus Research and Education Center were primarily used, while the best source of cow-calf production studies came from the Cattle Research Station at Ona and the Buck Island Ranch studies. Vegetable production BMPs were reviewed from research studies across the state, but focused mostly on work out of IFAS' Gulf Coast (Immokalee) and the old Bradenton Research and Education Centers. Though many of the research studies focused more on crop production responses to management practices as opposed to water quality responses, their results were very useful in bracketing the economical feasibility limits for BMPs. To further access the actual water quality responses, both field studies and hydrologic transport modeling were evaluated. The Watershed Assessment Model (WAM) model was used extensively in the Okeechobee and Caloosahatchee basins and provided BMP responses beyond the specific conditions covered by field studies.

A report developed by Dr. Harvey Harper (2003) for the northern Lake Okeechobee watershed was primarily used for the urban BMPs responses for P. Nitrogen responses were taken from reports developed by Harper and Baker (2003, 2007). The N reduction estimates were adjusted based on WAM modeling experience because the reductions reported by Harper and Baker were only associated with surface water reductions and therefore any loses to groundwater that might re-emerge elsewhere were not being accounted for. In particular, N in percolated stormwater can easily enter groundwater and eventually re-emerge downstream. This effect is most prominent in dry detention systems.

BMP implementation costs were typically not provided with the research studies and therefore had to be developed by SWET, Inc. Cost estimates tried to take into account the following factors: saved fertilizer, equipment and construction, operation and maintenance, energy/fuel, crop yield reduction, crop displacement, and land purchases. In agriculture when a BMP requires additional land for BMPs, such as for retention/detention systems, the area is typically carved out of existing land holdings, so the costs are associated with lost crop production (displacement), where as in urban settings, new land will typically need to be purchased for such systems. High land costs in urban settings will therefore make urban projects, particularly stormwater retrofit projects, very expensive.

The resulting BMP reduction estimates and costs for P and N are presented in Appendix A. These tables reflect the updated unit loads provided in Table 3. Table 8 provides a summary of the P unit loads and estimated BMP reduction factors for the three categories of owner implemented BMPs, cost share BMPs, and alternative practices. Owner implemented BMPs reflect those that would likely be implemented by land owners without incentives, while the cost share BMPs are those that a reasonably funded cost share program or modest regulatory approach would obtain implementation. The alternative practices are those that are more expensive but would be needed if additional nutrient reductions are needed beyond what the first two levels could obtain. The P reduction values provided in Table 8 are taken directly from Appendix A where the existing level of BMPs implemented has been taken into account in the "typical" value. The "typical" value was selected within the presented range of reduction responses that reflect existing conditions with no BMPs to those with high levels of BMPs implemented. These ranges also reflect natural variations due to soils and farm layouts, but the level of BMP implementation is the dominant factor. Therefore, assumptions had to be made as to the current level of BMPs for each land use.

Table 9 provides the same information as Table 8 except for N instead of P. This table provides a summary of the N unit loads and estimated BMP reduction factors for the three categories of owner implemented BMPs, cost share BMPs, and alternative practices.

Caloosahatchee River Watershed

Figure 2 shows the basins within the Caloosahatchee watershed. The 2004 land use distribution for the Caloosahatchee watershed was provided by SFWMD and is presented in Table 10. As can be seen, the table provides additional land use breakdowns beyond the twenty primary land use categories required for the project. These additional data were used during the development of the unit loads, but were integrated within the twenty categories for the final tables to prevent confusion. Measured data for the major structures on the C-43 canal were provided by the SFWMD and are presented in Table 11. Because of the influence of the Lake Okeechobee releases, only the basin (Freshwater West) between the S-78 and S-79 structures was considered reliable enough for comparisons to actual land source area discharges. Unmonitored flow releases from the Lake Okeechobee, Nicodemus Slough, and the S-4 basin into the Freshwater East basin were considered more problematic than potential bypass water around S-78 as documented by the WAM model results (SWET, 2008). Therefore, the loads differences between these two structures shown in Table 11 were used for verification of the land use unit loads. The high measured discharge rates are a concern and are discussed further below.

The initial estimates of the unit nutrient loads were developed from the Okeechobee Basin data provided in the BMP Letter Report (SWET, 2006b), general Florida estimates by Harper and Baker (2003 and 2007), WMM EMC estimates developed by CDM (2007), and the WAM modeling results for the USACE (SWET, 2008). The final N and P unit loads for the C-43 basin presented in Table 12 were developed as an iterative process starting with the initial unit loads estimates linked to a basin spreadsheet where the accumulative N and P loads from each basin could be calculated by multiplying the land use acreage by the unit loads. The net N and P loads were then compared to the measured basin and basin loads to verify if the net loads were at least in the ballpark and how the calculated and measured N and P loads for each of the basins compared. It was clear that the dominant land uses in the western basins were improved pasture and citrus with limited urban around the Le Belle area. The more highly developed area is located in the western (tidal and north coastal) basins. Using just the Freshwater West basin, however, it was possible to estimate the relative importance of the various land uses and adjustments were made accordingly to obtain a reasonable agreement of runoff and nutrient loads and concentrations for each of the basins. However, it was observed that measured runoff for the Freshwater West basin seems high at 22 inches per year as seen in Table 14, which makes the unit loads higher than expected. Therefore, the basin comparisons focused more on matching the concentrations because they would be less influenced by any flow errors that might be the result of unmeasured inter-basin transfers. Since the unit loads are a function of both concentration and flow, it was first necessary to establish reasonable runoff coefficients for the various land uses (Harper and Baker, 2007). The resulting annual average runoff for the various land uses are provided in Table 12. Table 12 also provides the resulting N and P unit loads and concentrations from the iterative process of adjusting individual land use unit loads which multiplied by the acreage of each land use within the basins (Table 13) to obtain reasonable basin runoff (Table 14), P loads (Table 15), and N loads (Table 16) comparison to observed data. The P unit load factors were adjusted individually. The N unit loads were also initially adjusted individually, but then a global multiplier factor was used to obtain reasonable matches to observed data at the basin level. The verification for the N and P loads and concentrations is also provided in Tables 15 and 16, respectively at the bottom of the tables. Note that the net calculated loads and concentrations are slightly higher than observed data because these represent net source loads which do not reflect the additional assimilation that is expected in the streams and canals before reaching the basin outlets. In-stream assimilation rates have been evaluated and new algorithms developed and upgraded by SWET (2001 and 2006a), where they found that P assimilation (20% to 50%) occurs mostly in the upland overland flow and small streams. Major sloughs/wetland systems were also found to have P assimilation rates in a similar range, while P assimilation rates in the canals and larger stream conveyances had much lower rates of 2% to 20%. Since the predominant flow features below where the unit P source loads are being estimated are canals and larger stream, the additional P assimilation was estimated to be in the order of 10%. Due to denitrification processes, N assimilation was estimated to be 50% larger than P, but very little data are available to verify the N values.

The next step was to establish BMP N and P reduction estimates for the Caloosahatchee watershed. This task was done by starting with the BMP reduction spreadsheets developed by SWET (2006b). These spreadsheets were expanded to include six additional land use categories and N responses. The BMP effectiveness values are based on the review and personal involvement in numerous studies and modeling projects around Florida. Typically, the studies provided more information on crop responses to water and fertility management than water quality responses. Where water quality responses were available they were limited to specific crop management and soil conditions. There are no specific reports that provided BMP effectiveness values for the basin and therefore the values for the C-43 had to be estimated based on best professional judgment utilizing models that simulate the primary processes within the soil-plant environment based on results from numerous field and laboratory studies.

A complete description of the BMP information used in developed the BMP effectiveness values will be provided in the Task 4 report of this project, and therefore will only be briefly summarized here. The primary sources of agricultural BMP information were research and extension reports completed by IFAS in association with various state agencies and grower groups, while urban BMP information were primarily from summary reports by Environmental Research and Design, Inc. and University of Central Florida. For all of the crops growth on the muck soils in the eastern part of the basin, particularly sugarcane and vegetable, studies done by the Everglades Research and Education Center were used. For citrus the studies by Brian Bowman and David Calvert at the Indian River Research and Education Center and Ashok Alva and S. Paramasivam at the Citrus Research and Education Center were primarily used, while the best source of cow-calf production studies came from the Cattle Research Station at Ona and the Buck Island Ranch studies. Vegetable production BMPs were reviewed from research studies across the state, but focused mostly on work out of IFAS' Gulf Coast (Immokalee) and the old Bradenton Research and Education Centers. Though many of the research studies focused more on crop production responses to management practices as opposed to water quality responses, their results were very useful in bracketing the economical feasibility limits for BMPs. To further access the actual water quality responses both field studies and hydrologic transport modeling was evaluated. The WAM model was used extensively in the Okeechobee and Caloosahatchee basins and provided BMP responses beyond the specific conditions covered by field studies.

A report developed by Dr. Harvey Harper (2003) for the northern Lake Okeechobee watershed was primarily used for the urban BMPs responses for P. Nitrogen responses were taken from reports developed by Harper and Baker (2003, 2007). The N reduction estimates were adjusted based on WAM modeling experience because the reductions reported by Harper and Baker were only associated with surface water reductions and therefore any loses to groundwater that might re-emerge elsewhere were not being accounted for. In particular, nitrogen in percolated stormwater can easily enter groundwater and eventually re-emerge downstream. This effect is most prominent in dry detention systems.

BMP implementation costs were typically not provided with the research studies and therefore had to be developed by SWET, Inc. Cost estimates tried to take into account the following factors: saved fertilizer, equipment and construction, operation and maintenance, energy/fuel, crop yield reduction, crop displacement, and land purchases. In agriculture when a BMP requires additional land for BMPs, such as for retention/detention systems, the area is typically carved out of existing land holdings so the costs are associated with lost crop production (displacement), where as in urban settings, new land will typically need to be purchased for such systems. High land costs in urban settings will therefore make urban projects, particularly stormwater retrofit projects, very expensive.

The resulting BMP reduction estimates and costs for P and N are presented in Appendix B. These tables reflect the updated unit loads provided in Table 12. Table 17 provides a summary of the P unit loads and estimated BMP reduction factors for the three categories of owner implemented BMPs, cost share BMPs, and alternative practices. Owner implemented BMPs reflect those that would likely be implemented by land owners without incentives, while the cost share BMPs are those that a reasonably funded cost share program or modest regulatory approach would obtain implementation. The alternative practices are those that are more expensive but would be needed if additional nutrient reductions are needed beyond what the first two levels could obtain. The nutrient reduction values provided in Table 17 are taken directly from Appendix B where the existing level of BMPs implemented has been taken into account in the "typical" value. The "typical" value was selected within the presented range of reduction responses that reflect existing conditions with no BMPs to those with high levels of BMPs implemented. These ranges also reflect natural variations due to soils and farm layouts, but the level of BMP implementation is the dominant factor. Therefore, assumptions had to be made as to the current level of BMPs for each land use.

Table 18 provides the same information as Table 17 except for N. This table provides a summary of the N unit loads and estimated BMP reduction factors for the three categories of owner implemented BMPs, cost share BMPs, and alternative practices.

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Figure 1. Basin Layout for the St. Lucie River Watershed

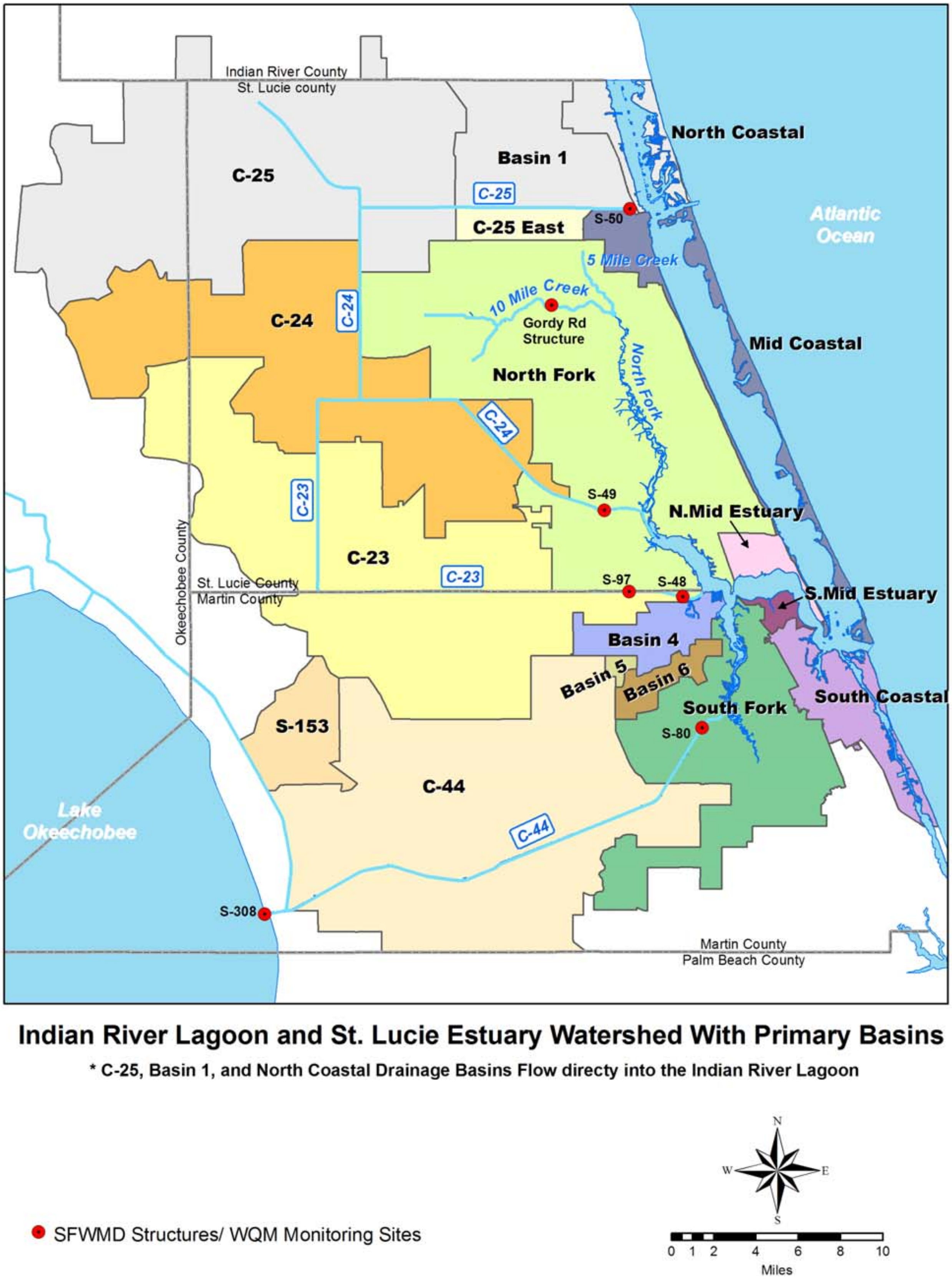

Figure 2. Basin Layout for the Caloosahatchee River Watershed

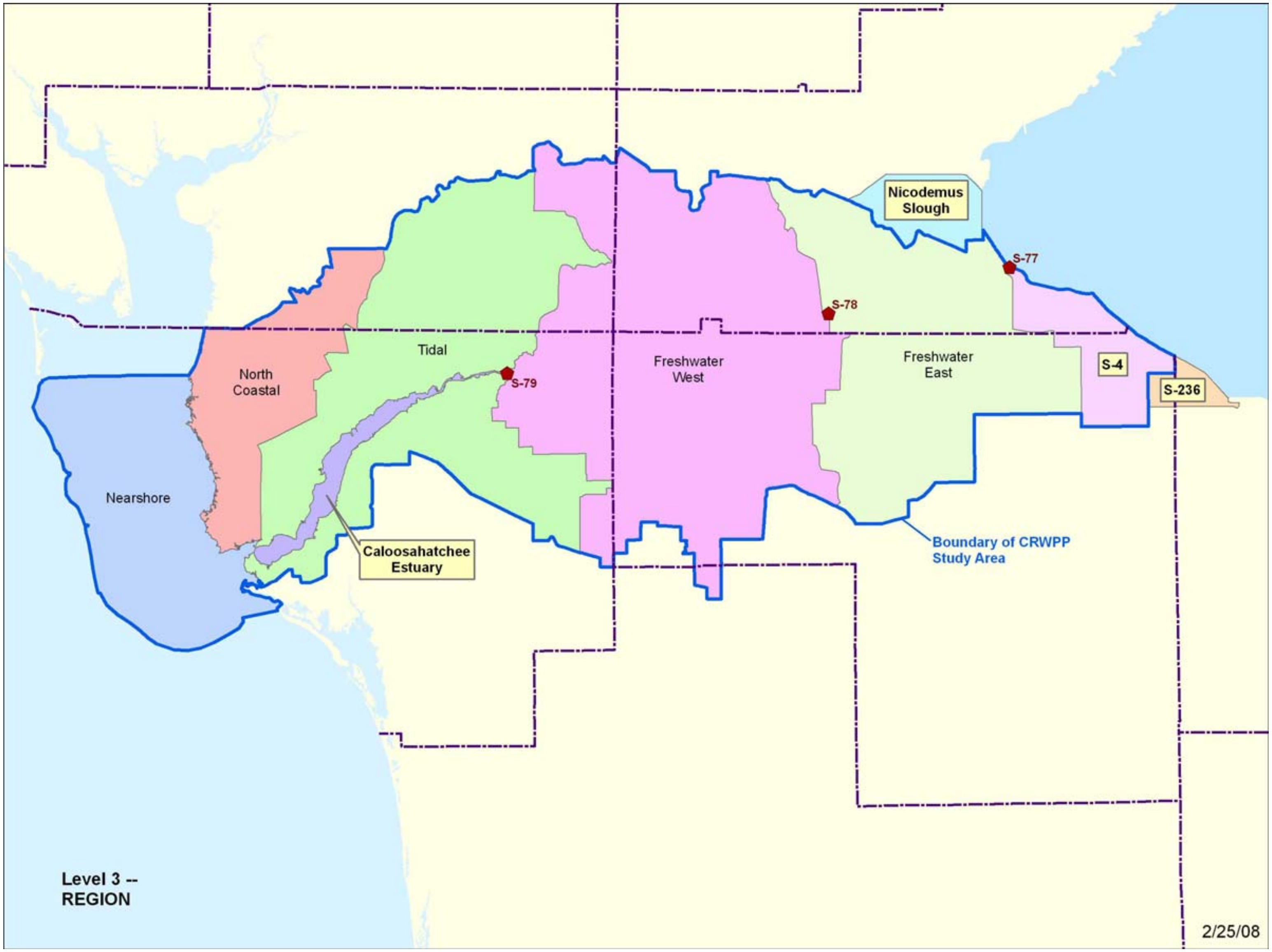

Table 1. Land Use Distribution in the St. Lucie Watershed

Land Use Category	Land Use Description	FLUCCS	Area (ac)	Percent	Sum_Area (ac)	Percent
Residential Low Density	Residential Low Density	1100	22,050	4.29%	22,050	4.30%
Residential Medium Density	Residential Medium Density	1200	38,206	7.43%	38,206	7.40%
Residential High Density	Residential High Density	1300	7,698	1.50%	7,698	1.50%
Other Urban	Commercial and Services	1400	5,090	0.99%	15,907	3.10%
	Industrial	1500	2,034	0.40%		
	Extractive	1600	640	0.12%		
	Institutional	1700	2,977	0.58%		
	Recreational	1800	5,167	1.00%		
Improved Pastures	Improved Pastures	2110	106,321	20.67%	106,321	20.70%
Unimproved Pastures	Unimproved Pastures	2120	15,033	2.92%	15,033	2.90%
Woodland Pastures/Rangeland	Woodland Pastures	2130	25,205	4.90%	39,351	7.70%
	Rangeland	3000	14,147	2.75%		
Row Crops	Row Crops	2140	7,881	1.53%	7,881	1.50%
Sugar Cane	Sugar Cane	2156	5,562	1.08%	5,562	1.10%
Citrus	Citrus	2210	116,442	22.64%	116,442	22.60%
Sod Farms	Sod Farms	2420	294	0.06%	294	0.10%
Ornamentals	Ornamentals	2430	1,246	0.24%	1,246	0.20%
Horse Farms	Horse Farms	2510	784	0.15%	784	0.20%
Dairies	Dairies	2520	419	0.08%	419	0.10%
Other Areas	Field Crops	2150	2,800	0.54%	4,108	0.80%
	Other Groves	2230	48	0.01%		
	Cattle Feeding Operations	2310	105	0.02%		
	Poultry Feeding Operations	2320	107	0.02%		
	Tree Nurseries	2410	463	0.09%		
	Specialty Farms	2500	133	0.03%		
	Aquaculture	2540	204	0.04%		
	Fallow Crop Land	2610	248	0.05%		
Tree Plantations	Tree Plantations	4400	0	0.00%	0	0.00%
Water	Water	5000	11,411	2.22%	11,411	2.20%
Natural Areas	Upland Forests	4000	37,608	7.31%	105,380	20.50%
	Wetlands	6000	61,052	11.87%		
	Barren Land	7000	2,613	0.51%		
	Open Land	1900	4,108	0.80%		
Transportation	Transportation	8100	5,665	1.10%	5,665	1.10%
Communication/Utilities	Communication	8200	91	0.02%	10,529	2.00%
	Utilities	8300	10,438	2.03%		
Total			**514,287**	**100.00%**	**514,287**	**100.00%**

Table 2 Summary of Measured Nitrogen and Phosphorus Load to SLE

Sub-watershed	Area (acres)	Average Annual Discharge(1) (1995-2005) (Acre-ft)	Calculated Runoff (in)	Average Annual TN Load(2) (1995-2005) (MTons)	Average Annual TN Conc. (Calculated) (1995-2005) (ppb)	Average Annual TP Load(2) (1995-2005) (MTons)	Average Annual TP Conc. (Calculated) (1995-2005) (ppb)
Basins 4 5 6	15055	23620	18.8	34	1182	6	218.96
C-23	112675	152789	16.3	330	1750	91	480.55
C-24	87706	178853	24.5	355	1609	76	343.25
C-44&S-153	129719	158194	14.6	300	1540	40	203.38
North Fork*	119168	126152	12.7	185	1191	43	278
Tidal St. Lucie**	49965	59408	14.3	91	1244	21	285.16
Lake Okeechobee	-	414754		922	1802	96	188.14
Total	514287	1113771		2218	1615	373	271.33

*North Fork basin includes North Fork and N. Mid. Estuary

**Tidal St. Lucie basin includes South Fork and S. Mid. Estuary

(1) Measured data are used for flow from C-23 basin, C-24 basin, C-44&S-153 basin, and Lake Okeechobee. WaSh Model output data are used for flow from North Fork basin, South Fork basin, and Basin 4 5 6.

(2) Measured data are used for TN and TP concentrations for C-23 basin, C-24 basin, C-44&S-153 basin, and Lake Okeechobee. WaSh Model output data are used for TN and TP concentrations for North Fork basin, South Fork basin, and Basin 4 5 6.

Table 3. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the St. Lucie Watershed

Land Use Category	Land Use Description	FLUCCS	Runoff (in/yr)	Unit N Load)	N Conc. (mg/l)	Unit P Load (lbs/acre/yr)	P Conc. (mg/l)
Residential Low Density	Residential Low Density[1]	1100	17.57	4.95	1.25	0.49	0.12
Residential Medium Density	Residential Medium Density[2]	1200	20.76	7.20	1.53	1.40	0.30
Residential High Density	Residential High Density[2]	1300	23.96	10.80	1.99	3.00	0.55
Other Urban	Commercial and Services[2]	1400	25.55	9.90	1.71	1.40	0.24
	Industrial[2]	1500	27.15	9.00	1.47	2.40	0.39
	Extractive[2]	1600	23.96	6.30	1.16	0.66	0.12
	Institutional[2]	1700	23.96	6.30	1.16	2.40	0.44
	Recreational[2]	1800	17.57	6.30	1.59	0.96	0.24
Improved Pastures	Improved Pastures	2110	19.16	9.99	2.30	1.90	0.44
Unimproved Pastures	Unimproved Pastures	2120	15.97	4.95	1.37	0.92	0.25
Woodland Pastures/Rangeland	Woodland Pastures	2130	15.97	3.69	1.02	0.88	0.24
	Rangeland	3000	15.97	3.69	1.02	0.28	0.08
Row Crops	Row Crops	2140	22.36	13.50	2.67	4.50	0.89
Sugar Cane	Sugar Cane	2156	19.16	7.20	1.66	0.63	0.15
Citrus	Citrus	2210	19.16	7.65	1.76	1.80	0.42
Sod Farms	Sod Farms	2420	19.16	8.10	1.87	2.52	0.58
Ornamentals	Ornamentals	2430	19.16	10.80	2.49	2.90	0.67
Horse Farms	Horse Farms	2510	15.97	14.40	3.99	1.82	0.50
Dairies	Dairies	2520	15.97	18.00	4.98	9.38	2.60
Other Areas	Field Crops	2150	15.97	5.96	1.65	2.96	0.82
	Mixed Crops	2160	19.16	9.90	2.28	3.50	0.81
	Fruit Orchards	2220	19.16	8.10	1.87	2.30	0.53
	Other Groves	2230	19.16	8.10	1.87	2.30	0.53
	Cattle Feeding Operations	2310	19.16	48.65	11.22	8.96	2.07
	Poultry Feeding Operations	2320	19.16	9.00	2.08	1.50	0.35
	Tree Nurseries	2410	15.97	10.80	2.99	2.90	0.80
	Specialty Farms	2500	15.97	7.20	1.99	1.82	0.50
	Aquaculture	2540	7.99	9.00	4.98	0.70	0.39
	Fallow Crop Land	2610	19.16	6.30	1.45	0.70	0.16
Tree Plantations	Tree Plantations	4400	15.97	2.79	0.77	0.18	0.05
Water	Water	5000	3.19	0.81	1.12	0.05	0.07
Natural Areas	Upland Forests (not including 4400's)	4000	14.37	2.25	0.69	0.28	0.09
	Wetlands	6000	1.60	1.35	3.74	0.01	0.03
	Barren Land	7000	23.96	6.30	1.16	0.75	0.14
	Open Land	1900	15.97	3.60	1.00	0.28	0.08
Transportation	Transportation	8100	27.15	8.28	1.35	1.65	0.27
Communication/Utilities	Communications	8200	15.97	5.40	1.49	0.48	0.13
	Utilities	8300	15.97	5.40	1.49	0.48	0.13

1 Assumed on Septic
2 Assumed Discharge from WWT outside basin

Table 4. Acreage of Land Uses within the St. Lucie Watershed

FLUCCS	Basins 4 5 6	C-23	C-24	C-44&S-153	North Fork*	Tidal St. Lucie**	Grand Total
1100	4315.6	1909.4	1236.1	1813.7	9445	3329.8	22049.7
1200	1236.1	303.7	2505.9	314.9	30453.4	3392.3	38206.3
1300	702.6		295	185.7	4784.2	1730.3	7697.8
1400	222.9	9	39.8	204.4	3453.9	1159.8	5089.8
1500	133.2	48.3	55.5	76.7	1552.3	167.8	2033.7
1600	0.8	411.5			92.3	135.2	639.8
1700	110.3	661.7	21.7	97.7	1567.1	518.3	2976.7
1800	683.8	254.8	665.6	209.5	2308.4	1045.2	5167.3
1900	110.8	9.8	74.7	148.7	3291.5	472.2	4107.5
2110	1006.7	33628	33949.7	23185	4998.8	9552.4	106320.6
2120	86.4	5062	6064.3	2167.9	558.4	1094.1	15033.1
2130	374.6	8697.3	6890.3	6457.9	1071.8	1712.9	25204.8
2140	156.1	1696.2	1550.3	852.5	1166.2	2459.9	7881.1
2150		1574.6	834.7	390.9			2800.2
2156				5240.1		321.7	5561.8
2210	30.2	32466.1	17487.8	42754.5	20678.2	3025.4	116442.2
2220							0
2230	5	17.1			26.2		48.3
2310		104.7					104.7
2320			44.3	62.5			106.8
2410	100.2	153.8	55.5	85.3	68.3	0.1	463.1
2420				294.1			294.1
2430	211		25.1	267.6	237.9	504.4	1246
2500				28.7	23.9	79.9	132.6
2510	53.7	54	14.1	591.6		71.1	784.4
2520		419.1					419.1
2540	60.1	70.4	23.3		9.5	40.8	204.2
2610		216.7			31.3		247.9
3000	394.5	1603.5	220.1	6383.5	3494	2051	14146.6
4000	2679	2723.8	1264.5	11535.9	12030.8	7373.6	37607.6
5000	382.5	1810.5	1218.4	1890.7	4317.3	1791.3	11410.7
6000	1262.5	16278.9	12248.2	15114.6	9485.1	6662.2	61051.5
7000		1108.1	297.8	939	235.2	33.2	2613.4
8100	297.6	455.4	521.1	611.2	2623.4	1156.6	5665.3
8200	10.9	10.2		5.6	64.3		91
8300	428.3	916.1	102.4	7808.5	1099.2	83.1	10437.6
Grand Total	15055.4	112674.5	87705.8	129718.9	119167.9	49964.7	514287.2

*North Fork basin includes North Fork and N.Mid.Estuary

**Tidal St. Lucie basin includes South Fork and S.Mid.Estuary

Table 5. Runoff in Acre-ft/yr to Stream within the St. Lucie Watershed by Land Use

FLUCCS	Basins 4 5 6	C-23	C-24	C-44&S-153	North Fork*	Tidal St. Lucie**	Grand Total
1100	6318	2795	1810	2655	13827	4875	32280
1200	2139	525	4336	545	52689	5869	66102
1300	1403	0	589	371	9551	3454	15367
1400	475	19	85	435	7355	2470	10838
1500	301	109	126	174	3512	380	4601
1600	2	821	0	0	184	270	1277
1700	220	1321	43	195	3128	1035	5942
1800	1001	373	974	307	3379	1530	7565
1900	147	13	99	198	4381	628	5467
2110	1608	53706	54219	37028	7983	15256	169799
2120	115	6737	8071	2885	743	1456	20007
2130	499	11575	9170	8595	1426	2280	33544
2140	291	3160	2889	1588	2173	4583	14684
2150	0	2096	1111	520	0	0	3727
2156	0	0	0	8369	0	514	8882
2210	48	51850	27929	68281	33024	4832	185964
2220	0	0	0	0	0	0	0
2230	8	27	0	0	42	0	77
2310	0	167	0	0	0	0	167
2320	0	0	71	100	0	0	171
2410	133	205	74	114	91	0	616
2420	0	0	0	470	0	0	470
2430	337	0	40	427	380	806	1990
2500	0	0	0	38	32	106	176
2510	71	72	19	787	0	95	1044
2520	0	558	0	0	0	0	558
2540	40	47	16	0	6	27	136
2610	0	346	0	0	50	0	396
3000	525	2134	293	8496	4650	2730	18827
4000	3209	3263	1515	13818	14410	8832	45046
5000	102	482	324	503	1149	477	3037
6000	168	2167	1630	2012	1262	887	8125
7000	0	2212	595	1875	470	66	5217
8100	673	1030	1179	1383	5935	2617	12818
8200	15	14	0	7	86	0	121
8300	570	1219	136	10392	1463	111	13891
Grand Total	**20417**	**149043**	**117341**	**172566**	**173382**	**66183**	**698,932**
(in/yr)	**16**	**16**	**16**	**16**	**17**	**16**	**16**

*North Fork basin includes North Fork and N.Mid.Estuary

**Tidal St. Lucie basin includes South Fork and S.Mid.Estuary

Verification

Lake Okee			414,754
	Calculated	Total	1,113,686
	Measured		1,113,771

Table 6. Net P Loads in Pounds/year to Stream within the St. Lucie Watershed by Land Use

FLUCCS	Basins 4 5 6	C-23	C-24	C-44&S-153	North Fork*	Tidal St. Lucie**	Grand Total
1100	2115	936	606	889	4628	1632	10804
1200	1731	425	3508	441	42635	4749	53489
1300	2108	0	885	557	14353	5191	23093
1400	312	13	56	286	4835	1624	7126
1500	320	116	133	184	3726	403	4881
1600	1	272	0	0	61	89	422
1700	265	1588	52	234	3761	1244	7144
1800	656	245	639	201	2216	1003	4961
1900	31	3	21	42	922	132	1150
2110	1913	63893	64504	44052	9498	18150	202009
2120	79	4657	5579	1994	514	1007	13830
2130	330	7654	6063	5683	943	1507	22180
2140	702	7633	6976	3836	5248	11070	35465
2150	0	4668	2475	1159	0	0	8301
2156	0	0	0	3301	0	203	3504
2210	54	58439	31478	76958	37221	5446	209596
2220	0	0	0	0	0	0	0
2230	12	39	0	0	60	0	111
2310	0	938	0	0	0	0	938
2320	0	0	66	94	0	0	160
2410	291	446	161	247	198	0	1343
2420	0	0	0	741	0	0	741
2430	612	0	73	776	690	1463	3613
2500	0	0	0	52	43	145	241
2510	98	98	26	1077	0	129	1428
2520	0	3931	0	0	0	0	3931
2540	42	49	16	0	7	29	143
2610	0	152	0	0	22	0	174
3000	110	449	62	1787	978	574	3961
4000	750	763	354	3230	3369	2065	10530
5000	19	91	61	95	216	90	571
6000	13	163	122	151	95	67	611
7000	0	831	223	704	176	25	1960
8100	491	751	860	1008	4329	1908	9348
8200	5	5	0	3	31	0	44
8300	206	440	49	3748	528	40	5010
Grand Total	**13264**	**159686**	**125049**	**153531**	**141301**	**59983**	**652814**
Conc.(ppbl)	**233**	**384**	**382**	**319**	**292**	**325**	**335**
Meas.Conc.(ppb)	**219**	**481**	**343**	**203**	**278**	**285**	
Lake Okee (lbs)							**211200**
Calc. (Mt/yr)	**6**	**73**	**57**	**70**	**64**	**27**	**393**
Measured (Mt/yr)	**6**	**91**	**76**	**40**	**43**	**21**	**373**

*North Fork basin includes North Fork and N.Mid.Estuary

**Tidal St. Lucie basin includes South Fork and S.Mid.Estuary

Table 7. Net N Loads in Pounds/year to Stream within the St. Lucie Watershed by Land Use

FLUCCS	Basins 4 5 6	C-23	C-24	C-44&S-153	North Fork*	Tidal St. Lucie**	Grand Total
1100	21362	9452	6119	8978	46753	16483	109146
1200	8900	2187	18042	2267	219264	24425	275085
1300	7588	0	3186	2006	51669	18687	83136
1400	2207	89	394	2024	34194	11482	50389
1500	1199	435	500	690	13971	1510	18303
1600	5	2592	0	0	581	852	4031
1700	695	4169	137	616	9873	3265	18753
1800	4308	1605	4193	1320	14543	6585	32554
1900	399	35	269	535	11849	1700	14787
2110	10057	335944	339158	231618	49938	95428	1062143
2120	428	25057	30018	10731	2764	5416	74414
2130	1382	32093	25425	23830	3955	6321	93006
2140	2107	22899	20929	11509	15744	33209	106395
2150	0	9384	4975	2330	0	0	16689
2156	0	0	0	37729	0	2316	40045
2210	231	248366	133782	327072	158188	23144	890783
2220	0	0	0	0	0	0	0
2230	41	139	0	0	212	0	391
2310	0	5094	0	0	0	0	5094
2320	0	0	399	563	0	0	961
2410	1082	1661	599	921	738	1	5001
2420	0	0	0	2382	0	0	2382
2430	2279	0	271	2890	2569	5448	13457
2500	0	0	0	207	172	575	955
2510	773	778	203	8519	0	1024	11295
2520	0	7544	0	0	0	0	7544
2540	541	634	210	0	86	367	1838
2610	0	1365	0	0	197	0	1562
3000	1456	5917	812	23555	12893	7568	52201
4000	6028	6129	2845	25956	27069	16591	84617
5000	310	1467	987	1531	3497	1451	9243
6000	1704	21977	16535	20405	12805	8994	82420
7000	0	6981	1876	5916	1482	209	16464
8100	2464	3771	4315	5061	21722	9577	46909
8200	59	55	0	30	347	0	491
8300	2313	4947	553	42166	5936	449	56363
Grand Total	**79917**	**762762**	**616731**	**803355**	**723011**	**303076**	**3288847**
Conc.(ppb)	**1404**	**1836**	**1885**	**1670**	**1496**	**1643**	**1688**
Meas.Conc.(ppb)	**1182**	**1750**	**1609**	**1540**	**1191**	**1244**	
Lake Okee (lbs)							**2028400**
Calc. (Mt/yr)	**36**	**347**	**280**	**365**	**329**	**138**	**2417**
Measured (Mt/yr)	**34**	**330**	**355**	**300**	**185**	**91**	**2217**

*North Fork basin includes North Fork and N.Mid.Estuary

**Tidal St. Lucie basin includes South Fork and S.Mid.Estuary

Table 8. Land Use Categories, Unit Load Factors, and P Reduction Factors for the St. Lucie Watershed

Land Use Category	Land Use Description	FLUCCS	Unit P Load (lbs/acre/yr)	Estimated Phosphorus Reduction		
				Owner Implemented BMPs	Cost Share BMPs	Alternative Practices
Residential Low Density	Residential Low Density[1]	1100	0.49	5%	5%	70%
Residential Medium Density	Residential Medium Density[2]	1200	1.40	5%	5%	70%
Residential High Density	Residential High Density[2]	1300	3.00	5%	5%	70%
Other Urban	Commercial/Industrial[2]	1400-1800	1.54	5%	5%	70%
Improved Pastures	Improved Pastures	2110	1.90	11%	19%	49%
Unimproved Pastures	Unimproved Pastures	2120	0.92	7%	13%	44%
Woodland Pastures/Rangeland	Woodland/Range Pastures	2130/3000	0.66	4%	6%	35%
Row Crops	Row Crops	2140	4.50	30%	30%	50%
Sugar Cane	Sugar Cane	2156	0.63	10%	23%	52%
Citrus	Citrus	2210	1.80	12%	5%	52%
Sod Farms	Sod Farms	2420	2.52	20%	27%	50%
Ornamentals	Ornamentals	2430	2.90	32%	35%	50%
Horse Farms	Horse Farms	2510	1.82	20%	22%	49%
Dairies	Dairies	2520	9.38	9%	28%	48%
Other Areas	Other Areas	2150-2610	2.78	15%	25%	36%
Tree Plantations	Tree Plantations	4400	0.18	1%	10%	50%
Water	Water	5000	0.05	0%	0%	0%
Natural Areas	Forrests/wetlands/Open	4000/6000	0.14	0%	0%	0%
Transportation	Transportation	8100	1.65	10%	23%	52%
Communication/Utilities	Communication/Utilities	8200/8300	0.48	5%	5%	50%

1 Assumed on Septic

2 Assumed all of Discharge from WWT outside basin

Table 9. Land Use Categories, Unit Load Factors, and N Reduction Factors for the St. Lucie Watershed

Land Use Category	Land Use Description	FLUCCS	Unit N Load (lbs/acre/yr)	Estimated Nitrogen Reduction		
				Owner Implemented BMPs	Cost Share BMPs	Alternative Practices
Residential Low Density	Residential Low Density[1]	1100	4.95	15%	15%	15%
Residential Medium Density	Residential Medium Density[2]	1200	7.20	25%	25%	15%
Residential High Density	Residential High Density[2]	1300	10.80	30%	25%	15%
Other Urban	Commercial/Industrial[2]	1400-1800	7.80	25%	25%	15%
Improved Pastures	Improved Pastures	2110	9.99	17%	10%	30%
Unimproved Pastures	Unimproved Pastures	2120	4.95	11%	8%	30%
Woodland Pastures/Rangeland	Woodland/Range Pastures	2130/3000	3.69	4%	6%	20%
Row Crops	Row Crops	2140	13.50	30%	30%	50%
Sugar Cane	Sugar Cane	2156	7.20	10%	23%	52%
Citrus	Citrus	2210	7.65	10%	5%	52%
Sod Farms	Sod Farms	2420	8.10	20%	27%	50%
Ornamentals	Ornamentals	2430	10.80	25%	25%	25%
Horse Farms	Horse Farms	2510	14.40	30%	22%	30%
Dairies	Dairies	2520	18.00	20%	40%	48%
Other Areas	Other Areas	2150-2610	7.91	15%	25%	36%
Tree Plantations	Tree Plantations	4400	2.79	5%	10%	25%
Water	Water	5000	0.81	0%	0%	0%
Natural Areas	Forrests/wetlands/Open	4000/6000	1.88	0%	0%	0%
Transportation	Transportation	8100	8.28	20%	23%	25%
Communication/Utilities	Communication/Utilities	8200/8300	5.40	5%	5%	50%

1 Assumed on Septic

2 Assumed all of Discharge from WWT outside basin

Table 10. Land Use Distribution for the Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Area (ac)	Percent	Area (ac)	Percent
Residential Low Density	Residential Low Density	1100	76,863	7.12%	76,863	7.10%
Residential Medium Density	Residential Medium Density	1200	33,396	3.09%	33,396	3.10%
Residential High Density	Residential High Density	1300	11,453	1.06%	11,453	1.10%
	Commercial and Services	1400	8,906	0.82%		
	Industrial	1500	2,648	0.25%		
	Extractive	1600	2,278	0.21%		
	Institutional	1700	3,675	0.34%		
Other Urban	Recreational	1800	6,062	0.56%	23,568	2.20%
Improved Pastures	Improved Pastures	2110	117,152	10.85%	117,152	10.80%
Unimproved Pastures	Unimproved Pastures	2120	23,827	2.21%	23,827	2.20%
	Woodland Pastures	2130	20,280	1.88%		
Woodland Pastures/Rangeland	Rangeland	3000	57,850	5.36%	78,130	7.20%
Row Crops	Row Crops	2140	9,656	0.89%	9,656	0.90%
Sugar Cane	Sugar Cane	2156	87,741	8.13%	87,741	8.10%
Citrus	Citrus	2210	96,684	8.95%	96,684	9.00%
Sod Farms	Sod Farms	2420	5,070	0.47%	5,070	0.50%
Ornamentals	Ornamentals	2430	861	0.08%	861	0.10%
Horse Farms	Horse Farms	2510	202	0.02%	202	0.00%
Dairies	Dairies	2520	56	0.01%	56	0.00%
	Field Crops	2150	5,326	0.49%		
	Mixed Crops	2160	17	0.00%		
	Fruit Orchards	2220	12	0.00%		
	Other Groves	2230	1,995	0.18%		
	Tree Nurseries	2410	971	0.09%		
	Specialty Farms	2500	165	0.02%		
	Aquaculture	2540	215	0.02%		
Other Areas	Fallow Crop Land	2610	2,209	0.20%	10,909	1.00%
Tree Plantations	Tree Plantations	4400	42,498	3.94%	42,498	3.90%
Water	Water	5000	130,368	12.07%	130,368	12.10%
	Upland Forests (not including 4400's)	4000	84,379	7.81%		
	Wetlands	6000	184,666	17.10%		
	Barren Land	7000	5,866	0.54%		
Natural Areas	Open Land	1900	49,378	4.57%	324,289	30.00%
Transportation	Transportation	8100	4,915	0.46%	4,915	0.50%
	Communications	8200	96	0.01%		
Communication/Utilities	Utilities	8300	2,063	0.19%	2,159	0.20%
Total			**1,079,796**	**100.00%**	**1,079,796**	**100.00%**

Table 11. Summary of Annual Flow and Loads for TP and TN along the main stem of the Caloosahatchee River (C-43 Canal)

Calendar Year	S-77 (02292000)					S-78 (02292480)					S-79 (02292900)					Basin Between S78 and S79				
	Flow	TP Load	TP Conc.	TN Load	TN Conc.	Flow	TP Load	TP Conc.	TN Load	TN Conc.	Flow	TP Load	TP Conc.	TN Load	TN Conc.	Flow	TP Load	TP Conc.	TN Load	TN Conc.
	acre-feet	mtons	ug/L	mtons	mg/L	acre-feet	mtons	ug/L	mtons	mg/L	acre-feet	mtons	ug/L	mtons	mg/L	acre-feet	mtons	ug/L	mtons	mg/L
1990	120,575	14.0	94	237.6	1.60	174,966	33.0	153	322.4	1.49	423,951	101.0	193	936.9	1.79	248,986	68	222	614	2.00
1991	63,594	7.3	93	136.2	1.74	288,783	72.1	202	670.0	1.88	922,265	193.2	170	1,890.5	1.66	633,481	121	155	1,221	1.56
1992	193,275	22.9	96	344.7	1.45	437,933	93.2	172	756.4	1.40	943,491	406.5	349	2,198.8	1.89	505,559	313	502	1,442	2.31
1993	500,243	30.7	50	1,382.3	2.24	645,118	68.2	86	972.4	1.22	1,230,588	182.0	120	2,334.1	1.54	585,470	114	158	1,362	1.89
1994	770,253	50.7	53	1,345.0	1.42	1,044,125	119.2	93	2,201.9	1.71	1,633,414	216.6	108	3,380.2	1.68	589,289	97	134	1,178	1.62
1995	2,110,116	113.5	44	4,311.3	1.66	2,381,744	186.4	63	3,244.1	1.10	3,379,883	314.1	75	5,482.4	1.32	998,139	128	104	2,238	1.82
1996	474,489	47.0	80	797.6	1.36	568,330	58.2	83	853.6	1.22	941,009	129.5	112	1,647.2	1.42	372,680	71	155	794	1.73
1997	158,049	16.2	83	393.5	2.02	290,448	36.2	101	661.3	1.85	756,311	114.8	123	1,413.3	1.51	465,864	79	137	752	1.31
1998	1,618,473	135.5	68	2,988.8	1.50	1,831,790	204.9	91	3,216.9	1.42	2,613,724	296.8	92	4,309.0	1.34	781,933	92	95	1,092	1.13
1999	564,104	52.4	75	945.3	1.36	848,093	123.6	118	1,602.2	1.53	1,578,821	324.1	166	3,041.8	1.56	730,729	201	222	1,440	1.60
2000	477,520	104.7	178	1,683.5	2.86	409,244	47.1	93	687.8	1.36	619,878	118.6	155	1,061.9	1.39	210,634	71	275	374	1.44
2001	72,771	9.0	101	172.2	1.92	176,661	66.0	303	462.5	2.12	835,815	232.8	226	1,694.6	1.64	659,154	167	205	1,232	1.52
2002	466,052	57.4	100	969.6	1.69	888,496	154.4	141	1,774.4	1.62	1,491,120	318.2	173	3,166.7	1.72	602,624	164	220	1,392	1.87
2003	1,396,713	101.5	59	2,454.0	1.42	1,745,887	209.3	97	3,239.4	1.50	2,589,761	335.0	105	4,529.1	1.42	843,874	126	121	1,290	1.24
2004	1,120,739	127.3	92	2,146.6	1.55	1,247,980	128.0	83	1,996.4	1.30	1,853,038	230.2	101	2,815.2	1.23	605,058	102	137	819	1.10
2005	2,266,435	384.6	138	4,597.7	1.64	2,898,397	476.4	133	5,821.6	1.63	3,734,684	577.7	125	6,740.1	1.46	836,287	101	98	918	0.89
2006	353,758	65.1	149	732.9	1.68	463,033	88.2	154	856.5	1.50	920,989	193.0	170	1,689.2	1.49	457,956	105	186	833	1.47
1990-2006	**748,656**	**78.8**	**85**	**1,508.2**	**1.63**	**961,237**	**127.3**	**107**	**1,725.9**	**1.46**	**1,556,985**	**252.0**	**131**	**2,843.0**	**1.48**	**595,748**	**125**	**170**	**1,117**	**1.52**
1995-2005	**975,042**	**104.5**	**87**	**1,950.9**	**1.62**	**1,207,915**	**153.7**	**103**	**2,141.8**	**1.44**	**1,854,004**	**272.0**	**119**	**3,263.7**	**1.43**	**646,089**	**118**	**148**	**1,122**	**1.41**

Table 12. Estimated Runoff, Unit N and P Loads and Concentration for 2004 Land Uses in the Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Runoff (in/yr)	Unit N Load (lbs/acre/yr)	N Conc. (mg/l)	Unit P Load (lbs/acre/yr)	P Conc. (mg/l)
Residential Low Density	Residential Low Density[1]	1100	27.43	7.26	1.17	0.68	0.11
Residential Medium Density	Residential Medium Density[2]	1200	32.42	10.56	1.44	1.93	0.26
Residential High Density	Residential High Density[2]	1300	39.90	15.84	1.75	4.14	0.46
	Commercial and Services[2]	1400	39.90	14.52	1.61	1.93	0.21
	Industrial[2]	1500	42.39	13.20	1.38	3.31	0.35
	Extractive[2]	1600	37.41	9.24	1.09	0.91	0.11
	Institutional[2]	1700	37.41	9.24	1.09	3.31	0.39
Other Urban	Recreational[2]	1800	27.43	9.24	1.49	1.32	0.21
Improved Pastures	Improved Pastures	2110	29.93	14.65	2.16	1.93	0.29
Unimproved Pastures	Unimproved Pastures	2120	24.94	7.26	1.29	0.99	0.18
	Woodland Pastures	2130	24.94	5.41	0.96	0.83	0.15
Woodland Pastures/Rangeland	Rangeland	3000	19.95	5.41	1.20	0.25	0.06
Row Crops	Row Crops	2140	34.91	19.80	2.51	3.45	0.44
Sugar Cane	Sugar Cane	2156	29.93	10.56	1.56	0.55	0.08
Citrus	Citrus	2210	29.93	11.22	1.66	0.90	0.13
Sod Farms	Sod Farms	2420	29.93	11.88	1.75	2.79	0.41
Ornamentals	Ornamentals	2430	29.93	15.84	2.34	4.00	0.59
Horse Farms	Horse Farms	2510	24.94	21.12	3.74	2.51	0.45
Dairies	Dairies	2520	24.94	26.40	4.68	12.94	2.29
	Field Crops	2150	24.94	8.74	1.55	4.09	0.73
	Mixed Crops	2160	29.93	14.52	2.14	4.83	0.71
	Fruit Orchards	2220	29.93	11.88	1.75	3.17	0.47
	Other Groves	2230	29.93	11.88	1.75	3.17	0.47
	Cattle Feeding Operations	2310	29.93	71.35	10.54	12.37	1.83
	Poultry Feeding Operations	2320	29.93	13.20	1.95	2.07	0.31
	Tree Nurseries	2410	24.94	15.84	2.81	4.00	0.71
	Specialty Farms	2500	24.94	10.56	1.87	2.51	0.45
	Aquaculture	2540	12.47	13.20	4.68	0.97	0.34
Other Areas	Fallow Crop Land	2610	29.93	9.24	1.36	0.97	0.14
Tree Plantations	Tree Plantations	4400	14.96	4.09	1.21	0.21	0.06
Water	Water	5000	4.99	1.19	1.05	0.07	0.06
	Upland Forests (not including 4400's)	4000	14.96	3.30	0.97	0.10	0.03
	Wetlands	6000	7.48	1.98	1.17	0.01	0.01
	Barren Land	7000	37.41	9.24	1.09	1.04	0.12
Natural Areas	Open Land	1900	24.94	5.28	0.94	0.39	0.07
Transportation	Transportation	8100	49.88	12.14	1.08	2.28	0.20
	Communications	8200	27.43	7.92	1.28	0.66	0.11
Communication/Utilities	Utilities	8300	24.94	7.92	1.40	0.66	0.12

1 Assumed on Septic
2 Assumed about 70% of Discharge from WWT outside basin

Table 13. Acreage of Land Uses within the Caloosahatchee Watershed

FLUCCS	Caloosahatchee Estuary	Freshwater East	Freshwater West	Nearshore	North Coastal	S-4	Tidal	Grand Total
1100	19	3,015	14,869	4236	24,084	548	30,092	76,863
1200	65	383	1,758	1741	1,825	1,506	26,118	33,396
1300	15	59	398	983	1,434	77	8,486	11,453
1400	8	191	688	421	384	428	6,787	8,906
1500		236	445	6	23	1,264	673	2,648
1600		553	22	3	340	68	1,292	2,278
1700	0	105	245	91	475	213	2,545	3,675
1800	11	76	472	1193	1,039	257	3,014	6,062
1900	1	2,437	25,047	522	6,947	204	14,220	49,378
2110	1	36,795	55,555	231	2,381	797	21,392	117,152
2120		5,752	12,736	30	436		4,873	23,827
2130	3	5,924	10,033	67	83		4,171	20,280
2140		1,080	6,354	363	228		1,632	9,656
2150		422	1,269	8	56	38	3,533	5,326
2156		52,751	2,058			32,932		87,741
2160			17					17
2210		26,593	69,008	193		66	824	96,684
2220							12	12
2230			53	1793	6		143	1,995
2410		174	111	185		270	230	971
2420		289	2,947				1,833	5,070
2430		16	369	160	15		300	861
2500			79			17	68	165
2510		140	38				24	202
2520		18					38	56
2540		27	91				97	215
2610		133	1,124	80	68		803	2,209
3000	50	4,966	21,510	3087	8,929	278	19,030	57,850
4000	51	7,791	23,793	3396	10,881	359	38,108	84,379
4400		12,923	28,403		69		1,103	42,498
5000	15780	2,061	3,639	94206	6,848	717	7,117	130,368
6000	275	30,329	63,513	24493	21,682	1,193	43,181	184,666
7000		1,910	2,244	67	456	675	514	5,866
8100	6	741	645	36	488	330	2,668	4,915
8200		20	24		10		42	96
8300	1	388	171	62	395	268	777	2,063
Grand Tota	16,285	198,299	349,734	137653	89,583	42,504	245,738	1,079,796

Table 14. Runoff in Acre-ft/year to Streams within the Caloosahatchee Watershed by Land Use

FLUCCS	Caloosahatchee Estuary	Freshwater East	Freshwater West	Nearshore	North Coastal	S-4	Tidal	Grand Total
1100	43	6892	33990	9683	55055	1253	68788	175704
1200	176	1035	4749	4703	4930	4069	70559	90221
1300	50	196	1323	3268	4768	256	28216	38081
1400	27	635	2288	1400	1277	1423	22567	29612
1500	0	834	1572	21	81	4465	2378	9355
1600	0	1724	69	9	1060	212	4027	7101
1700	0	327	764	284	1481	664	7933	11456
1800	25	174	1079	2727	2375	587	6890	13857
1900	2	5064	52051	1085	14437	424	29551	102614
2110	2	91758	138540	576	5938	1988	53346	292148
2120	0	11953	26467	62	906	0	10127	49515
2130	6	12311	20850	139	172	0	8668	42144
2140	0	3142	18486	1056	663	0	4748	28093
2150	0	877	2637	17	116	79	7342	11068
2156	0	131548	5132	0	0	82124	0	218804
2160	0	0	42	0	0	0	0	42
2210	0	66316	172089	481	0	165	2055	241106
2220	0	0	0	0	0	0	30	30
2230	0	0	132	4471	15	0	357	4975
2410	0	362	231	384	0	561	478	2018
2420	0	721	7349	0	0	0	4571	12643
2430	0	40	920	399	37	0	748	2147
2500	0	0	164	0	0	35	141	343
2510	0	291	79	0	0	0	50	420
2520	0	37	0	0	0	0	79	116
2540	0	28	95	0	0	0	101	223
2610	0	332	2803	200	170	0	2002	5509
3000	83	8256	35760	5132	14844	462	31637	96176
4000	64	9714	29667	4234	13567	448	47516	105210
4400	0	16113	35415	0	86	0	1375	52990
5000	6559	857	1512	39154	2846	298	2958	54184
6000	171	18908	39596	15270	13517	744	26921	115128
7000	0	5954	6995	209	1421	2104	1602	18285
8100	25	3080	2681	150	2028	1372	11089	20428
8200	0	46	55	0	23	0	96	219
8300	2	806	355	129	821	557	1615	4287
Grand Total	7,235	400,330	645,938	95,245	142,636	104,289	460,562	1,856,254

Verification

Calculated Runoff	645,938
Measured Runoff	646,089
(inches)	22.17

Table 15. Net P Loads in Pounds/year to Stream within the Caloosahatchee Watershed by Land Use

FLUCCS	Caloosahatchee Estuary	Freshwater East	Freshwater West	Nearshore	North Coastal	S-4	Tidal	Grand Total
1100	13	2,039	10,054	2,864	16,286	371	20,348	51,975
1200	126	740	3,396	3,364	3,526	2,910	50,460	64,521
1300	62	244	1,648	4,070	5,937	319	35,132	47,415
1400	15	369	1,329	813	742	827	13,112	17,206
1500	-	782	1,474	20	76	4,186	2,229	8,770
1600	-	504	20	3	310	62	1,177	2,075
1700	-	348	811	301	1,573	705	8,429	12,172
1800	15	101	625	1,580	1,376	340	3,993	8,031
1900	0	942	9,678	202	2,684	79	5,495	19,080
2110	2	71,088	107,332	446	4,600	1,540	41,329	226,338
2120	-	5,715	12,654	30	433	-	4,842	23,675
2130	2	4,905	8,307	55	69	-	3,454	16,792
2140	-	3,726	21,921	1,252	787	-	5,630	33,313
2150	-	1,726	5,192	33	229	155	14,454	21,789
2156	-	29,119	1,136	-	-	18,178	-	48,433
2160	-	-	82	-	-	-	-	82
2210	-	23,854	61,900	173	-	59	739	86,726
2220	-	-	-	-	-	-	38	38
2230	-	-	168	5,691	19	-	454	6,332
2410	-	696	444	740	-	1,081	920	3,886
2420	-	806	8,215	-	-	-	5,110	14,133
2430	-	64	1,477	640	60	-	1,201	3,446
2500	-	-	198	-	-	43	171	414
2510	-	352	95	-	-	-	60	507
2520	-	233	-	-	-	-	492	725
2540	-	26	88	-	-	-	94	208
2610	-	128	1,086	77	66	-	776	2,134
3000	12	1,234	5,343	767	2,218	69	4,727	14,370
4000	5	753	2,298	328	1,051	35	3,681	8,151
4400	-	2,675	5,879	-	14	-	228	8,797
5000	1,089	142	251	6,500	473	49	491	8,995
6000	4	419	876	338	299	16	596	2,548
7000	-	1,977	2,323	69	472	699	532	6,071
8100	14	1,687	1,469	82	1,111	751	6,075	11,191
8200	-	13	16	-	7	-	28	64
8300	1	257	113	41	262	178	515	1,367
Grand Total	1,360	157,662	277,903	30,481	44,679	32,652	237,011	781,770

Verification Data for Freshwater West

Calculated	277,903	lbs/year
	0.158	mg/l
Measured	260,240	lbs/year
	0.148	mg/l

Table 16. Net N Loads in Pounds/year to Stream within the Caloosahatchee Watershed by Land Use

FLUCCS	Caloosahatchee Estuary	Freshwater East	Freshwater West	Nearshore	North Coastal	S-4	Tidal	Grand Total
1100	138	21,889	107,949	30,753	174,850	3,978	218,468	558,025
1200	686	4,044	18,564	18,385	19,272	15,903	275,806	352,662
1300	238	935	6,304	15,571	22,715	1,220	134,418	181,416
1400	116	2,773	9,990	6,113	5,576	6,215	98,547	129,315
1500	-	3,115	5,874	79	304	16,685	8,884	34,954
1600	-	5,110	203	28	3,142	628	11,938	21,049
1700	-	970	2,264	841	4,389	1,968	23,516	33,957
1800	102	702	4,361	11,023	9,600	2,375	27,849	56,013
1900	5	12,867	132,248	2,756	36,680	1,077	75,082	260,716
2110	15	539,120	813,992	3,385	34,886	11,678	313,436	1,716,511
2120	-	41,760	92,463	218	3,165	-	35,378	172,984
2130	16	32,061	54,299	363	449	-	22,573	109,755
2140	-	21,384	125,809	7,187	4,514	-	32,314	191,189
2150	-	3,689	11,093	70	490	332	30,883	46,556
2156	-	557,051	21,732	-	-	347,762	-	926,545
2160	-	-	247	-	-	-	-	247
2210	-	298,373	774,270	2,165	-	741	9,245	1,084,794
2220	-	-	-	-	-	-	143	143
2230	-	-	630	21,301	71	-	1,699	23,701
2410	-	2,756	1,758	2,930	-	4,277	3,643	15,381
2420	-	3,433	35,010	-	-	-	21,776	60,232
2430	-	253	5,845	2,534	238	-	4,752	13,638
2500	-	-	834	-	-	180	718	1,742
2510	-	2,957	803	-	-	-	507	4,266
2520	-	475	-	-	-	-	1,003	1,478
2540	-	356	1,201	-	-	-	1,280	2,838
2610	-	1,229	10,386	739	628	-	7,420	20,411
3000	271	26,876	116,412	16,707	48,324	1,505	102,990	313,084
4000	168	25,710	78,517	11,207	35,907	1,185	125,756	278,451
4400	-	52,881	116,225	-	282	-	4,513	173,902
5000	18,747	2,448	4,323	111,917	8,135	852	8,455	154,877
6000	545	60,051	125,756	48,496	42,930	2,362	85,498	365,639
7000	-	17,648	20,735	619	4,213	6,237	4,749	54,202
8100	73	8,999	7,833	437	5,926	4,008	32,400	59,688
8200	-	158	190	-	79	-	333	760
8300	8	3,073	1,354	491	3,128	2,123	6,154	16,339
Grand Tota	21,127	1,755,149	2,709,474	316,316	469,895	433,288	1,732,127	7,437,458

Verification

Calculated	2,709,474	lbs/year
	1.543	mg/l
Measured	2,468,224	lbs/year
	1.405	mg/l

Table 17. Land Use Categories, Unit Load Factors, and P Reduction Factors for the Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Unit P Load (lbs/acre/yr)	Estimated Phosphorus Reduction		
				Owner Implemented BMPs	Cost Share BMPs	Alternative Practices
Residential Low Density	Residential Low Density[1]	1100	0.68	5%	5%	70%
Residential Medium Density	Residential Medium Density[2]	1200	1.93	5%	5%	70%
Residential High Density	Residential High Density[2]	1300	4.14	5%	5%	70%
Other Urban	Commercial/Industrial[2]	1400-1800	2.05	5%	5%	70%
Improved Pastures	Improved Pastures	2110	1.93	11%	19%	49%
Unimproved Pastures	Unimproved Pastures	2120	0.99	7%	13%	44%
Woodland Pastures/Rangeland	Woodland/Range Pastures	2130/3000	0.40	4%	6%	35%
Row Crops	Row Crops	2140	3.45	30%	30%	50%
Sugar Cane	Sugar Cane	2156	0.55	10%	23%	52%
Citrus	Citrus	2210	0.90	12%	20%	42%
Sod Farms	Sod Farms	2420	2.79	20%	27%	50%
Ornamentals	Ornamentals	2430	4.00	32%	35%	50%
Horse Farms	Horse Farms	2510	2.51	20%	22%	49%
Dairies	Dairies	2520	12.94	9%	28%	48%
Other Areas	Other Areas	2150-2610	3.20	15%	25%	36%
Tree Plantations	Tree Plantations	4400	0.21	1%	10%	50%
Water	Water	5000	0.07	0%	0%	0%
Natural Areas	Forrests/wetlands/Open	4000/6000	0.11	0%	0%	0%
Transportation	Transportation	8100	2.28	10%	23%	52%
Communication/Utilities	Communication/Utilities	8200/8300	0.66	5%	5%	50%

1 Assumed on Septic

2 Assumed about 70% of Discharge from WWT outside basin

Table 18. Land Use Categories, Unit Load Factors, and N Reduction Factors for Caloosahatchee Watershed

Land Use Category	Land Use Description	FLUCCS	Unit N Load (lbs/acre/yr)	Estimated Nitrogen Reduction		
				Owner Implemented BMPs	Cost Share BMPs	Alternative Practices
Residential Low Density	Residential Low Density[1]	1100	7.26	15%	15%	15%
Residential Medium Density	Residential Medium Density[2]	1200	10.56	25%	25%	15%
Residential High Density	Residential High Density[2]	1300	15.84	30%	25%	15%
Other Urban	Commercial/Industrial[2]	1400-1800	11.68	25%	25%	15%
Improved Pastures	Improved Pastures	2110	14.65	17%	10%	30%
Unimproved Pastures	Unimproved Pastures	2120	7.26	11%	8%	30%
Woodland Pastures/Rangeland	Woodland/Range Pastures	2130/3000	5.41	4%	6%	20%
Row Crops	Row Crops	2140	19.80	30%	30%	50%
Sugar Cane	Sugar Cane	2156	10.56	10%	23%	52%
Citrus	Citrus	2210	11.22	10%	20%	42%
Sod Farms	Sod Farms	2420	11.88	20%	27%	50%
Ornamentals	Ornamentals	2430	15.84	25%	25%	25%
Horse Farms	Horse Farms	2510	21.12	30%	22%	30%
Dairies	Dairies	2520	26.40	20%	40%	48%
Other Areas	Other Areas	2150-2610	10.18	15%	25%	36%
Tree Plantations	Tree Plantations	4400	4.09	5%	10%	25%
Water	Water	5000	1.19	0%	0%	0%
Natural Areas	Forrests/wetlands/Open	4000/6000	2.96	0%	0%	0%
Transportation	Transportation	8100	12.14	20%	23%	25%
Communication/Utilities	Communication/Utilities	8200/8300	7.92	5%	5%	50%

1 Assumed on Septic

2 Assumed about 70% of Discharge from WWT outside basin

Appendix A
Current condition assumptions, existing loads, potential load reductions, and costs of implementation for the primary land uses in the St. Lucie River watershed

Table of Contents for BMP Assessment Tables

BMPs for Low Density Residential

Assume for Typical Condition

Low Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	0.49	lbs-P/ac/yr
Existing P Concentration	0.12	mg/l
Average Annual Runoff	17.57	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	8359	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	6531	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	87	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	1437	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	8359	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	4019	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	2985	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	41796	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	83592	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	2985	Fast

BMPs for Medium Density Residential

Assume for Typical Condition

Medium Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	1.40	lbs-P/ac/yr
Existing P Concentration	0.30	mg/l
Average Annual Runoff	20.76	in/yr

BMPs	Type	P Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	2926	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	2286	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	30	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	503	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	2926	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	1407	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	1045	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	14629	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	29257	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	1045	Fast

BMPs for High Density Residential

Assume for Typical Condition

High Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	3.00	lbs-P/ac/yr
Existing P Concentration	0.55	mg/l
Average Annual Runoff	23.96	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	1365	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	1067	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	14	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	235	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	1365	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	656	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	488	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	6827	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	13653	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	488	Fast

BMPs for Other Urban

Assume for Typical Condition

Medium Density Residential with Mixed Commercial		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	1.54	lbs-P/ac/yr
Existing P Concentration	0.30	mg/l
Average Annual Runoff	22.80	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	2656	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	2075	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	28	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	456	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	2656	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	1277	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	949	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs

2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	13279	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	26558	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	949	Fast

BMPs for Cow Calf Production

Improved Pastures

Assume for Typical Condition

3 ac / cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 3 lbs P/ac		
No retention or wetland restoration		
Bahia grass		
Animals have access to streams		
Existing P Load	1.90	lbs-P/ac/yr
Existing P Concentration	0.44	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 30	10	2.2	2.2	12	Slow
Better N and Micros Fertilization	Owner	0 to 20	3	5.5	5.5	96	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	46	Slow
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	31	Moderate
Reduced Stocking Rate[4] (4ac /cow)	Owner	0 to 10	3	165	52.8	926	Slow
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Cost share	0 to 20	10	11	3.52	19	Fast
Provide Alternative Shade to move cattle from streams	Alternative	0 to 10	2	16.5	5.28	139	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	12	Fast
Critical Area Fencing	Cost share	2 to 20	5	44	14.08	148	Fast
Retention Basin by Working Pens	Cost share	2 to 10	5	3.3	1.056	11	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	148	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	49	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	37	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	20 to 90	70	220	70.4	53	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost of BMP ($/ac)	Annual Cost per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	30	49.5	15.84	28	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	11	11	4	17	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	19	38.5	12	34	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	49	110	35	38	Fast

BMPs for Cow Calf Production

Unimproved Pasture

Assume for Typical Condition

8 ac per cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 1 lbs P/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing P Load	0.92	lbs-P/ac/yr
Existing P Concentration	0.25	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	2.2	239	Slow
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	38	Slow
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	64	Moderate
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	38	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	26	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	128	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	38	Fast
Stormwater R/D	Cost share	2 to 15	7	22	7.04	109	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	96	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	110	35.2	77	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	20	13.2	4.224	23	Moderate
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	7	2.2	1	11	Slow
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	13	11	4	29	Moderate
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	44	55	18	43	Fast

BMPs for Cow Calf Production

Rangeland and Wooded Pasture

Assume for Typical Condition

16ac per cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 0 lbs P/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing P Load	0.66	lbs-P/ac/yr
Existing P Concentration	0.18	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**P Reduction[1]** Range %	Typical %	**Initial Cost of BMP[2]** ($/ac)	**Annual Cost[3]** **per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**Quickness of Response**
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	2.2	331	Slow
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	53	Slow
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	88	Moderate
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	53	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	35	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	177	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	53	Fast
Stormwater R/D	Cost share	2 to 20	10	22	7.04	106	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	132	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	40	110	35.2	132	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	10	13.2	4.224	64	Moderate
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	4	2.2	1	26	Slow
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	6	11	4	88	Moderate
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	35	55	18	76	Fast

BMPs for Row Crop

Assume for Typical Condition

Potatoes Spring Crop		
Assumed average farm size of 100 ac		
Existing P fertilization of 100 lbs P/ac		
No retention or wetland restoration		
Seepage Irrigation with 60' furrows		
Existing P Load	4.50	lbs-P/ac/yr
Existing P Concentration	0.89	mg/l
Average Annual Runoff	22.36	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	11	11	8	Slow
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	3.52	8	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	23	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	3.52	39	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	3.52	16	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	17.6	98	Fast
Stormwater R/D	Cost share	10 to 55	25	220	70.4	63	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	8	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	550	176	78	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	60	220	70.4	26	Moderate
Owner BMP Program Reduced P Fertilization	20 to 70	30	11	3.52	3	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	30	209	66.88	50	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	50	440	140.8	63	Fast

BMPs for Sugarcane

Assume for Typical Condition

3 year ratoon		
Assumed average farm size of 400 ac		
Existing P fertilization of 30 lbs P/ac		
Limited retention or wetland restoration		
Seepage Irrigation with 330' furrows		
Existing P Load	0.63	lbs-P/ac/yr
Existing P Concentration	0.15	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility pH management		0 to 20	10	0	0	0	Fast
Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	0	0	0	Slow
Water Management (irrigation and drainage, in-field retention)	Cost share	0 to 20	10	11	3.52	56	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	168	Fast
Stormwater R/D	Cost share	5 to 45	15	110	35.2	372	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	80	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	220	70.4	160	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P fertilization, water management, and limited wetland restoration/retention	10 to 70	33	110	35	169	Moderate
Owner BMP Program Reduced P Fertilization	10 to 50	10	2.2	0	0	Slow
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	238	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	52	275	88	269	Fast

BMPs for Citrus

Assume for Typical Condition

Two row crown bedded		
Assumed average farm size of 200 ac		
Grass Management between Trees		
Pond retention with limited wetland restoration		
Micro jet irrigation and fertigation of young stock		
Existing P Load	1.80	lbs-P/ac/yr
Existing P Concentration	0.41	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to 25	10	0	0	0	Slow
Better N and Micros Fertilization	Owner	0 to 5	2	0	0	0	Slow
Water Management (irrigation and drainage)	Cost share	0 to 20	5	0	0	0	Fast
Water Reuse from Retention/Detention Ponds[4]	Alternative	0 to 50	10	33	10.56	59	Fast
Grass Management between Trees	Owner	0 to 5	2	22	7.04	196	Moderate
Grassed Waterways	Alternative	0 to 15	5	110	35.2	391	Fast
Stormwater R/D[5]	Alternative	10 to 60	40	440	140.8	196	Fast
Wetland Restoration	Alternative	5 to 20	10	44	14.08	78	Fast
Edge-of-farm Stormwater R/D and Chemical Treatment[6]	Alternative	20 to 90	70	220	70.4	56	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Values shown are for using existing ponds for water reuse, if new facilities are needed then cost would increase significantly.
5 Average of pre/post 1984 stormwater management requirements, i.e. P > .6ppm if developed prior to 1984 and less if developed after 1984.
Groves developed after 1984 would probably have stormwater R/D systems, so little addition benefit would be expected for newer groves.
6 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Better N Management, Grass Management between Trees, additional Stormwater Retention, and limited Wetland Restoration/Retention	10 to 50	17	75	24	245	Moderate
Owner BMP Program Reduced P Fertilization, Better N Management, and Grass Management between Trees	0 to 25	12	5.5	0	0	Slow
Cost Share BMP Program Water Management (irrigation and drainage)	0 to 20	5	77	24.64	274	Fast
Alternative BMP Program Fertigation, Grassed Waterways, and Edge-of-farm Stormwater R/D with Chemical Treatment	20 to 90	52	242	77	83	Fast

BMPs for Sod / Turf Grass

Assume for Typical Condition

Bermudagrass
Assumed average farm size of 100 ac
Existing P fertilization of 70 lbs P/ac
No retention or wetland restoration
Seepage Irrigation with 100' furrows

Existing P Load	2.52	lbs-P/ac/yr
Existing P Concentration	0.58	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	Type	P Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2.2	2.2	4	Slow
Water Management (irrigation and drainage, riser board control)	Cost Share	0 to 20	10	11	3.52	14	Fast
Erosion Control (Buffer Strips and sediment traps)	Alternative	0 to 15	5	55	17.6	140	Fast
Stormwater R/D	Cost Share	5 to 40	25	110	35.2	56	Fast
Wetland Restoration	Cost Share	2 to 15	8	11	3.52	17	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	330	105.6	84	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	Annual Cost P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P fertilization, water management, additional stormwater retention, and limited wetland restoration	10 to 70	47	110	35.2	30	Moderate
Owner BMP Program Reduced P Fertilization	10 to 50	20	2.2	2.2	4	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	27	107.8	34	51	Fast
Alternative BMP Program Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 70	50	330	105.6	84	Fast

BMPs for Ornamentals

Assume for Typical Condition		
Ornamental Nursery		
Assumed average farm size of 10 ac		
Existing P fertilization of 160 lbs P/ac		
No retention or wetland restoration		
Overhead Irrigation		
Existing P Load	2.90	lbs-P/ac/yr
Existing P Concentration	0.67	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	11	11	13	Slow
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	4	12	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	11	36	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	4	61	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	4	24	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	18	152	Fast
Stormwater R/D	Cost share	10 to 65	40	220	70	61	Fast
Wetland Restoration	Cost share	0 to 10	4	11	4	30	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	550	176	121	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	67	220	70	36	Moderate
Owner BMP Program Reduced P Fertilization	20 to 70	32	11	4	4	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	35	209	67	66	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	50	440	141	97	Fast

BMPs for Horse Farms

Assume for Typical Condition

1 ac / horse
Assumed average farm size of 10 ac
Existing P fertilization of 5 lbs P/ac
No retention or wetland restoration
Bahia grass

Existing P Load	1.82	lbs-P/ac/yr
Existing P Concentration	0.50	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	Type	P Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 30	15	2.2	2.2	8	Slow
Better N and Micros Fertilization	Owner	0 to 20	10	5.5	5.5	30	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	48	Slow
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	32	Moderate
Reduced Stocking Rate[4] (2ac /horse)	Owner	0 to 10	20	165	52.8	145	Slow
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move animals from streams	Cost share	0 to 20	5	11	3.52	39	Fast
Provide Alternative Shade to move animals from streams	Alternative	0 to 10	1	16.5	5.28	290	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	13	Fast
Critical Area Fencing	Cost share	2 to 20	2	44	14.08	387	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	155	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	52	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	39	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	20 to 90	70	220	70.4	55	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	42	49.5	15.84	21	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	20	11	4	10	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	22	38.5	12	31	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	49	110	35	39	Fast

BMPs for Dairies

Assume for Typical Condition

- 1000 head Dairy, dry cows pastured on site, 400 heifer/springers on site
- Assumed average farm size of 700 ac
- Existing P fertilization of 0 lbs P/ac
- No existing retention or wetland restoration
- Stargrass Pastures
- Animals are fenced from streams

Existing P Load	9.38	lbs-P/ac/yr
Existing P Concentration	2.59	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Barn Waste							
Feed Ration Management	Owner	0 to 25	8	2.2	2.2	3	Slow
Solids Separation for Off Site Disposal	Alternative	0 to 10	3	5.5	1.76	6	Slow
Expanded Waste Storage Ponds	Alternative	----	----	----	----	----	----
Expanded Sprayfields	Alternative	----	----	----	----	----	----
Improved Pasture Management (See Cow-Calf Imp.. Pasture)	Owner	10 to 40	20	16.5	5.28	3	Moderate
Improved Forage/Sprayfield Management - P balanced, new crops	Owner	0 to 15	5	0	0	0	Slow
HIA Management							
Add Housing to Move Animals off Fields[4]	Alternative	30 to 70	50	3,929	1257	268	Slow
Stormwater Retention / Expanded Sprayfield	Alternative	20 to 70	40	440	140.8	38	Moderate
Edge-of-field Chemical Treatment[5]	Alternative	50 to 90	70	550	176	27	Fast
Buffer Strips	Alternative	0 to 10	5	44	14.08	30	Moderate
Stormwater R/D	Cost Share	15 to 50	30	1100	352	125	Fast
Wetland Restoration	Cost Share	5 to 20	10	11	3.52	4	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	50 to 90	70	550	176	27	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Value only include implementation cost, i.e. doesn't include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Includes associated waste pond and sprayfield expansions
5 High O&M Costs

Owner/Cost Share BMP Program	20 to 65	37	1045	334.4	301	Moderate
Stormwater R/D and Wetland Restoration						
Feed Management						
Owner BMP Program	0 to 25	9	2.2	2	7	Slow
Feed Ration Management						
Cost Share BMP Program	20 to 60	28	1042.8	333.696	316	Fast
Stormwater R/D and Wetland Restoration						
Alternative BMP Program	20 to 90	48	550	176	39	Fast
Barn Waste						
Solids Separation for Off Site Disposal	0 to 10	3	6	1.76	6	Slow
Expanded Waste Storage Ponds[4]	----	----	----	----	----	----
Expanded Sprayfields[4]	----	----	----	----	----	----
HIA Management						
Add Housing to Move Animals off Fields[4]	30 to 70	50	3929	1257	268	Slow
Stormwater Retention / Expanded Sprayfield	20 to 70	40	440	141	38	Moderate
Edge-of-field Chemical Treatment[5]	50 to 90	70	550	176	27	Fast
Buffer Strips	0 to 10	5	44	14	30	Moderate
Edge-of-farm stormwater R/D and Chemical Treatment[5]	50 to 90	70	550	176	27	Fast

BMPs for Field Crop (Hayland) Production

Assume for Typical Condition

Assumed average farm size of 500 ac		
Existing P fertilization of 60 lbs P/ac		
No retention or wetland restoration		
Various Land Uses including hay, orchards, poultry, etc.		
Existing P Load	2.78	lbs-P/ac/yr
Existing P Concentration	0.77	mg/l
Average Annual Acres	15.97	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 50	15	2.2	2.2	5	Slow
Better N and Micros Fertilization	Owner	0 to 20	3	5.5	5.5	66	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	32	Slow
Buffer Strips	Cost share	0 to 10	5	44	14.08	101	Fast
Stormwater R/D	Cost share	10 to 40	20	55	17.6	32	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	13	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	36	220	70.4	70	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 60	40	50	15.84	14	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	15	11	4	8	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	25	39	12	18	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	36	110	35	35	Fast

BMPs for Pine Plantation

Assume for Typical Condition

Planted Pine Plantation (20 yr rotation)		
Assumed average farm size of 200 ac		
Existing P fertilization of 5 lbs P/ac		
No retention or wetland restoration		
Existing P Load	0.18	lbs-P/ac/yr
Existing P Concentration	0.05	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Reduced P Fertilization (testing, placement, and type)	Owner	0 to 10	1	0	0	0	Slow
Stormwater R/D	Cost share	2 to 15	8	22	22	1528	Fast
Wetland Restoration	Cost share	1 to 5	2	11	3.52	978	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	110	35.2	391	Fast

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4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Stormwater R/D, and limited Wetland Restoration	2 to 25	11	22	22	1111	Moderate
Owner BMP Program Reduced P Fertilization	0 to 25	1	0	0	0	Slow
Cost Share BMP Program Stormwater R/D and limited Wetland Restoration	10 to 50	10	22	20	1111	Fast
Alternative BMP Program Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	50	100	32	355	Fast

BMPs for Transportation Corridors

Assume for Typical Condition

- 50% Paved Surface
- Bahia Grass Shoulders
- Existing P fertilization of 15 lbs P/ac
- Limited retention or wetland restoration

Existing P Load	1.65	lbs-P/ac/yr
Existing P Concentration	0.27	mg/l
Average Annual Runoff	27.15	in/yr

BMPs		**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
			Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility	pH management		0 to 20	10	0	0	0	Fast
	Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	0	0	0	Slow
Stormwater R/D		Cost share	5 to 45	15	110	35.2	142	Fast
Wetland Restoration		Cost share	2 to 15	7	11	3.52	30	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]		Alternative	20 to 90	70	220	70.4	61	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P fertilization, water management, and limited wetland restoration/retention	10 to 70	33	110	35	65	Moderate
Owner BMP Program Reduced P Fertilization	10 to 50	10	2.2	0	0	Slow
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	91	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-System stormwater R/D and Chemical Treatment	20 to 90	52	275	88	103	Fast

BMPs for Communications and Utilities

Assume for Typical Condition		
Marginally Maintained Bahia Grass		
No Pond retention		
Existing P Load	0.48	lbs-P/ac/yr
Existing P Concentration	0.13	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry/Wet Retention 0.25"	Cost share	0 to 20	2	1280	409.6	42667	Fast
Wet Restoration	Cost share	0 to 20	3	1600	512	35556	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	8533	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	4103	Fast

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4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization,limited dry/wet retention, and wetland restoration	0 to 20	10	6400	2048	42667	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Selective limited dry/wet retention and Wetland Restoration	5 to 50	5	6400	2048	85333	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	15 to 80	50	3200	1024	4267	Fast

BMPs for Low Density Residential

Assume for Typical Condition

Low Density Residential
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 1.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	4.95	lbs-P/ac/yr
Existing N Concentration	1.24	mg/l
Average Annual Runoff	17.57	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 30	15	11	3.52	5	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 40	15	6400	2048	2758	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	2586	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	65	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	190	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	1379	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	1724	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 50	30	6411	2051.52	1381	Fast
Owner BMP Program Reduced N Fertilization	0 to 30	15	11	3.52	5	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	10 to 40	15	6400	2048	2758	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	1379	Fast

BMPs for Medium Density Residential

Assume for Typical Condition		
Medium Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2		
Limited Pond retention		
Limited Lawn Irrigation		
Existing N Load	7.20	lbs-N/ac/yr
Existing N Concentration	1.53	mg/l
Average Annual Runoff	20.76	in/yr

BMPs	Type	N Reduction[1]		Initial Cost	Annual Cost[3]		Quickness
		Range	Typical	of BMP[2]	per acre	N Removed	of
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	Response
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 50	25	15	4.8	3	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	1138	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1778	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	44	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	130	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	948	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	1185	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	50	6415	2052.8	570	Fast
Owner BMP Program Reduced N Fertilization	0 to 60	25	15	4.8	3	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	25	6400	2048	1138	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	948	Fast

BMPs for High Density Residential

Assume for Typical Condition

High Density Residential
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	10.80	lbs-N/ac/yr
Existing N Concentration	1.99	mg/l
Average Annual Runoff	23.96	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 60	30	15	4.8	1	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	759	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1185	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	30	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	87	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	632	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	790	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	55	6415	2052.8	346	Fast
Owner BMP Program Reduced N Fertilization	0 to 60	30	15	4.8	1	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	25	6400	2048	759	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	632	Fast

BMPs for Other Urban

Assume for Typical Condition

Mixed Commercial, Industrial, institutional, recreation
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	7.80	lbs-N/ac/yr
Existing N Concentration	1.51	mg/l
Average Annual Runoff	22.80	in/yr

BMPs	Type	N Reduction[1]		Initial Cost	Annual Cost[3]		Quickness
		Range	Typical	of BMP[2]	per acre	N Removed	of
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	Response
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 50	25	15	4.8	2	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	1051	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1642	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	41	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	120	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	876	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	1094	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	50	6415	2052.8	527	Fast
Owner BMP Program Reduced N Fertilization	0 to 50	25	15	4.8	2	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	10 to 50	25	6400	2048	1051	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	876	Fast

BMPs for Cow Calf Production

Improved Pastures

Assume for Typical Condition

- 3 ac / cow
- Assumed average farm size of 500 ac
- Existing N fertilization of 120 lbs N/ac
- No retention or wetland restoration
- Bahia grass
- Animals have access to streams

Existing N Load	9.99	lbs-N/ac/yr
Existing N Concentration	2.30	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 30	15	2.2	2.2	1	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	18	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	9	Fast
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	6	Fast
Reduced Stocking Rate[4] (4ac /cow)	Owner	0 to 10	5	165	52.8	106	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Cost share	0 to 20	10	11	3.52	4	Fast
Provide Alternative Shade to move cattle from streams	Alternative	0 to 10	2	16.5	5.28	26	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	2	Fast
Critical Area Fencing	Cost share	2 to 20	5	44	14.08	28	Fast
Retention Basin by Working Pens	Cost share	2 to 10	5	3.3	1.056	2	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	28	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	9	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	7	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	220	70.4	14	Fast

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4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	27	49.5	15.84	6	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement	0 to 25	17	11	4	2	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	10	38.5	12	12	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	110	35	12	Fast

BMPs for Cow Calf Production

Unimproved Pasture

Assume for Typical Condition

8 ac per cow		
Assumed average farm size of 500 ac		
Existing N fertilization of 60 lbs N/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing N Load	4.95	lbs-N/ac/yr
Existing N Concentration	1.37	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 20	9	1.2	1.2	3	Fast
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	7	Fast
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	12	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	7	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	5	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	24	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	7	Fast
Stormwater R/D	Cost share	2 to 15	7	22	7.04	20	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	18	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	28	Fast

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4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	19	13.2	4.224	4	Fast
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	11	2.2	1	1	Fast
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 30	8	11	4	9	Fast
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	55	18	12	Fast

BMPs for Cow Calf Production

Rangeland and Wooded Pasture

Assume for Typical Condition

16ac per cow		
Assumed average farm size of 500 ac		
Existing N fertilization of 10 lbs N/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing N Load	3.69	lbs-N/ac/yr
Existing N Concentration	1.02	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	Type	N Reduction[1] Range %	N Reduction[1] Typical %	Initial Cost of BMP[2] ($/ac)	Annual Cost[3] per acre ($/ac/yr)	Annual Cost[3] N Removed ($/lb/ac/yr)	Quickness of Response
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	1	27	Fast
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	10	Fast
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	16	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	10	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	6	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	32	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	10	Fast
Stormwater R/D	Cost share	2 to 20	10	22	7.04	19	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	24	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	38	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	10	13.2	4.224	11	Fast
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	4	2.2	1	5	Fast
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	6	11	4	16	Fast
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 50	20	55	18	24	Fast

BMPs for Row Crop

Assume for Typical Condition

Potatoes Spring Crop		
Assumed average farm size of 100 ac		
Existing N fertilization of 225 lbs N/ac		
No retention or wetland restoration		
Seepage Irrigation with 60' furrows		
Existing N Load	13.50	lbs-N/ac/yr
Existing N Concentration	2.67	mg/l
Average Annual Runoff	22.36	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	18	18	4	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	3.52	3	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	8	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	3.52	13	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	3.52	5	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	17.6	33	Fast
Stormwater R/D	Cost share	10 to 55	25	220	70.4	21	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	3	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	550	176	26	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	60	220	70.4	9	Fast
Owner BMP Program Reduced N Fertilization	20 to 70	30	11	3.52	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	30	209	66.88	17	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	5 to 70	50	440	140.8	21	Fast

BMPs for Sugarcane

Assume for Typical Condition

3 year ratoon on organic soils		
Assumed average farm size of 400 ac		
Existing N fertilization of 30 lbs N/ac		
Limited retention or wetland restoration		
Seepage Irrigation with 330' furrows		
Existing N Load	7.20	lbs-N/ac/yr
Existing N Concentration	1.66	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**N Reduction2**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility pH management		0 to 20	10	1	1	1	Fast
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2	2	1	Fast
Water Management (irrigation and drainage, in-field retention)	Cost share	0 to 20	10	11	3.52	5	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	15	Fast
Stormwater R/D	Cost share	5 to 45	15	110	35.2	33	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	7	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	220	70.4	20	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

	Range %	Typical %	Initial Cost	Per acre	N Removed	Quickness
Owner/Cost Share BMP Program Reduced N fertilization, water management, and limited wetland restoration/retention	10 to 70	33	110.8	35	15	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	10	3	1	1	Fast
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	21	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-farm stormwater R/D and Chemical Treatment	5 to 70	52	275	88	24	Fast

BMPs for Citrus

Assume for Typical Condition

Two row crown bedded		
Assumed average farm size of 200 ac		
Grass Management between Trees		
Pond retention with limited wetland restoration		
Micro jet irrigation and fertigation of young stock		
Existing N Load at 160 lb-N/ac/yr fertilizer	7.65	lbs-N/ac/yr
Existing N Concentration	1.76	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 25	10	20	6.4	8	Fast
Better Micros Fertilization	Owner	0 to 5	2	0	0	0	Fast
Water Management (irrigation and drainage)	Cost share	0 to 20	5	0	0	0	Fast
Water Reuse from Retention/Detention Ponds[4]	Alternative	0 to 50	10	33	10.56	14	Fast
Grass Management between Trees	Owner	0 to 5	2	22	7.04	46	Fast
Grassed Waterways	Alternative	0 to 15	5	110	35.2	92	Fast
Stormwater R/D[5]	Alternative	10 to 60	40	440	140.8	46	Fast
Wetland Restoration	Alternative	5 to 20	10	44	14.08	18	Fast
Edge-of-farm Stormwater R/D and Chemical Treatment[6]	Alternative	5 to 70	50	220	70.4	18	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Values shown are for using existing ponds for water reuse, if new facilities are needed then cost would increase significantly.
5 Average of pre/post 1984 stormwater management requirements, i.e. P > .6ppm if developed prior to 1984 and less if developed after 1984. Groves developed after 1984 would probably have stormwater R/D systems, so little addition benefit would be expected for newer groves.
6 High O&M Costs

Program	N Reduction Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Better N Management, Grass Management between Trees, additional Stormwater Retention, and limited Wetland Restoration/Retention	10 to 50	15	490	156.8	137	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Better Micros Fertilization	0 to 25	10	20	6.4	8	Fast
Cost Share BMP Program Water Management (irrigation and drainage)	0 to 20	5	470	150.4	393	Fast
Alternative BMP Program Fertigation, Grassed Waterways, and Edge-of-farm Stormwater R/D with Chemical Treatment	5 to 70	52	242	77	19	Fast

BMPs for Sod / Turf Grass

Assume for Typical Condition

Bermudagrass
Assumed average farm size of 100 ac
Existing N fertilization of 190 lbs N/ac
No retention or wetland restoration
Seepage Irrigation with 100' furrows

Existing N Load	8.10	lbs-N/ac/yr
Existing N Concentration	1.87	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	Type	N Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2.2	2.2	1	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 20	10	11	3.52	4	Fast
Erosion Control (Buffer Strips and sediment traps)	Alternative	0 to 15	5	55	17.6	43	Fast
Stormwater R/D	Cost share	5 to 40	25	110	35.2	17	Fast
Wetland Restoration	Cost share	2 to 15	8	11	3.52	5	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	330	105.6	26	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N fertilization, water management, additional stormwater retention, and limited wetland restoration	10 to 70	47	110	35.2	9	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	20	2.2	2.2	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	27	107.8	34	16	Fast
Alternative BMP Program Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 70	50	330	105.6	26	Fast

BMPs for Ornamentals

Assume for Typical Condition

Ornamental Nursery		
Assumed average farm size of 10 ac		
Existing N fertilization of 160 lbs N/ac		
No retention or wetland restoration		
Overhead Irrigation		
Existing N Load	10.80	lbs-N/ac/yr
Existing N Concentration	2.49	mg/l
Average Annual Runoff	19.16	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	25	11	11	4	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	4	3	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	11	10	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	4	16	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	4	7	Fast
Off Season Cover Crop	Cost share	0 to 30	15	55	18	11	Fast
Stormwater R/D	Cost share	10 to 65	40	220	70	16	Fast
Wetland Restoration	Cost share	0 to 10	4	11	4	8	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	550	176	33	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	50	220	70	13	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	25	11	4	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	25	209	67	25	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	10 to 50	25	440	141	52	Fast

BMPs for Horse Farms

Assume for Typical Condition

1 ac / horse		
Assumed average farm size of 10 ac		
Existing N fertilization of 180 lbs N/ac		
No retention or wetland restoration		
Bahia grass		
Existing N Load	14.40	lbs-N/ac/yr
Existing N Concentration	3.98	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	Type	N Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 60	30	4.2	4.2	1	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	13	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	6	Fast
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	4	Fast
Reduced Stocking Rate[4] (2ac /horse)	Owner	0 to 20	10	165	52.8	37	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move animals from streams	Cost share	0 to 20	5	11	3.52	5	Fast
Provide Alternative Shade to move animals from streams	Alternative	0 to 10	1	16.5	5.28	37	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	2	Fast
Critical Area Fencing	Cost share	2 to 20	2	44	14.08	49	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	20	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	7	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	5	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	220	70.4	10	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 70	52	49.5	15.84	2	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement	0 to 60	30	11	4	1	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	22	38.5	12	4	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	110	35	8	Fast

BMPs for Dairies

Assume for Typical Condition

1000 head Dairy, dry cows pastured on site, 400 heifer/springers on site		
Assumed average farm size of 700 ac		
Existing N fertilization of 100 lbs N/ac		
No existing retention or wetland restoration		
Stargrass Pastures		
Animals are fenced from streams		
Existing N Load	18.00	lbs-N/ac/yr
Existing N Concentration	4.98	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**N Reduction[1]** Range %	Typical %	**Initial Cost of BMP[2]** ($/ac)	**Annual Cost[3] per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	**Quickness of Response**
Barn Waste							
Feed Ration Management	Owner	0 to 25	1	2.2	2.2	12	Fast
Solids Separation for Off Site Disposal	Alternative	0 to 10	1	5.5	1.76	10	Fast
Expanded Waste Storage Ponds	Alternative	----	----	----	----	----	----
Expanded Sprayfields	Alternative	----	----	----	----	----	----
Improved Pasture Management (See Cow-Calf Imp.. Pasture)	Owner	10 to 40	20	16.5	5.28	1	Fast
Improved Forage/Sprayfield Management - N/P balanced, new crops	Owner	0 to 15	5	0	0	0	Fast
HIA Management							
Add Housing to Move Animals off Fields[4]	Alternative	30 to 70	50	3,929	1257	140	Fast
Stormwater Retention / Expanded Sprayfield	Alternative	20 to 70	40	440	140.8	20	Fast
Edge-of-field Chemical Treatment[5]	Alternative	5 to 30	15	550	176	65	Fast
Buffer Strips	Alternative	0 to 10	5	44	14.08	16	Fast
Stormwater R/D	Cost share	15 to 50	30	1100	352	65	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	2	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	550	176	20	Fast

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4 Includes associated waste pond and sprayfield expansions
5 High O&M Costs

Owner/Cost Share BMP Program Stormwater R/D and Wetland Restoration N Fertilizer Reduction	20 to 65	60	1045	334.4	97	Fast
Owner BMP Program N Fertilzer Management	10 to 40	20	2.2	0.704	0	Fast
Cost Share BMP Program Stormwater R/D and Wetland Restoration	20 to 60	40	1042.8	333.696	46	Fast
Alternative BMP Program	20 to 90	48	750	240	28	Fast
Barn Waste						
Solids Separation for Off Site Disposal	0 to 10	1	6	1.76	10	Fast
Expanded Waste Storage Ponds[4]	----	----	----	----	----	----
Expanded Sprayfields[4]	----	----	----	----	----	----
HIA Management						
Add Housing to Move Animals off Fields[4]	30 to 70	50	3929	1257	140	Fast
Stormwater Retention / Expanded Sprayfield	20 to 70	40	440	141	20	Fast
Edge-of-field Chemical Treatment[5]	5 to 30	15	550	176	65	Fast
Buffer Strips	0 to 10	5	44	14	16	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	5 to 70	50	550	176	20	Fast

BMPs for Field Crop (Hayland) Production

Assume for Typical Condition

Assumed average farm size of 500 ac		
Existing N fertilization of 180 lbs N/ac		
No retention or wetland restoration		
Various Land Uses including hay, orchards, poultry, etc.		
Existing N Load	7.91	lbs-N/ac/yr
Existing N Concentration	2.19	mg/l
Average Annual Acres	15.97	in/yr

BMPs	Type	N Reduction[1] Range %	N Reduction[1] Typical %	Initial Cost of BMP[2] ($/ac)	Annual Cost[3] per acre ($/ac/yr)	Annual Cost[3] N Removed ($/lb/ac/yr)	Quickness of Response
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 50	15	2.2	2.2	2	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	23	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	11	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	36	Fast
Stormwater R/D	Cost share	10 to 40	20	55	17.6	11	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	4	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	220	70.4	18	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 60	40	58	18.56	6	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement	0 to 25	15	11	4	3	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	25	47	15	8	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 70	36	110	35	12	Fast

BMPs for Pine Plantation

Assume for Typical Condition

Planted Pine Plantation (20 yr rotation)
Assumed average farm size of 200 ac
Existing N fertilization of 5 lbs N/ac
No retention or wetland restoration

Existing N Load	2.79	lbs-N/ac/yr
Existing N Concentration	0.77	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	Type	N Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Reduced N Fertilization (testing, placement, and type)	Owner	0 to 15	5	3	3	22	Fast
Stormwater R/D	Cost share	2 to 15	8	22	22	99	Fast
Wetland Restoration	Cost share	1 to 5	2	11	3.52	63	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	50	Fast

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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Stormwater R/D, and limited Wetland Restoration	2 to 25	15	22	22	53	Fast
Owner BMP Program Reduced N Fertilization	0 to 15	5	3	0	0	Fast
Cost Share BMP Program Stormwater R/D and limited Wetland Restoration	3 to 20	10	16.5	12.76	46	Fast
Alternative BMP Program Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 50	25	110	35.2	50	Fast

BMPs for Transportation Corridors

Assume for Typical Condition

- 50% Paved Surface
- Bahia Grass Shoulders
- Existing N fertilization of 35 lbs N/ac
- Limited retention or wetland restoration

Existing N Load	8.28	lbs-N/ac/yr
Existing N Concentration	1.35	mg/l
Average Annual Runoff	27.15	in/yr

BMPs		Type	N Reduction1		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
			Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Fertility	pH management		0 to 20	3	2	2	8	Fast
	Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2	2	1	Fast
Stormwater R/D		Cost share	5 to 45	15	110	35.2	28	Fast
Wetland Restoration		Cost share	2 to 15	7	11	3.52	6	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]		Alternative	5 to 50	25	220	70.4	34	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N fertilization, water management, and limited wetland restoration/retention	10 to 70	43	111.8	36	10	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	20	4	1	5	Fast
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	18	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-System stormwater R/D and Chemical Treatment	5 to 50	25	220	70	34	Fast

BMPs for Communications and Utilities

Assume for Typical Condition

Marginally Maintained Bahia Grass
No Pond retention

Existing N Load	5.40	lbs-N/ac/yr
Existing N Concentration	1.49	mg/l
Average Annual Runoff	15.97	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Fast
Dry/Wet Retention 0.25"	Cost share	0 to 20	2	1280	409.6	3793	Fast
Wet Restoration	Cost share	0 to 20	3	1600	512	3160	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	759	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	365	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization,limited dry/wet retention, and wetland restoration	0 to 20	10	6400	2048	3793	Moderate
Owner BMP Program Reduced N Fertilization	0 to 10	5	0	0	0	Fast
Cost Share BMP Program Selective limited dry/wet retention and Wetland Restoration	5 to 50	5	6400	2048	7585	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	15 to 80	50	3200	1024	379	Fast

Appendix B
Current condition assumptions, existing loads, potential load reductions, and costs of implementation for the primary land uses in the Caloosahatchee River watershed

Table of Contents for BMP Assessment Tables

BMPs for Low Density Residential

Assume for Typical Condition

Low Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	0.68	lbs-P/ac/yr
Existing P Concentration	0.11	mg/l
Average Annual Runoff	27.43	in/yr

BMPs	**Type**	**P Reduction**[1]		**Initial Cost**	**Annual Cost**[3]		**Quickness**
		Range	Typical	**of BMP**[2]	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	6057	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	4732	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	63	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	1041	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	6057	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	2912	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	2163	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs

2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	30287	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	60574	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	2163	Fast

BMPs for Medium Density Residential

Assume for Typical Condition

Medium Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns		
Limited Pond retention		
Limited Lawn Irrigation		
Existing P Load	1.93	lbs-P/ac/yr
Existing P Concentration	0.26	mg/l
Average Annual Runoff	32.42	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	2120	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	1656	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	22	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	364	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	2120	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	1019	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	757	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	10600	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	21201	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	757	Fast

BMPs for High Density Residential

Assume for Typical Condition

High Density Residential
Assumed average development size of 200 ac
Moderately Managed Lawns
Limited Pond retention
Limited Lawn Irrigation

Existing P Load	4.14	lbs-P/ac/yr
Existing P Concentration	0.46	mg/l
Average Annual Runoff	39.90	in/yr

BMPs	Type	P Reduction[1]		Initial Cost	Annual Cost[3]		Quickness
		Range	Typical	of BMP[2]	per acre	P Removed	of
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	Response
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	989	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	773	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	10	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	170	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	989	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	476	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	353	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	4947	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	9894	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	353	Fast

BMPs for Other Urban

Assume for Typical Condition

Medium Density Residential with Mixed Commercial
Assumed average development size of 200 ac
Moderately Managed Lawns
Limited Pond retention
Limited Lawn Irrigation

Existing P Load	2.05	lbs-P/ac/yr
Existing P Concentration	0.25	mg/l
Average Annual Runoff	36.34	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry Retention/Swales 0.25"	Cost share	20 to 80	50	6400	2048	2001	Fast
Wet Detention - 0.25"	Cost share	30 to 90	80	8000	2560	1563	Fast
Street Sweeping	Cost share	0 to 25	15	20	6.4	21	Fast
Sediment/Baffle Boxes	Cost share	10 to 60	20	440	140.8	344	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	2001	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	962	Fast
Stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	3200	1024	715	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 20	10	6400	2048	10003	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	5	6400	2048	20006	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	20 to 90	70	3200	1024	715	Fast

BMPs for Cow Calf Production

Improved Pastures

Assume for Typical Condition

3 ac / cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 3 lbs P/ac		
No retention or wetland restoration		
Bahia grass		
Animals have access to streams		
Existing P Load	1.93	lbs-P/ac/yr
Existing P Concentration	0.29	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 30	10	2.2	2.2	11	Slow
Better N and Micros Fertilization	Owner	0 to 20	3	5.5	5.5	95	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	46	Slow
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	30	Moderate
Reduced Stocking Rate[4] (4ac /cow)	Owner	0 to 10	3	165	52.8	911	Slow
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Cost share	0 to 20	10	11	3.52	18	Fast
Provide Alternative Shade to move cattle from streams	Alternative	0 to 10	2	16.5	5.28	137	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	12	Fast
Critical Area Fencing	Cost share	2 to 20	5	44	14.08	146	Fast
Retention Basin by Working Pens	Cost share	2 to 10	5	3.3	1.056	11	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	146	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	49	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	36	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	20 to 90	70	220	70.4	52	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	30	49.5	15.84	27	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	11	11	4	17	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	19	38.5	12	34	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	49	110	35	37	Fast

BMPs for Cow Calf Production

Unimproved Pasture

Assume for Typical Condition

8 ac per cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 1 lbs P/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing P Load	0.99	lbs-P/ac/yr
Existing P Concentration	0.18	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	2.2	221	Slow
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	35	Slow
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	59	Moderate
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	35	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	24	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	118	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	35	Fast
Stormwater R/D	Cost share	2 to 15	7	22	7.04	101	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	89	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	110	35.2	71	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	20	13.2	4.224	21	Moderate
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	7	2.2	1	10	Slow
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	13	11	4	27	Moderate
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	44	55	18	40	Fast

BMPs for Cow Calf Production

Rangeland and Wooded Pasture

Assume for Typical Condition

16ac per cow		
Assumed average farm size of 500 ac		
Existing P fertilization of 0 lbs P/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing P Load	0.40	lbs-P/ac/yr
Existing P Concentration	0.08	mg/l
Average Annual Runoff	21.24	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	2.2	552	Slow
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	88	Slow
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	147	Moderate
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	88	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	59	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	294	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	88	Fast
Stormwater R/D	Cost share	2 to 20	10	22	7.04	177	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	221	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	40	110	35.2	221	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	10	13.2	4.224	106	Moderate
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	4	2.2	1	44	Slow
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	6	11	4	147	Moderate
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	35	55	18	126	Fast

BMPs for Row Crop

Assume for Typical Condition

Potatoes Spring Crop		
Assumed average farm size of 100 ac		
Existing P fertilization of 100 lbs P/ac		
No retention or wetland restoration		
Seepage Irrigation with 60' furrows		
Existing P Load	3.45	lbs-P/ac/yr
Existing P Concentration	0.44	mg/l
Average Annual Runoff	34.91	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	11	11	11	Slow
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	3.52	10	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	31	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	3.52	51	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	3.52	20	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	17.6	128	Fast
Stormwater R/D	Cost share	10 to 55	25	220	70.4	82	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	10	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	550	176	102	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	60	220	70.4	34	Moderate
Owner BMP Program Reduced P Fertilization	20 to 70	30	11	3.52	3	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	30	209	66.88	65	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	50	440	140.8	82	Fast

BMPS for Sugarcane

Assume for Typical Condition		
3 year ratoon		
Assumed average farm size of 400 ac		
Existing P fertilization of 30 lbs P/ac		
Limited retention or wetland restoration		
Seepage Irrigation with 330' furrows		
Existing P Load	0.55	lbs-P/ac/yr
Existing P Concentration	0.08	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	Type	P Reduction[1] Range %	P Reduction[1] Typical %	Initial Cost of BMP[2] ($/ac)	Annual Cost[3] per acre ($/ac/yr)	Annual Cost[3] P Removed ($/lb/ac/yr)	Quickness of Response
Fertility pH management		0 to 20	10	0	0	0	Fast
Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	0	0	0	Slow
Water Management (irrigation and drainage, in-field retention)	Cost share	0 to 20	10	11	3.52	64	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	191	Fast
Stormwater R/D	Cost share	5 to 45	15	110	35.2	425	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	91	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	220	70.4	182	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P fertilization, water management, and limited wetland restoration/retention	10 to 70	33	110	35	193	Moderate
Owner BMP Program Reduced P Fertilization	10 to 50	10	2.2	0	0	Slow
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	272	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	52	275	88	307	Fast

BMPs for Citrus

Assume for Typical Condition

- Two row crown bedded
- Assumed average farm size of 200 ac
- Grass Management between Trees
- Pond retention with limited wetland restoration
- Micro jet irrigation and fertigation of young stock

Existing P Load	0.90	lbs-P/ac/yr
Existing P Concentration	0.13	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**P Reduction[1]** Range %	Typical %	**Initial Cost of BMP[2]** ($/ac)	**Annual Cost[3]** per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	**Quickness of Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to 25	10	0	0	0	Slow
Better N and Micros Fertilization	Owner	0 to 5	2	0	0	0	Slow
Water Management (irrigation and drainage)	Cost share	0 to 20	5	0	0	0	Fast
Water Reuse from Retention/Detention Ponds[4]	Cost share	0 to 50	10	33	10.56	118	Fast
Grass Management between Trees	Owner	0 to 5	2	22	7.04	392	Moderate
Grassed Waterways	Alternative	0 to 15	5	110	35.2	785	Fast
Stormwater R/D[5]	Cost share	10 to 60	40	440	140.8	392	Fast
Wetland Restoration	Cost share	5 to 20	10	44	14.08	157	Fast
Edge-of-farm Stormwater R/D and Chemical Treatment[6]	Alternative	20 to 90	70	220	70.4	112	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Values shown are for using existing ponds for water reuse, if new facilities are needed then cost would increase significantly.
5 Average of pre/post 1984 stormwater management requirements, i.e. P > .6ppm if developed prior to 1984 and less if developed after 1984. Groves developed after 1984 would probably have stormwater R/D systems, so little addition benefit would be expected for newer groves.
6 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	Per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Better N Management, Grass Management between Trees, additional Stormwater Retention, and limited Wetland Restoration/Retention	10 to 50	32	75	24	261	Moderate
Owner BMP Program Reduced P Fertilization, Better N Management, and Grass Management between Trees	0 to 25	12	5.5	0	0	Slow
Cost Share BMP Program Stormwater R/D and Wetland Restoration	5 to 50	20	77	24.64	137	Fast
Alternative BMP Program Fertigation, Grassed Waterways, and Edge-of-farm Stormwater R/D with Chemical Treatment	20 to 90	42	242	77	206	Fast

BMPS for Sod / Turf Grass

Assume for Typical Condition	
Bermudagrass	
Assumed average farm size of 100 ac	
Existing P fertilization of 70 lbs P/ac	
No retention or wetland restoration	
Seepage Irrigation with 100' furrows	
Existing P Load	2.79 lbs-P/ac/yr
Existing P Concentration	0.41 mg/l
Average Annual Runoff	29.93 in/yr

BMPs	**Type**	**P Reduction[1]** Range %	Typical %	**Initial Cost of BMP[2]** ($/ac)	**Annual Cost[3]** **per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**Quickness of Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2.2	2.2	4	Slow
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 20	10	11	3.52	13	Fast
Erosion Control (Buffer Strips and sediment traps)	Alternative	0 to 15	5	55	17.6	126	Fast
Stormwater R/D	Cost share	5 to 40	25	110	35.2	51	Fast
Wetland Restoration	Cost share	2 to 15	8	11	3.52	16	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	330	105.6	76	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P fertilization, water management, additional stormwater retention, and limited wetland restoration	10 to 70	47	110	35.2	27	Moderate
Owner BMP Program Reduced P Fertilization	10 to 50	20	2.2	2.2	4	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	27	107.8	34	46	Fast
Alternative BMP Program Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 70	50	330	105.6	76	Fast

BMPs for Ornamentals

Assume for Typical Condition

Ornamental Nursery		
Assumed average farm size of 10 ac		
Existing P fertilization of 160 lbs P/ac		
No retention or wetland restoration		
Overhead Irrigation		
Existing P Load	4.00	lbs-P/ac/yr
Existing P Concentration	0.59	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**P Reduction**[1]		**Initial Cost**	**Annual Cost**[3]		**Quickness**
		Range %	Typical %	**of BMP**[2] ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	11	11	9	Slow
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	4	9	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	11	26	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	4	44	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	4	18	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	18	110	Fast
Stormwater R/D	Cost share	10 to 65	40	220	70	44	Fast
Wetland Restoration	Cost share	0 to 10	4	11	4	22	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	50	550	176	88	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	67	220	70	26	Moderate
Owner BMP Program Reduced P Fertilization	20 to 70	32	11	4	3	Slow
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	35	209	67	48	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 90	50	440	141	70	Fast

BMPs for Horse Farms

Assume for Typical Condition

1 ac / horse		
Assumed average farm size of 10 ac		
Existing P fertilization of 5 lbs P/ac		
No retention or wetland restoration		
Bahia grass		
Existing P Load	2.51	lbs-P/ac/yr
Existing P Concentration	0.44	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 30	15	2.2	2.2	6	Slow
Better N and Micros Fertilization	Owner	0 to 20	10	5.5	5.5	22	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	35	Slow
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	23	Moderate
Reduced Stocking Rate[4] (2ac /horse)	Owner	0 to 10	20	165	52.8	105	Slow
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move animals from streams	Cost share	0 to 20	5	11	3.52	28	Fast
Provide Alternative Shade to move animals from streams	Alternative	0 to 10	1	16.5	5.28	210	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	9	Fast
Critical Area Fencing	Cost share	2 to 20	2	44	14.08	280	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	112	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	37	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	28	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	20 to 90	70	220	70.4	40	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	42	49.5	15.84	15	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	20	11	4	7	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	22	38.5	12	22	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	49	110	35	29	Fast

BMPs for Dairies

Assume for Typical Condition		
1000 head Dairy, dry cows pastured on site, 400 heifer/springers on site		
Assumed average farm size of 700 ac		
Existing P fertilization of 0 lbs P/ac		
No existing retention or wetland restoration		
Stargrass Pastures		
Animals are fenced from streams		
Existing P Load	12.94	lbs-P/ac/yr
Existing P Concentration	2.29	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Barn Waste							
Feed Ration Management	Owner	0 to 25	8	2.2	2.2	2	Slow
Solids Separation for Off Site Disposal	Alternative	0 to 10	3	5.5	1.76	5	Slow
Expanded Waste Storage Ponds	Alternative	----	----	----	----	----	----
Expanded Sprayfields	Alternative	----	----	----	----	----	----
Improved Pasture Management (See Cow-Calf Imp.. Pasture)	Owner	10 to 40	20	16.5	5.28	2	Moderate
Improved Forage/Sprayfield Management - P balanced, new crops	Owner	0 to 15	5	0	0	0	Slow
HIA Management							
Add Housing to Move Animals off Fields[4]	Alternative	30 to 70	50	3,929	1257	194	Slow
Stormwater Retention / Expanded Sprayfield	Alternative	20 to 70	40	440	140.8	27	Moderate
Edge-of-field Chemical Treatment[5]	Alternative	50 to 90	70	550	176	19	Fast
Buffer Strips	Alternative	0 to 10	5	44	14.08	22	Moderate
Stormwater R/D	Cost share	15 to 50	30	1100	352	91	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	3	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	50 to 90	70	550	176	19	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Value only include implementation cost, i.e. doesn't include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 Includes associated waste pond and sprayfield expansions

5 High O&M Costs

Owner/Cost Share BMP Program	20 to 65	37	1045	334.4	218	Moderate
Stormwater R/D and Wetland Restoration						
Feed Management						
Owner BMP Program	0 to 25	9	2.2	2	7	Slow
Feed Ration Management						
Cost Share BMP Program	20 to 60	28	1042.8	333.696	316	Fast
Stormwater R/D and Wetland Restoration						
Alternative BMP Program	20 to 90	48	550	176	28	Fast
Barn Waste						
Solids Separation for Off Site Disposal	0 to 10	3	6	1.76	5	Slow
Expanded Waste Storage Ponds[4]	----	----	----	----	----	----
Expanded Sprayfields[4]	----	----	----	----	----	----
HIA Management						
Add Housing to Move Animals off Fields[4]	30 to 70	50	3929	1257	194	Slow
Stormwater Retention / Expanded Sprayfield	20 to 70	40	440	141	27	Moderate
Edge-of-field Chemical Treatment[5]	50 to 90	70	550	176	19	Fast
Buffer Strips	0 to 10	5	44	14	22	Moderate
Edge-of-farm stormwater R/D and Chemical Treatment[5]	50 to 90	70	550	176	19	Fast

BMPs for Field Crop (Hayland) Production

Assume for Typical Condition		
Assumed average farm size of 500 ac		
Existing P fertilization of 60 lbs P/ac		
No retention or wetland restoration	0.14	
Various Land Uses including hay, orchards, poultry, etc.		
Existing P Load	3.20	lbs-P/ac/yr
Existing P Concentration	0.53	mg/l
Average Annual Acres	26.63	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, split, placement, and type)	Owner	0 to 50	15	2.2	2.2	5	Slow
Better N and Micros Fertilization	Owner	0 to 20	3	5.5	5.5	57	Slow
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	28	Slow
Buffer Strips	Cost share	0 to 10	5	44	14.08	88	Fast
Stormwater R/D	Cost share	10 to 40	20	55	17.6	28	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	11	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	36	220	70.4	61	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
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3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 60	40	50	15.84	12	Moderate
Owner BMP Program P Reduced to zero, Better N Management, Grass Management, and Feeder/Minerals and Water Placement	0 to 25	15	11	4	7	Slow
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	25	39	12	15	Moderate
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 90	36	110	35	31	Fast

BMPS for Pine Plantation

Assume for Typical Condition

- Planted Pine Plantation (20 yr rotation)
- Assumed average farm size of 200 ac
- Existing P fertilization of 5 lbs P/ac
- No retention or wetland restoration

Existing P Load	0.21	lbs-P/ac/yr
Existing P Concentration	0.06	mg/l
Average Annual Runoff	14.96	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**of Response**
Reduced P Fertilization (testing, placement, and type)	Owner	0 to 10	1	0	0	0	Slow
Stormwater R/D	Cost share	2 to 15	8	22	22	1329	Fast
Wetland Restoration	Cost share	1 to 5	2	11	3.52	850	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	110	35.2	340	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	P Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Stormwater R/D, and limited Wetland Restoration	2 to 25	11	22	22	1111	Moderate
Owner BMP Program Reduced P Fertilization	0 to 25	1	0	0	0	Slow
Cost Share BMP Program Stormwater R/D and limited Wetland Restoration	10 to 50	10	22	20	1111	Fast
Alternative BMP Program Edge-of-farm Stormwater R/D and Chemical Treatment	20 to 70	50	100	32	355	Fast

BMPS for Transportation Corridors

Assume for Typical Condition							
50% Paved Surface							
Bahia Grass Shoulders							
Existing P fertilization of 15 lbs P/ac							
Limited retention or wetland restoration							
Existing P Load	2.28	lbs-P/ac/yr					
Existing P Concentration	0.20	mg/l					
Average Annual Runoff	49.88	in/yr					

BMPs	**Type**	**P Reduction[1]** Range %	Typical %	**Initial Cost of BMP[2]** ($/ac)	**Annual Cost[3]** **per acre** ($/ac/yr)	**P Removed** ($/lb/ac/yr)	**Quickness of Response**
Fertility pH management		0 to 20	10	0	0	0	Fast
Reduced P Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	0	0	0	Slow
Stormwater R/D	Cost share	5 to 45	15	110	35.2	103	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	22	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 90	70	220	70.4	44	Fast
Owner/Cost Share BMP Program Reduced P fertilization, water management, and limited wetland restoration/retention		10 to 70	33	110	35	47	Moderate
Owner BMP Program Reduced P Fertilization		10 to 50	10	2.2	0	0	Slow
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention		10 to 60	23	107.8	34	66	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-System stormwater R/D and Chemical Treatment		20 to 90	52	275	88	74	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

BMPs for Communications and Utilities

Assume for Typical Condition

Marginally Maintained Bahia Grass		
No Pond retention		
Existing P Load	0.66	lbs-P/ac/yr
Existing P Concentration	0.12	mg/l
Average Annual Runoff	25.05	in/yr

BMPs	**Type**	**P Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**P Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Slow
Dry/Wet Retention 0.25"	Cost share	0 to 20	2	1280	409.6	30918	Fast
Wet Restoration	Cost share	0 to 20	3	1600	512	25765	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	6184	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	2973	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced P Fertilization,limited dry/wet retention, and wetland restoration	0 to 20	10	6400	2048	30918	Moderate
Owner BMP Program Reduced P Fertilization	0 to 10	5	0	0	0	Slow
Cost Share BMP Program Selective limited dry/wet retention and Wetland Restoration	5 to 50	5	6400	2048	61836	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	15 to 80	50	3200	1024	3092	Fast

BMPs for Low Density Residential

Assume for Typical Condition

Low Density Residential
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 1.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	7.26	lbs-P/ac/yr
Existing N Concentration	1.17	mg/l
Average Annual Runoff	27.43	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 30	15	11	3.52	3	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 40	15	6400	2048	1881	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1763	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	44	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	129	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	940	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	1175	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 50	30	6411	2051.52	942	Fast
Owner BMP Program Reduced N Fertilization	0 to 30	15	11	3.52	3	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	10 to 40	15	6400	2048	1881	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	940	Fast

BMPs for Medium Density Residential

Assume for Typical Condition

Medium Density Residential		
Assumed average development size of 200 ac		
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2		
Limited Pond retention		
Limited Lawn Irrigation		
Existing N Load	10.56	lbs-N/ac/yr
Existing N Concentration	1.44	mg/l
Average Annual Runoff	32.42	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 50	25	15	4.8	2	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	776	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1212	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	30	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	89	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	646	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	808	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	50	6415	2052.8	389	Fast
Owner BMP Program Reduced N Fertilization	0 to 60	25	15	4.8	2	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	25	6400	2048	776	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	646	Fast

BMPs for High Density Residential

Assume for Typical Condition

High Density Residential
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	15.84	lbs-N/ac/yr
Existing N Concentration	1.75	mg/l
Average Annual Runoff	39.90	in/yr

BMPs	Type	N Reduction[1]		Initial Cost	Annual Cost[3]		Quickness
		Range	Typical	of BMP[2]	per acre	N Removed	of
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	Response
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 60	30	15	4.8	1	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	517	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	808	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	20	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	59	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	431	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	539	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Program	Range %	Typical %	Initial Cost ($/ac)	Per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	55	6415	2052.8	236	Fast
Owner BMP Program Reduced N Fertilization	0 to 60	30	15	4.8	1	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	5 to 50	25	6400	2048	517	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	431	Fast

BMPs for Other Urban

Assume for Typical Condition

Mixed Commercial, Industrial, institutional, recreation
Assumed average development size of 200 ac
Moderately Managed Lawns Mid-IFAS 3.5 lb-N/1000ft2
Limited Pond retention
Limited Lawn Irrigation

Existing N Load	11.68	lbs-N/ac/yr
Existing N Concentration	1.42	mg/l
Average Annual Runoff	36.34	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS low, placement, and type)	Owner	0 to 50	25	15	4.8	2	Fast
Dry Retention/Swales[4] 0.25"	Cost share	10 to 50	25	6400	2048	701	Fast
Wet Detention - 0.25"	Cost share	10 to 40	20	8000	2560	1096	Fast
Street Sweeping	Cost share	0 to 10	2	20	6.4	27	Fast
Sediment/Baffle Boxes	Cost share	2 to 30	15	440	140.8	80	Fast
Dry Detention - Regional	Alternative	5 to 35	15	3200	1024	584	Fast
Wet Detention - Regional	Alternative	5 to 30	15	4000	1280	731	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Adjusted down to correct for reported Dry Detention reductions not including ground water re-emergent N loads.

Owner/Cost Share BMP Program Reduced N Fertilization, Swales, and limited Dry Retention/Sweeping	0 to 70	50	6415	2052.8	352	Fast
Owner BMP Program Reduced N Fertilization	0 to 50	25	15	4.8	2	Fast
Cost Share BMP Program Limited Dry Retention, Street Sweeping, Sediment R/D and Wetland Restoration	10 to 50	25	6400	2048	701	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	5 to 35	15	3200	1024	584	Fast

BMPs for Cow Calf Production

Improved Pastures

Assume for Typical Condition

- 3 ac / cow
- Assumed average farm size of 500 ac
- Existing N fertilization of 120 lbs N/ac
- No retention or wetland restoration
- Bahia grass
- Animals have access to streams
- Existing N Load 14.65 lbs-N/ac/yr
- Existing N Concentration 2.16 mg/l
- Average Annual Runoff 29.93 in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 30	15	2.2	2.2	1	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	13	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	6	Fast
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	4	Fast
Reduced Stocking Rate[4] (4ac /cow)	Owner	0 to 10	5	165	52.8	72	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Cost share	0 to 20	10	11	3.52	2	Fast
Provide Alternative Shade to move cattle from streams	Alternative	0 to 10	2	16.5	5.28	18	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	2	Fast
Critical Area Fencing	Cost share	2 to 20	5	44	14.08	19	Fast
Retention Basin by Working Pens	Cost share	2 to 10	5	3.3	1.056	1	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	19	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	6	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	5	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	220	70.4	10	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	27	49.5	15.84	4	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement	0 to 25	17	11	4	1	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	10	38.5	12	8	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	110	35	8	Fast

BMPs for Cow Calf Production

Unimproved Pasture

Assume for Typical Condition

8 ac per cow		
Assumed average farm size of 500 ac		
Existing N fertilization of 60 lbs N/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing N Load	7.26	lbs-N/ac/yr
Existing N Concentration	1.29	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 20	9	1.2	1.2	2	Fast
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	5	Fast
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	8	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	5	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	3	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	16	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	5	Fast
Stormwater R/D	Cost share	2 to 15	7	22	7.04	14	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	12	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	19	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	19	13.2	4.224	3	Fast
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	11	2.2	1	1	Fast
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 30	8	11	4	6	Fast
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	55	18	8	Fast

BMPs for Cow Calf Production

Rangeland and Wooded Pasture

Assume for Typical Condition

16ac per cow		
Assumed average farm size of 500 ac		
Existing N fertilization of 10 lbs N/ac		
No retention or wetland restoration		
Bahia grass / native		
Animals have access to streams		
Existing N Load	5.41	lbs-N/ac/yr
Existing N Concentration	1.12	mg/l
Average Annual Runoff	21.24	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Better N and Micros Fertilization - No P added	Owner	0 to 10	1	2.2	1	18	Fast
Grass Management (chopping, mowing, burning, etc.)	Owner	0 to 10	2	2.2	0.704	7	Fast
Improved Grazing Management							
Rotational Grazing (limited)	Cost share	0 to 5	3	5.5	1.76	11	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move cattle from streams	Owner	0 to 10	5	5.5	1.76	7	Fast
Feeder/Minerals and Water Placement	Owner	0 to 10	3	2.2	0.704	4	Fast
Critical Area Fencing	Alternative	2 to 10	3	11	3.52	22	Fast
Retention Basin by Working Pens	Cost share	2 to 10	3	3.3	1.056	7	Fast
Stormwater R/D	Cost share	2 to 20	10	22	7.04	13	Fast
Wetland Restoration	Cost share	2 to 10	4	11	3.52	16	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	26	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Some rotational grazing, new water facilities, retention basin basin by working pens, improved grass management, feed placement, and moderate wetland restoration/retention	5 to 30	10	13.2	4.224	8	Fast
Owner BMP Program Improved Grass Management, Watering Facilities, and Feed Placement	0 to 20	4	2.2	1	3	Fast
Cost Share BMP Program Some Rotational Grazing, retention basin basin by working pens, and moderate wetland restoration/retention	5 to 25	6	11	4	11	Fast
Alternative BMP Program Critical Area Fencing and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 50	20	55	18	16	Fast

BMPs for Row Crop

Assume for Typical Condition

Potatoes Spring Crop		
Assumed average farm size of 100 ac		
Existing N fertilization of 225 lbs N/ac		
No retention or wetland restoration		
Seepage Irrigation with 60' furrows		
Existing N Load	19.80	lbs-N/ac/yr
Existing N Concentration	2.50	mg/l
Average Annual Runoff	34.91	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	20 to 70	30	18	18	3	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	3.52	2	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	5	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	3.52	9	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	3.52	4	Fast
Off Season Cover Crop	Cost share	0 to 10	4	55	17.6	22	Fast
Stormwater R/D	Cost share	10 to 55	25	220	70.4	14	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	2	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	550	176	18	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	60	220	70.4	6	Fast
Owner BMP Program Reduced N Fertilization	20 to 70	30	11	3.52	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	30	209	66.88	11	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	5 to 70	50	440	140.8	14	Fast

BMPS for Sugarcane

Assume for Typical Condition

- 3 year ratoon on organic soils
- Assumed average farm size of 400 ac
- Existing N fertilization of 30 lbs N/ac
- Limited retention or wetland restoration
- Seepage Irrigation with 330' furrows

Existing N Load	10.56	lbs-N/ac/yr
Existing N Concentration	1.56	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**N Reduction2**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	**of Response**
Fertility pH management		0 to 20	10	1	1	1	Fast
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2	2	1	Fast
Water Management (irrigation and drainage, in-field retention)	Cost share	0 to 20	10	11	3.52	3	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	10.56	10	Fast
Stormwater R/D	Cost share	5 to 45	15	110	35.2	22	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	5	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	220	70.4	13	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N fertilization, water management, and limited wetland restoration/retention	10 to 70	33	110.8	35	10	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	10	3	1	1	Fast
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	14	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-farm stormwater R/D and Chemical Treatment	5 to 70	52	275	88	16	Fast

BMPs for Citrus

Assume for Typical Condition		
Two row crown bedded		
Assumed average farm size of 200 ac		
Grass Management between Trees		
Pond retention with limited wetland restoration		
Micro jet irrigation and fertigation of young stock		
Existing N Load at 160 lb-N/ac/yr fertilizer	11.22	lbs-N/ac/yr
Existing N Concentration	1.66	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	Type	N Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 25	10	20	6.4	6	Fast
Better Micros Fertilization	Owner	0 to 5	2	0	0	0	Fast
Water Management (irrigation and drainage)	Cost share	0 to 20	5	0	0	0	Fast
Water Reuse from Retention/Detention Ponds[4]	Cost share	0 to 50	10	33	10.56	9	Fast
Grass Management between Trees	Owner	0 to 5	2	22	7.04	31	Fast
Grassed Waterways	Alternative	0 to 15	5	110	35.2	63	Fast
Stormwater R/D[5]	Cost share	10 to 60	40	440	140.8	31	Fast
Wetland Restoration	Cost share	5 to 20	10	44	14.08	13	Fast
Edge-of-farm Stormwater R/D and Chemical Treatment[6]	Alternative	5 to 70	50	220	70.4	13	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP

2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.

3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.

4 Values shown are for using existing ponds for water reuse, if new facilities are needed then cost would increase significantly.

5 Average of pre/post 1984 stormwater management requirements, i.e. P > .6ppm if developed prior to 1984 and less if developed after 1984.
Groves developed after 1984 would probably have stormwater R/D systems, so little addition benefit would be expected for newer groves.

6 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced P Fertilization, Better N Management, Grass Management between Trees, additional Stormwater Retention, and limited Wetland Restoration/Retention	10 to 50	30	490	156.8	47	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Better Micros Fertilization	0 to 25	10	20	6.4	6	Fast
Cost Share BMP Program Stormwater R/D and Wetland Restoration	5 to 50	20	470	150.4	67	Fast
Alternative BMP Program Fertigation, Grassed Waterways, and Edge-of-farm Stormwater R/D with Chemical Treatment	5 to 70	42	242	77	16	Fast

BMPS for Sod / Turf Grass

Assume for Typical Condition

Bermudagrass		
Assumed average farm size of 100 ac		
Existing N fertilization of 190 lbs N/ac		
No retention or wetland restoration		
Seepage Irrigation with 100' furrows		
Existing N Load	11.88	lbs-N/ac/yr
Existing N Concentration	1.75	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2.2	2.2	1	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 20	10	11	3.52	3	Fast
Erosion Control (Buffer Strips and sediment traps)	Alternative	0 to 15	5	55	17.6	30	Fast
Stormwater R/D	Cost share	5 to 40	25	110	35.2	12	Fast
Wetland Restoration	Cost share	2 to 15	8	11	3.52	4	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	20 to 70	50	330	105.6	18	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N fertilization, water management, additional stormwater retention, and limited wetland restoration	10 to 70	47	110	35.2	6	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	20	2.2	2.2	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	27	107.8	34	11	Fast
Alternative BMP Program Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	20 to 70	50	330	105.6	18	Fast

BMPs for Ornamentals

Assume for Typical Condition

Ornamental Nursery
Assumed average farm size of 10 ac
Existing N fertilization of 160 lbs N/ac
No retention or wetland restoration
Overhead Irrigation

Existing N Load	15.84	lbs-N/ac/yr
Existing N Concentration	2.34	mg/l
Average Annual Runoff	29.93	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range %	Typical %	**of BMP[2]** ($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	**of Response**
Fertility							
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	25	11	11	3	Fast
Water Management (irrigation and drainage, riser board control)	Cost share	0 to 40	10	11	4	2	Fast
Water Reuse from Retention/Detention Ponds	Alternative	0 to 20	10	33	11	7	Fast
Erosion Control (sediment trap in front of risers)	Alternative	0 to 5	2	11	4	11	Fast
Off Season In-Field Retention	Cost share	0 to 15	5	11	4	4	Fast
Off Season Cover Crop	Cost share	0 to 30	15	55	18	7	Fast
Stormwater R/D	Cost share	10 to 65	40	220	70	11	Fast
Wetland Restoration	Cost share	0 to 10	4	11	4	6	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	550	176	22	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Owner/Cost Share BMP Program Reduced N Fertilization, Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 80	50	220	70	9	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	25	11	4	1	Fast
Cost Share BMP Program Water Management, additional Stormwater Retention, Cover Crop, and limited Wetland Restoration/Retention	10 to 50	25	209	67	17	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds, Erosion Control, and Edge-of-farm stormwater R/D and Chemical Treatment	10 to 50	25	440	141	36	Fast

BMPs for Horse Farms

Assume for Typical Condition

1 ac / horse		
Assumed average farm size of 10 ac		
Existing N fertilization of 180 lbs N/ac		
No retention or wetland restoration		
Bahia grass		
Existing N Load	21.12	lbs-N/ac/yr
Existing N Concentration	3.74	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 60	30	4.2	4.2	1	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	9	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	4	Fast
Improved Grazing Management							
Rotational Grazing	Cost share	0 to 30	3	5.5	1.76	3	Fast
Reduced Stocking Rate[4] (2ac /horse)	Owner	0 to 20	10	165	52.8	25	Fast
HIA and Direct Water Access Prevention							
Improved Watering Facilities to move animals from streams	Cost share	0 to 20	5	11	3.52	3	Fast
Provide Alternative Shade to move animals from streams	Alternative	0 to 10	1	16.5	5.28	25	Fast
Feeder/Minerals and Water Placement	Owner	0 to 30	3	2.2	0.704	1	Fast
Critical Area Fencing	Cost share	2 to 20	2	44	14.08	33	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	13	Fast
Stormwater R/D	Cost share	5 to 40	15	44	14.08	4	Fast
Wetland Restoration	Cost share	2 to 15	5	11	3.52	3	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	220	70.4	7	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 This practice would typically be unacceptable to most farmers, but if significant feed is being purchased then it should be considered
5 High O&M Costs

Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 70	52	49.5	15.84	1	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement	0 to 60	30	11	4	1	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention	10 to 50	22	38.5	12	3	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 60	30	110	35	6	Fast

BMPs for Dairies

Assume for Typical Condition

1000 head Dairy, dry cows pastured on site, 400 heifer/springers on site
Assumed average farm size of 700 ac
Existing N fertilization of 100 lbs N/ac
No existing retention or wetland restoration
Stargrass Pastures
Animals are fenced from streams

Existing N Load	26.40	lbs-N/ac/yr
Existing N Concentration	4.67	mg/l
Average Annual Runoff	24.94	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Barn Waste							
Feed Ration Management	Owner	0 to 25	1	2.2	2.2	8	Fast
Solids Separation for Off Site Disposal	Alternative	0 to 10	1	5.5	1.76	7	Fast
Expanded Waste Storage Ponds	Alternative	----	----	----	----	----	----
Expanded Sprayfields	Alternative	----	----	----	----	----	----
Improved Pasture Management (See Cow-Calf Imp.. Pasture)	Owner	10 to 40	20	16.5	5.28	1	Fast
Improved Forage/Sprayfield Management - N/P balanced, new crops	Owner	0 to 15	5	0	0	0	Fast
HIA Management							
Add Housing to Move Animals off Fields[4]	Alternative	30 to 70	50	3,929	1257	95	Fast
Stormwater Retention / Expanded Sprayfield	Alternative	20 to 70	40	440	140.8	13	Fast
Edge-of-field Chemical Treatment[5]	Alternative	5 to 30	15	550	176	44	Fast
Buffer Strips	Alternative	0 to 10	5	44	14.08	11	Fast
Stormwater R/D	Cost share	15 to 50	30	1100	352	44	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	1	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	Alternative	5 to 70	50	550	176	13	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Value only include implementation cost, i.e. doesn't include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 Includes associated waste pond and sprayfield expansions
5 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program	20 to 65	60	1045	334.4	66	Fast
Stormwater R/D and Wetland Restoration						
N Fertilizer Reduction						
Owner BMP Program	10 to 40	20	2.2	0.704	0	Fast
N Fertilzer Management						
Cost Share BMP Program	20 to 60	40	1042.8	333.696	32	Fast
Stormwater R/D and Wetland Restoration						
Alternative BMP Program	20 to 90	48	750	240	19	Fast
Barn Waste						
Solids Separation for Off Site Disposal	0 to 10	1	6	1.76	7	Fast
Expanded Waste Storage Ponds[4]	----	----	----	----	----	----
Expanded Sprayfields[4]	----	----	----	----	----	----
HIA Management						
Add Housing to Move Animals off Fields[4]	30 to 70	50	3929	1257	95	Fast
Stormwater Retention / Expanded Sprayfield	20 to 70	40	440	141	13	Fast
Edge-of-field Chemical Treatment[5]	5 to 30	15	550	176	44	Fast
Buffer Strips	0 to 10	5	44	14	11	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[5]	5 to 70	50	550	176	13	Fast

BMPs for Field Crop (Hayland) Production

Assume for Typical Condition

Assumed average farm size of 500 ac		
Existing N fertilization of 180 lbs N/ac		
No retention or wetland restoration		
Various Land Uses including hay, orchards, poultry, etc.		
Existing N Load	10.18	lbs-N/ac/yr
Existing N Concentration	1.69	mg/l
Average Annual Acres	26.63	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility							
Reduced N Fertilization (IFAS, placement, and type)	Owner	0 to 50	15	2.2	2.2	1	Fast
Better Micros Fertilization	Owner	0 to 20	3	5.5	5.5	18	Fast
Grass Management (variety, mowing, burning, irrigation, etc.)	Owner	0 to 20	2	5.5	1.76	9	Fast
Buffer Strips	Cost share	0 to 10	5	44	14.08	28	Fast
Stormwater R/D	Cost share	10 to 40	20	55	17.6	9	Fast
Wetland Restoration	Cost share	5 to 20	10	11	3.52	3	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 70	50	220	70.4	14	Fast
Owner/Cost Share BMP Program P reduced to zero, Better N Management, Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Improved Grass Management, Feed Placement, Critical Area Fencing, and Moderate Wetland Restoration/Retention		10 to 60	40	58	18.56	5	Fast
Owner BMP Program Reduced N Fertilization (IFAS, placement, and type) Grass Management, and Feeder/Minerals and Water Placement		0 to 25	15	11	4	2	Fast
Cost Share BMP Program Rotational Grazing, New Water Facilities, Retention Basin by Working Pens, Critical Area Fencing, and Moderate Wetland Restoration/Retention		10 to 50	25	47	15	6	Fast
Alternative BMP Program Provide Alternative Shade to move cattle from streams and Edge-of-farm Stormwater R/D and Chemical Treatment		5 to 70	36	110	35	10	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

BMPS for Pine Plantation

Assume for Typical Condition		
Planted Pine Plantation (20 yr rotation)		
Assumed average farm size of 200 ac		
Existing N fertilization of 5 lbs N/ac		
No retention or wetland restoration		
Existing N Load	4.09	lbs-N/ac/yr
Existing N Concentration	1.21	mg/l
Average Annual Runoff	14.96	in/yr

BMPs	Type	N Reduction[1]		Initial Cost of BMP[2]	Annual Cost[3]		Quickness of Response
		Range %	Typical %	($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	
Reduced N Fertilization (testing, placement, and type)	Owner	0 to 15	5	3	3	15	Fast
Stormwater R/D	Cost share	2 to 15	8	22	22	67	Fast
Wetland Restoration	Cost share	1 to 5	2	11	3.52	43	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	110	35.2	34	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization, Stormwater R/D, and limited Wetland Restoration	2 to 25	15	22	22	36	Fast
Owner BMP Program Reduced N Fertilization	0 to 15	5	3	0	0	Fast
Cost Share BMP Program Stormwater R/D and limited Wetland Restoration	3 to 20	10	16.5	12.76	31	Fast
Alternative BMP Program Edge-of-farm Stormwater R/D and Chemical Treatment	5 to 50	25	110	35.2	34	Fast

BMPS for Transportation Corridors

Assume for Typical Condition

- 50% Paved Surface
- Bahia Grass Shoulders
- Existing N fertilization of 35 lbs N/ac
- Limited retention or wetland restoration

Existing N Load	12.14	lbs-N/ac/yr
Existing N Concentration	1.07	mg/l
Average Annual Runoff	49.88	in/yr

BMPs	**Type**	**N Reduction1**		**Initial Cost of BMP[2]**	**Annual Cost[3]**		**Quickness of Response**
		Range %	Typical %	($/ac)	**per acre** ($/ac/yr)	**N Removed** ($/lb/ac/yr)	
Fertility — pH management		0 to 20	3	2	2	5	Fast
Reduced N Fertilization (testing, split, placement, and type)	Owner	10 to 50	20	2	2	1	Fast
Stormwater R/D	Cost share	5 to 45	15	110	35.2	19	Fast
Wetland Restoration	Cost share	2 to 15	7	11	3.52	4	Fast
Edge-of-farm stormwater R/D and Chemical Treatment[4]	Alternative	5 to 50	25	220	70.4	23	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMP
2 Costs presented on per acre of entire farm basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

	Range %	Typical %	Initial Cost ($/ac)	Annual Cost per acre ($/ac/yr)	Annual Cost N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N fertilization, water management, and limited wetland restoration/retention	10 to 70	43	111.8	36	7	Fast
Owner BMP Program Reduced N Fertilization	10 to 50	20	4	1	6	Fast
Cost Share BMP Program Water Management and limited Wetland Restoration/Retention	10 to 60	23	107.8	34	12	Fast
Alternative BMP Program Water Reuse from Retention/Detention Ponds and Edge-of-System stormwater R/D and Chemical Treatment	5 to 50	25	220	70	23	Fast

BMPs for Communications and Utilities

Assume for Typical Condition

Marginally Maintained Bahia Grass		
No Pond retention		
Existing N Load	7.92	lbs-N/ac/yr
Existing N Concentration	1.40	mg/l
Average Annual Runoff	25.05	in/yr

BMPs	**Type**	**N Reduction[1]**		**Initial Cost**	**Annual Cost[3]**		**Quickness**
		Range	Typical	**of BMP[2]**	**per acre**	**N Removed**	**of**
		%	%	($/ac)	($/ac/yr)	($/lb/ac/yr)	**Response**
Fertility							
Reduced P Fertilization (testing, placement, and type)	Owner	0 to10	5	0	0	0	Fast
Dry/Wet Retention 0.25"	Cost share	0 to 20	2	1280	409.6	2586	Fast
Wet Restoration	Cost share	0 to 20	3	1600	512	2155	Fast
Dry Detention - Regional	Alternative	15 to 35	25	3200	1024	517	Fast
Wet Detention - Regional	Alternative	40 to 80	65	4000	1280	249	Fast

1 Estimated values assume no other BMPs applied. Note, combined BMPs will reduce effectiveness of individual BMPs
2 Costs presented on per acre of entire development basis unless otherwise noted. Costs value only include implementation cost, i.e. does not include O&M Costs.
3 The annual cost include amortized capital costs at 10% interest over a twenty-year life span and a 20% per year of capital cost for annual O&M.
4 High O&M Costs

Program	Range %	Typical %	Initial Cost ($/ac)	per acre ($/ac/yr)	N Removed ($/lb/ac/yr)	Quickness of Response
Owner/Cost Share BMP Program Reduced N Fertilization,limited dry/wet retention, and wetland restoration	0 to 20	10	6400	2048	2586	Moderate
Owner BMP Program Reduced N Fertilization	0 to 10	5	0	0	0	Fast
Cost Share BMP Program Selective limited dry/wet retention and Wetland Restoration	5 to 50	5	6400	2048	5172	Fast
Alternative BMP Program Stormwater R/D with Chemical Treatment	15 to 80	50	3200	1024	259	Fast

APPENDIX E

CALOOSAHATCHEE RIVER WATERSHED RESEARCH AND WATER QUAILTY MONITORING PROGRAM

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1.0 INTRODUCTION

1.1. Background

The Caloosahatchee River and Estuary, located on the southwest coast of Florida, and the St. Lucie Estuary, located on the east coast of Florida, are coastal systems that have been highly altered from their natural state by human intervention and engineering controls. Drainage in the South Florida Region has been modified on a regional scale by the Central and Southern Florida Flood Control Project. Local watersheds of both estuaries have been drained to accommodate agriculture and urban development. The estuaries themselves have been dredged for navigation, while shorelines have been bulk-headed.

Both suffer from a disruption in the natural magnitude and timing of freshwater inflows, which results in fluctuations of salinity large enough to cause mortality of estuarine and marine organisms (Haunert and Startzman, 1985; Chamberlain and Doering, 1998). Both also exhibit signs of eutrophication, which include blooms of algae (micro, macro and nuisance), low dissolved oxygen (DO), and periodic fish kills (DeGrove, 1981; Chamberlain and Hayward, 1996). In addition, critical habitat is also degraded. The water quality and quantity problems experienced by the two estuaries are interrelated. The nutrient load that causes eutrophication of an estuary is a function of both water quality (nutrient concentration) and the quantity of freshwater inflow that transports the nutrient. The solution to problems in the two estuaries will involve changes in the quality and quantity of freshwater inflow (e.g. Lake Okeechobee Watershed Construction Project, Phase II Technical Plan, 2008).

While the primary intent of the Caloosahatchee River Watershed Protection Plan (CRWPP) is to address these problems, it is important to consider the context within which the plan will be implemented. Current assumptions regarding planned projects, land use, and water supply demand may change and lead to improvements above and beyond those anticipated by the CRWPP. Ongoing and future operating plans for water management facilities should be coordinated among the federal, state, and local entities that influence the fate of water resources in the river watersheds. Additionally, continued population growth and predicted changes in climate may also affect the future water quality and quantity.

To deal with the complexity of interactions between the water management system, its operation and the response of the natural system, it is imperative that a robust research, modeling and monitoring program be in place to guide adaptive management strategies. Such strategies will ensure cumulative benefits and optimization of water management.

1.2. Enabling Legislation

In response to the water quality and quantity problems in both estuaries, the Florida Legislature passed the Northern Everglades and Estuaries Protection Program (Senate Bill 392, Florida Senate 2007), which modified Section 373.4595, F.S. This new legislation requires the South Florida Water Management District (SFWMD), in collaboration with the Florida Department of Environmental Protection (FDEP) and the

Florida Department of Agriculture and Consumer Services (FDACS), to develop watershed protection plans for Lake Okeechobee, the St. Lucie Estuary and the Caloosahatchee Estuary.

The protection plans are composed of three parts: a construction project, a pollutant control program and a research and water quality monitoring program. This document describes the Research and Water Quality Monitoring Program (R&WQMP) for the Caloosahatchee River Watershed and Estuary. Subsections 373.4595(4)(a)3 and (4)(b)3, F.S., specifically require that SFWMD develop research and water quality monitoring programs for the Caloosahatchee River and St. Lucie River Watersheds.

This document will set forth research and monitoring programs that support the goals of the CRWPP by building on existing research and monitoring conducted by SFWMD, other state and federal agencies, local governments, as well as non-governmental organizations. One purpose of the R&WQMP is to serve a coordinating function that focuses activities specifically on the St. Lucie and Caloosahatchee estuaries and their associated watersheds.

Research and monitoring in the St. Lucie and Caloosahatchee rivers and estuaries have been ongoing for more than 40 years (Phillips, 1960; Gunter and Hall, 1962). A variety of recent programs, including Surface Water Improvement and Management (SWIM), Comprehensive Everglades Restoration Plan/REstoration COordination & VERification (CERP/RECOVER), and water supply planning and rule-making efforts, have added to this body of knowledge. However, our ability to predict the outcomes of solutions to water quantity and water quality problems is hampered by significant gaps and uncertainties in the understanding of the two estuarine systems and their watersheds. For example, despite its importance, we do not yet fully understand how various factors interact to control the concentration of DO in either estuary. By reducing uncertainty and filling gaps in our knowledge, the R&WQMP will increase our ability to find robust, scientifically based solutions and more accurately predict the response of these estuaries to changes in water quality and quantity.

1.3. Document Structure

The Caloosahatchee Research and Water Quality Monitoring Plan (CR&WQMP) has five chapters, including this Introduction.

Chapter 2 identifies the specific goals and objectives of the CR&WQMP, based on the Northern Everglades Legislation. It shows how research, modeling, and monitoring contribute to the adaptive management of nutrient load reduction goals and the implementation and operation of programs and projects designed to achieve them.

Chapter 3 presents our current state of knowledge regarding hydrology, water quality and aquatic habitat. Of particular relevance to the CR&WQMP are reviews of nutrient loading, salinity envelopes and effects of Lake Okeechobee on delivery of water to the Caloosahatchee Estuary.

Chapter 4 is a summary of existing monitoring programs for hydrology, water quality, and aquatic habitat. The programs are evaluated based on their ability to meet program goals. Potential improvements also are identified. Finally, a recommended monitoring plan along with associated costs of implementation is described.

Chapter 5 summarizes ongoing research and modeling applicable to program goals. Plans for future research and modeling are described and prioritized. Integration of research, modeling and monitoring will establish scientifically sound performance measures and support improvements to the estuary through the adaptive management process.

1.4. Literature Cited

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2.0 GOALS AND OBJECTIVES OF MONITORING AND RESEARCH

2.1. Goals and Objectives

Section 373.4595, F.S. specifically identifies three goals for the St. Lucie and the Caloosahatchee River Watershed Protection Programs: (1) achieve pollutant load reductions based upon adopted total maximum daily loads (TMDL), (2) establish salinity envelopes and freshwater inflow targets, and (3) reduce the frequency and duration of undesirable salinity ranges while meeting other water–related needs in the region. The legislation also requires an annual progress report as part of the consolidated annual report required in Section 373.036(7), also known as the South Florida Environmental Report (SFER). The report includes a summary of the conditions of hydrology, water quality, and aquatic habitat in the Northern Everglades, based on the results of the Research and Water Quality Monitoring Programs (R&WQMP). Lastly, the legislation requires that the South Florida Water Management District (SFWMD) conduct an evaluation of the programs every three years. The evaluation shall identify modifications to facilities of the River Watershed Construction Projects, as appropriate, or any other elements of the St. Lucie and Caloosahatchee River Watershed Protection Plans.

This latter requirement is particularly important because it specifies how the River Watershed Research and Water Quality Monitoring Programs will be integrated with the River Watershed Protection Programs and their component parts. An adaptive management feedback loop will allow information generated as a result of monitoring, modeling, and research activities to assist and support the periodic assessments and provide a basis for identifying potential modifications.

Research, modeling, and monitoring are essential for the design and operation of programs to restore and protect the Caloosahatchee and St. Lucie estuaries. The following objectives are key to the success of the CR&WQMP. Section 373.4595 requires the establishment of a program that:

The research program should build upon SFWMD's existing monitoring, research, and modeling programs.

The program should be sufficient to carry out, comply with, or assess the plans, programs, and other responsibilities of Section 373.4595.

The research program should provide for an assessment of the water volumes and timing from Lake Okeechobee and the watersheds and their relative contributions to the timing and volume of water delivered to each estuary.

The research program must provide technical information regarding inflow targets and salinity envelopes for both estuaries.

The research program should provide for the scientific studies that are necessary to support the design and operation of the Caloosahatchee River Watershed Construction Project facilities.

The program should facilitate creation of predictive and/or numeric modeling tools in order to fulfill the requirement to assess plans and programs and to predict and evaluate progress toward overall protection program objectives. These tools can be used to (1) evaluate and quantify the nutrient load reduction achieved by source control programs, construction projects and/or operational modifications and progress toward restoration of natural hydrology and targeted water quality, and (2) evaluate the effectiveness of collective source control programs developed by SFWMD, Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS).

The research program should provide the empirical data and conceptual understanding of the St. Lucie River and Caloosahatchee River Watersheds and estuarine receiving waters to support and improve predictive models and identify new water quality management measures.

Necessary data should be collected to quantify loads for pollutants requiring a TMDL, including concentration and freshwater discharge.

Monitoring of salinity should be sufficient to measure the frequency and duration of salinities that are undesirable for those biotic resources upon which salinity envelopes are based.

Monitoring of the biotic resources (oysters and seagrasses) should be sufficient to determine if reductions in undesirable salinities and/or nutrient loads have the desired ecological result.

Monitoring should support annual reporting of the conditions of hydrology, water quality, and aquatic habitat required by the legislation.

The application of adaptive management is an integral part of the Caloosahatchee River Watershed Protection Plan. **Figure 2.1** depicts the role of monitoring, modeling, and research in adaptive management. Analysis of monitoring results determines if the frequency and duration of undesirable salinity ranges is declining and if load reductions are being met. If progress is not being met, results of research and modeling can identify reasons why. Information from monitoring, modeling, and research can be used to identify refinements to flow and salinity envelopes, pollutant load reduction goals, and changes to facility operations and implementation priorities.

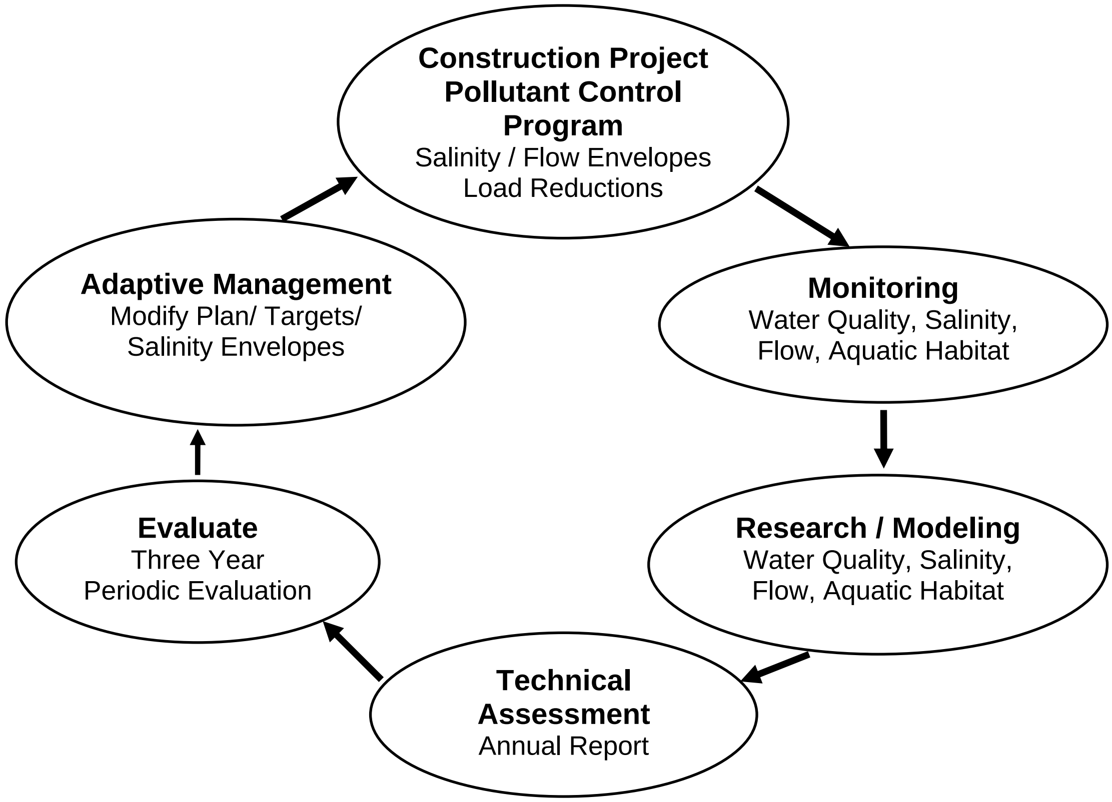


Figure 2-1. Monitoring, modeling, research, and adaptive management in the River Watershed Protection Program

3.0 THE RIVER AND ITS WATERSHED; STATUS, TRENDS AND TARGETS IN HYDROLOGY, SALINITY AND AQUATIC HABITATS

This chapter addresses three requirements of the Caloosahatchee River Watershed Protection Program: salinity and freshwater inflow goals; effects of discharges from Lake Okeechobee on delivery of water to the estuaries; and status and trends in hydrology, water quality, and aquatic habitat.

The Caloosahatchee Estuary often receives excessive freshwater discharges from its local watersheds, especially during the wet season. This situation is often exacerbated by regulatory discharges from Lake Okeechobee. Conversely, there are often periods during the dry season when flows from the Caloosahatchee River (C-43) to its estuary completely stop. Recognizing these facts, the legislation enabling the Caloosahatchee and St. Lucie River Watershed Protection Programs requires inclusion of a "goal for salinity envelopes and freshwater inflow targets for the estuaries based upon existing research and documentation. The goal may be revised as new information is available. This goal shall seek to reduce the frequency and duration of undesirable salinity ranges while meeting other water related needs of the region, including water supply and flood protection, while recognizing the extent to which inflows are within the control and jurisdiction of the district." The legislation further requires "an assessment of the water volumes and timing from the Lake Okeechobee and Caloosahatchee River Watersheds and their relative contributions to the timing and volume of water delivered to the estuary." Lastly, the legislation requires an annual report that "shall include a summary of the conditions of the hydrology, water quality, and aquatic habitat in the Northern Everglades."

This chapter begins with a description of the Caloosahatchee River Watershed Protection Plan (CWRPP) study area and the historical changes that have occurred. A discussion of the current status and trends in hydrology including the influence of discharges from Lake Okeechobee on the delivery of water to the Caloosahatchee Estuary follows. The final sections summarize status and trends in nutrient loading, water quality, and aquatic habitat, as well as salinity envelopes and freshwater inflow targets.

3.1. Delineation of Study Area

3.1.1. River and Estuary

The study area of the CRWPP includes portions of Lee, Charlotte, Collier, Glades, and Hendry counties and can be divided into 10 major sub-watersheds **(Figure 3.1-1**) with a total area of over 1 million acres.

The Caloosahatchee River, its estuary, and associated watershed are located on the lower west coast of Florida (**Figure 3.1-2**). The Caloosahatchee River (C-43) runs 70 kilometers (km) from Lake Okeechobee at Moore Haven (S-77) to the Franklin Lock and Dam (S-79) at Olga. Separating fresh and brackish water, the Franklin Lock demarcates the head of the Caloosahatchee Estuary, which extends 42 km downstream to Shell Point, where it empties into San Carlos Bay in the southern portion of the greater Charlotte Harbor system.

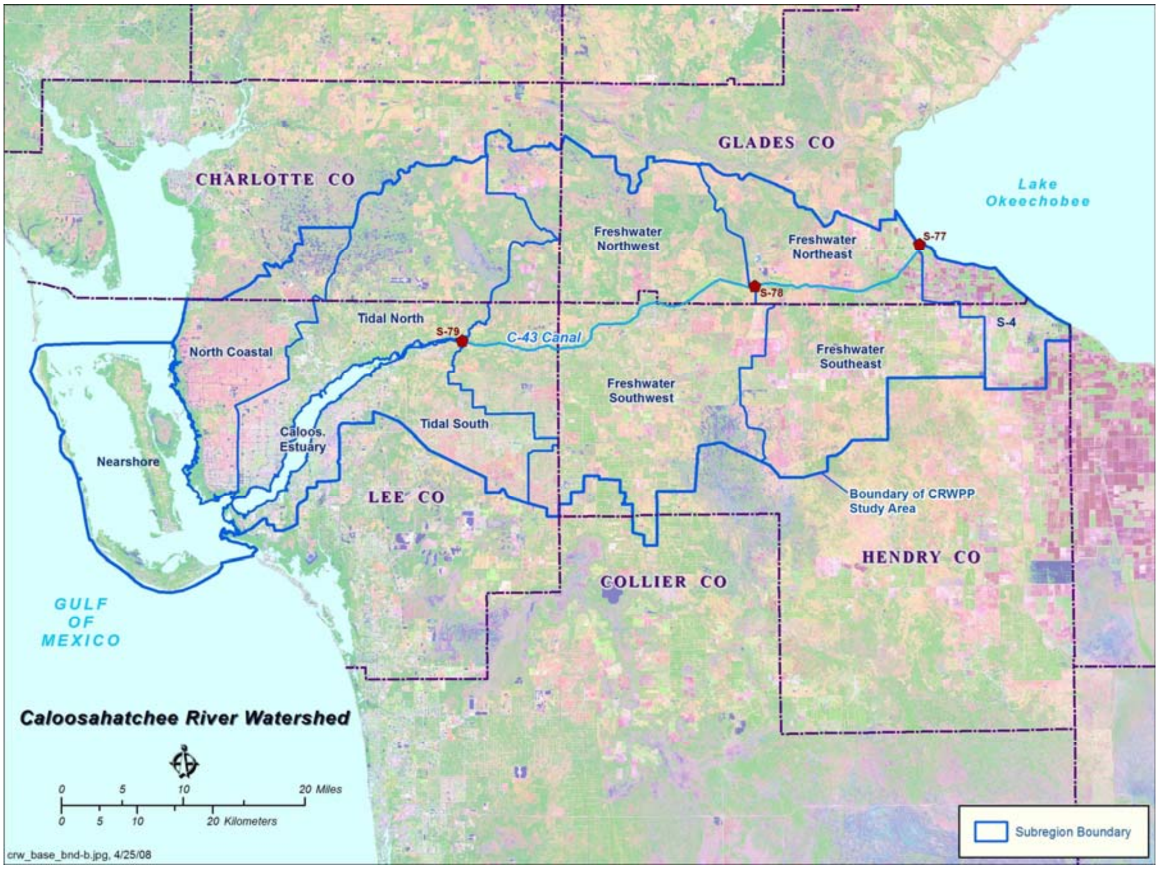


Figure 3.1-1. Sub-watersheds of the CRWPP study area.

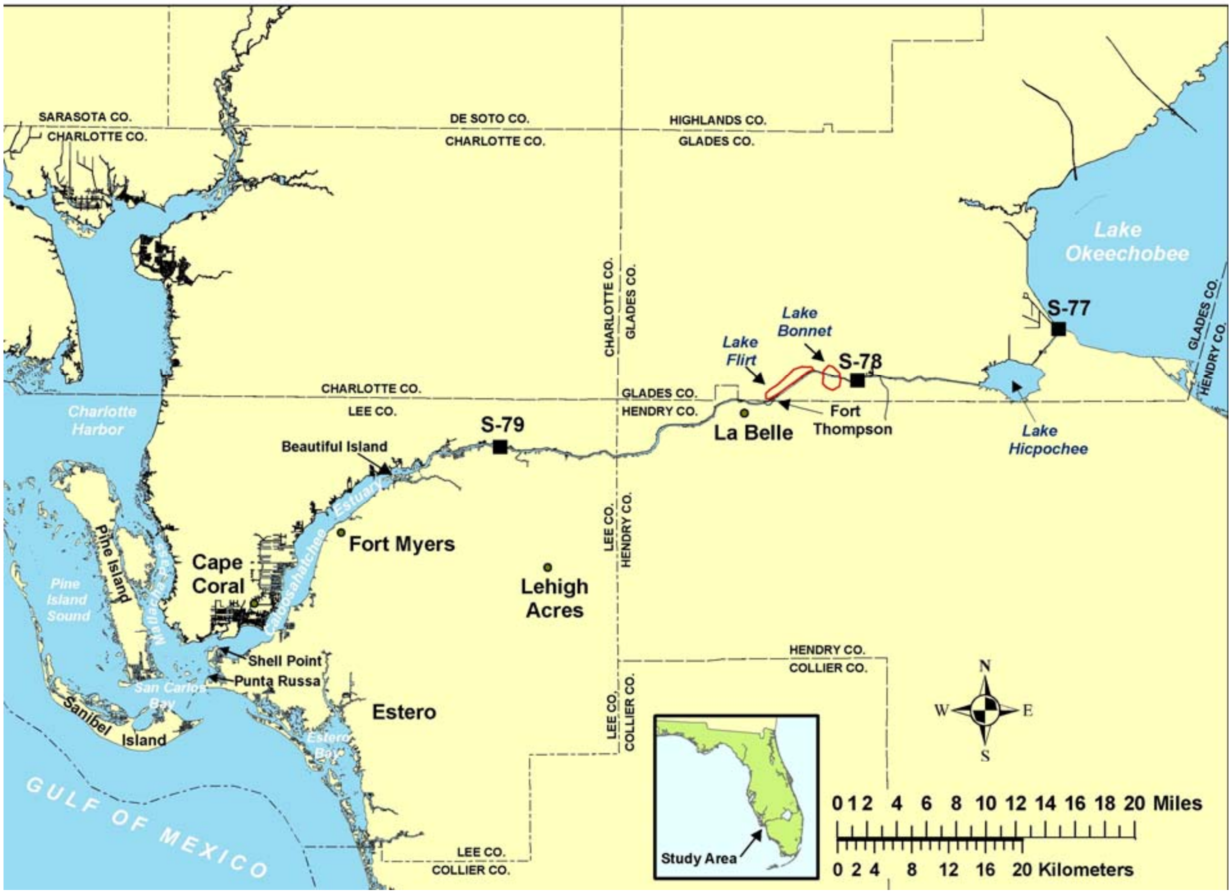


Figure 3.1-2. Location of the Caloosahatchee River (C-43) and Estuary.

Upstream of S-79, the C-43 ranges from 50 to 130 meters (m) in width (164 – 426 ft) and from 6 to 9 m in depth (19.7 – 29.5 ft). On the north side of the river, the land slopes from an elevation high of 23 m (75 ft) down to the river, and on the south side, the land slopes from an elevation high of 13 m (42.6 ft). Flaig and Capece (1998) reported the river gradually drops about 6 m (19.7 ft) National Geodetic Vertical Datum (NGVD) along its longitudinal axis from Lake Okeechobee to S-79, with most of the elevation loss occurring below Lake Flirt. In the tidal basins downstream of S-79, the landscape is relatively flat with little or no topographical relief.

The estuarine portion of the system is located downstream of the S-79 and extends 42 kilometers (km) to Shell Point. The width of the estuary is irregular, ranging from 160 m (525 ft) in the upper portion to 2,500 m (8,200 ft) near its mouth (Scarlatos,1988). The narrow section between the Franklin Lock and Beautiful Island has a mean depth of about 6 m, while the area downstream has an average depth of 1.5 m (Scarlatos, 1988). The surface area of the estuary is about 65 km^2 (16,000 acres).

Water leaving the estuary at Shell Point enters San Carlos Bay. Most of this water takes a southerly route, flowing to the Gulf of Mexico under the Sanibel Causeway (Goodwin, 1996). When freshwater inflows are high, tidal action pushes some of this water back up into Matlacha Pass and Pine Island Sound. Additionally, some water exits to the south and flows into Estero Bay through Matanzas Pass.

3.1.2. Watershed Changes and Connection to Lake Okeechobee

The Caloosahatchee River and Estuary comprise a system that has been highly altered from its natural state by human intervention and engineering. Before human intervention, the Caloosahatchee River was a sinuous river originating near Lake Flirt, approximately 3.2 km (2 miles) east of La Belle at Fort Thompson (**Figure 3.1-2**). Beginning in the 1880s, the river has been straightened and deepened, losing 76 river bends and 13.2 km (8.2 miles) of river length as a consequence (Antonini et al., 2002). The river also was connected to Lake Okeechobee. Three water control structures have been added. The first structures, S-77 on Lake Okeechobee and S-78 at Ortona, were completed in the 1930s. The last, S-79 at Olga, was completed in 1966 to assure a freshwater supply for Lee County and to prevent saltwater intrusion (Antonini et al., 2002). The river is no longer free-flowing and is operated as two pools: one at an elevation of about 3.3 m (11 ft) between S-77 and S-78, and the other between S-78 and S-79 at an elevation of about 0.9 m (3 ft). The Caloosahatchee River is now part of the Okeechobee Waterway, allowing boat traffic between Ft. Myers and Stuart, Florida. It provides irrigation water, drainage and potable water, as well as conveyance of regulatory releases of water from Lake Okeechobee to tide. Modifications to the Caloosahatchee River allowed development in the watershed. A network of secondary and tertiary canals now overlays the Caloosahatchee River Watershed. This network provides conveyance for both drainage and irrigation to accommodate citrus groves, sugar cane, cattle grazing, and urban development.

The estuarine portion of the Caloosahatchee River west of S-79 has also been significantly altered (Chamberlain and Doering, 1998a). Early descriptions of the Caloosahatchee Estuary characterize it as barely navigable, owing to extensive shoals and oyster bars (Sackett, 1888). A navigation channel has been dredged and a causeway was built across the mouth of San Carlos Bay in the 1960s. Historic oyster bars upstream of Shell Point have been mined and removed to be used in the construction of roads. Seven automobile bridges and one railroad bridge connect the north and south shores of the estuary.

The changes to the estuary and its watershed, combined with population growth, have had major effects on the Caloosahatchee Estuary. First, the delivery of freshwater to the estuary at S-79 has been altered and is more variable with higher wet season discharges and lower dry season discharges. Large volumes of freshwater during the wet season can flush all salt from the estuary. By contrast, inflow at S-79 can stop entirely during the dry season. Saltwater intrudes to S-79, sometimes reaching 20 parts per trillion (ppt) (Chamberlain and Doering, 1998a; 1998b). Fluctuations of this magnitude at the head and mouth of the estuary cause mortality of organisms at both ends of the salinity gradient (Doering et al., 2002).

Alterations to the delivery of freshwater, combined with structural changes to the estuary, are thought to have had lasting ecological consequences. The Sanibel Causeway, which crosses the mouth of San Carlos Bay at Punta Rassa, may have influenced the seaward end of the system. The US Fish and Wildlife Service (1960) predicted that this barrier would restrict exchange with the Gulf, retain freshwater and lower the salinity in Southern Charlotte Harbor. Reductions in salinity were predicted to adversely affect a flourishing bay scallop fishery, which, in fact, collapsed after the construction of the causeway. Twenty years later, the Florida Department of Natural Resources (Harris et al., 1983) reported a significant decline in seagrass cover in deeper areas and attributed this, in part, to an increased amount of colored freshwater.

A second problem is eutrophication. Nutrient loading to the Caloosahatchee Estuary has been a concern since the late 1970s and early 1980s. A waste load allocation study in the Caloosahatchee conducted by the Florida Department of Environmental Regulation concluded that the estuary had reached its nutrient loading limits, as indicated by elevated Chlorophyll a and low oxygen concentrations. A Chlorophyll-*a* concentration of,20 micrograms/liter (µg/L), a total nitrogen (TN) concentration of 1.0 milligram per liter (mg/L) and a total phosphorus (TP) concentration of (0.15 mg/L) were established as upper limits for acceptable water quality in the region of the estuary between Cape Coral and Beautiful Island (Degrove, 1981). Similarly, McPherson and Miller (1990) concluded that additional nitrogen loading would result in increases in phytoplankton and benthic algae.

Since 2000, a series of large, widespread macro and micro algal blooms have focused attention on nutrient issues in the Caloosahatchee region (**Table 3.1-3**). Blue-green algal blooms occur in the Caloosahatchee Estuary and red tides in San Carlos Bay, Pine Island Sound and in the Gulf near Sanibel. Macro-algal blooms occur as massive accumulations of drift algae, primarily on the Gulf beaches of Sanibel and Ft. Myers Beach.

Table 3.1-3. Occurrence of large, widespread nuisance algal blooms in the Caloosahatchee Region by year.

	Nuisance Algal Blooms		
Year	Blue-green	Red Tide	Macro-Algae
2000	X		
2001			
2002			
2003	X		X
2004			X
2005	X	X	X
2006		X	X

3.2. Watershed Hydrology and Loading

This subsection describes the hydrology of the Caloosahatchee River Watershed, focusing on the timing and distribution of rainfall in the watershed and runoff to the estuary ranging from S-79 to Shell Point.

3.2.1. Caloosahatchee River Basin Hydrology

3.2.1.1. Freshwater Basins

Seven of the major basins in the study area drain into the Caloosahatchee Estuary (**Figure 3.1-1**). The S-4 Basin and the four freshwater basins located east of the Franklin Lock and Dam (S-79) comprise the larger Caloosahatchee River Basin (590,534 acres). These drain into the Caloosahatchee River, which discharges to the estuary at S-79. West of S-79 runoff flows to the estuary from the North Tidal Basin (163,505 acres) and South Tidal Basin (82,234 acres). As illustrated later in this chapter, another major source of freshwater to the estuary is Lake Okeechobee.

3.2.1.2. Rainfall Summary

While the climate of South Florida is wet subtropical, variation in annual, seasonal and monthly rainfall can be quite large. Annual average rainfall for the period 1976-2005 in the Caloosahatchee River Basin is 53.14 inches (1.35 meters). This equates to about 2.53 million acre feet (ac-ft) of water from rainfall. Flaig and Capece (1998) reported a slight, but not significant, increasing trend in rainfall of 0.06 in (0.15 cm) per year during the period 1972-1994. During the period 1995-2005, the average rainfall has been 56.39 inches (1.43 m). During these 11 years, rainfall has varied between 116% and 65% of the average (**Figure 3.2-1**) and included one severe drought (2000) and two active hurricane seasons, the latter resulting in above average lake levels and subsequent regulatory discharges during 2004 and 2005.

Approximately 74% of the precipitation occurs during the summer wet season from May through October (**Figure 3.2-2**). For the 30-year period of record, 1976-2005, the wet season rainfall averaged 39.36 inches, with the vast majority occurring during June, July, August, and September, when rainfall can exceed 8 inches (20.3 cm) per month. This pattern was slightly more pronounced during 1995-2005, when June rainfall averaged 10 inches (25.4 cm) and total wet season rainfall accounted for 76% of the average annual total. Within-month variability can also be high, as exemplified by June, when its minimum rainfall was 4.86 inches during 1998 and the maximum was 16.94 inches(43 cm) in 2002.

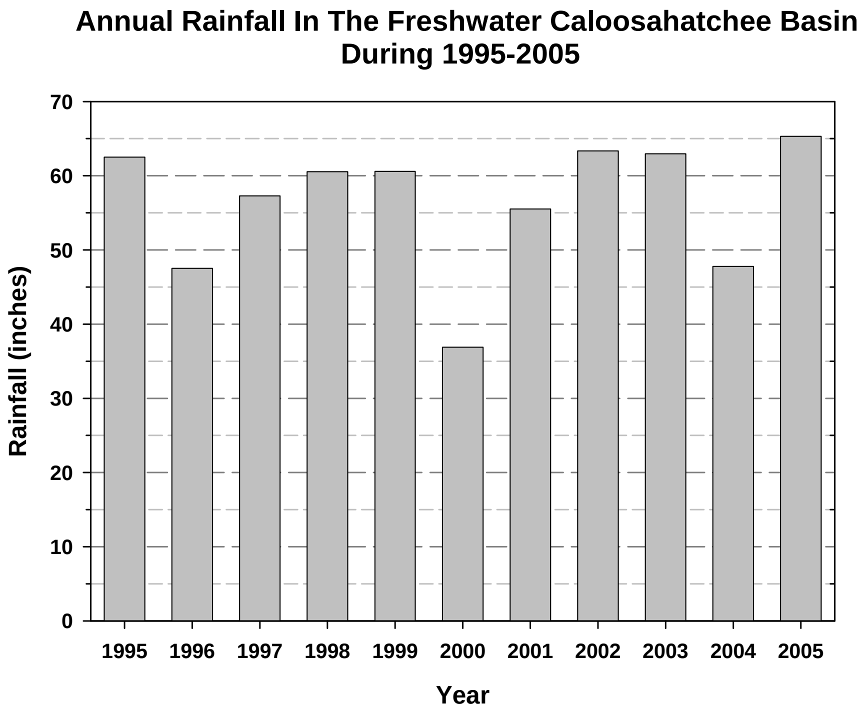


Figure 3.2-1. Average rainfall in the Caloosahatchee River Watershed during each year of the study period 1995-2005.

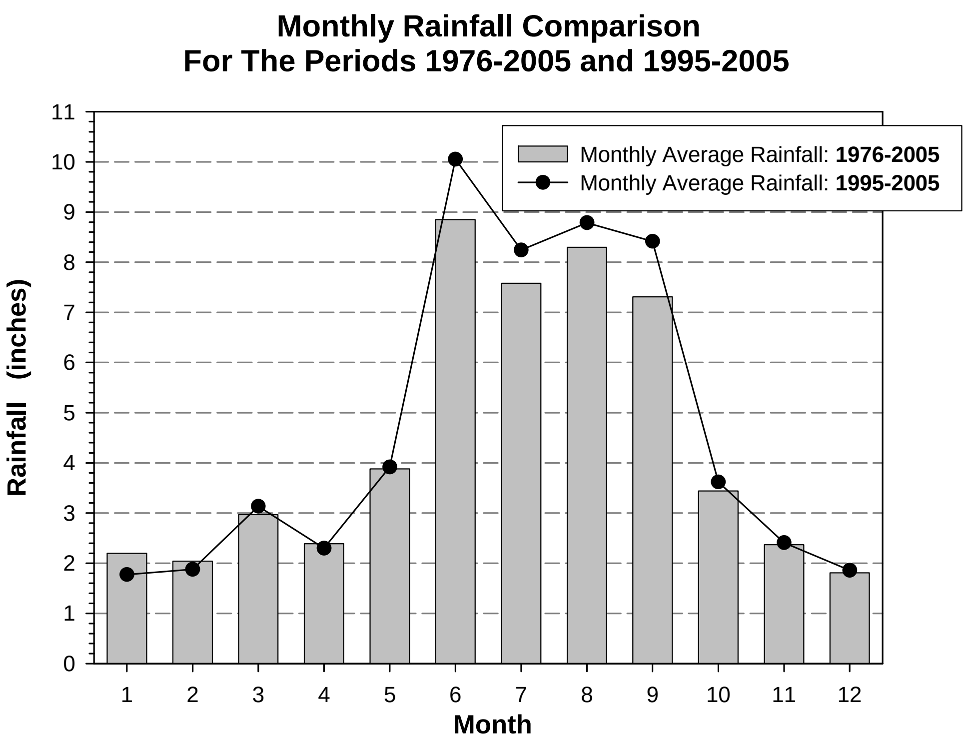


Figure 3.2-2. Average monthly rainfall in the Caloosahatchee River Watershed during the period of records: 1976-2005 (each month, n = 30); and 1995-2005 (each month, n = 11).

3.2.1.3. Freshwater Inflow

The three water control structures (S-77, S-78, S-79) on the Caloosahatchee River, where flow is calculated daily, allow determination of combined runoff from the eastern basins (Freshwater Northeast, Freshwater Southeast and S-4) and the western basins (Freshwater Northwest and Freshwater Southwest). Flows to the estuary from the Tidal Basins west of S-79 are less well known. Estimates come from complex numerical models, simpler land-use based spreadsheet models, and synoptic (point-in-time) sampling.

In general, about half the discharge at S-79 is attributable to runoff from the eastern and western basins and half to Lake Okeechobee. On average, over the period 1995-2005, the eastern basins accounted for 19% (352,604 ac-ft/yr) of the discharge to the estuary at S-79. The western basins accounted for 32.8% (614,515 ac-ft/yr) and flows from Lake Okeechobee accounted for nearly half (48.2% or 901,515 ac-ft/yr) of the discharge. Of the basin runoff, 63.5% came from the western basins and 36.5% came from the eastern basins. The average annual discharge at S-79 was about 1.87 million ac-ft/yr with an average flow rate of 2,575 cubic feet per second (cfs). The long-term average discharge from the Lake at S-77 is 1334 cfs. Discharge at S-78 averaged 1725 cfs.

Discharge through S-79 varies on daily, monthly and annual time scales (**Figure 3.2-3**). This variability is primarily driven by the large difference in rainfall between months and year, and fluctuation in Lake Okeechobee discharge. The latter occurs because lake water levels can change drastically between years due to the variable rainfall input from the lake's northern watersheds. This variability is reflected on an annual time scale in **Figure 3.2-4**, which partitions total annual discharges into fractions derived from the eastern and western basins and Lake Okeechobee. Annual basin runoff follows the pattern of annual rainfall and contributes a low of about 40% of the flow in wet years (1995, 1998, and 2005) to a high of 98% during a drought year (2001). Thus, the contribution from the lake varies from a high of about 60% during wet years to a low of 2% during drought years.

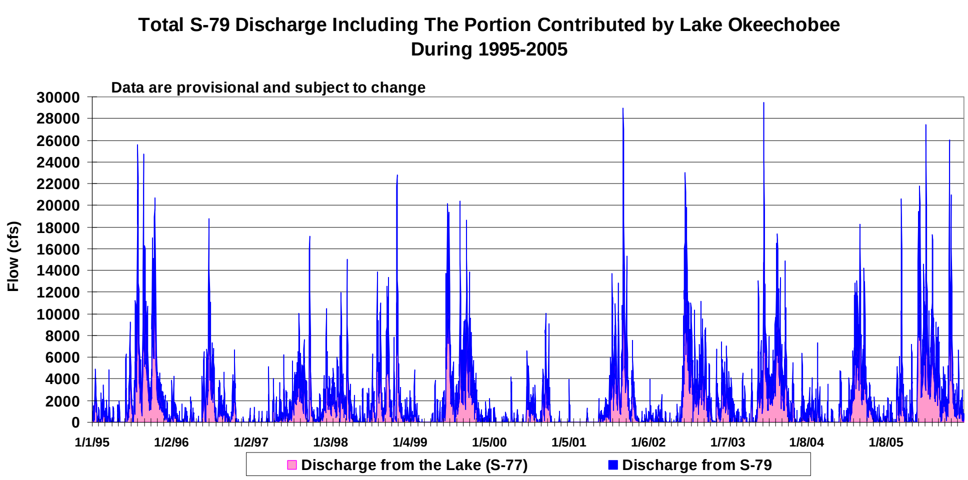


Figure 3.2-3. Daily freshwater flow through S-79 during the 1995-2005 study period, indicating the estimated contribution from Lake Okeechobee.

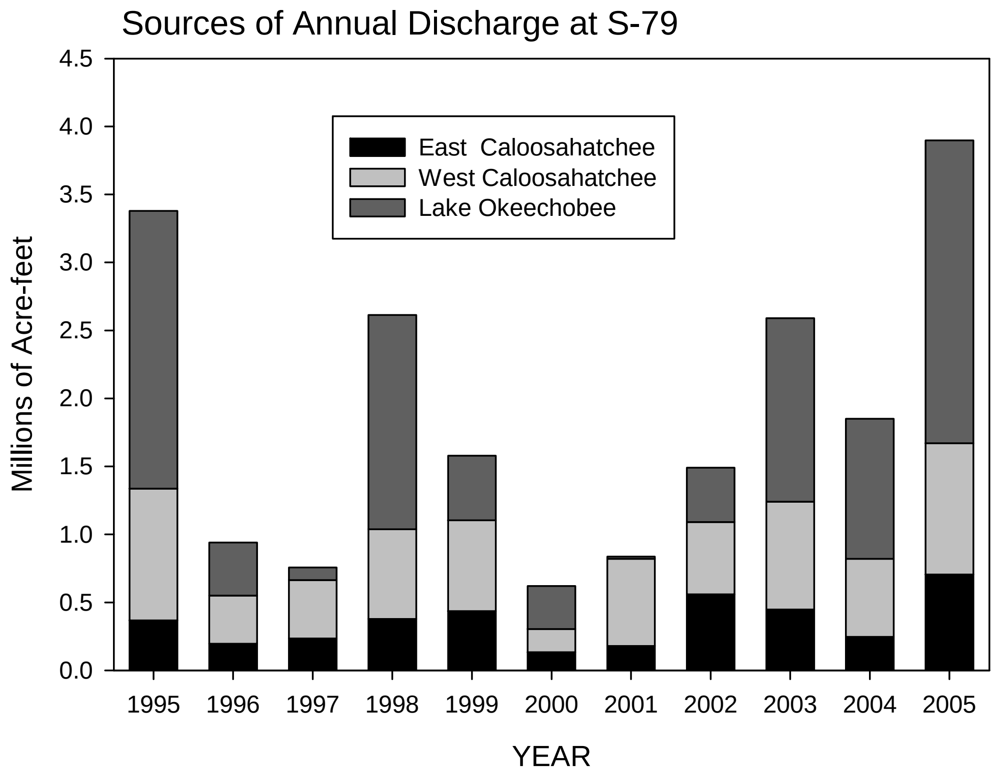


Figure 3.2-4. Annual average freshwater volume discharged through S-79 during 1995-2005. Flow is partitioned into contributions from the eastern and western basins and Lake Okeechobee.

Rainfall also causes a large seasonal signal in discharge to the Caloosahatchee Estuary at S-79 (**Figure 3.2-5**). On average, runoff from the basins east of S-79 is four times higher in the wet than in the dry season. The seasonal distribution of total annual runoff from the eastern and western basins follows that of rainfall, with 20% occurring during the dry season and 80% during the wet season. On average, discharges from Lake Okeechobee comprise 35% of the total flow at S-79 during the wet season and 71% during the dry season. Two factors account for the dominance of Lake discharge during the dry season. During relatively wet years, regulatory releases from Lake Okeechobee often extend into the dry season, when discharge from the basin is low. During the dry season basin discharge can reach very low levels and discharge at S-79 can stop completely. In recent years, if water has been available in the lake during such periods, low level releases have been made to lower salinity in the downstream estuary.

An estuary must have a supply of freshwater to exist. However, too much or too little can be damaging. A series of ecological flow thresholds has been identified for management purposes. Thresholds are primarily based on the tolerance limits of submerged aquatic plants that live in the Caloosahatchee Estuary (Chamberlain and Doering, 1998a; 1998b; Doering et al., 2002). At flows below 450 cfs, salinity in the upper estuary exceeds the tolerance of Tape Grass (*Vallisneria americana*), which is a salt tolerant freshwater species. Similarly, at mean monthly flows greater than 2800 cfs, salinity near the mouth of the estuary becomes low enough to cause mortality of seagrasses living there. At flows greater than 4500 cfs, seagrasses in San Carlos Bay begin to decline. Mean monthly flows greater than 6500 cfs cause high mortality of seagrasses in San Carlos Bay and begin to push low salinity water into the Gulf of Mexico.

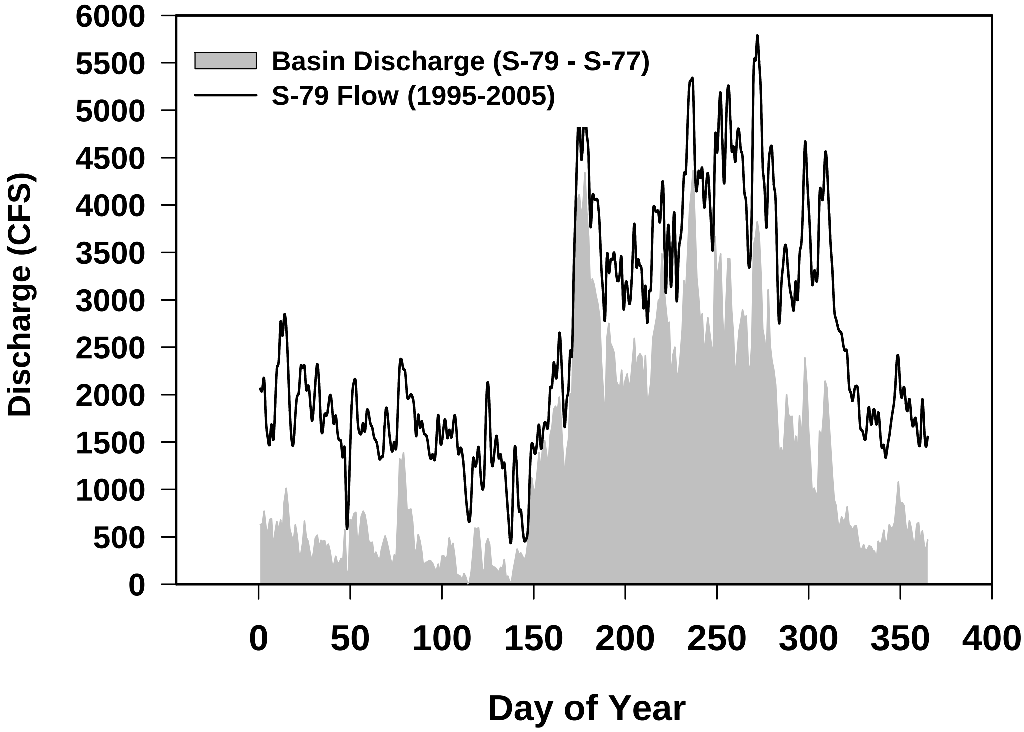


Figure 3.2-5. Average daily discharge at S-79 and from the Caloosahatchee River Basin only, over the period 1995-2005 (each day, n=11).

The distribution of mean monthly flows at S-79, with and without the contribution from Lake Okeechobee, is shown in **Figure 3.2-6**. About 25% of the mean monthly flows from the entire Caloosahatchee River Basin are between 0 and 250 cfs, with 59% less than 1,000 cfs and only 4% exceeding 4,500 cfs. When lake flows are included, only 40% of the mean monthly flows at S-79 are below 1,000 cfs, with 19% being greater than 4500 cfs. During the period 1995-2005, there were 28 months of flows at S-79 below 450 cfs, 47 months above 2,800 cfs, 25 months greater than 4,500 cfs and 13 months above 6,500 cfs **(Figure 3.2-7)**. When the contribution of the lake is removed, the number of flows below 450 cfs increases to 53 months, but the number of high flows decreases significantly, with 23 months greater than 2,800 cfs, four months greater than 4,500 cfs and 0 months greater than 6,500 cfs **(Figure 3.2-8)**.

Compared to watershed runoff alone, additional flows from Lake Okeechobee increase the duration (number of consecutive months) of high flows and decrease the duration of low flows. From an ecological perspective, discharges from Lake Okeechobee increase the frequency and duration of high flows that damage the marine portions of the estuary, but decrease the frequency and duration of the damaging low flows that impact upstream, low salinity regions.

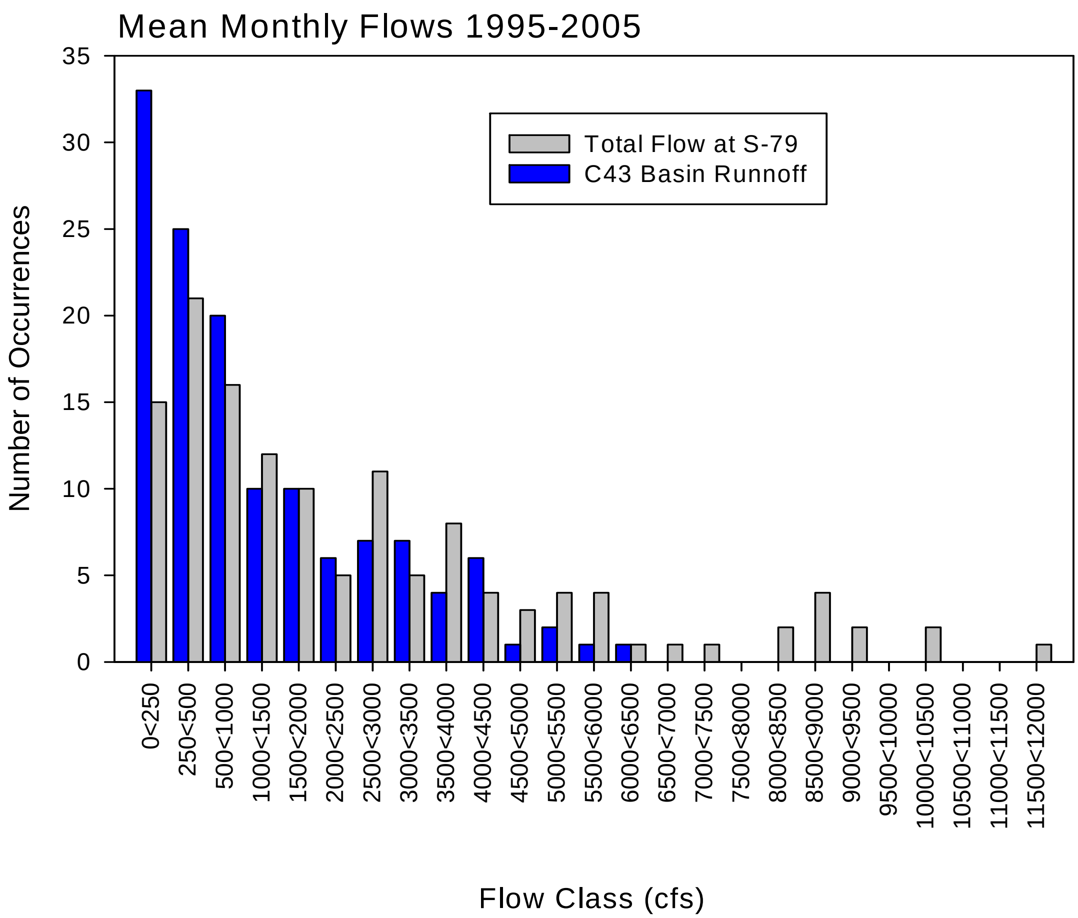


Figure 3.2-6. The number and percent frequency of mean monthly flow ranges though S-79. Flow range intervals are 0 cfs, 1-250cfs, 251-500cfs, etc. Each bar is stationed at the top of its represented range.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan	5406	2348	68	5632	665	809	154	490	3870	1651	1401
Feb	3819	331	472	8296	98	17	0	454	1887	1902	1183
Mar	2681	267	250	10156	7	342	30	693	738	902	3074
Apr	1274	1017	458	6376	780	1351	32	237	714	642	2531
May	124	696	357	2095	301	2914	126	431	1958	267	3410
Jun	1731	4304	832	477	3601	494	474	3753	5904	700	8634
Jul	3394	3813	1401	821	3185	1029	2115	5441	3591	582	11593
Aug	8287	1012	2500	3195	2690	486	2999	2795	7469	4040	8939
Sep	9357	389	2009	2759	3961	1816	5454	5024	8962	5518	4916
Oct	10391	1037	884	1024	4853	798	1657	1709	4692	9356	4063
Nov	6785	24	394	2578	4170	148	447	766	1369	3918	8921
Dec	2708	272	2840	296	1779	0	311	2816	1695	1101	5638

Flow < 450 cfs
Flow > 2800 cfs
Flow > 4500 cfs
Flow > 6500 cfs

Figure 3.2-7. Mean monthly discharges at S-79 (1995-2005).

Month	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan	691	680	56	1348	665	212	153	316	1246	486	311
Feb	566	91	64	2335	91	17	0	214	327	820	370
Mar	324	262	200	1826	5	79	30	231	550	274	2147
Apr	180	134	454	562	208	281	32	26	327	177	318
May	92	688	343	218	252	66	126	107	1078	43	683
Jun	1619	**3200**	755	431	**3533**	471	474	**3623**	**4410**	675	6154
Jul	**3304**	1615	1398	805	**3176**	1012	2111	4914	2424	541	**5027**
Aug	**4378**	1001	2496	**3184**	2671	294	**2998**	2256	**4474**	**4040**	**4209**
Sep	**3494**	323	1994	2747	**3961**	1774	**5454**	**3138**	**3186**	**4217**	1873
Oct	**5587**	1024	866	1004	**2833**	779	1634	849	1291	1717	**2968**
Nov	1381	14	394	2569	626	41	433	731	485	408	2629
Dec	398	27	1905	294	202	0	100	1593	668	168	880

Flow < 450 cfs
Flow > 2800 cfs
Flow > 4500 cfs
Flow > 6500 cfs

Figure 3.2-8. Mean monthly discharges at S-79 without the contribution from Lake Okeechobee (1995-2005).

3.2.1.4. Tidal Caloosahatchee Basins

As stated earlier, flows into the estuary from the North and South Tidal Basins are not well known, having been quantified through modeling efforts or synoptic samples only. The North and South Tidal Basins discharge to the estuary downstream of S-79. They make up 28% of the watershed area. The total tidal basin area considered by Konya (2003) was 270,000 acres, 9% more than the 246,000 acres **(Table 3.1-1**) identified for this CWRPP. Konya (2003) used basin modeling tools to estimate the annual average tidal basin discharge (340,000 ac-ft) for the period 1965-1995. Camp, Dresser and McKee (2007) used the public domain Watershed Management Model (WMM) and estimated the average rate of discharge from the two tidal basins combined to be 820 cfs, which corresponds to 593,000 ac-ft per year. Given an average annual discharge of 1.87 million ac-ft at S-79, and the two estimates of tidal basin inflow, the total flow to the Caloosahatchee Estuary could be 2.21 – 2.46 million ac-ft, with the Tidal Basins contributing 15-25%.

There are a limited number of flow measurements for creeks (n=9) and wastewater treatment facilities (n=4) in the tidal basin, west of S-79. Environmental Research & Design, Inc. (ERD, Inc., 2002) collected synoptic flow measurements during three wet season months and three dry season months between 2000 and 2002. Their work showed that, during very dry conditions, inflows from the tidal basins west of S-79 can be significantly greater than flows from S-79. During a drought period in 2001, when S-79 was closed, 56% of the measured freshwater inflow came from wastewater treatment facilities.

Because S-79 is normally the overwhelming source of freshwater to the estuary, Bierman (1993) calculated the hydraulic residence time of water in the estuary based on flow at S-79 (**Figure 3.2-9**). As expected, the residence time depends on the volume of flow. Historical flows from S-79 (mean= 1,599 cfs; 1967-1995) equate to an average residence time of approximately one month. However, as indicated earlier, the average flow during

1995-2005 (2,575 cfs) is greater than the 1967-2005 period; thus, the average residence time during 1995-2005 may be closer to two to three weeks.

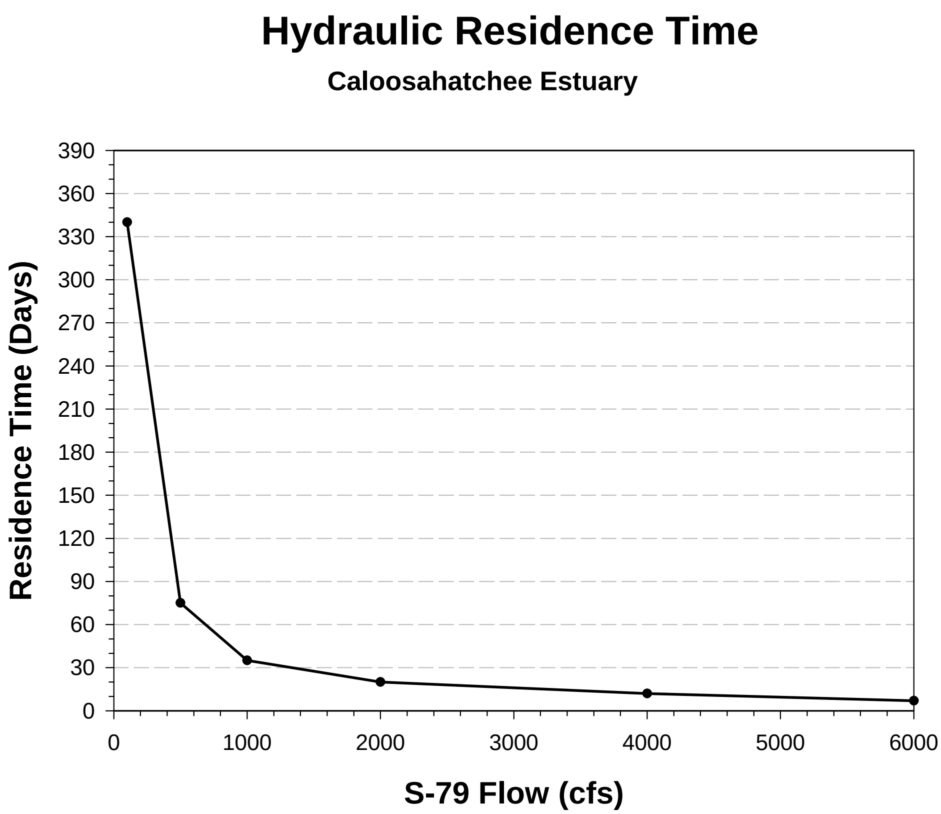


Figure 3.2-9. Hydraulic residence time in the Caloosahatchee Estuary: the amount of days required for water entering the estuary through S-79 to pass Shell Point (Bierman 1993).

3.2.2. Water Quality and Nutrient Loading

3.2.2.1. Water Quality

Average nutrient concentrations were calculated for the period 1995 to 2005 at each of the major water control structures on the Caloosahatchee River (C-43) (**Table 3.2-1**). Concentrations of nitrate, TP, soluble reactive phosphorus (dissolved inorganic P) increase from the lake (S-77) to the Franklin Lock (S-79). TN concentrations are highest at S-77 and exceed the Florida median at all three structures. Median TP concentrations exceeded the Florida median at S-78 and S-79. At least one nutrient exhibited an increasing trend in concentration over time at each of the three structures. However, common to all three was an increase in TP concentration **(Figure 3.2-10)**.

Janicki Environmental Inc. (2007) described trends in water quality at watershed stations downstream of S-79 using the Kendall Tau Statistic. Trends were characterized as "steep" if the rate of change was greater than 5% of the median per year and shallow if less than 5%. In the Orange River, shallow increasing trends were found for conductivity, DO, Total Kjeldahl Nitrogen (TKN), and TN at two of the three stations examined. A decrease in DO was observed at the other station. The one sampling station in Telegraph Creek exhibited a shallow increasing trend in nitrate and nitrite and a shallow decreasing trend for biochemical oxygen demand (BOD). Of 27 stations located mainly in tidal creeks on the north and south shores of the Caloosahatchee Estuary, 74% (20 of 27) showed shallow increases in the concentration of ammonia. Another 44% (12 of 27) exhibited shallow increases in TN and soluble reactive phosphorus (dissolved inorganic phosphorus).

Table 3.2-1. Average and median nutrient concentrations (mg/L) during the period 1995-2005. So as not to emphasize any one time period average values were calculated for each month in the POR before calculating values in the table. Also given are median concentrations for TP and TN for Florida Streams after Hand 2004.

					Percentiles				
Parameter	No of Obs	Mean	Std Dev		75%	50%	25%		Florida Median
Structure S-77									
Total Nitrogen	132	1.68	0.47		1.80	1.60	1.39		1.05
Nitrate + Nitrite	132	0.10	0.11		0.10	0.05	0.03		
Ammonia	132	0.06	0.06		0.07	0.04	0.03		
Total Phosphorus	132	0.098	0.058		0.123	0.078	0.061		0.080
Soluble Reactive P	132	0.041	0.045		0.051	0.025	0.015		
Structure S-78									
Total Nitrogen	64	1.53	0.40		1.63	1.45	1.31		1.05
Nitrate + Nitrite	64	0.14	0.12		0.22	0.11	0.04		
Ammonia	64	0.07	0.05		0.09	0.05	0.03		
Total Phosphorus	64	0.114	0.069		0.141	0.098	0.078		0.080
Inorganic Phosphorus	64	0.072	0.064		0.097	0.055	0.034		
Structure S-79									
Total Nitrogen	62	1.49	0.30		1.67	1.45	1.29		1.05
Nitrate + Nitrite	62	0.27	0.17		0.37	0.25	0.15		
Ammonia	62	0.05	0.04		0.07	0.04	0.03		
Total Phosphorus	62	0.124	0.056		0.149	0.120	0.082		0.080
Inorganic Phosphorus	62	0.089	0.046		0.113	0.088	0.054		

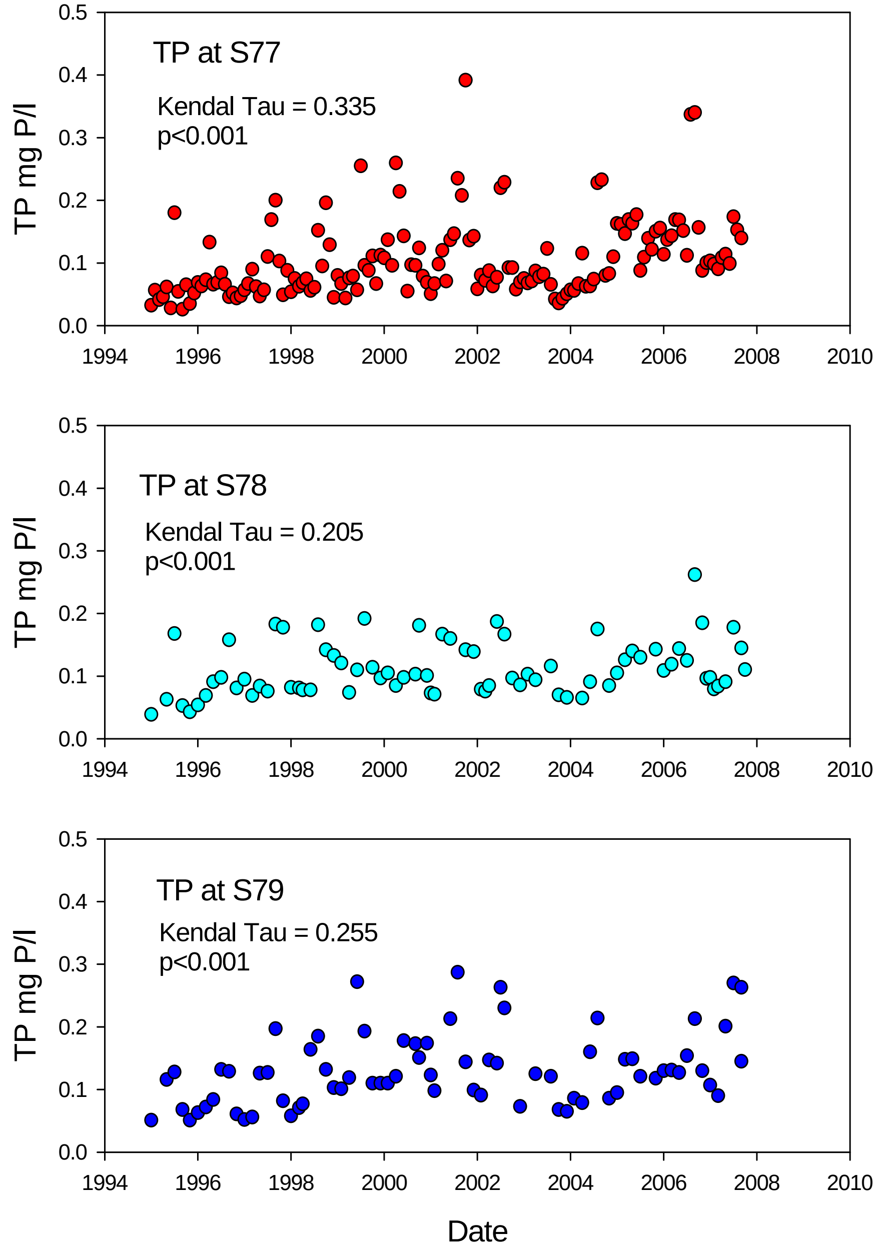


Figure 3.2-10. Increasing trend in total phosphorus concentration at all three water control structures on the Caloosahatchee River.

3.2.2.2. Nutrient Loading

The magnitude and some characteristics of nutrient loading to the Caloosahatchee Estuary from contributing watersheds are considered here. A full accounting of inputs from all possible sources is beyond the scope of this section. While there are many sub-basins within the larger watersheds comprising the study area, a detailed description of loading from each of these has not been attempted, mainly owing to a lack of empirical data. Rather, the reader is referred to a recent nutrient load assessment modeling effort by Camp, Dresser and McKee (2007) using the public domain Watershed Management Model (WMM). Here, we examine measured loads from Lake Okeechobee at S-78, which divides the Caloosahatchee River Watershed into eastern and western sections, and at S-79, located at the head of the Caloosahatchee Estuary. Finally, we compare loads upstream of S-79 to those entering the estuary directly from the Tidal Caloosahatchee Basin, west of S-79.

Recently, Crean and Iricanin (2007) calculated nutrient loads at S-77, S-78, and S-79 for water years (May through April) 1991-2006 (**Tables 3.2-2** through **3.2-4**). [*Note: These three tables are found at the end of this section in landscape format*]. Inter-annual variation is large. For example, the maximum annual TN load (5,442 metric tons of N) at S-79 is almost 15 times greater than the minimum (368 metric tons of N). Annual fluctuations in the magnitude of both total and inorganic loads were primarily driven by fluctuations in annual discharge (**Table 3.2-5**). Doering and Chamberlain (2005) found similar results for annual and daily TN and TP loads at S-79. Depending on the nutrient, flow discharges explained between 50% and 90% of the daily variation. Variation in concentration, the other component of load, explained between 2% and 25% of the daily variation (Doering and Chamberlain, 2005).

There were significant increasing trends in some of the loads at all structures, but not in freshwater discharge. Loads of TP increased at S-77 and S-78, perhaps reflecting the increase in TP concentration at these sites. The loads of inorganic N and P to the estuary at S-79 appear to have increased over the past 16 years. However, if the present period of record is truncated at 2002, all trends at all structures disappear. This result suggests that the increasing trends observed between 1991 and 2006 are due to loads that occurred in the four most recent water years. On average, about 50% of the TN load and 30% of the TP load at S-79 come from Lake Okeechobee at S-77.

The percentage of the TN and TP loads that was inorganic differed for the two nutrients and changed from S-77 at Lake Okeechobee to the Franklin Lock **(Table 3.2-6)**. The inorganic fraction of the phosphorus load was three to four times higher than that of the nitrogen load. The inorganic fraction of both loads increased in a downstream direction. At S-79, the head of the estuary, about 66% of the phosphorus load was inorganic, while only 20% of the nitrogen load was inorganic.

The scientific foundation for the management of eutrophication rests on the concept of nutrient limitation (Smith et al., 1999). The nutrient that is present in the environment in the least quantity relative to plant demands will limit growth. The concept implies that: (1) one key nutrient should be the primary limiting factor for plant growth in a given ecosystem; (2) the growth of plants should be proportional to the rate of supply (loading) of this nutrient; and (3) the control of eutrophication should be accomplished by restricting the loading of this key nutrient to the ecosystem (Smith et al., 1999).

Molar ratios of nitrogen to phosphorus are often used to identify the limiting nutrient. Molar N to P ratios of the inorganic load decrease from S-77 to S-79, but are all less than the Redfield ratio, suggesting that the inorganic load would lead to nitrogen limitation of primary production in the downstream estuary **(Figure 3.2-11)**. Molar ratios of the total load also decrease in a downstream direction, but are all greater than 16N:1P. If the total load were all readily available to primary producers, phosphorus limitation would be indicated. Consequently, in the Caloosahatchee Estuary, the availability of both organic nitrogen and phosphorus may ultimately determine which nutrient could become limiting and which nutrient must be controlled.

Nutrients also enter the Caloosahatchee Estuary from its tidal basin located to the west of S-79. The first attempt to quantify the relative magnitude of nutrient loads from the Caloosahatchee River Basin upstream of S-79 and from the tidal basin, downstream of S-79, was by ERD (2003). ERD took synoptic measurements of flows and nutrient concentrations at S-79 and from a number of tidal creeks and wastewater treatment facilities that discharge into the estuary downstream of S-79. In general, S-79 delivered 90% or more of the daily load during average wet season and dry season conditions. Tidal creeks and waste water treatment facilities delivered 10% or less of the TN or TP load. As with loads at S-79, there is significant variability between wet and dry seasons. During dry periods, when no water is flowing over S-79, downstream inflows can become extremely important sources of both nutrients and freshwater. Estimates based on land use are somewhat different and suggest a higher contribution from the Tidal Basin. Wetland Solutions Inc. (2005, unpublished white paper) estimated that 28% of the TN load came from Lake Okeechobee, 50% from the East and West Caloosahatchee basins and 21% from the Tidal Basin. Of the TP load, they estimated that Lake Okeechobee supplied 11%, the East and West Caloosahatchee Basins supplied 63% and the Tidal Basin supplied 26%. Camp, Dresser and McKee made similar estimates using the Water Management Model **(Table 3.2-7)**, but suggested that the tidal basin supplied a higher percentage of the TP load (41%). Their distribution of the TN load among the three sources also differed from that presented by Wetland Solutions (2005).

The most current estimate of nutrient loading to the Caloosahatchee Estuary is derived from the WMM (Camp, Dresser and McKee 2007) and is approximately 4,370 metric tons of nitrogen and 440 metric tons of phosphorus per year. This loading rate is compared to that of other estuaries in **Figure 3.2-12.** On the basis of estuarine water surface area, the load to the Caloosahatchee Estuary is relatively high.

3.2.2.3. Conclusions

Although estimates differ, it is clear from the two land use models that eliminating or significantly reducing discharges from Lake Okeechobee would constitute a significant reduction in both the TN and TP load. Significant nutrient loads come from watersheds up and downstream of S-79. This fact, coupled with increases in nitrogen concentrations in the Tidal Basin and increases in TP loads upstream of S-79, suggest that load reducing management measures will need to be implemented both up and downstream of S-79.

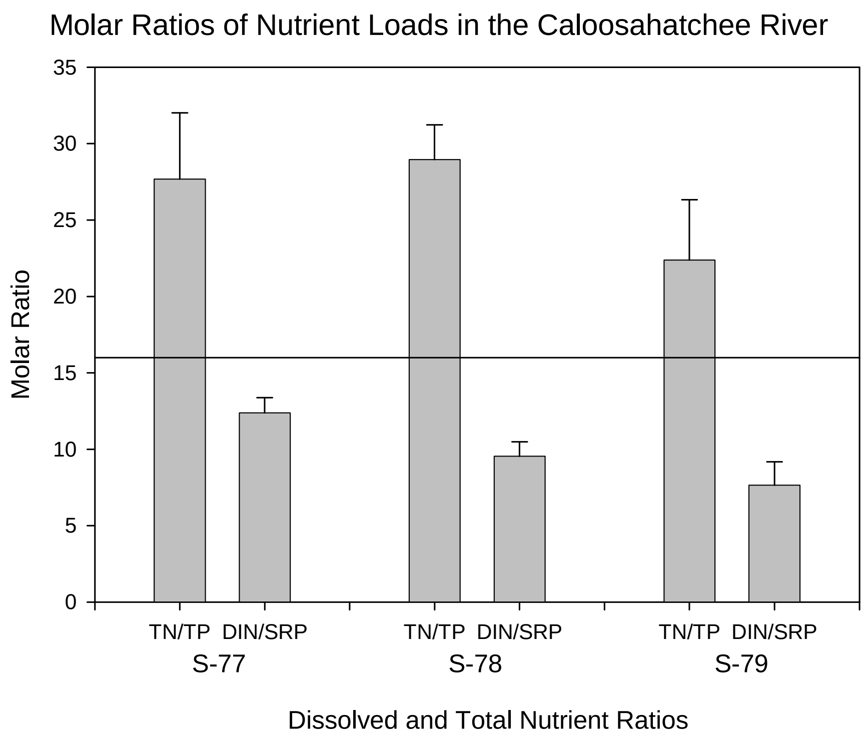


Figure 3.2-11. Reference line is at the Redfield Ratio of 16 N: 1P.

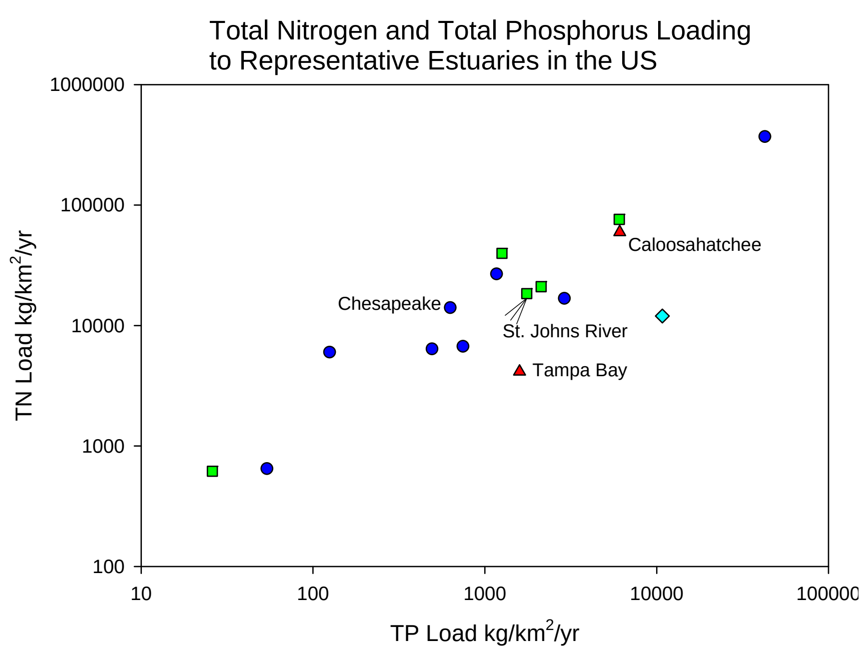


Figure 3.2-12. Comparison of total nitrogen and phosphorus loading to some U.S. estuaries. Triangle=west coast of Florida, squares =South Atlantic, circle=Mid-Atlantic, and diamond=Pacific Coast. Source for all but the Caloosahatchee Estuary: Bricker et al. 2007.

Table 3.2-2. Hydraulic and nutrient loads and flow-weighted mean concentrations at S-77 from 1991-2006. MT=metric ton

Water Year	Inflow Volume	Nutrient Loads				Flow-Weighted Mean Concentration			
		Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen	Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen
	($m^3 \times 10^6$)	(metric tons)				(µg/L)	(µg/L)	(mg/L)	(mg/L)
1991	88.0	7.6	2.6	156	18.6	86.7	29.0	1.77	0.21
1992	76.7	6.7	1.4	114	12.3	86.9	18.1	1.48	0.16
1993	697	44.6	15.0	1,523	54.3	64.0	21.5	2.18	0.08
1994	157	8.7	1.9	208	6.9	55.4	12.0	1.32	0.04
1995	1,810	85.6	34.5	2,500	319	47.3	19.0	1.38	0.18
1996	1,962	97.9	32.8	3,391	341	49.9	16.7	1.73	0.17
1997	443	33.0	6.3	673	34.3	74.6	14.2	1.52	0.08
1998	1,888	129	49.4	2,932	259	68.4	26.2	1.55	0.14
1999	319	23.0	7.4	460	30.7	71.9	23.2	1.44	0.10
2000	791	92.0	21.5	1,385	130	116.2	27.2	1.75	0.16
2001	424	62.3	11.1	1,182	74.1	147.1	26.1	2.79	0.17
2002	157	12.9	2.5	263	15.6	82.0	15.6	1.67	0.10
2003	846	76.1	27.8	1,353	96.2	90.0	32.9	1.60	0.11
2004	1,630	96.1	21.5	2,301	181	58.9	13.2	1.41	0.11
2005	1,493	173	72.4	2,511	472	116.0	48.5	1.68	0.32
2006	2,684	362	134.0	4,307	711	134.8	49.9	1.60	0.26

Table 3.2-3. Hydraulic and nutrient loads and flow-weighted mean concentrations at S-78 by 1991 through 2006. MT=metric ton

Water Year	Inflow Volume	Nutrient Loads				Flow-Weighted Mean Concentration			
		Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen	Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen
	(m^3 X 10^6)	(metric tons)				(µg/L)	(µg/L)	(mg/L)	(mg/L)
1991	206	33.2	21.9	368	69.8	161.6	106.5	1.79	0.34
1992	349	70.4	47.6	610	112	201.7	136.4	1.75	0.32
1993	1,020	120	74.7	1,243	133	117.2	73.3	1.22	0.13
1994	341	43.0	16.9	679	188	126.1	49.5	1.99	0.55
1995	2,080	152	75.5	2,951	368	72.9	36.3	1.42	0.18
1996	2,340	164	68.4	2,575	246	70.2	29.2	1.10	0.11
1997	511	47.7	24.8	642	114	93.3	48.4	1.26	0.22
1998	2,075	174	94	2,998	354	83.8	45.3	1.44	0.17
1999	554	68.0	44.4	881	130	122.8	80.2	1.59	0.23
2000	1,126	131	91.7	1,683	371	116.5	81.5	1.50	0.33
2001	373	36.9	21.9	541	86.9	98.9	58.6	1.45	0.23
2002	308	72.4	58.5	597	81.4	235.0	189.8	1.94	0.26
2003	1,387	183	117	2,278	411	131.7	84.5	1.64	0.30
2004	2,018	188	102	2,931	324	93.3	50.3	1.45	0.16
2005	1,765	171	102	2,365	397	96.8	57.9	1.34	0.22
2006	3,327	446	218	5,442	998	134.1	65.6	1.64	0.30

Table 3.2-4. Hydraulic and nutrient loads and flow-weighted mean concentrations at S-79 by water year from 1991 through 2006. MT=metric ton

Water Year	Inflow Volume	Nutrient Loads				Flow-Weighted Mean Concentration			
		Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen	Total Phosphorus	Soluble Reactive Phosphorus	Total Nitrogen	Dissolved Inorganic Nitrogen
	(m^3 X 10^6)	(metric tons)				(µg/L)	(µg/L)	(mg/L)	(mg/L)
1991	576	112	64.1	1,072	157	194.1	111.2	1.86	0.27
1992	1,126	197	146	1,828	414	174.6	129.5	1.62	0.37
1993	1,783	445	180	3,064	399	249.6	101.2	1.72	0.22
1994	958	139	61.1	1,968	692	144.9	63.8	2.05	0.72
1995	2,815	264	178	4,521	647	93.7	63.1	1.61	0.23
1996	3,497	274	182	4,097	754	78.3	52.2	1.17	0.22
1997	954	115	81.4	1,384	264	120.4	85.3	1.45	0.28
1998	3,077	262	199	4,076	658	85.3	64.6	1.32	0.21
1999	1105	154	124	1,665	359	139.3	112.0	1.51	0.32
2000	2,020	335	235	3,129	811	165.8	116.2	1.55	0.40
2001	593	97.1	76.4	850	251	163.7	128.7	1.43	0.42
2002	1,153	245	219	1,852	465	212.2	189.8	1.61	0.40
2003	2,232	353	232	3,798	738	158.3	103.8	1.70	0.33
2004	3,039	316	217	4,169	839	104.0	71.5	1.37	0.28
2005	2,503	279	190	3,303	712	111.4	75.9	1.32	0.28
2006	4,331	540	319	6,251	1,448	124.7	73.6	1.44	0.33

Table 3.2-5. Correlation (Pearson) of annual freshwater discharge (Inflow) and nutrient loads at major structures on the Caloosahatchee River (C43). Results of tests for temporal trends (WYear) using the Kendall Tau statistic are given. n=16 years in all cases. Values are statistically significant at p<0.05 unless otherwise denoted with ns=not significant.

		Inflow	TN Load	DIN Load	TP Load	SRP Load
S-77	WYear	0.359 ns	0.367	0.383	0.500	0.410
	Inflow		0.985	0.908	0.847	0.838
S78	WYear	0.317 ns	0.333 ns	0.417	0.483	0.487
	Inflow		0.976	0.848	0.907	0.844
S-79	WYear	0.350 ns	0.283 ns	0.417	0.316 ns	0.483
	Inflow		0.972	0.854	0.762	0.796

Table 3.2-6. Relative composition (% of total load that is inorganic) of nitrogen and phosphorus loads at the water control structures along the Caloosahatchee River.

Percent of Total Load that is Inorganic			
	S-77	S-78	S-79
% SRP	29	58	67
% DIN	9	16	21

Table 3.2-7. Summary of nutrient loads (metric tons/year) derived from the Water Management Model (CDM, 2007).

	Total Nitrogen Load		Total Phosphorus Load	
	MT / Year	%	MT / Year	%
Lake Okeechobee	1648	38	49	11
East & West Caloosahatchee	1438	33	208	48
Tidal Caloosahatchee	1283	29	180	41
Total	4369	100	437	100

3.3. Estuary Salinity, Water Quality, Aquatic Habitats

This subchapter discusses salinity, water quality, and related aquatic habitats; highlights the ecological importance of each of these issues; and demonstrates their relationship to the hydrology and ecology of the estuary.

3.3.1. Salinity: Range, Stratification and Flow Correlation

Salinity in an estuary varies as a function of a number of factors including wind, tides, evaporation, and freshwater inflow. This section focuses on the spatial and temporal variation of salinity in the Caloosahatchee Estuary and on the specific influence of freshwater inflow. The discussion of spatial variation considers both longitudinal variation (variation from the head to the mouth of the estuary), as well as variation in the vertical dimension. The latter is important because when the estuary stratifies, bottom waters can become anoxic.

3.3.1.1. Data

The discussion here is based on the temperature and conductivity data collected by the South Florida Water Management District (SFWMD) at multiple continuous monitoring sites **(Figure 3.3-1)**. Salinity is calculated from conductivity and temperature. Data are collected every 15 minutes. The location of each station and length of the associated period of record are given in **Table 3.3-1**.

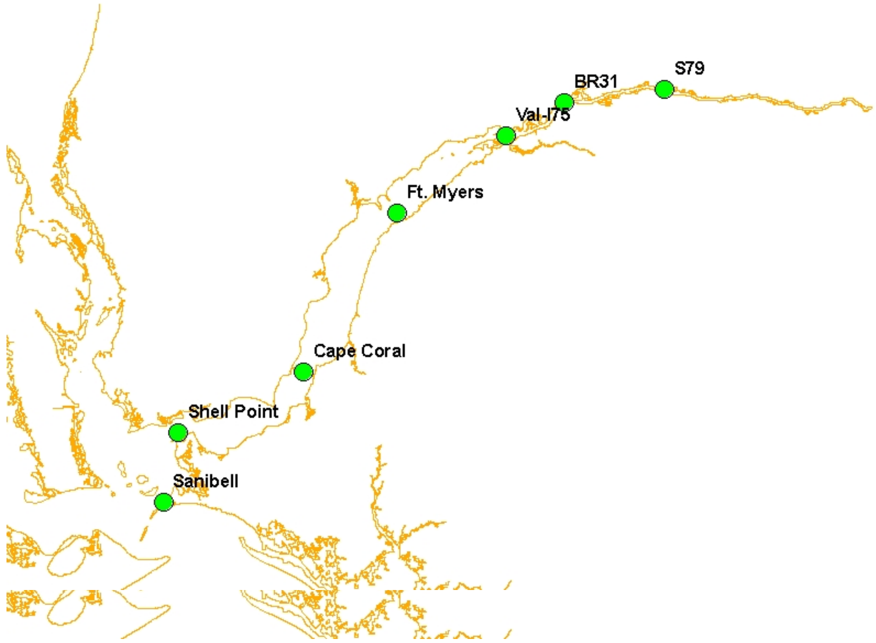


Figure 3.3-1. Location of the monitoring sites.

Table 3.3-1. Salinity Data Sources.

ID	Station Name	Location	Monitoring data	North Latitude	West Longitude
1	S79	Caloosahatchee River	16 years data, 15-minutes interval, 1/22/92-present	26.72	81.7
2	BR31	Caloosahatchee River	16 years data, 15-minutes interval, 1/22/92-present	26.72	81.76
3	Val I75	Caloosahatchee River	2 years data, 15-minutes interval, 12/22/05-present	26.7	81.8
4	Ft. Myers	Caloosahatchee River	16 years data, 15-minutes interval, 1/22/92-present	26.65	81.87
5	Cape Coral	Caloosahatchee River	5 years data, 15-minutes interval, 8/3/02-present	26.56	81.93
6	Shell Point	Caloosahatchee River	13 years data, 15-minutes interval, 1/22/1992-7/19/01, 1/9/05-present	26.53	82.01
7	Sanibel	San Carlos Bay	13 years data, 15-minutes interval, 1/22/92-8/12/04	26.49	82.02

Table 3.3-2. Statistical Summary of daily mean salinity (ppt) in the Caloosahatchee Estuary for stations with more than two years of data.

Station	Days of record	Mean	Standard deviation	Minimum	Percentile					Maximum
					5	25	50	75	95	
S79	5298	3	5	0	0	0	0	4	14	27
BR31	5640	3	5	0	0	0	0	5	14	24
Ft. Myers	5075	7	7	0	0	0	5	12	20	28
Cape Coral	1989	12	9	0	0	3	12	19	28	33
Shell Point	4054	24	8	2	9	19	26	31	36	41
Sanibel	4133	29	6	8	18	25	29	33	36	43

In the Caloosahatchee Estuary, temporal and spatial fluctuations in salinity are largely driven by freshwater discharge at S-79, which is the major source of freshwater to the estuary. In general, salinity increases in a downstream direction as distance from S-79 and proximity to the Gulf of Mexico increase **(Table 3.3-2)**. At any given location in the estuary, there is considerable temporal variation **(Figure 3.3.2, Table 3.3-2),** which occurs between days, seasons (wet vs. dry), and years. Correlation analysis confirms that much of this variability is driven by discharge at S-79 (**Figure 3.3-3**). In general, the correlation between daily discharge and salinity increases in a downstream direction (R^2 for BR31 =0.336, Ft. Myers R^2=0.534, Cape Coral R^2=0.730, Shell Point R^2= 0.720). The statistical results are, in part, influenced by the fact that upstream stations become completely fresh after a certain threshold of daily flow. After this point, salinity does not vary with flow and the correlation is less significant.

Seasonally, salinity in the Caloosahatchee Estuary follows the annual pattern of rainfall and runoff. Lower levels of salinity prevail during the wet season months (June to October), due to freshwater releases from Lake Okeechobee and rainfall events in the watershed. Higher salinities are observed during the dry season months (November to May), due to limited rainfall, watershed runoff and smaller, less frequent releases from Lake Okeechobee (**Figure 3.3-4** gives some examples). Occasionally, hypersaline conditions (salinity reaching 38 ppt) are found at Shell Point and Sanibel during extremely dry conditions. The wide range bounded by the 25th and 95th percentiles indicates considerable year-to-year variability in average salinity for a particular month.

The range of variation that occurs over the course of one day can also be large (**Table 3.3-3).** The maximum range in salinity observed during one day can be comparable to the range in daily average salinity observed over the entire period of record. For example, the maximum range during one day at Cape Coral is 22.3 ppt, 67% of the 33 ppt range in daily average salinity over the period of record. The range of variation observed during one day depends on the tidal range, as well as the location of the salt wedge. On average, the tidal range diminishes by about 10 cm from the inlet to the middle estuary (Ft. Myers).

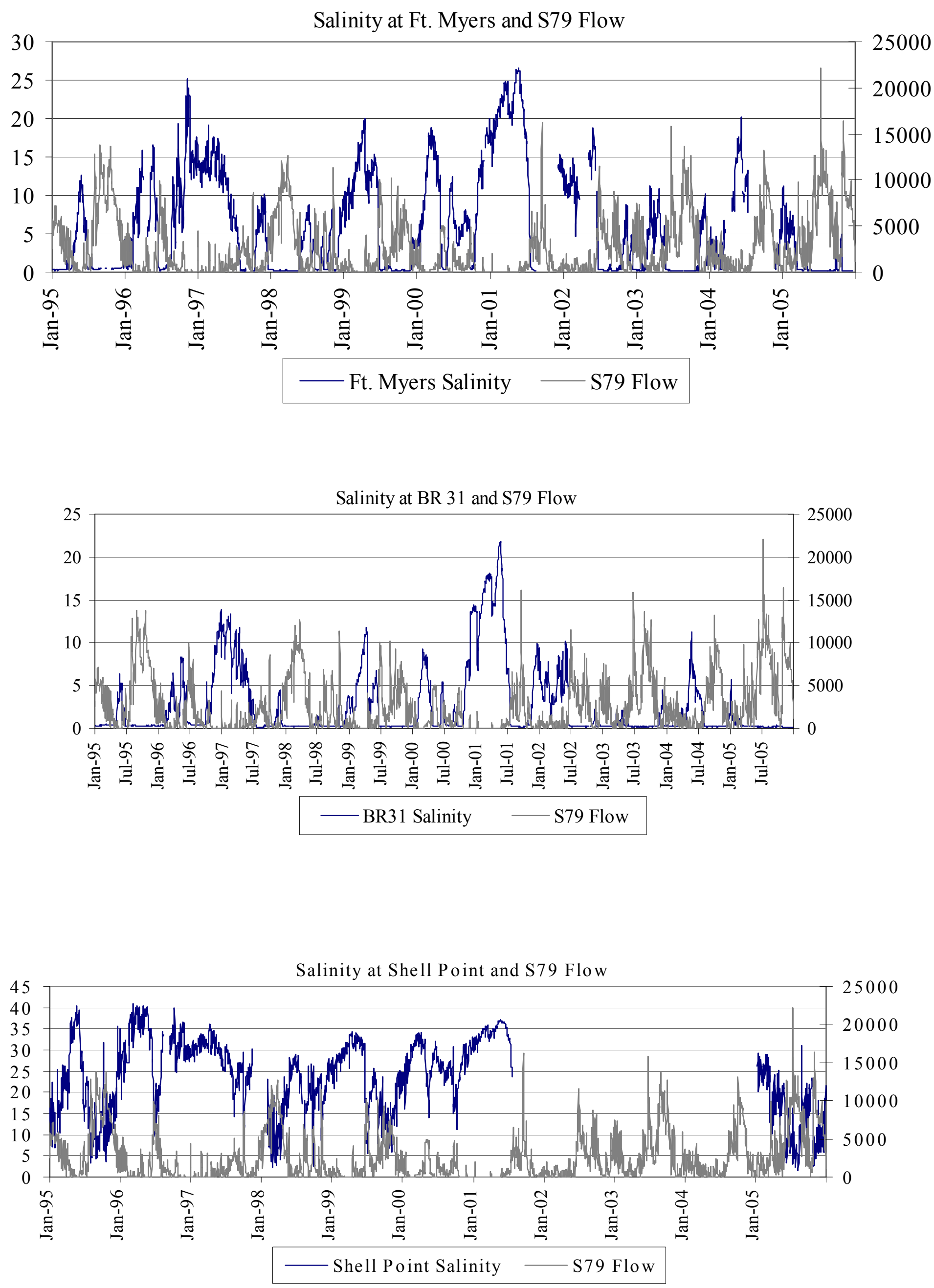


Figure 3.3-2. Daily salinity compared against S79 flow variation at three stations in the Caloosahatchee Estuary (see Figure 3.3.1 for locations).

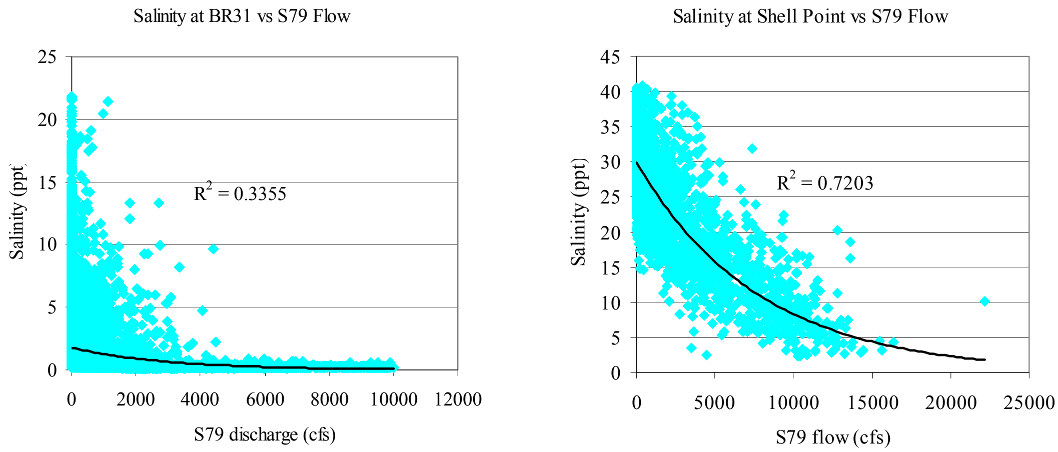
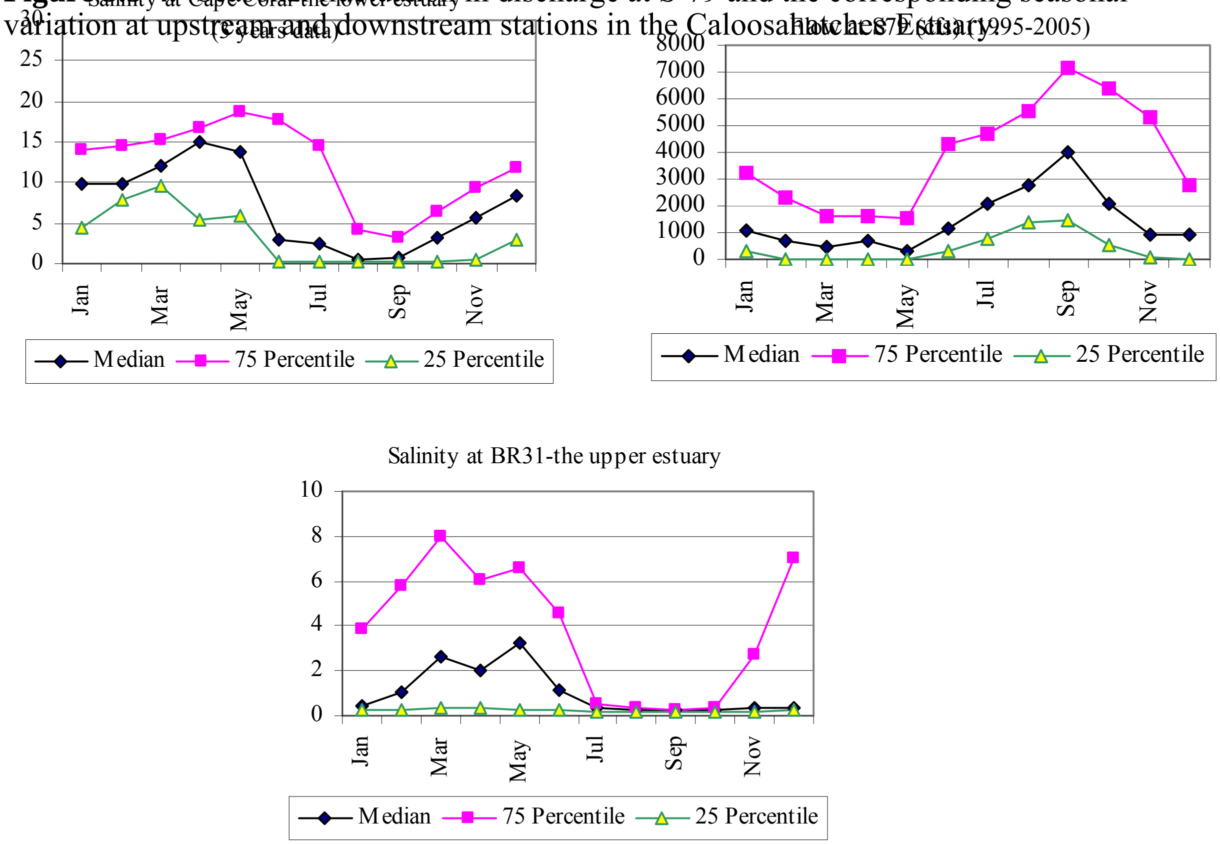


Figure 3.3-3. Correlation (R2) between daily average salinity at upstream and downstream stations and daily freshwater discharge at S-79.

Figure 3.3-4. Seasonal fluctuation in discharge at S-79 and the corresponding seasonal variation at upstream and downstream stations in the Caloosahatchee Estuary.



3.3.1.2. Stratification

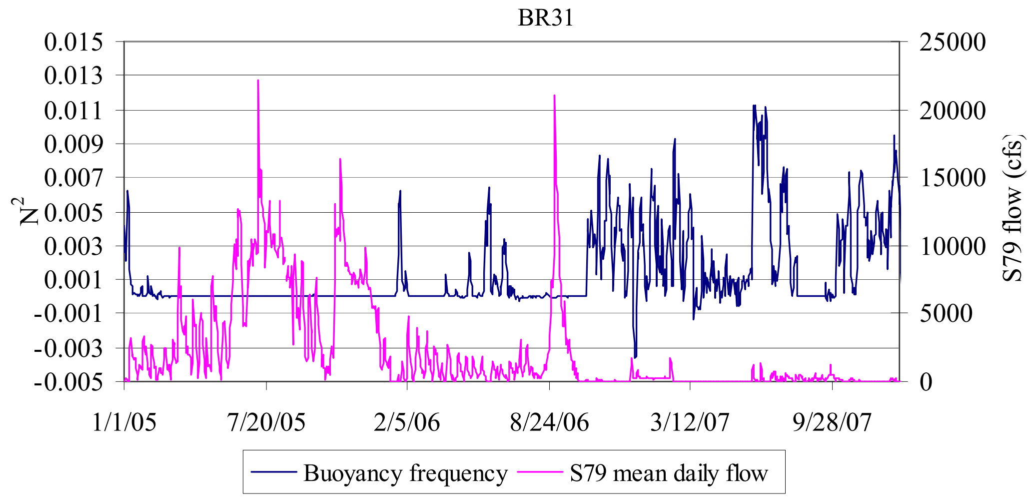
Salinity stratification is important in estuaries because it can prevent ventilation of bottom waters leading to low concentrations of DO. By confining phytoplankton in a surface layer where there is sufficient light, stratification can also encourage algal blooms.

The strength of stratification can be quantified by the Brunt-Väisälä buoyancy frequency. It is defined as:

$$N^2 = -\frac{g}{\rho}\frac{\partial \rho}{\partial z}$$

Where N is the buoyancy frequency, g is gravity, ρ is density and z is depth.

In the upper estuary at BR31, stratification is associated with relatively low discharges from S-79 (**Figures 3.3-5 and 3.3-6**). High discharges either mix the water column completely or turn the system fresh, eliminating density differences. By contrast, in the lower estuary at Shell Point, stratification occurs at high rates of discharge from S-79. Thus, the two ends of the estuary stratify and are most susceptible to depletion of oxygen in bottom water under different flow conditions.



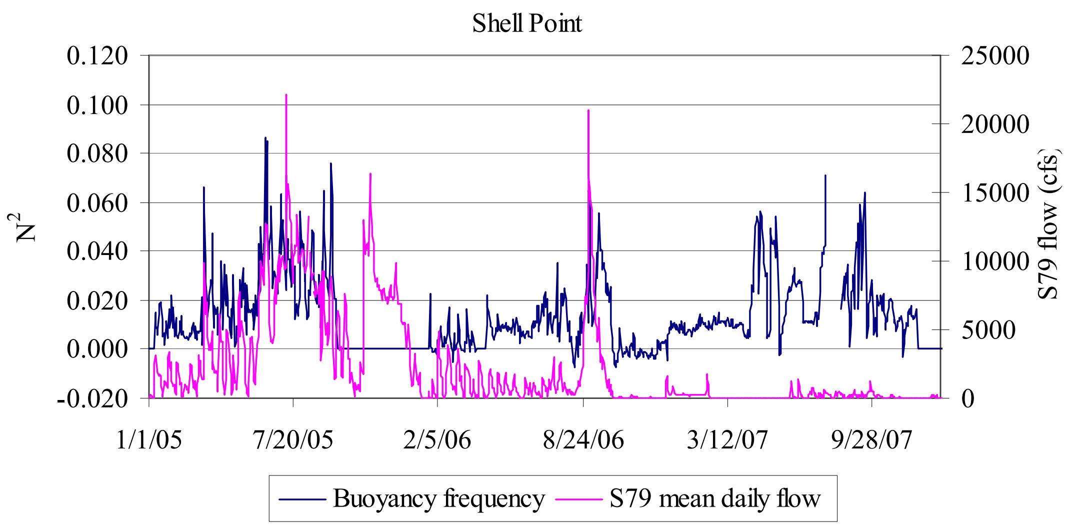
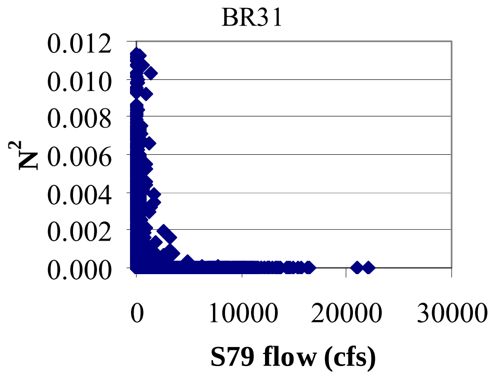


Figure 3.3-5. Stratification, as measured by the buoyancy frequency, and freshwater inflow at BR31 near the head of the estuary and at Shell Point near the mouth.



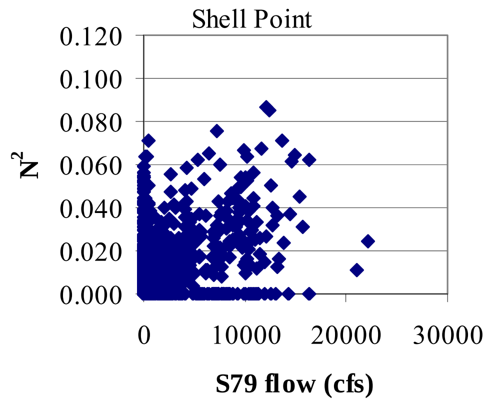


Figure 3.3-6. Relationship between stratification and freshwater inflow at BR31 near the head of the estuary and at Shell Point near the mouth.

Table 3.3-3. Daily range of tide and salinity from 2005 to 2007.

Daily Range	BR31	Ft. Myers	Cape Coral	Shell Point
Maximum (daily range, cm)		94.0		116.0
Average of daily range (cm)		41.5		52.9
Minimum (daily range, cm)		15.0		26.8
Maximum (daily range, ppt)	4.7	9.9	22.3	26.8
Average of daily range (ppt)	0.5	1.9	4.4	10.2
Minimum (daily range, ppt)	0.0	0.0	0.0	0.8
Flow threshold (cfs)	4,000	5,600	7,700	at least 10,000

3.3.2. Water Quality Status and Trends

This section reviews the status, trends and factors controlling water quality in the brackish and saltwater regions of the study area including the Caloosahatchee Estuary, San Carlos Bay, and Pine Island Sound. Status and trends in water quality have been summarized several times in recent years, including: Doering and Chamberlain (1998); Doering and Chamberlain (1999); Janicki et al (2003); Doering and Chamberlain (2005); Janicki et al (2007); and, most recently, Crean and Iricanin (2007). These investigations involve analysis of monthly monitoring data collected by local municipalities, counties and state agencies.

The synoptic concentration data produced by almost all water quality monitoring programs supports the analysis of status and trends. However, the identification of factors that control water quality is usually achieved through a correlation analysis with external factors, such as freshwater inflow, tides and wind. Internal rate processes, such as phytoplankton productivity or regeneration of nutrients by bottom sediments are rarely included in routine monitoring programs. Such is the case for the Caloosahatchee Estuary. As a result, a complete accounting of the factors controlling the variation of water quality in the Caloosahatchee Estuary is not yet possible.

3.3.2.1. Spatial and Temporal Patterns

The major input of freshwater to the Caloosahatchee Estuary occurs at its head at the Franklin Lock and Dam (S-79) (ERD, 2003). Discharge at this point is a major factor influencing the spatial and temporal distribution of water quality constituents.

Figure 3.3-7, taken from Doering and Chamberlain (1998), depicts the spatial variation in concentration of several water quality constituents between S-79 (0 km) and a sampling station in Pine Island Sound (59 km). All water quality parameters varied as a function of distance from S-79, except turbidity. All other parameters except total suspended solids (TSS) decreased in magnitude as the distance from S-79 increased. TSS increased with increasing distance. Some parameters, like color and TSS, changed monotonically from S-79 to Pine Island Sound. A more general pattern, shown by nutrients and Chlorophyll-*a*, was the most precipitous change occurring with the estuary (0-40 km) and negligible or smaller changes occurring in San Carlos Bay (40-50 km) and Pine Island Sound (60 km). More recently, Doering et al (2006) analyzed data collected from S-79 into San Carlos Bay and found a similar spatial distribution of nutrients and other water quality constituents.

Temporal fluctuations are also driven by freshwater discharge. When compared to the dry season, higher discharges in the wet season generally lead to higher nutrient concentrations (**Figure 3.3-8**). Oxygen (not shown) was an exception, having a higher concentration in the dry season, perhaps owing to cooler temperatures.

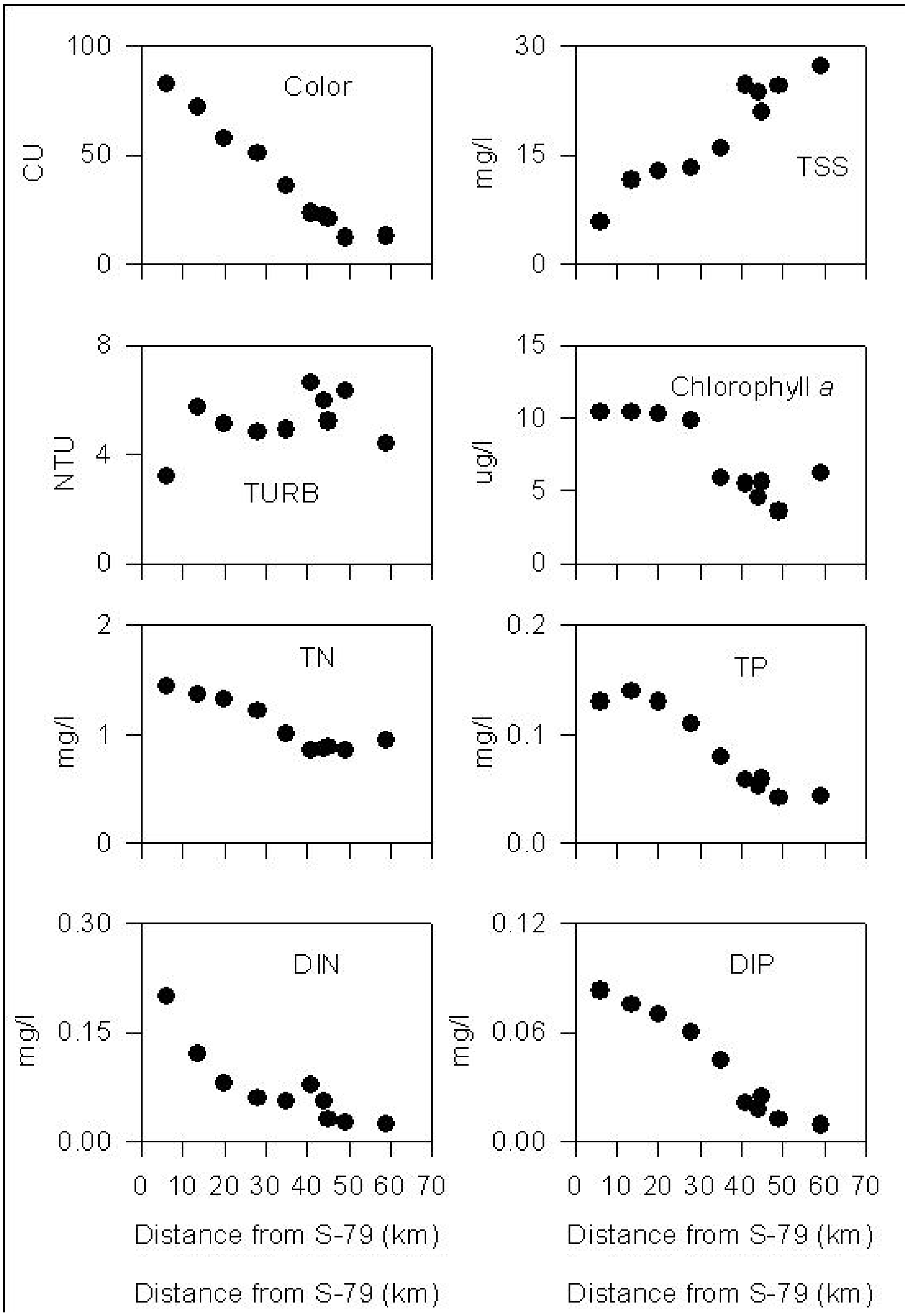


Figure 3.3-7. Average distribution of selected water quality parameters as a function of distance from S-79 (0 km). DIN=dissolved inorganic nitrogen, DIP=dissolved inorganic phosphorus, TN= total nitrogen, TP= total phosphorus.

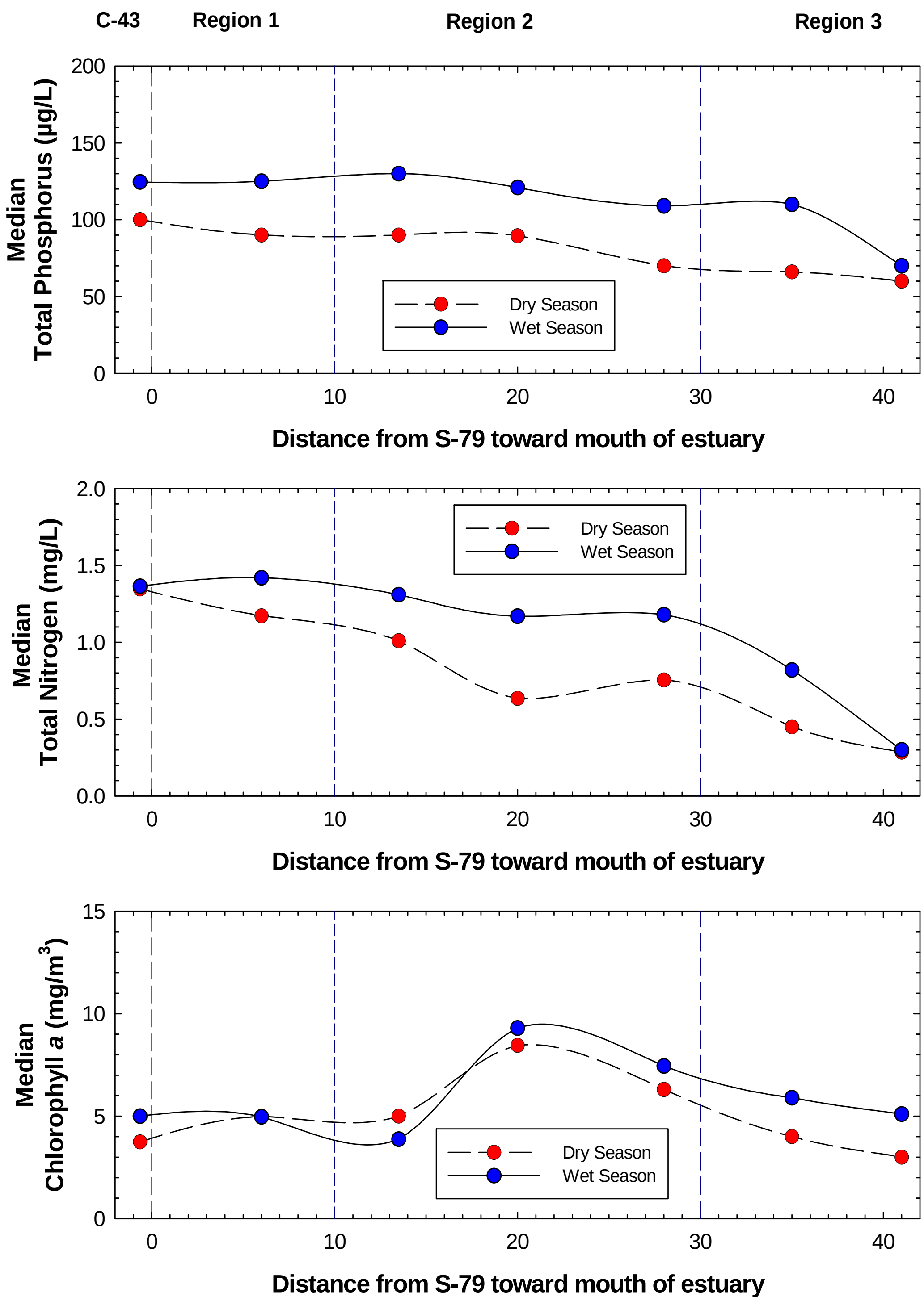


Figure 3.3-8. Seasonal median levels in the Caloosahatchee Estuary with distance from Structure S-79. The vertical lines denote the three regions of the estuary.

Table 3.3-4. Summary of water quality for four regions of the Caloosahatchee Estuary for the period from October 1994 through December 2006. One region is located upstream of S-79 and the other three regions are located in the estuary between S-79 and Shell Point.

Parameter	Mean	±	Standard Deviation	Minimum	Percentiles					Maximum
					5th	25th	50th	75th	95th	
Station ~0.6 km upstram of S-79 (C-43)										
Salinity (PSU)	0.3	±	0.1	<0.2	<0.2	<0.2	0.2	0.3	0.5	2.3
Apparent Color (PCU)	103.8	±	53.8	40.0	49.8	64.0	80.4	134.3	213.8	260.0
Dissolved Oxygen (mg/L)	5.6	±	1.9	0.2	2.8	4.1	5.6	7.4	8.4	10.4
Total Phosphorus (µg/L)	115.9	±	57.8	15.0	27.8	77.8	110.0	140.0	230.0	360.0
Total Nitrogen (mg/L)	1.35	±	0.32	<0.05	0.91	1.17	1.36	1.51	1.86	2.43
Chlorophyll *a* (mg/m^3)	8.3	±	13.5	0.3	1.1	2.5	4.2	8.2	32.0	80.7
Stations 0 - 10 km from S-79 (Region1)										
Salinity (PSU)	1.3	±	3.0	<0.2	<0.2	0.2	0.3	0.5	7.2	22.2
Apparent Color (PCU)	103.1	±	57.2	20.4	41.8	60.7	80.2	138.0	221.5	282.0
Dissolved Oxygen (mg/L)	5.6	±	2.1	0.1	2.6	3.9	5.5	7.2	8.7	13.3
Total Phosphorus (µg/L)	125.3	±	83.7	15.0	37.0	72.0	110.0	160.0	280.8	680.0
Total Nitrogen (mg/L)	1.26	±	0.37	<0.05	0.64	1.08	1.26	1.49	1.86	2.36
Chlorophyll *a* (mg/m^3)	8.7	±	10.2	0.3	1.1	2.7	5.0	9.9	33.1	50.0
Stations 10 -30 km from S-79 (Region 2)										
Salinity (PSU)	4.7	±	6.4	<0.2	0.2	0.2	0.8	7.7	18.3	30.9
Apparent Color (PCU)	88.3	±	58.9	6.1	27.0	44.3	67.6	118.0	208.1	379.0
Dissolved Oxygen (mg/L)	6.6	±	1.9	0.4	3.6	5.1	6.8	7.9	9.4	13.4
Total Phosphorus (µg/L)	111.6	±	74.2	15.0	25.0	63.8	100.0	140.0	240.0	730.0
Total Nitrogen (mg/L)	1.04	±	0.47	<0.05	0.30	0.71	1.03	1.33	1.84	2.69
Chlorophyll *a* (mg/m^3)	11.8	±	17.5	0.3	1.5	3.2	5.8	12.4	40.9	119.0
Stations >30 km from S-79 (Region 3)										
Salinity (PSU)	17.9	±	10.6	<0.2	0.6	8.1	19.6	27.0	32.7	38.1
Apparent Color (PCU)	45.3	±	44.1	3.5	8.0	19.0	30.0	53.0	136.2	274.0
Dissolved Oxygen (mg/L)	6.6	±	1.4	2.7	4.1	5.7	6.7	7.6	8.8	12.7
Total Phosphorus (µg/L)	100.4	±	131.2	16.0	25.0	36.0	70.0	120.8	266.5	1130
Total Nitrogen (mg/L)	0.55	±	0.50	<0.05	<0.05	0.16	0.38	0.84	1.40	2.51
Chlorophyll *a* (mg/m^3)	6.1	±	6.7	0.2	0.9	2.6	4.0	7.2	17.3	51.1

Monthly and, perhaps, shorter-term variations in water quality constituents in the Caloosahatchee Estuary are driven, at least in part, by discharge at S-79. A correlation analysis (**Table 3.3-5**), as presented by Doering and Chamberlain (1999), indicated that every water quality parameter examined was correlated with freshwater discharge in some region of the estuary. Several general patterns emerged. Some parameters (color, TN, NO_X, NH_4, K_d) were positively correlated with discharge when the correlation was significant. By contrast, TSS was negatively correlated with discharge. TP and Chlorophyll-*a* were negatively correlated with discharge at the head of the estuary, but positively correlated farther downstream. Like TP, dissolved inorganic P was negatively correlated with discharge at the head of the estuary. Lastly, the effects of discharge on some parameters (color, salinity) could be detected statistically up to 59 km from S-79 in Pine Island Sound. For others (NH_4, TSS) the influence of discharge could be detected only in the upstream regions.

The relationship between Chlorophyll-*a* and freshwater discharge in the Caloosahatchee Estuary was first described by Doering and Chamberlain (1998). They showed that the location of the maximum chlorophyll concentration in the estuary moved progressively downstream as discharge at S-79 increased. Secondly, the magnitude of the maximum concentration decreased as discharge increased. Doering et al. (2006) further investigated the relationship between freshwater discharge at S-79 and Chlorophyll-*a* in the downstream estuary and San Carlos Bay.

Linear regression of Chlorophyll-*a* concentration and discharge at S-79 revealed a negative relationship in the upper estuary, no significant relationship in the mid-estuary and a positive one in the lower estuary and San Carlos Bay. However, there was apparent curvature in the relationships with discharge (**Figure 3.3-9**) (Doering et al., 2006). In the mid/lower estuary and San Carlos Bay, the concentration of Chlorophyll-*a* increased with increasing discharge up to a maximum and then began to decrease. In the mid-estuary, this inflection point occurred at a 30-day average discharge of about 85 m^3/sec (3,000 cfs). To the right of the inflection point, Chlorophyll-*a* concentration was positively correlated with discharge ($r = 0.384$, $p<0.001$, $n=90$) and to the left negatively correlated ($r = -0.463$, $p<0.02$, $n=25$). In the lower estuary ($r = 0.326$, $p<0.01$, $n=131$) and San Carlos Bay ($r = 0.390$, $p<0.01$, $n=109$), the concentration of Chlorophyll-*a* was positively correlated at discharges of less than 127 – 141 m^3/sec (4,500 – 5,000 cfs). At higher flows, linear correlation coefficients were negative but not statistically significant (lower estuary $r = -0.400$, $p<0.15$, $n=10$; San Carlos Bay $r = -0.533$, $p<0.12$, $n=10$). The negative relationship between concentration and discharge in the upper estuary over the entire flow range and the negative relationships at high discharge in downstream regions were interpreted as an indication of "wash out" (Doering et al., 2006).

Table 3.3-5. Spearman's Rank correlation (r) between mean daily discharge (cfs) at the Franklin Lock and Dam (S-79), calculated for the 30 days prior to sampling and water quality in five regions of the Caloosahatchee Estuary. Kilometers are distance downstream from S-79. Correlation coefficients calculated using transformed (log + 1) data. All r statistically significant ($p<0.05$) except where noted by ns = not statistically significant. Number of observations (n) for k was 21 – 36.

	Head	Upper Estuary	Lower Estuary	San Carlos Bay	Pine Island Sound
Kilometer	0 – 14	14 – 28	28 - 41	41 - 49	59
Salinity	-0.939	-0.968	-0.889	-0.901	-0.832
Color	0.844	0.902	0.880	0.776	0.449
TN	0.133 ns	0.439	0.532	0.286	-0.035 ns
NO_X	0.506	0.724	0.434	0.355	0.196 ns
NH_4	0.487	0.282	0.231 ns	0.208 ns	0.118 ns
TP	-0.538	-0.050 ns	0.251 ns	0.297	0.002 ns
DIP	-0.328	-0.061 ns	0.084 ns	0.183 ns	0.131 ns
TSS	-0.748	-0.660	-0.244	-0.111 ns	-0.047 ns
Chlorophyll-*a*	-0.525	0.041 ns	0.470	0.442	0.136 ns
K	0.071 ns	0.668	0.743	0.820	0.423 ns
n	55 - 62	56 - 62	56 - 62	57 - 60	37 - 40

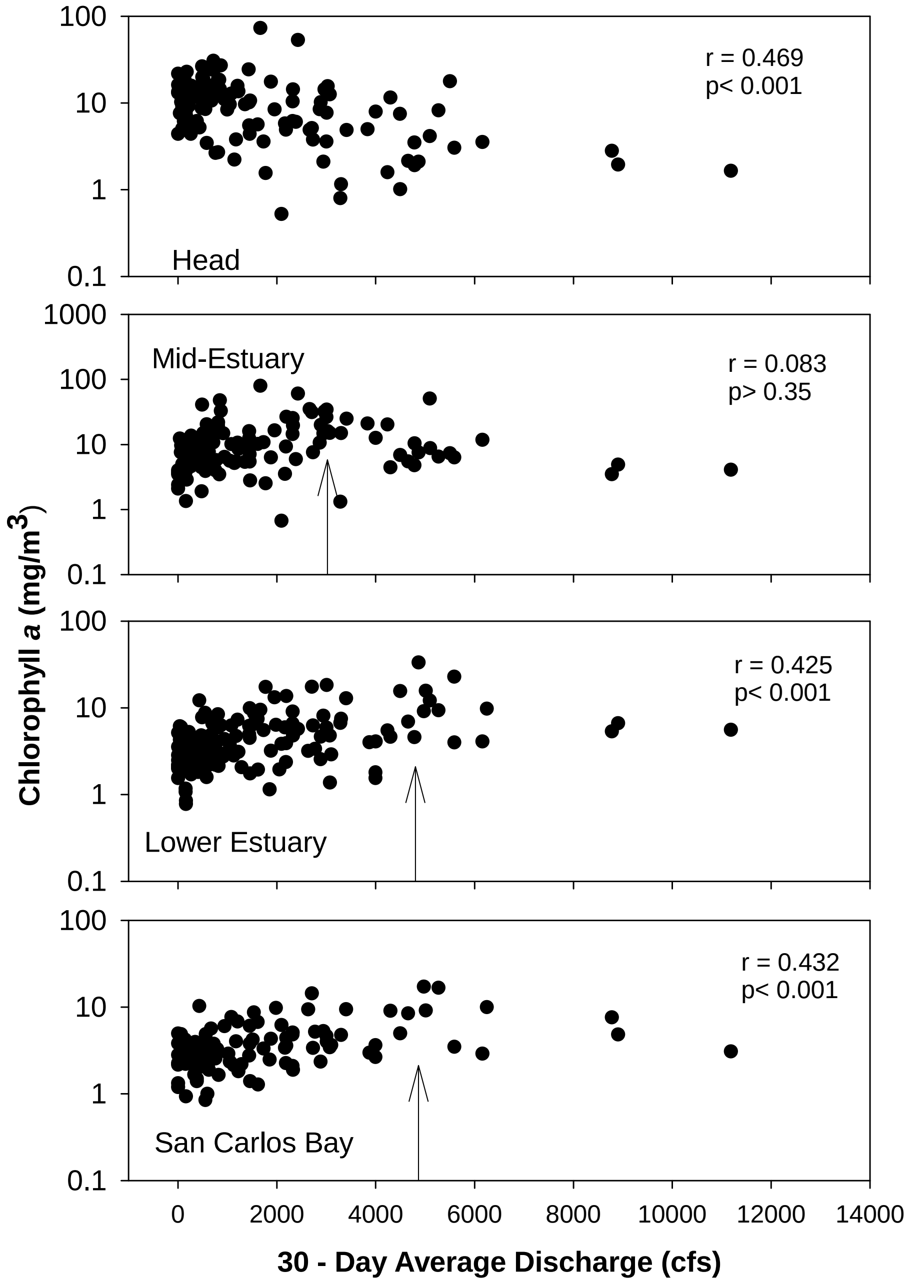


Figure 3.3-9. Relationships between Chlorophyll-a concentration and average freshwater discharge at S-79 over the 30 days prior to sampling. Arrow indicates inflection point. Also given is spearman's rank correlation coefficient r.

3.3.2.2. Source of Freshwater and Estuarine Water Quality

The artificial connection of Lake Okeechobee to the Caloosahatchee River and its estuary represents a unique anthropogenic manipulation of hydrology. As a result, the Caloosahatchee River has two major sources of fresh water: one from its watershed, and the other from Lake Okeechobee. The contribution of each source to the freshwater discharge reaching the downstream estuary varies and either may dominate. Doering and Chamberlain (1999) analyzed routine monitoring data to determine the effects of total river discharge and source of discharge (river basin, lake) on water quality in the downstream estuary. Parameters examined were color, total suspended solids, light attenuation, Chlorophyll-*a*, and total and dissolved inorganic nitrogen and phosphorus. In general, the concentrations of color and total/dissolved inorganic nitrogen increased, while total suspended solids decreased as total discharge increased.

When the river basin was the major source, the concentrations of nitrogen nutrients (except ammonia) and color in the estuary were relatively higher than when the lake was the major source. Light attenuation was greater when the river basin dominated freshwater discharge to the estuary (**Table 3.3-6**). Concentrations of TP, dissolved inorganic phosphorus TSS and Chlorophyll-*a* were also greater when most of the discharge came from the basin, but not at all flow rates. The analysis indicates that water quality in the downstream estuary changes as a function of both total discharge and source of discharge. Relative to discharge from the river basin, releases from Lake Okeechobee do not detectably increase concentrations of nutrients, color, or TSS in the estuary. The lower concentrations associated with discharges from Lake Okeechobee may be attributable to the unique morphometry of this system. The western edge of the lake is comprised of a large (40,000 ha) wetland marsh, which effectively filters nutrients before water leaves the lake at S-77.

Table 3.3-6. Effects of source of freshwater (River Basin or Lake Okeechobee) discharged at S-79 on water quality in the Caloosahatchee Estuary. Arithmetic means (std) are shown. Statistical analysis conducted on log (value + 1) transformed data. Parameters are those for which ANOVA showed a significant source effect and no interactions between the source effect and other main effects. *Significant difference between sources at $p<0.05$, n=122-130 for basin and n=98-102 for lake.

Parameter	Basin	Lake
Salinity (ppt)	14.78 (10.91)	17.55 (11.78)
Color (cu) *	58 (45)	36 (30)
TN (mg/L) *	1.24 (0.39)	1.05 (0.46
NOX (mg/L) *	0.09 (0.13)	0.04 (0.07)
NH4 (mg/L)	0.03 (0.03)	0.03 (0.04)
K (/meter) *	2.78 (1.88)	1.70 (1.18)

3.3.2.3. Relationship to State Standards and Norms

3.3.2.3.1. Status and Trends

Crean and Iricanin (2007) recently summarized water quality in the Caloosahatchee Estuary (**Table 3.3-4**). Water quality in the Caloosahatchee Estuary can be assessed by comparison to various standards, targets and norms. Doering and Chamberlain (1998) compared nutrient concentrations to the TN (1.0 mg/L), TP (0.15 mg/L) and Chlorophyll-*a* (20 µg/l) standards established for the upper estuary by the Florida Department of Environmental Regulation (DeGrove 1981). Most exceedances occurred in the estuary upstream of Ft. Myers, where over 60% of the TN samples and 20 to 30% of the TP samples were above target values. The chlorophyll target was exceeded in up to 15% of the samples. A commonly accepted value of 15 µg/l for good seagrass growth (Dennison et al. 1993) was exceeded in up to 30% of the samples. Dissolved oxygen (DO) concentrations falling below the state standard of 4 mg/L, or the generally accepted threshold for hypoxia (2 mg/L), were relatively rare and confined to the upper reaches of the Caloosahatchee Estuary. Low DO concentration tended to occur during the warmer months of May - October. Doering and Chamberlain (2005) analyzed a larger data set and found DO concentrations below 4 mg/L in 35% of the samples. In the upper and mid-estuarine regions, Chlorophyll-*a* concentrations exceeded the nutrient standard of 11 µg/l in 40% of the samples. In the lower estuary and San Carlos Bay, the vast majority of measured concentrations were below 11 µg/l.

Trends in water quality have been analyzed by Janicki Environmental for the Charlotte Harbor National Estuary Program in 2003 and again in 2007 using the Seasonal Kendall Tau statistic. The results show that salinity has exhibited a decrease in all regions of Southern Charlotte Harbor from the Caloosahatchee Estuary to Pine Island Sound. Nitrate and/or nitrate + nitrite, as well as TKN, have increased at a minimum of one station in each region as well. Similar trends in concentration were not observed just upstream of S-79 in the Caloosahatchee River (CES01). River water has a higher concentration of nitrogen species than ocean water. Therefore, the increase in nitrogen may be due to the increase in the fraction of freshwater that is indicated by the decrease in salinity. The increase in nitrate+nitrite in the downstream estuary, detected by Janicki Environmental (2007), is consistent with the increase in DIN loading apparent in the data of Crean and Iricinan (2007).

Analysis of monthly monitoring data has clearly demonstrated the influence of both the quantity and source (Lake Okeechobee vs. Caloosahatchee River Basin) of freshwater discharge at S-79 on water quality in the downstream estuary. However, little is known about the influence of inputs from tidal creeks and wastewater treatment facilities downstream of S-79. Patterns of nutrient cycling within the estuary itself are even less well known.

3.3.3. Aquatic Habitats

SFWMD uses a resource-based or Valued Ecosystem Component (VEC) approach to manage estuarine water quality and quantity. The VEC approach was developed by the

U.S. Environmental Protection Agency (USEPA, 1987) as part of its National Estuary Program. The definition of a VEC can be fairly broad: "Any part of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process." Importance may be determined on the basis of scientific concern or based on cultural values (SFWMD, 2001). The approach has been modified to focus on providing critical estuarine habitat. In many instances, that habitat is biological and typified by one or more prominent species (Chamberlain and Doering, 1998; Doering et al., 2002; SFWMD, 2006). In other cases, the habitat may be physical, such as an open water oligohaline zone (SFWMD, 2002). Enhancing and maintaining these biological and physical habitats should lead to a generally healthy and diverse ecosystem.

The freshwater quantity and quality required by the VEC ultimately determine the solution to be implemented in the upstream watershed, whether it is construction of new infrastructure, changes in operational protocols or implementation of best management practices (BMP). The approach furnishes both a goal, as defined by VEC requirements, and a predictive tool for evaluation of alternative solutions. This section focuses on two prominent biological habitats as VECs: submerged aquatic vegetation (SAV) and oysters.

3.3.3.1. Submerged Aquatic Vegetation Distribution, Relationship with Water Quality

Beds of SAV are important to the ecology of shallow estuarine and marine environments. SAV may provide habitat for many benthic and pelagic organisms, function as nurseries for juveniles and other early life stages, stabilize sediments, improve water quality and form the basis of a detrital food web (Kemp et al., 1984**;** Fonseca and Fisher, 1986; Carter et al., 1988; Killgore et al., 1989; Lubbers et al., 1990). Because of the importance of SAV beds, estuarine restoration initiatives often focus on SAV (Batiuk et al., 1992; Johansson and Greening, 2000; Virnstein and Morris, 2000). SAV are commonly monitored to gauge the health of estuarine systems (Tomasko et al., 1996) and their environmental requirements can form the basis for water quality goals (Dennison et al., 1993; Stevenson et al., 1993).

Although there are species-specific variations, SAV distributions in coastal areas are limited by four environmental factors: light, salinity, temperature and nutrients (Dennison et al., 1993**;** Kemp et al., 2004). In coastal ecosystems, salt-tolerant freshwater SAV - such as tape grass (*Vallisneria americana*) and Widgeon grass (*Ruppia maritima*) can establish in upper estuarine reaches that have oligohaline conditions. These SAV may be sensitive to salinity intrusions during low flow conditions. Farther downstream in the more marine reaches of coastal ecosystems, several species of seagrasses may occur in South Florida, including: *Halodule wrightii, Thalassia testudinum*, and *Syringodium filiforme***.** The seagrasses tend to be more sensitive to high inflow conditions that decrease salinity.

In addition to salinity, the central role of light availability for SAV is well established. Changes in water clarity can impact density, depth distribution and species able to grow in a given area. Water quality variables such as total suspended solids, turbidity, chlorophyll *a*, color or dissolved organic matter may directly contribute to light attenuation and thus impact SAV growth and survival. More indirectly, SAV losses may be attributable to eutrophication. The hypothesized mechanisms whereby nutrient additions may lead to reductions in SAV involve the promotion of algal growth. This can be either phytoplanktonic (Jupp and Spence, 1997) or epiphytic (Phillips et al., 1978). Either results in a reduction in light available to vascular plants (Sand-Jensen, 1977). Additional stress mechanisms such as inhibition of molecular transport across plant epidermal surfaces may also be implicated (Sand-Jensen, 1977).

Temperature, although less studied and not usually under regulatory control, also contributes to growth and survival. Seasonal patterns are an indication of the influence and importance of temperature on SAV, with the best growth generally occurring in the range of 22-30^{o}C. In addition, temperature impacts photosynthesis by altering the rate of the biochemical reactions of photosynthesis. The species type and climate may also be important considerations for temperature effects. The semi-tropical South Florida environment represents the northern boundaries of tropical species such as *T. testudinum* and relatively cold winters may impart thermal stress. By contrast, hot summers may stress temperate species (e.g., tape grass) living near their southern limit in South Florida.

3.3.3.1.1. Caloosahatchee

In the Caloosahatchee Estuary, studies have documented that SAV distribution is strongly related to limits on their physiological response to salinity and light (Greenawalt-Boswell et al., 2006). Except at the distribution margins, plant location in the estuary generally depends on salinity, while growth characteristics controlling plant height and depth strongly relate to light attenuation within tolerable salinity ranges.

Vallisneria americana (tape grass, wild celery) is an important upper estuarine SAV species. When present, this species is located near the shoreline in the upper estuary to a depth of about 1.0 m. *Vallisneria americana* (*V. americana*) is a salt-tolerant freshwater angiosperm that may grow in the oligohaline reaches of estuaries in the Northeastern and Southeastern United States (Bourn, 1932; Lowden, 1982). In the upper Caloosahatchee Estuary it serves as an indicator of low salinity or oligohaline conditions. Its greatest coverage occurs from Beautiful Island to just past the Ft. Myers bridges (Hoffacker et al., 1994; Chamberlain and Doering, 1998b) (**Figure 3.3-10)**.

Downstream, sparse beds of the seagrass *Halodule wrightii* (shoal grass) extend up from San Carlos Bay almost to the Cape Coral Bridge (Hoffacker et al., 1994; Chamberlain and Doering, 1998b). Like *V. americana*, it is restricted to the shoreline margins. McNulty et al. (1972) and Harris et al. (1983) mapped SAV in the lower estuary upstream of Shell Point, as well as throughout the outer embayments**.** *Halodule wrightii* is the only seagrass species consistently located upstream of Shell Point **(Figure 3.3-10; Sites 5 and 6).** Downstream, it forms mixed beds with *Thalassia testudinum* and other less common species in San Carlos Bay **(Figure 3.3-10; Sites 7 and 8)** and Pine Island Sound.

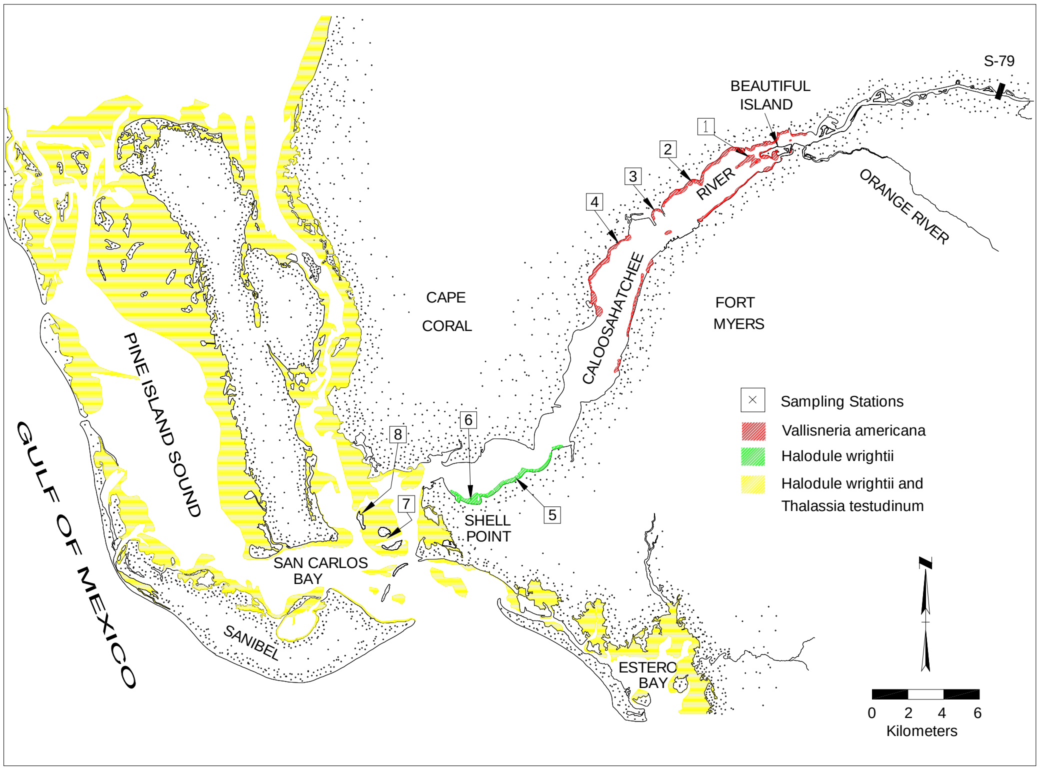


Figure 3.3-10. SAV Distribution in Caloosahatchee Estuary.

3.3.3.1.2. Vallisneria americana

During times of extended low inflow conditions, when salinity is too high, tape grass becomes very sparse and can disappear completely (Chamberlain et al., 1995; Doering et al., 2002, SFWMD, 2000). Sampling of *V. americana* density and water quality parameters at several stations in the upper estuary (**Figure 3.3-11**) indicates tape grass density was greatest at the beginning of the period of record. Tape grass beds were depleted following a drought in 2000 – 2001, when freshwater inflow from S-79 and other sources was very low, resulting in unusually high salinity conditions that persisted for many months. Subsequent to this drought, no plants were observed during sampling for two and a half years, until tape grass began to reappear during the 2003 wet season. Despite periods of ample fresh water, only limited re-establishment of small rosettes has occurred during the period of 2003 - 2007 (six years following the drought). The limited rebound that has occurred suggests that other factors besides salinity affected plant growth. Hunt and Doering (2005) demonstrated that light can also become limiting in the upper estuary, especially after a drought. A second drought began in 2007 and caused salinity to exceed 25 ppt, resulting again in the total loss of tape grass from the estuary. Recovery of the plants is not expected for at least two-to-three years, unless additional restoration measures are provided.

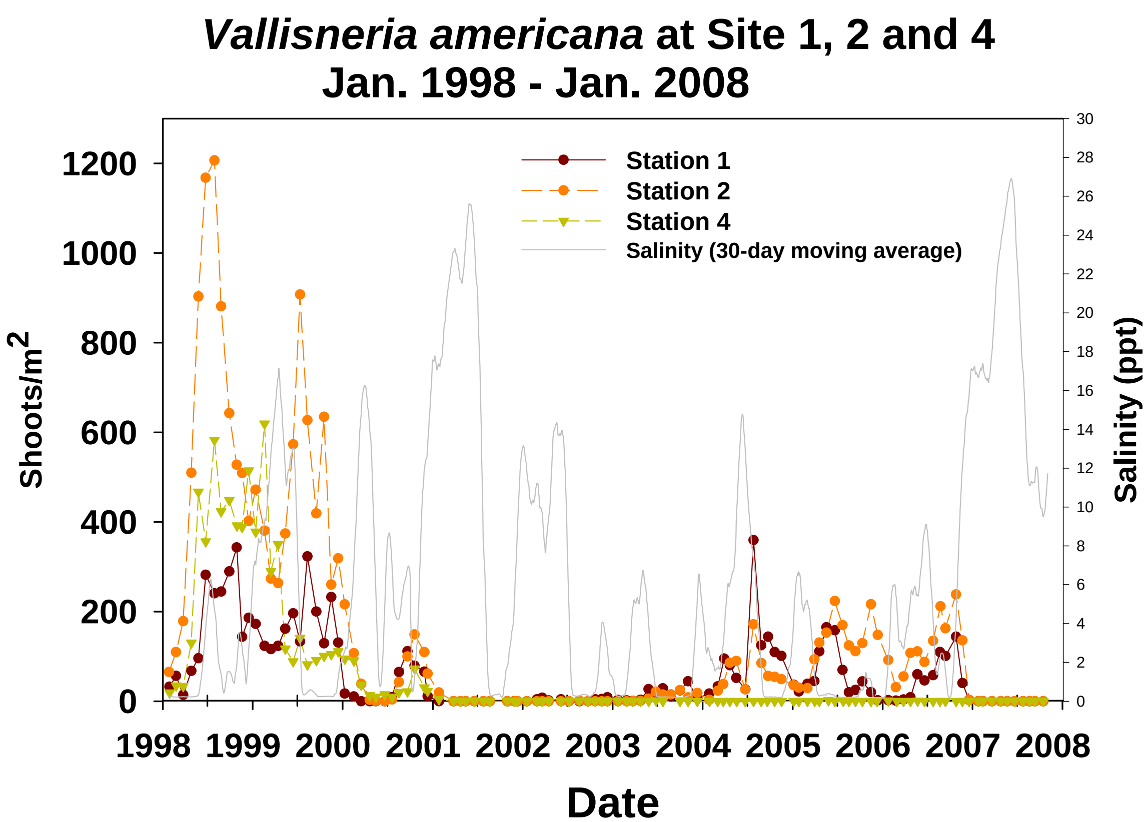


Figure 3.3-11. Vallisneria americana in the upper Caloosahatchee Estuary. Note: Station 3 (not shown) was discontinued in 1999.

To address the multiple environmental variables affecting growth and survival, a numerical model for *V. americana* was developed. This tool integrates both field and laboratory data to predict the effect of different environmental variables on growth, survival, and re-establishment (SFWMD, 2003; Hunt and Doering, 2005). It has been applied to help meet management challenges associated with altered quantities of freshwater delivery in the Caloosahatchee Estuary (SFWMD, 2003). The model was recently updated with new light attenuation relationships and re-calibrated (Hunt 2007, in review).

The *V. americana* model may provide useful information to help establish light attenuation or water clarity targets in the upper estuary. A critical component of water quality assessment should include consideration for the light requirements of re-growth, particularly after significant stress - such as severe droughts - impact the beds. The seasonal timing of preferred light conditions may also play an important role and should be evaluated further (Hunt, in review). Specific goal-related analyses would be needed to establish specific water clarity targets that would support re-establishment and sustained presence of *V.americana* beds.

3.3.3.1.3. Seagrass

Halodule wrightii has a fairly wide salinity tolerance (McMahan 1968). It prefers relatively high salinity (as high as 44 ppt), but can survive relatively low salinity to 3.5 ppt (Zieman and Zieman, 1989). This wide tolerance is probably why it is the only true seagrass species encountered upstream of Shell Point. Monitoring results (**Figure 3.3-12**) indicate that, of all areas where shoal grass is present, the lowest biomass is found upstream, where salinity is more diluted and most variable (Chamberlain et al., 1995; Chamberlain and Doering, 1998b; Doering et al., 2002). Recent monitoring depicts a rapid decrease in density in San Carlos Bay (**Figure 3.3-12; Stations 7 and 8**) at the end of 2005, during and following large discharges related to tropical storms in 2004 and 2005. However, full recovery occurred during next year's growing season, with winter-dry season densities in 2007 being greater than during previous years.

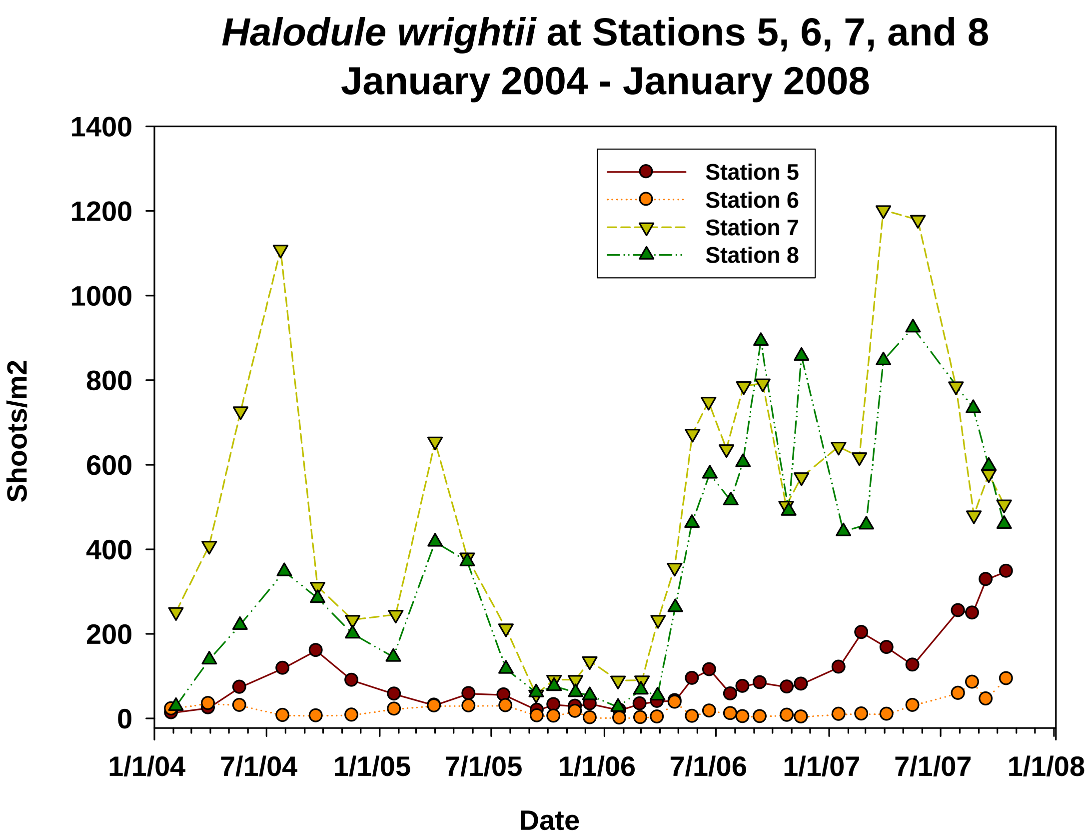


Figure 3.3-12. Halodule wrightii in the lower Caloosahatchee Estuary and San Carlos Bay. Data collected by the Sanibel-Captiva Conservation Foundation.

Turtle grass beds do not exist upstream of Shell Point. As with *Halodule*, monitoring results (**Figure 3.3-13**) depict a declining density that corresponds with the tropical storms of 2004 and 2005. Plant shoot counts approached < 20% of normal at the end of 2005. This decrease in *T. testudinum* density and its percentage of general seagrass composition persisted into 2007 compared to *Halodule*'s recovery (**Figure 3.3-13**). This may have implications for the fish community (diversity and abundance) that utilize these beds (Robbins and Boyes, 2007).

Comparison of map coverage by Harris et al. (1983) determined there has been a substantial loss in seagrass since 1940. This loss was due, in part, to changes in freshwater flow patterns (salinity variability) and physical alteration in the estuary and watershed, as well as changes in water management practices (Chamberlain and Doering, 1998a). Harris et al. (1983) reported that the greatest loss appeared to be from deeper beds, which indicates a change in water clarity. This change is probably due, in part, to the increased freshwater inflow reaching the downstream beds and associated decreased water quality (e.g., increased water color).

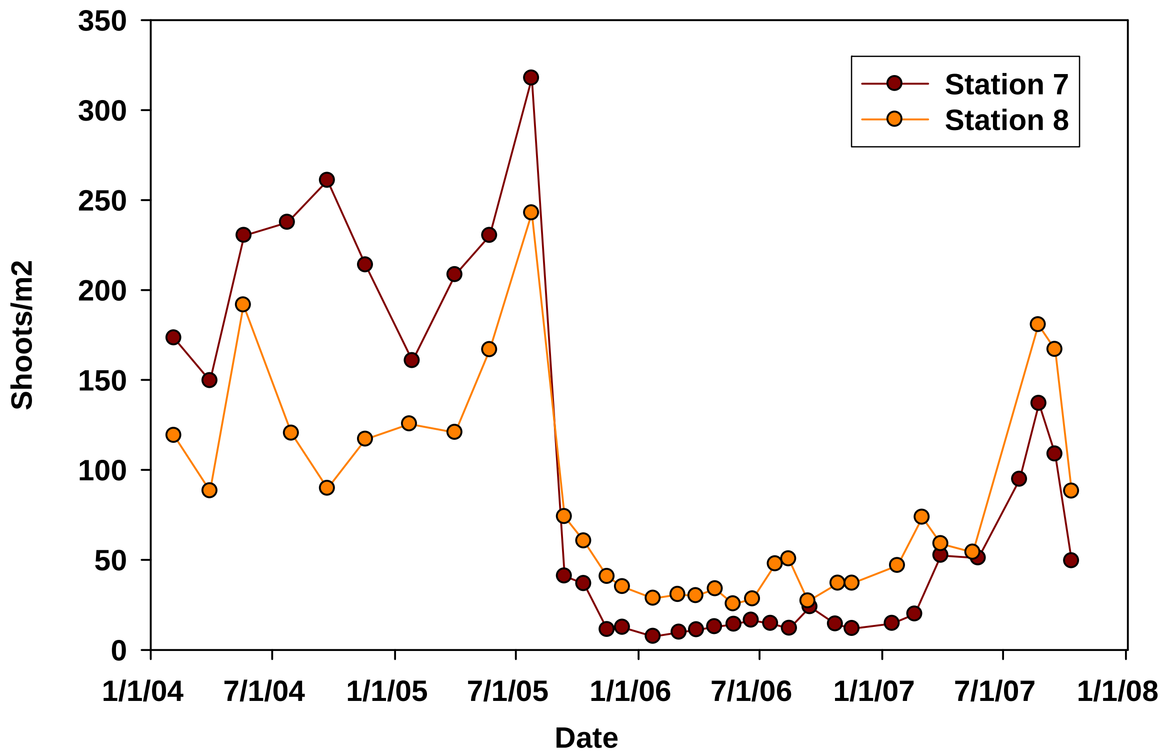


Figure 3.3-13. Thalassia testudinum in San Carlos Bay. Data collected by the Sanibel-Captiva Conservation Foundation.

3.3.3.2. Oysters: Distribution and Relationship with Water Quality

The Eastern Oyster (*Crassostrea virginica*) occupies estuarine and near shore habitats throughout the eastern and Gulf of Mexico coasts of the United States. In Florida, oysters occur along both the Atlantic and Gulf of Mexico coasts in almost all estuarine and near shore waters. This animal supported a subsistence fishery even before European colonization of the United States (MacKenzie et al., 1997). Throughout recent history, the Eastern Oyster has provided an important economic and cultural resource to coastal inhabitants. In addition to its direct economic benefits, the oyster also provides essential habitat for many other estuarine inhabitants (Wells, 1961; Bahr and Lanier, 1981). These include numerous species of decapod crustaceans and fishes (**Table 3.3-7).** Alterations in freshwater flow have reduced or eliminated many oyster reef areas and have impacted both the timing and extent of oyster reproduction (Berrigan et al., 1991). The diverse community associated with the oyster reefs has been impacted to an equivalent or greater degree. Oysters are included among several prominent species identified as estuarine resources for which water management practices have been proposed. The proposed practices for freshwater releases will maintain salinity levels required by each of the respective estuarine species (USACE and SFWMD, 2007).

An oyster can filter 4-34 liters of water per hour, removing phytoplankton, particulate organic carbon, sediments, pollutants, and microorganisms from the water column. Therefore, large populations of oysters can significantly increase water quality including water clarity (Newell et al., 2002; Cerco and Noel, 2007). As water clarity increases, photosynthetic active radiation (PAR) can penetrate to greater depths, which creates additional potential habitat for desirable SAV. Furthermore, oyster filter feeding assists assist in transferring organic carbon to other oyster reef invertebrates by producing dense organic waste particles that quickly become populated with high protein bacteria. These waste particles provide a nutritious food source for numerous deposit feeding benthic inhabitants that, in turn, increases estuarine productivity (Dame and Patten, 1981).

Table 3.3-7. Decapod crustaceans and fishes collected June – October, 2002 during longitudinal sampling of the Caloosahatchee River and Estuary (from Tolley, et al., 2006).

Species	Common Name	Number Collected
Decapods		
Farfantepenaeus sp.	penaeid shrimp	24
Palaemonetes pugio	daggerblade grass shrimp	7
Palaemonetes vulgaris	marsh grass shrimp	36
Alpheus heterochaelis	bigclaw snapping shrimp 107	107
Petrolisthes armatus	green porcelain crab	1343
Libinia dubia	longnose spider crab	3
Portunas gibbesii	Iridescent swimming crab	1
Eurypanopeus depressus	flatback mud crab	3442
Menippe mercenaria	Florida stone crab	19
Panopeus lacustris	knotfinger mud crab	11
Rhithropanopeus harrisii	Harris mud crab	1
Fishes		
Opsanus beta	gulf toadfish	46
Gobiesox strumosus	skilletfish	59
Anarchopterus criniger	fringed pipefish	1
Eucinostomus sp.	mojarra	16
Archosargus probatocephalus	sheepshead	1
Lagodon rhomboides	pinfish	5

Species	Common Name	Number Collected
Bairdiella chrysoura	silver perch	13
Chasmodes saburrae	Florida blenny	62
Hypsoblennius hentz	feather blenny	6
Lupinoblennius nicholsi	highfin blenny	2
Bathygobius soporator	frillfin goby	3
Gobiosoma bosc	naked goby	2
Gobiosoma robustum	code goby	177
Sphoeroides nephelus	southern puffer	1

3.3.3.2.1. Caloosahatchee

Existing oyster habitat in the Caloosahatchee River and Estuary has been estimated to cover approximately 18 acres (**Figure 3.3-14**), based on a survey conducted in 2004 (RECOVER, 2007). This coverage is much reduced from the historic anecdotal evidence (Sackett, 1888), when navigation was difficult through the lower part of the Caloosahatchee Estuary upstream of Shell Point due to the oyster bars. This change is, in part, a result of alteration in estuarine hydrodynamics and salinity, but also due the large-scale removal of oysters and their substrate to provide construction and road material for local development.

Oyster monitoring in the Caloosahatchee River and Estuary began in 2000 and covers the range of locations where they are found (**Figures 3.3-14** and **3.3-15**). The monitoring program was intended to describe the life history (spawning, recruitment, distribution) of the oyster in relation to freshwater inflow or its proxy salinity. In addition, the extent and intensity of infection by the protozoan parasite, *Perkinsus marinus*, was investigated. *Perkinsus* has devastated oyster populations in the Gulf of Mexico, where it is currently the primary pathogen of oysters (Soniat, 1996). The current distribution of oysters is determined by a number of environmental factors, including available hard substrate for juveniles, water temperature and salinity. During their study, Volety et al (2003) concluded that salinity conditions were best suited for oyster growth just upstream of Shell Point. However, this upstream area is also the most vulnerable to high mortality when large freshwater releases cause salinity to fall below threshold tolerance, sometimes for prolonged periods.

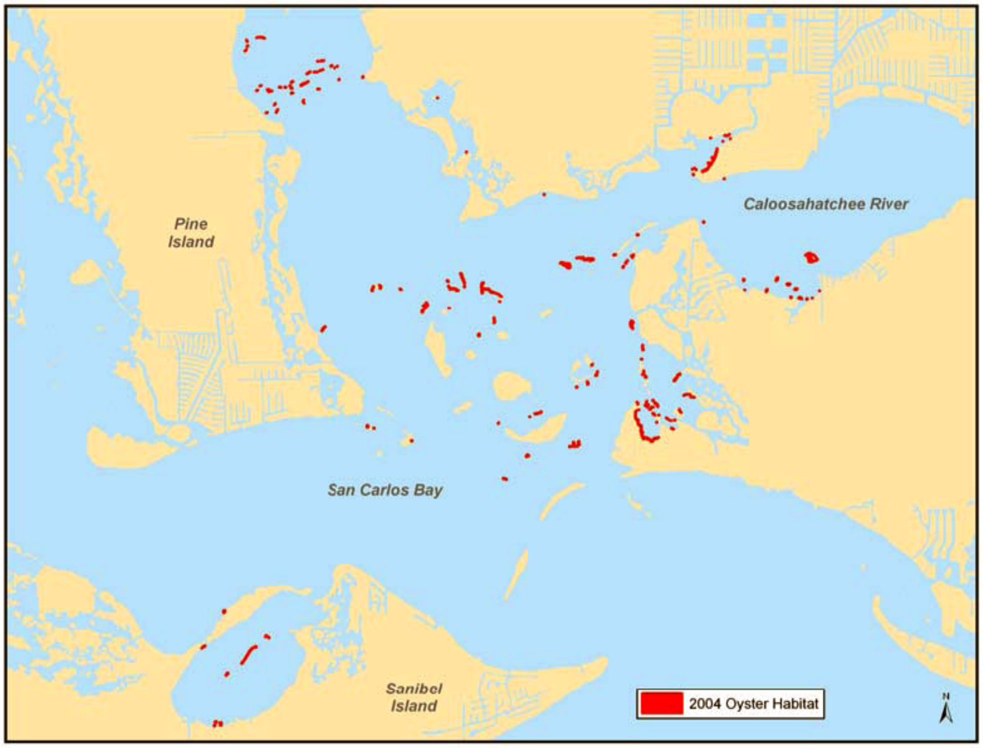


Figure 3.3-14. Existing Oyster Habitat in the Caloosahatchee River and Estuary. From RECOVER, 2007. Data Source: RECOVER Oyster Monitoring Network, 2004.

Figure 3.3-15. From Volety, et al, 2003. Aerial of the study area in the Caloosahatchee Estuary (USGS aerial [Online]. Stations sampled from upstream to downstream are Piney Point (PP), Iona Cove (IC), Cattle Dock Point (CD), Bird Island (BI), Kitchel Key (KK), and Tarpon Bay (TB).

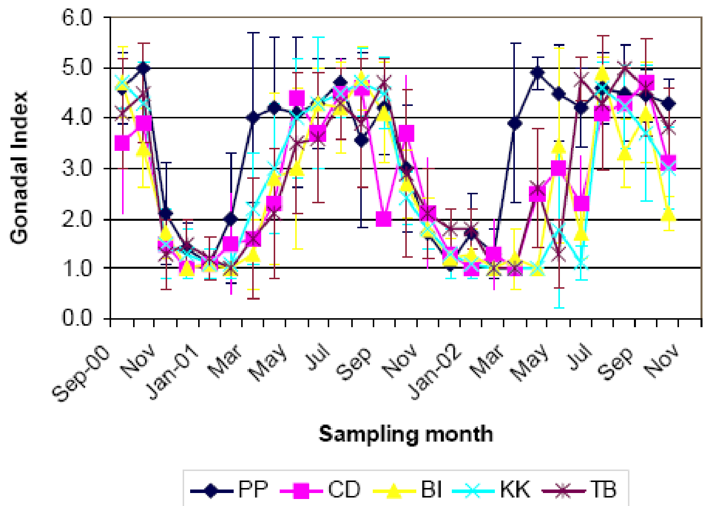


Figure 3.3-16. From Volety, et al, 2003. Gonadal Index of oysters from Piney Point (PP), Cattle Dock (CD), Bird Island (BI), Kitchel Key (KK) and Tarpon Bay (TB). Stations PP, CD, BI, KK and TB are from upstream to downstream. Gonadal index values correspond to active spawning by oysters.

Oysters in southwest Florida spawn continuously, with peak recruitment (spat settlement) occurring during May to November. Recruitment near Shell Point and possibly upstream begins to peak in March (**Figure 3.3-16**), a full three months earlier than in San Carlos Bay, thus making these newly settled juveniles vulnerable to large releases from S-79. Large freshwater flows at this time and during the summer also expose oyster larvae to lethal low salinities. These flows may also flush larvae to more downstream locations, where there may not be suitable substrate for settlement and salinities may be too high after the initial flush subsides.

In the Caloosahatchee Estuary, when summer temperatures reach 32ºC, *P. marinus* infection prevalence and intensity should be high. However, the increased input of freshwater during the summer wet season decreases salinities, keeping infection levels low. Similarly, during winter, when freshwater releases are low, salinities are usually highest (~30-40 ppt) and infection should be high. However, temperatures are lower (~15-18ºC) at this time of the year, resulting in low infection levels despite high salinity. Temperatures and salinities in the Caloosahatchee Estuary act antagonistically, keeping *P. marinus* infections usually at low levels year-round (**Figure 3.3-17**).

Suitable substrate in preferred locations is currently one of the limiting factors for oyster recovery in the Caloosahatchee Estuary. Volety et al. (2003) indicated that because of high spat recruitment at intermediate salinities, along with good growth rates and low disease, it is very feasible to reestablish oyster reefs upstream of Shell Point. This can be done by strategically placing oyster substrate and cultch in suitable areas, if provided the ability to control current [high] freshwater inflows.

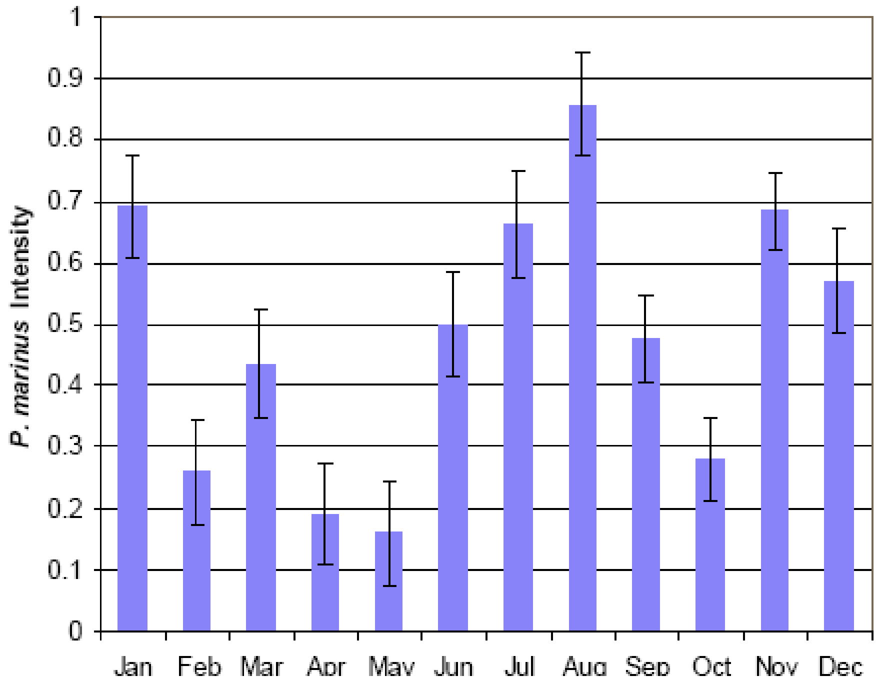


Figure 3.3-17. From Volety, et al. 2003. Mean P. marinus (DERMO) intensity in oysters from all the sampling locations during the study period. Infection intensity from all stations was averaged monthly (N = 100 - 130 / month). Results suggest that while infections are relatively higher during times of high temperatures (Jun - Sep) (see Figure 3.2-7) and during times of high salinities (Nov - Jan) (see Figure 3.2-8), on a scale of 0-5, overall infection intensities are low (<1.0).

3.4. Salinity Envelope and Freshwater Inflow Targets for the Caloosahatchee Estuary

As described in previous sections, the physical changes to the Caloosahatchee Estuary, in combination with alteration of the natural freshwater inflow, have caused unnatural, large-scale fluctuations in its salinity and water quality. The resulting impacts to seagrass, oysters, benthic invertebrates, and fishes can be dramatic and long lasting. SFWMD uses a resource-based approach to address water management issues in estuaries (Chamberlain and Doering, 1998a; Sklar and Browder, 1998).

3.4.1. Technical Basis for Development

SFWMD has employed a combination of the Valued Ecosystem Component (VEC) approach and the habitat overlap concept of Browder and Moore (1981) to address water quantity issues in the Caloosahatchee Estuary. The VEC approach is the general name given to a method developed by the U.S. Environmental Protection Agency (USEPA, 1987) to guide monitoring programs in the National Estuary Program. The approach has been modified to focus on providing critical estuarine habitat. In some cases, that habitat might be physical, such as an open water oligohaline zone. In other cases, the habitat is biological and typified by one or more prominent species (e.g., an oyster bar, seagrass bed). For the Caloosahatchee Estuary, beds of SAV and oysters have been identified as primary VEC.

The overlap concept of Browder and Moore (1981) forms the basis for relating freshwater discharge to VEC or other estuarine resources (Sklar and Browder, 1998). The concept of static and dynamic habitat overlap (Browder and Moore, 1981) is based on the ideas of Gunter (1961) that estuaries serve a nursery function and salinity determines the distribution of species within an estuary, and indeed, different life stages of the same species. In addition, the concept recognizes the importance of the appropriate physical or static habitat to the nursery function and ability of the estuary to support diverse and abundant biotic populations. Freshwater inflow positions favorable salinities relative to important stationary habitat factors, such as shoreline, water depth, and bottom type (Browder and Moore, 1981). In the present application, ecologically supportive freshwater inflows produce a temporal and spatial overlap between grass beds, oyster bars and physiologically tolerable salinity.

Salinity and flow envelopes are determined by: (1) identifying important resources and their location in an estuarine system (e.g. oysters, SAV); (2) determining the salinity tolerances of these resources; (3) determining the relationship between freshwater inflow and the distribution of salinity within in the estuary; and (4) determining the freshwater discharge that produces overlap between a resource and its tolerable salinity. The salinity tolerance information can be used to identify a salinity envelope (with an upper bound and lower bound). The boundaries of the envelope depend on what level of VEC performance is desired. An envelope that prevents mortality of existing VEC may be different from one that allows a VEC to complete its entire life cycle. The relationship between salinity and freshwater discharge can in turn be used to identify a range of freshwater inflows (with a lower bound and an upper bound) that maintains salinity within the prescribed envelope at appropriate locations in the estuary. In general, the upper or lower limits of salinity envelopes define boundaries that can be tolerated by indicator organisms for about a month or longer. The flows associated with these envelopes are therefore mean monthly flows.

Given the shape of the estuary, the fact that the major source of freshwater is at the head of the system and the distribution of submerged angiosperm grasses **(Figure 3.4-1)** and oysters is along its longitudinal axis, the Caloosahatchee Estuary is well-suited for this combined approach. Tape grass (*V. americana)* is a salt-tolerant freshwater species and serves as a VEC for the upper estuary. When present, it is located near the shoreline to a depth of about 1.0 m. It can range from ~16 km to 32 km upstream of Shell Point, but the greatest density is between 24 and 30 km (SFWMD, 2000).

In the lower estuary, the marine seagrass, *Halodule wrightii* (shoal grass), serves as a VEC. Monitoring results indicate that the only species of seagrass normally present upstream of Shell Point is shoal grass. It is located between 2 to 10 km, but the greatest density is often between 2 and 6 km (Doering et al., 2002). Downstream, a mixture of shoal grass and *T. testudinum* (turtle grass) is a prominent biotic feature in San Carlos Bay to a depth that can exceed 2.0 m (Corbett and Hale, 2006; CHNEP, 2006). The same mixture of seagrass, including *Syringodium filiforme*, is common in lower Pine Island Sound. A third VEC, the Eastern Oyster **(***Crassostrea virginica*) population is centered around Shell Point. (**Figure 3.3-14).**

3.4.1.1. Salinity Tolerances of VEC

3.4.1.1.1. Tape Grass

Maximum growth, density and canopy height occurs during summer months, when salinity is 0-3% (Doering et al., 1999; 2001; 2002). Qualitative field observations (Chamberlain and Doering, 1998a), information from the literature (Kraemer et al., 1999; Bortone and Turpin, 2000; French, 2001), and routine, quantitative field monitoring indicate that the canopy height and shoot density declines as salinity rises above 10%. In laboratory experiments, Doering et al. (1999; 2001) found decreasing but positive growth as salinity increased from 0% to 10%. Growth ceased between 10% and 15%, and mortality occurred at salinities greater than 15%.

3.4.1.1.2. Seagrasses

*S*hoal grass has a wide salinity tolerance (McMahan 1968), but prefers salinity close to full strength marine water. It does not survive prolonged exposure to salinity < 3.5 ppt (Zieman and Zieman, 1989). Monitoring results indicate that of all areas where *Halodule* is present, the lowest biomass is found upstream of Shell Point, where salinity is more diluted and most variable (Chamberlain et al., 1995). Shoal grass survives best where the long term average salinity in the estuary is above 20% and is sparest where variability (± 1 standard deviation) extends below 20%, (Chamberlain and Doering, 1998b). In laboratory experiments lasting about 6 weeks, *Halodule* from the Caloosahatchee Estuary exhibited positive growth at salinities above 12%, ceased growing between 6% and 12% and died at salinities below 6%.

In general, turtle grass does not grow where salinity routinely falls below 17%. Literature summarized by Zieman and Zieman (1989) indicates that the optimum salinity range for turtle grass is 24-35 ppt, but it can thrive in hypersaline conditions. Field observations from the Caloosahatchee estuary indicate the optimal range to be 22-36 ppt (Doering and Chamberlain 2000). In laboratory studies, with unlimited light conditions using plants from the Caloosahatchee Estuary, Doering and Chamberlain (2000) found net production of shoots during the summer wet season at salinities of 18 ppt or greater. Net production of shoots ceased at 12 ppt and mortality occurred at 6 ppt.

3.4.1.1.3. Oysters

Field and lab research on oysters from the Caloosahatchee Estuary suggest that they grow best at a salinity of 14 to 28 ppt (Volety et al., 2003). In general, the lower limit is physiological while the upper limit is ecological, being determined by disease and predation. While adult oysters can survive salinities as low as 5 ppt for up to 8 weeks, juveniles cannot survive for more than a week. Adults cannot survive salinities lower than 3 ppt. In laboratory experiments, Volety et al. (2003) also noted mortality of juveniles at high (35 ppt) salinity.

3.4.2. Flow and Salinity Envelopes

This section summarizes salinity envelopes for the Caloosahatchee Estuary based on the tolerances of VEC. It also identifies rates of freshwater discharge that position tolerable salinities in the area of the estuary where VEC are found. Freshwater discharges are those occurring at the Franklin Lock and Dam (S-79). The overwhelming majority of inflow to the estuary passes through S-79 and inflows from downstream tidal tributaries are not well known. Estimates of flows come from a variety of sources, including regressions (salinity vs. freshwater inflow) (Doering et al., 2002; Volety et al., 2003) or hydrodynamic models (Doering et al., 2002; SFWMD, 2003). These relationships are summarized in **Table 3.4-1**.

Table 3.4-1. Valued ecosystem component locations (Distance from Shell Point, Figure 1) with corresponding supportive salinity and S-79 average monthly flow ranges.

Location	Biotic Resource	Salinity (ppt)			S-79 Flow (cfs)		
		Lower Limit	Optimum Range	Maximum Limit	Lower Limit	Optimum Range	Maximum Limit
Upper Estuary (24-30 km east)	Tape grass	NA	0 - 3	Monthly >10 Daily >20	450	~600 - 1500	
Lower Estuary (2-6 km east)	Shoal grass	6	>20	NA	NA	<1000	>2800
Shell Point & upstream (2- 6 km)	Oysters	3-5	14 - 28	35	0	500-2000	4000
San Carlos Bay (~0-4 km west)	Seagrass (shoal and turtle grass)	< 6	22 - 36	NA	NA	<1500	>4500
Lower Pine Island Sound (~10-14 km west)	Seagrass (shoal and turtle grass)	< 6	22 - 36	NA	NA	<3000	>6500

As apparent in **Table 3.4-1**, low flow and high salinity are a concern for the upper estuary, while high flow and low salinity are troubling for the saltier, more marine regions. In addition, as high flows increase in magnitude, the greater the area affected by low salinity. Recognizing that the bounds of a flow or salinity envelope depend on the desired performance of a VEC, Table 1 identifies both optima that can be used to derive an "optimum envelope" and minima and maxima that can be used to derive envelopes that prevent severe mortality.

For the estuary between Shell Point and Km 30, a lower bound of 450 cfs (10 ppt) would allow tape grass to survive in the upper estuary and an upper bound of 2,800 cfs (6 ppt) would allow shoal grass and oysters to survive in the lower estuary. At flows over 4,500 cfs, turtle grass in central San Carlos Bay experiences salinity below its optimal range. At 6,500 cfs, salinity falls below the accepted threshold (17 ppt) for a sustainable population and seagrasses in Pine Island are affected.

Based on optimal salinities, an optimal flow envelope for the estuary (Shell Point and Km 30) would be 600 cfs to 1,000 cfs. Flow less than 1,500 cfs and 3,000 cfs would preserve optimal salinities for San Carlos Bay and Pine Island Sound, respectively.

3.4.2.1. Additional Considerations

A central assumption of the VEC approach, as applied here, is that environmental conditions that are good for VEC will be good for other organisms, as well. At seven stations along the longitudinal salinity gradient, research and field surveys were conducted by the SFWMD to determine the response of other estuarine resources to changes in freshwater inflow (Chamberlain and Doering, 1998a and b; Chamberlain et al., 1995; 1999; 2001). These additional resources include bay anchovy, larval fish, fish eggs, zooplankton and benthic macroinvertebrates. **Table 3.4-2** lists these biota and preferred flow, based on the research and provisional analysis. The suggested flow ranges for some other important species and biotic groups that were not sampled also are provided, based on a literature review (Chamberlain et al., 1995). In general, the flow limits that protect and benefit VECs also are supportive of these other resources.

The envelopes described here are based on salinity tolerances of VEC and the flows from S-79 that achieve them. In addition to salinity, many other water quality parameters vary with freshwater inflow. Other water quality parameters certainly influence the success of VEC and consideration of these may influence flow optima or bounds of envelopes. Seagrasses are a prime example. Greenawalt-Boswell et al. (2006) concluded that the two major factors controlling the distribution of seagrasses in the Charlotte Harbor estuarine system were salinity and light availability. In turn, light penetration is controlled by color, turbidity and Chlorophyll-*a* (Corbett and Hale, 2006). Color can be a major contributor to light penetration and varies with freshwater inflow (Doering and Chamberlain, 1996).

To address the combined roles of salinity and other water quality parameters, Chamberlain (Doering and Chamberlain, 2005) investigated the relationship between seagrass coverage, depth and discharge at S-79. The rationale for this analysis was that salinity might be most important for grasses' living at shallow depths where light is rarely, if ever limiting. By contrast, for grasses living at deeper depths, reductions in light that accompany lower salinity water might be more damaging than the low salinity itself. For a full presentation of results, the reader is referred to (Doering and Chamberlain, 2005). An example will be given here.

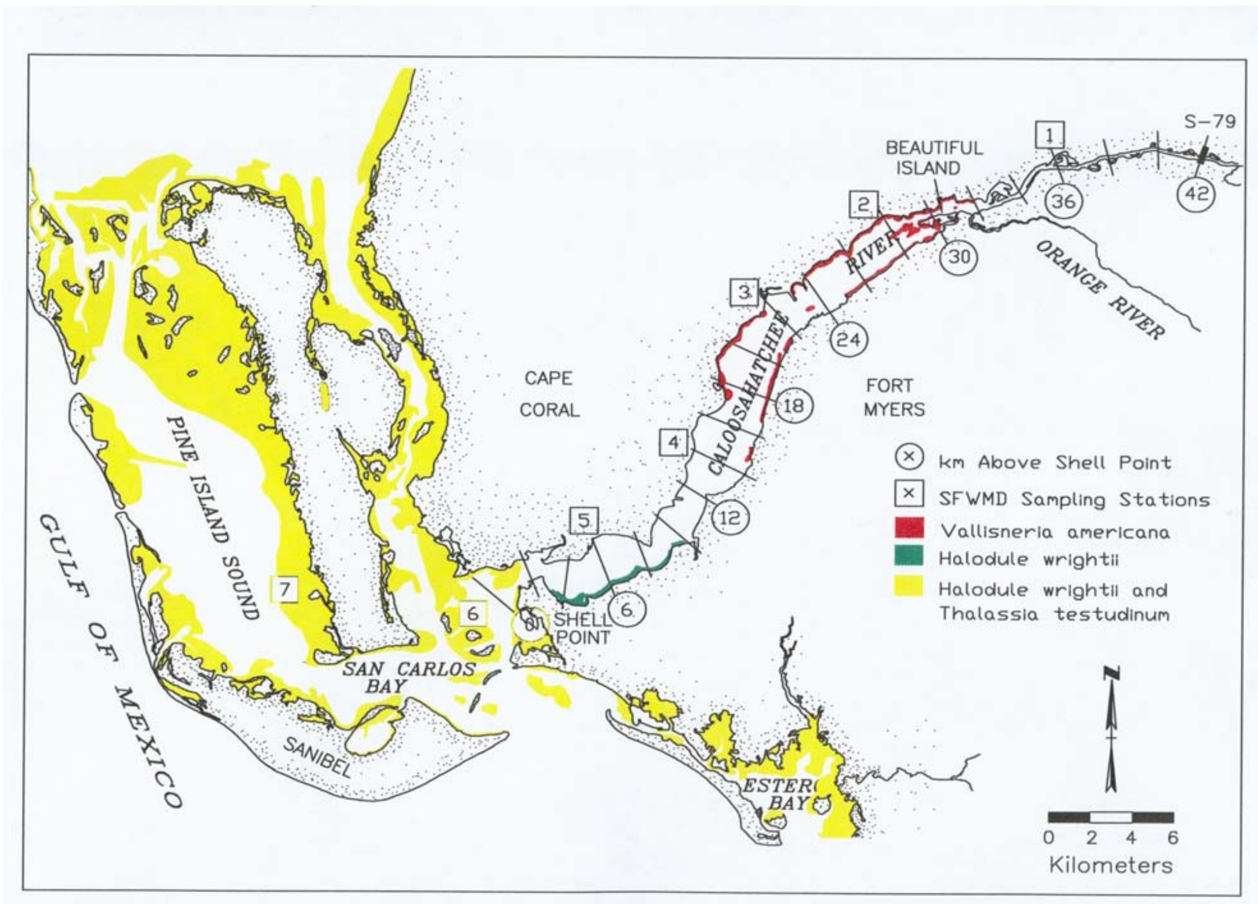


Figure 3.4-1. Location of grass beds in the Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound.

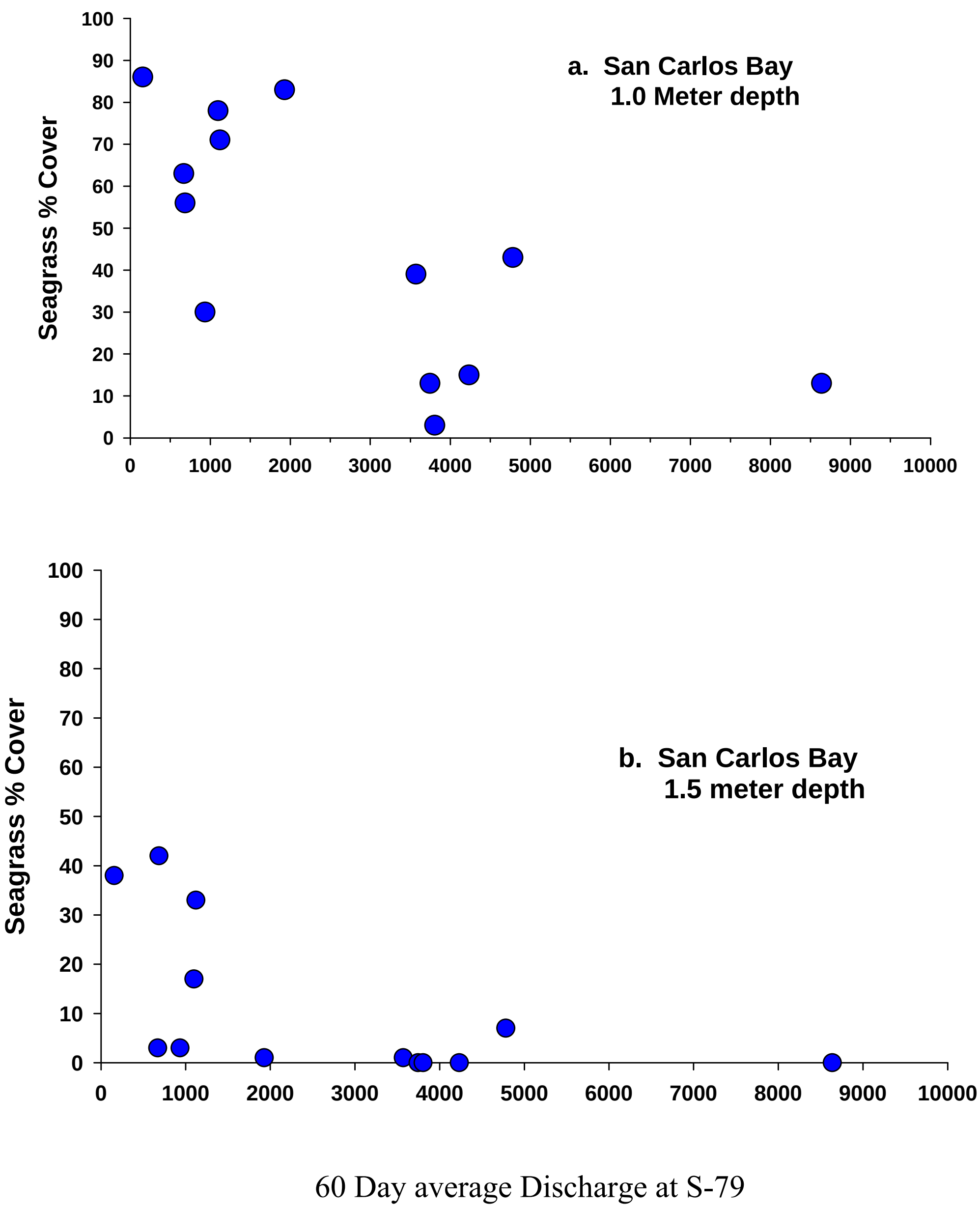


Figure 3.4-2. Percent cover of seagrass (shoal grass & turtle grass) in San Carlos Bay at two depths, as a function of discharge at S-79.

In San Carlos Bay, the percent cover of seagrasses living at a depth of 1.0 m decreases linearly as discharge from S-79 increases (**Figure 3.4-2**). This relationship implies that seagrasses living at 1.0 m would disappear at flows greater than about 4,000 cfs. Given the variability in the relationship, this estimate agrees reasonably with the 4,500 cfs limit derived from consideration of salinity tolerances. By contrast, the percent cover of seagrasses living at 1.5 m falls off dramatically at flows greater than 1,000 cfs, a critical flow far lower than the salinity based estimate (**Figure 3.4-2)**.

There are clear implications for management. The adoption of depth limits for seagrass growth in San Carlos Bay and other parts of the Charlotte Harbor system (Corbett and Hale, 2006) would necessitate revision of flow envelopes at S-79. The kinds and causes for the relationships investigated by Chamberlain (Doering and Chamberlain, 2005) (**Figure 3.4-2**) require further clarification. To better understand the co-influence of salinity, light, and other water constituents, further development of the habitat suitability index and ecosystem models, like those developed by Hunt et al. (2003; 2004; 2005), may represent a fruitful approach.

3.4.2.2. General Salinity Envelope and Corresponding Freshwater Inflows

In general, the desired salinity envelope is pictorially summarized in **Figure 3.4-1** and consists of:

- < **10** ppt upstream of the Ft. Myers Bridges (measure at the Ft. Myers Yacht Basin)
- **15** ppt at the Cape Coral Bridge and **~ 20** ppt in Iona Cove
- **14 - 28** ppt just upstream of Shell Pt
- ~ **25** ppt (range 22 ppt – 36 ppt) in San Carlos Bay.

The general monthly average flow range approach to support this envelope is:

- Maintain mean monthly flows greater than 450 cfs.
- The great majority of flows should be in the range 450 -800 cfs, the most supportive of the widest range of species.
- Limit the flows greater than about 2800 cfs and avoid flows that exceed 4000-4500 cfs, which harm seagrass beds as far as lower Pine Island Sound.
- End destructive flows that exceed 6,500 cfs, which destroy marine life far from the estuary mouth and sends poor water quality up Pine Island Sound and into the Gulf of Mexico.

3.4.2.3. Specific Hydrologic Performance Measures

In combination with the above flow distribution, the following monthly average flow limits at S-79 have been used by recent projects as performance measures to evaluate project success at reducing harmful flow volumes. These same flow limits are recommended for the NEEPP.

S-79 Average Monthly Inflows

HT 1. For each alternative, compare the number of times that the combined mean monthly inflows at S-79 from the Caloosahatchee River Watershed and Lake Okeechobee fall below a low-flow limit of **450** cfs, or exceed 2,800, 4,500, and 6,500 cfs. The alternative that exceeds these flow limits the fewest number of times will be considered better for protecting aquatic vegetation, oysters, and fish communities.

HT 2. For each alternative, compare the frequency for just one month (not followed by another month) that the combined S-79 mean monthly low-flow limit of **450** cfs and high flow limits of 2,800, 4,500, and 6,500 cfs were not met, as well as the frequency for two, three, four, etc. consecutive months. The alternative with the fewest number of consecutive months exceeding these flow limits will be considered better for protecting estuarine aquatic resources.

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

As part of the South Florida Restudy and LOPP, water management alternatives were evaluated that incorporated a range of infrastructure changes. The adopted plan, when built, is predicted to reduce drastically the number of regulatory discharges from Lake Okeechobee that elevates freshwater inflow to the Caloosahatchee Estuary.

HT 4. For NEEP, in combination with CERP and LOPP infrastructure alternatives compare the number of days that regulatory discharges from Lake Okeechobee are made to the Caloosahatchee River. The preferred management alternative will have the least daily discharge volume, the fewest number of total days of discharge and the fewest number of consecutive days. Special consideration will be provided for pulse releases that may benefit the estuary.

HT 5. For each alternative, compare the frequency distribution of the combined monthly average freshwater inflows through S-79 from the watershed and Lake Okeechobee for the entire period of record being evaluated. The alternative with the frequency distribution of inflows that best approaches the range defined in the above table will be considered better for protecting and restoring estuarine resources, while further promoting biotic diversity. Specifically, the most desirable alternative will maximize up to 75% of the flows from S-79 in the **450-800** cfs range and almost all the remaining inflow in the 800 to 2800 cfs range.

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4.0 ESTUARINE AND WATERSHED MONITORING IN THE CALOOSAHATCHEE ESTUARY

4.1. Introduction

Within the context of a River Watershed Protection Program, environmental monitoring has two major purposes: to quantify long-term change and to support adaptive management. Quantification of long-term change measures progress towards program goals, such as the Total Maximum Daily Load (TMDL). Application of adaptive management leads to improved infrastructure design, facility operations, and habitat and water quality protection. These monitoring roles have been endorsed by the National Oceanographic and Atmospheric Administration (NOAA). NOAA has defined ecological monitoring as, "*The systematic data collection that provides information on changes that can indicate problems and/or progress towards target criteria or performance standards, which, when met, indicated that established ecological goals have been reached*" (NOAA 2002). More recently, NOAA has defined restoration monitoring as, "*The systematic collection of data that provides information useful for measuring project performance at a variety of scales (locally, regionally and nationally), determining when modification of efforts is necessary, and building long-term public support for habitat protection and restoration*" (NOAA, 2003).

These definitions identify four components of a monitoring program: (1) systematic collection of data that (2) measures change or progress towards (3) a goal, be it a level of project performance or a target, and can be used to (4) determine when modifications to the programs or project are required (support adaptive management). The issue of spatial scale is also raised.

An important first step in developing a monitoring plan is to identify the goals of the project being monitored and identify the types of information that are required to measure progress towards those goals.

Relevant goals of the Caloosahatchee River Watershed Protection Program, as stated in Section 373.4595, F.S., are:

1. Achieve pollutant load reductions based upon adopted TMDLs
2. Establish salinity envelopes and freshwater inflow targets
3. Reduce the frequency and duration of undesirable salinity ranges while meeting other water-related regional needs

The legislation also requires an annual report that includes a summary of the conditions of hydrology, water quality and aquatic habitat in the Northern Everglades, based on the results of the Research and Water Quality Monitoring Programs (R&WQMPs).

Section 373.4595, F.S. requires that monitoring for the Caloosahatchee River Watershed Protection Program build upon existing monitoring programs. There are a considerable number of ongoing water quality and aquatic habitat monitoring programs in the Caloosahatchee Estuary and its watersheds. It is beyond the scope of this chapter to provide detailed descriptions of each of these programs. Rather, this chapter summarizes the existing long-term monitoring programs for water quality, salinity, freshwater inflow, and biotic resources (oysters and seagrasses) that support goals of the Caloosahatchee River Watershed Protection Plan (CRWPP). An assessment of the ability of those monitoring programs to meet these goals in space and time is also presented.

Lastly, the recommended monitoring plan, which was formulated to fulfill the goals and reporting requirements, is presented. This monitoring plan will provide the concentration and flow data necessary to calculate and track nutrient and other material loads from the watershed to the estuary. The plan also includes salinity, water quality, and aquatic habitat monitoring to quantify changes associated with anticipated reductions in flows and loads resulting from implementation of the CRWPP. Additional water quality parameters are recommended to support adaptive management.

When monitoring is conducted by several organizations, methodological differences and central housing of data can become problematic. These problems will be addressed in the first three year review.

4.2. Watershed Monitoring

4.2.1. Flow Monitoring in the Caloosahatchee River Basin

The measurement of freshwater inflows is required for calculation of nutrient loads and for establishing salinity and flow envelopes. The U.S. Army Corps of Engineers, the South Florida Water Management District (SFWMD) and the U.S. Geological Survey (USGS), provide daily estimates of discharge at the major water control structures along the Caloosahatchee River (S-77, S-78, and S-79).

There have been few measurements of freshwater inflows to the Caloosahatchee Estuary from the Tidal Basin west of S-79. To quantify these flows, eight additional flow sites and one cooperative site with Lee County were added by the USGS, in cooperation with Florida Department of Environmental Protection (FDEP) (**Figure 4.2-1**). These nine hydrologic data flow sites were installed in 2007. Three stations are located in the Caloosahatchee Estuary, while the remaining six sites are in tidal tributaries.

4.2.1.1. Assessment

Historically, freshwater flows and nutrient loads for the Caloosahatchee River and Estuary were calculated at the upstream basins of the system using structures S-77, S-78, and S-79. Although the basins east of the Franklin locks contributed the bulk of freshwater and nutrients, there has been a dearth of freshwater flow data west of the Franklin locks. The additional nine flow sites (**Figure 4.2-1**) maintained by USGS, FDEP, and Lee County will allow calculation of loads and provide data for calibration of watershed loading models and estuarine hydrodynamic models.

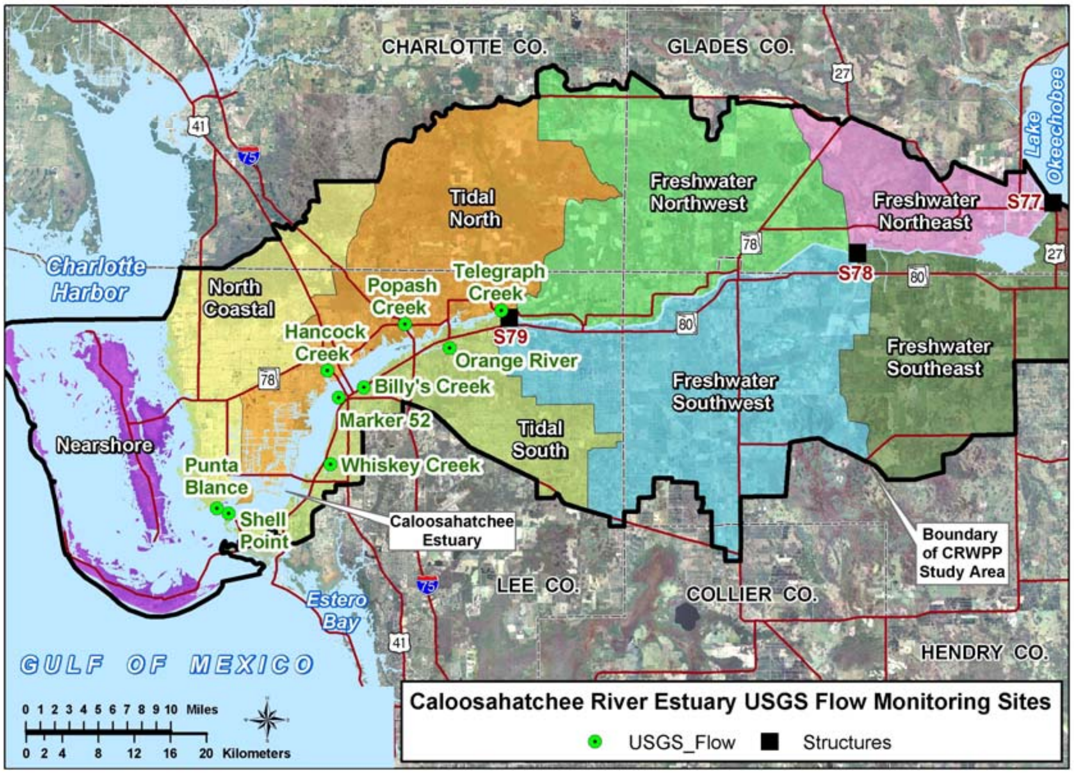

Figure 4.2-1. Caloosahatchee River Flow Monitoring Sites.

4.2.2. Water Quality

This section summarizes the water quality monitoring efforts conducted at freshwater sites in the watersheds that eventually drain into the Caloosahatchee Estuary. These efforts include the Caloosahatchee River and its watershed, which are mostly located to the east of the Franklin Lock and Dam (S-79). Also included are the Tidal Basins located to the west of S-79. Watershed monitoring efforts are being carried out by several state and local governmental agencies, as listed below. Each entity has its own monitoring objectives, design, and procedures for quality assurance, quality control, data management, assessment, and reporting. This section describes existing water quality monitoring programs and assesses whether the current monitoring efforts are sufficient to address change, load allocation, and adaptive management. Sampling site locations are shown in **Figure 4.2-2** and **Figure 4.2-3,** while **Table 4.2-1** lists core analytes.

4.2.2.1. Lee County

Surface water quality monitoring in the Caloosahatchee River Watershed is undertaken mainly by Lee County. Their program was initiated in 1990 and is managed by the County's Environmental Laboratory. The County samples on a monthly basis at 55 fixed stations, located at freshwater sites to the east and west of S-79. Data from this program are maintained at the Environmental Laboratory and uploaded into STORET and can be viewed at a new website maintained by the County at: http://lcems.edats.com/.

4.2.2.2. South Florida Water Management District

The major objective of the SFWMD's water quality monitoring programs is to provide water quality and nutrient loading data that can be used in conjunction with hydrologic data to assess potential downstream impacts on the Caloosahatchee Estuary. The projects (CR and X) include four stations (**Table 4.2-1**) and extend from Lake Okeechobee west to S-79. Surface water samples are collected bimonthly and stored in SFWMD's central database, DBHYDRO. SFWMD also collects pesticide data at four stations, one on a quarterly basis and three on a semi-annual basis, depending on the parameter. The purpose of the pesticide monitoring program is to establish a baseline, assess compliance with permit requirements, and determine long-term, as well as short-term, trends.

4.2.2.3. East County Water Control District

The East County Water Control District conducts water quality monitoring at 25 stations to meet the requirements of National Pollutant Discharge Elimination System (NPDES) permits and to ensure that activities within the East County do not negatively impact surface water quality.

4.2.2.4. Sanibel-Captiva Conservation Foundation

Sanibel-Captiva Conservation Foundation (SCCF) established the River, Estuary and Coastal Observing Network (RECON), which is a network of optical water quality sensors deployed throughout the Caloosahatchee River and Estuary to provide real-time water quality data to scientists, policy makers, and the general public. SCCF maintains two sites in the freshwater Caloosahatchee River (C-43) as per **Figure 4.2-2.** Data are collected at 30-minute intervals and transmitted via a global system for mobile communication (GSM) for near real-time publication at http://recon.sccf.org/.

4.2.2.5. City of Ft. Myers

The City of Ft. Myers Stormwater Management section conducts water quality monitoring at nine fixed stations in the tidal Caloosahatchee River Watershed on a monthly basis, in collaboration with Lee County's Environmental Laboratory. This program was initiated in 2005 to meet the requirements of NPDES permits and to ensure that activities within the city do not negatively impact surface water quality.

4.2.2.6. City of Cape Coral

The City of Cape Coral Environmental Resources Division has been monitoring 31 sites within the City since 1990, on a monthly basis. Samples also are collected twice annually for metals and yearly for pesticides. In addition, the City manages a volunteer *Canal Watch* program that samples 43 stations on a monthly basis (**Table 4.2-1**).

4.2.2.7. Assessment

Monitoring east of S-79 is sufficient for determining long-term trends and characterizing the quality of water entering the estuary at S-79, exiting the East Caloosahatchee Basin at S-78 and exiting Lake Okeechobee at S-77. The frequency of water quality sampling at S-79 and S-78 may not be sufficient for accurate calculation of load and this issue requires investigation. Since individual tributaries to the C-43 are not routinely sampled, tracking progress towards the TMDL at spatial scales smaller than the East and West Caloosahatchee Basins is not possible. Dissolved forms of organic nitrogen are not currently sampled.

Table 4.2-1. Caloosahatchee River Watershed Water Quality Monitoring

Caloosahatcee River Watershed and Tidal Basin Water Quality Monitoring Inventory					
Organization/ Program	**Number of Stations**	**Location**	**Frequency**	**Period**	**Analytes**
Caloosahatcee River Watershed					
Lee County	6 (fixed)	Caloosahatchee freshwater tributaries	Monthly	1990 to present	Chlorophyll a ; Pheophytin; Biochemical Oxygen Demand; Cadmium; Chloride; Color; Conductivity; Copper; Dissolved Oxygen; Enterococci; Fecal coliform Ammonia; Nitrite; Nitrate; Nitrate + Nitrite; Ortho Phosphorus; Lead; pH; Silica; Total Phosphorus; Water Temperature; Total Kjeldahl Nitrogen; Total Nitrogen; Total Suspended Solids; Turbidity; Velocity
SFWMD/BGA	2 (fixed)	Caloosahatchee River	Sampled on request	2005-2007	chlorophyll a, chlorophyll a corrected, microcystin, dissolved oxygen, pH, secci depth, temperature, total depth.
SFWMD/CR	4 (fixed)	Caloosahatchee River	Bimonthly	1979 to present	alkalinity, calcium, chloride, color, conductivity, dissolved oxygen, potassium, magnesium, sodium, ammonia, nitrite, nitrite+nitrate, orthophosphate, pH, silica, sulfate, temperature, total Kjeldahl nitrogen, total phosphorus, total suspended solids, turbidity.
SFWMD/PEST	4 (fixed) surface water	Caloosahatchee River	Quarterly	1979 to present	organophosphorus, organonitrogen, organochlorine compounds.
	3 (fixed) sediment		Semiannually	1988 to present	
SFWMD/X	1 (fixed)	Caloosahatchee River	Bi-weekly	1973 to present	alkalinity, chloride, color, ammonia, nitrite, nitrite+nitrate, orthophosphate, total dissolved solids, total Kjeldahl nitrogen, total phosphorus, total suspended solids, turbidity, dissolved oxygen, conductivity, temperature, and pH.
SFWMD/CESWQ	1 (fixed)	Caloosahatchee river	Monthly	1999-present	chlorophyll a, chlorophyll a corrected, color, nitrite, nitrate, nitrite+nitrate, ammonia, total Kjeldahl nitrogen, total nitrogen, total organic carbon, total phosphorus, orthophosphate, silica, total suspended solids, turbidity, dissolved oxygen, conductivity, temperature, pH, PAR, salinity, secci depth, total depth.
SFWMD/CESWQ Release	1 (fixed)	Caloosahatchee river	Sampled on request	2001-present	chlorophyll a, chlorophyll a corrected,total nitrogen, total phosphorus, dissolved oxygen, conductivity, temperature, pH, PAR, salinity, secci depth, total depth
East County Water Control District	25 (fixed)	Caloosahatchee freshwater tributaries/canals	Quarterly	1984 to present	Total Nitrogen; Total Kjeldahl Nitrogen; Nitrite; Nitrate; Ammonia; Total Phosphorus
			Monthly	1984 to present	Total Suspended Solids; Total Dissolved Solids; Cloride; BOD; Fecal streptococcus ; Fecal Coliforms; Conductivity; Turbidity; Dissolved Oxygen; pH; Velocity; Direction of Flow; Total Depth; Sample Depth; Air temperature; Water temperature
SCCF/RECON	2 in-situ sites-LOBOS	Riverbend and Moore Haven	30-minute intervals	2007/2008-present	Nitrate; Chlorophyll; Colored Dissolved Organic Matter (CDOM); Conductivity; Dissolved Oxygen; Oxygen Saturation;Turbidity; Salinity; Temperature; Depth
Caloosahatchee Tidal Basin					
City of Cape Coral	31 (fixed)	Freshwater and Saltwater Canals within City	Monthly	1990-present	Nitrogen; Total Nitrogen; Dissolved Oxygen; Total Phosphorus; Turbidity; Total Dissolved Solids; Total Suspended Solids; Water Temperature; pH; Conductivity; Secchi depth; Fecal streptococcus and Fecal coliforms; Biochemical Oxygen Demand
City of Ft. Myers	9 (fixed)	Caloosahatchee Tidal	Monthly	2005-present	Biological Oxygen Demand; Chemical Oxygen Demand; Aluminum; Cadmium; Chloride; Conductivity; Copper; Dissolved Oxygen; Enterococci; Fecal Coliform; Ammonia; Nitrite; Nitrate; Nitrate + Nitrite; Ortho Phosphorus; Lead; pH; TCMF05; Total Dissolved Solids; Temperature; Total Hardness; Total Kjeldahl Nitrogen; Total Nitrogen; Total Phosphorus; Total Suspended Solids; Turbidity, Zinc
Lee County	49 (fixed)	Caloosahatchee freshwater tributaries	Monthly	1990 to present	Chlorophyll a ; Pheophytin; Biochemical Oxygen Demand; Cadmium; Chloride; Color; Conductivity; Copper; Dissolved Oxygen; Enterococci; Fecal coliform Ammonia; Nitrite; Nitrate; Nitrate + Nitrite; Ortho Phosphorus; Lead; pH; Silica; Total Phosphorus; Water Temperature; Total Kjeldahl Nitrogen; Total Nitrogen; Total Suspended Solids; Turbidity; Velocity

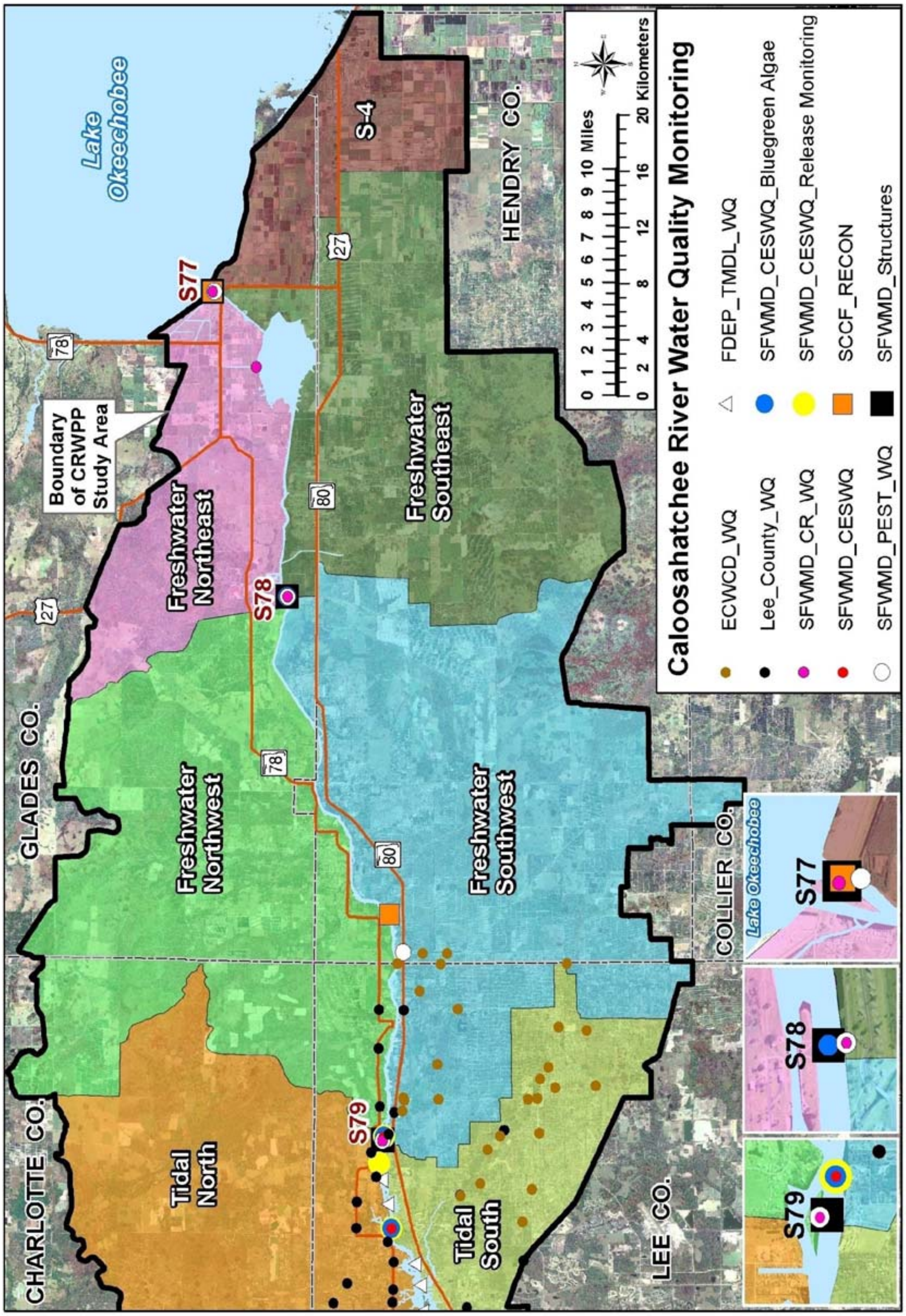

Figure 4.2-2. Caloosahatchee River Watershed Water Quality Monitoring Stations

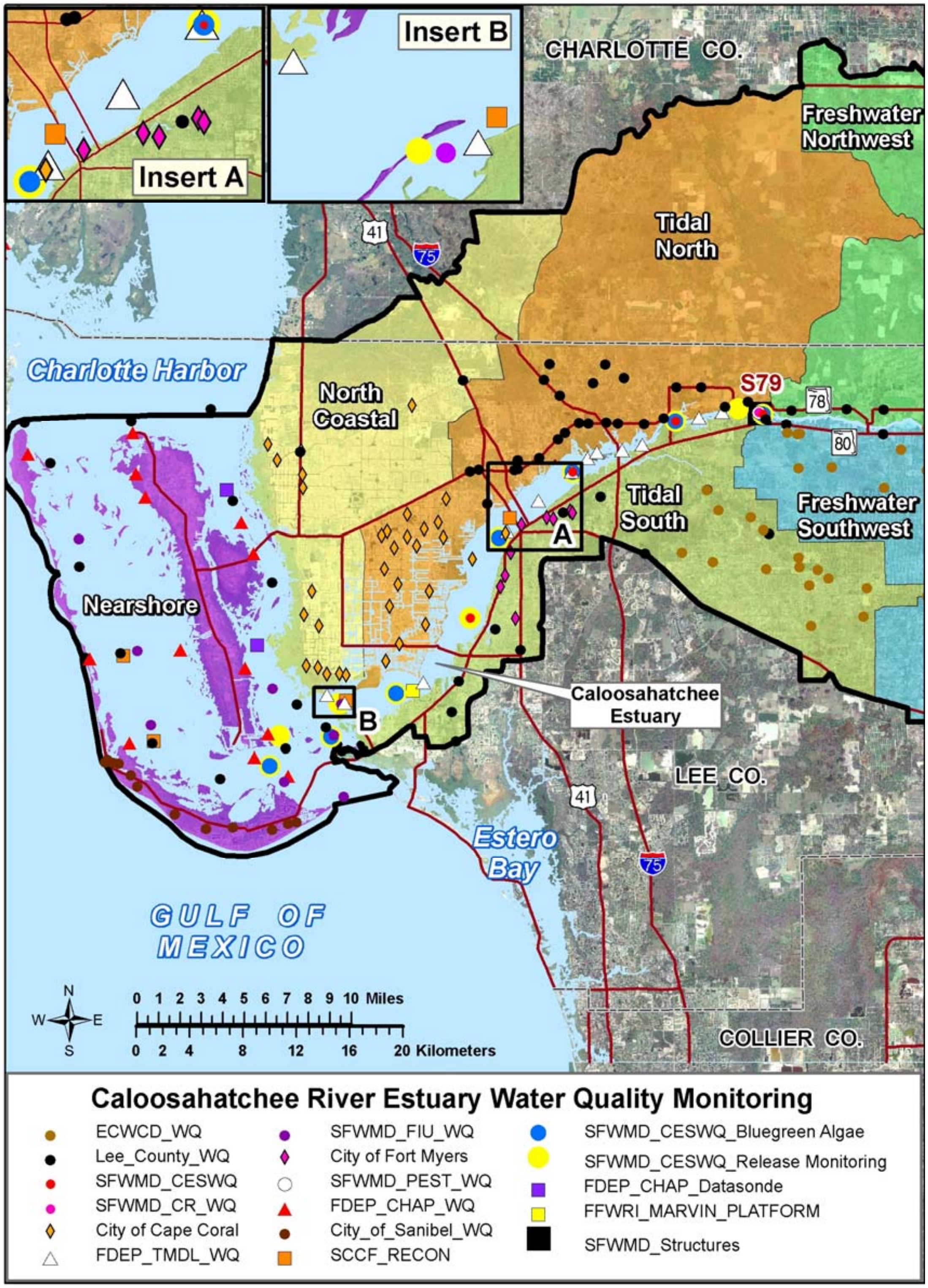

Figure 4.2-3. Caloosahatchee River Water Quality Monitoring west of S-79.

4.3. Estuarine Monitoring

This section summarizes monitoring in the estuarine and marine waters of the study area that supports the goals of the CRWPP. Monitoring focuses on salinity to support salinity envelopes. Monitoring also focuses on water quality to support the TMDL and aquatic habitats (oysters and submerged aquatic vegetation).

4.3.1. Estuarine Salinity

Two current salinity monitoring programs exist in the Caloosahatchee River and Estuary. One is maintained by SFWMD and the other program was recently established by the SCCF. Station locations are shown in **Figure 4.3-1.**

4.3.1.1. The SFWMD Program

SFWMD initiated a continuous, long-term salinity monitoring program in the Caloosahatchee River in 1992. Temperature and specific conductivity are collected at 20% and 80% of total depth. The original plan included five stations: S-79, Bridge 31(BR31), Ft. Myers, Shell Point, and the Sanibel Causeway. Stations at the Cape Coral Bridge and at the I-75 Bridge were added in August 2002 and December 2005, respectively. Both daily average salinity data and 15-minute interval data can be accessed from the SFWMD DBHYDRO database.

4.3.1.2. River Estuary Coastal Observing Network Program by Sanibel Captiva Conservation Foundation

In 2007, the SCCF Marine Laboratory launched the River Estuary Coastal Observing Network (RECON) project to track changes in water quality from Lake Okeechobee to the Gulf of Mexico (**Figure 4.3-1**). At present, five sensors have been deployed within estuarine waters. Each station collects salinity data, along with other water quality constituents, at three meters below the water surface at 30-minute intervals. Real time or archived data can be viewed at the SCCF's website, http://recon.sccf.org. In addition to salinity, temperature, depth, turbidity, colored dissolved organic matter (CDOM), nitrate, DO, and Chlorophyll-*a* are collected.

4.3.1.3. Assessment

The salinity information currently being collected is adequate to determine the frequency and duration of undesirable salinity ranges resulting from Caloosahatchee River discharges at S-79. The FDEP Aquatic Preserves Program has recently established two stations in Matlacha Pass that will further enhance salinity monitoring capability. Salinity monitoring data will also track Minimum Flow and Level (MFL) criteria at Ft. Myers and continue to support hydrodynamic modeling efforts.

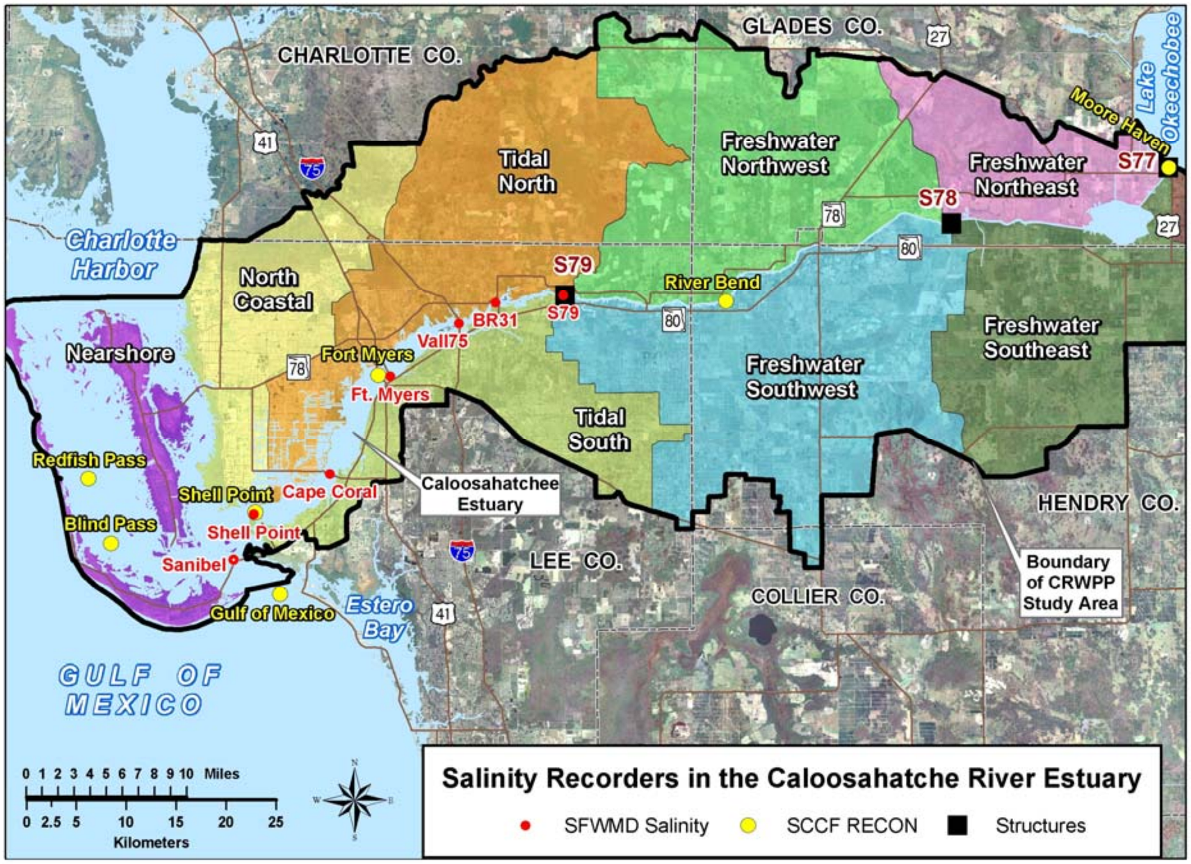

Figure 4.3-1. Location of the Estuarine Salinity Monitoring Stations. Black Dots are SFWMD Stations; Red Dots are Sanibel Captiva Conservation Foundation Stations.

4.3.2. Water Quality

The existing water quality monitoring effort established for the estuarine portion of the Caloosahatchee River is being carried out by numerous governmental entities at state, regional, and local levels, as well as universities and private organizations. A summary of these existing programs are provided below. **Table 4.3-1** lists the programs and parameters collected and analyzed. **Figure 4.2-3** shows the monitoring sites for these programs.

4.3.2.1. South Florida Water Management District

SFWMD established eight fixed stations, under the CESWQ Monitoring Program, in April 1999 as an ongoing water quality monitoring program (SFWMD and Florida Center for Environmental Studies). Since 2002, SFWMD has maintained four fixed stations as part of CESWQ and samples five random, stratified, water quality stations for the Charlotte Harbor National Estuary Program's (CHNEP) Coastal Charlotte Harbor Monitoring Network (CCHMN) (see below).

Another collaborative effort was established with Florida International University to sample thirteen fixed stations in Lower Charlotte Harbor and Estero Bay on a monthly basis, in the Southeast Environmental Research Center (SERC) Water Quality Monitoring Network. SFWMD also established the Caloosahatchee Release Monitoring program in December 2001 for event monitoring at 11 fixed sites. From August 2005 to December 2006, monitoring was conducted for Chlorophyll-*a* and microcystin in the Caloosahatchee Estuary. This monitoring is now conducted "as needed," based on the presence of blue-green algae.

4.3.2.2. Charlotte Harbor National Estuary Program

The CHNEP coordinates the CCHMN. In support of its long-term monitoring strategy, an inter-agency, collaborative program was initiated in April 2001 for the coastal Charlotte Harbor region, including the tidal Caloosahatchee, Peace and Myakka Rivers, and Estero and southern Lemon Bays. South West Florida Water Management District (SWFWMD), SFWMD, Charlotte and Lee Counties, Florida Fish and Wildlife Conservation Commission – Fish and Wildlife Research Institute (FWC-FWRI), the Cities of Sanibel and Cape Coral, and FDEP Charlotte Harbor Aquatic Preserve monitor the region on a monthly basis using a stratified, random sampling design.

4.3.2.3. Lee County

Lee County samples fourteen sites in Pine Island Sound and Matlacha Pass downstream of the Caloosahatchee Estuary. The water quality monitoring program initially started in 1990 and is managed by the County's Environmental Lab.

4.3.2.4. City of Cape Coral

The City of Cape Coral Environmental Resources Division initiated its water quality monitoring in 1990 and monitors two sites monthly in the upper Caloosahatchee River.

4.3.2.5. Florida Department of Environmental Protection South District

FDEP conducts short term monitoring for a variety of programs (e.g. identification of impaired waters, TMDL monitoring, compliance). Most recently, FDEP initiated a program for monthly monitoring of 12 stations in the Caloosahatchee River to the west of S-79.

4.3.2.6. Sanibel-Captiva Conservation Foundation

In addition to the freshwater sites at Riverbend and Moore Haven east of S-79, SCCF maintains five in-situ monitoring sites within the Estuary to the west of S-79.

4.3.2.7. Florida Fish and Wildlife Research Institute

The Florida Fish and Wildlife Research Institute collects real-time water quality data through a set of sensors mounted on a platform. The platform, named the MERHAB Autonomous Research Vessel for In-Situ Sampling (MARVIN), measures various water quality parameters and collects meteorological data. MARVIN was deployed to the Caloosahatchee River in January 2005. MARVIN has been located between the I-75 Bridge and the railroad trestle since 2005, to allow researchers to monitor water quality parameters associated with discharges from Lake Okeechobee and the surrounding watershed. A second MARVIN was recently located at Peppertree Point near Iona Cove. MARVIN data are transmitted every three hours to http://www.marvindata.org/.

4.3.2.8. City of Sanibel

The City of Sanibel developed an Ambient and Storm Event Water Quality Monitoring Program in 2001 to track changes in water quality related to land use changes over time. This program includes fixed station NPDES monitoring on a monthly basis, which consists of 12 sites throughout the Sanibel River and a few sites in Blind Pass, located at the western end of the island.

4.3.2.9. The Charlotte Harbor Estuaries Volunteer Water Quality Monitoring Network

This program is administered by the FDEP Charlotte Harbor Aquatic Preserve staff. A corps of trained volunteers take synoptic water quality samples at 46 fixed stations across the greater Charlotte Harbor estuarine system (including Estero Bay) once a month, at sunrise. This program started in 1998, and the data are publicly available at http://www.dep.state.fl.us/coastal/sites/charlotte/volunteer/waterquality.htm1. The other water quality monitoring program conducted by the Charlotte Harbor Aquatic Preserve is the Datasonde program, which has two fixed stations in Matlacha Pass and measures water quality every 15 minutes. This program also collects monthly water quality data, including nutrients and depth.

Table 4.3-1. Caloosahatchee River Water Quality Monitoring in the Estuary west of S-79

Caloosahtachee River Estuary Water Quality Monitoring Inventory					
Organization/ Program	**Number of Stations**	**Location**	**Frequency**	**Period**	**Analytes**
SFWMD/CESWQ	3 (fixed)	Caloosahatchee River	Monthly	1999-present	chlorophyll a, chlorophyll a corrected, color, nitrite, nitrate, nitrite+nitrate, ammonia, total Kjeldahl nitrogen, total nitrogen, total organic carbon, total phosphorus, orthophosphate, silica, total suspended solids, turbidity, dissolved oxygen, conductivity, temperature, pH, PAR, salinity, secci depth, total depth.
SFWMD/CESWQ-Release Monitoring	10(fixed)	Caloosahatchee River	Sampled on request	2001-present	Chlorophyll a, Chlorophyll a corrected, Conductivity, Temperature, pH, Salinity, Dissolved Oxygen, PAR
SFWMD/CESWQ-Release Monitoring	10(fixed)	Caloosahatchee River	Sampled on request	2001-present	Chlorophyll a, Chlorophyll a corrected, Conductivity, Temperature, pH, Salinity, Dissolved Oxygen, PAR
SFWMD/FIU	8 (fixed)	San Carlos Bay and Pine Island Sound	Monthly	1999-present	Salinity; Temperature; Total Phosphorus; Nitrite; Nitrate; Ammonia; Total Oxidized Nitrogen; Silica; Dissolved Oxygen: Total Organic Carbon; Turbidity; NOX, Dissolved Inorganic Nitrogen, Total Inorganic Nitrogen, Total Organic Nitrogen, SRP, Chlorophyll a, Specific Conductivity
SFWMD/BGA	6 (fixed)	Caloosahatchee River	Sampled on request	2005-2007	chlorophyll a, chlorophyll a corrected, microcystin, dissolved oxygen, pH, secci depth, temperature, total depth.
CHNEP/SFWMD	5 (random)	Tidal Caloosahatchee River	Monthly	2000-present	Chlorophyll a; Orthophosphate; Total Phosphorus; Total Kjeldahl Nitrogen; Total Nitrogen; Nitrate-Nitrite; Ammonia; Conductivity; Color; Photosynthecially Active Radiation; pH; Total Organic Carbon; Dissolved Oxygen; Salinity; Turbidity; Secchi Depth; Temperature; Total Suspended Solids
CHNEP/ Lee County	5 each (random)	Pine Island Sound and Estero Bay	Monthly	2001-present	
CHNEP/ Cape Coral	5 (random)	Matlacha Pass	Monthly	2001-present	
CHNEP/City of Sanibel	5 (random)	San Carlos Bay	Monthly	2001-present	
CHNEP/FDEP/Lee County	5 (random)	Bokkelia	Monthly	2001-present	
Lee County	14 (fixed)	Pine Island Sound & Matlacha Pass	Monthly	1990-present	Nitrate; Nitrite; Ammonia; Total Kjeldahl Nitrogen; Total Nitrogen; Ortho Phosphorus; Organic Phosphorus; Total Phosphorus; Turbidity; Total Dissolved Solids; Total Suspended Solids; Water Temperature; pH; Conductivity; Secchi depth; Fecal streptococcus and Fecal coliforms; Biochemical Oxygen Demand

Table 4.3-1. Continued.

Organization/ Program	Number of Stations	Location	Frequency	Period	Analytes
City of Cape Coral	2 (fixed)	Caloosahatchee River	Monthly	1990-present	Nitrate; Nitrite; Ammonia; Total Kjeldahl Nitrogen; Total Nitrogen; Ortho Phosphorus; Organic Phosphorus; Total Phosphorus; Turbidity; Total Dissolved Solids; Total Suspended Solids; Water Temperature; pH; Conductivity; Secchi depth; Fecal streptococcus and Fecal coliforms; Biochemical Oxygen Demand
FDEP/TMDL	12 (fixed)	Caloosahatchee River	Monthly	2008	Chlorophyll a; Dissolved Oxygen; Total Phosphorus; Orthophosphate; pH; Temperature; Total Nitrogen; Nitrate + Nitrite; Total Kjeldahl Nitrogen; Alkalinity; Color; Biological Oxygen Demand; Total Organic Carbon; Turbidity; Conductivity
SCCF/RECON	5 in-situ sites-LOBOS	Ft. Myers; Shell Point; Blind Pass; Redfish Pass; Gulf of Mexico	30-minute intervals	2007/2008-present	Nitrate; Chlorophyll; Colored Dissolved Organic Matter (CDOM); Conductivity; Dissolved Oxygen; Oxygen Saturation;Turbidity; Salinity; Temperature; Depth
Florida Fish and Wildlife Research Institute/MARVIN	2 sites	Caloosahatchee River	3 hour intervals	Marvin 1: 2005-present; Marvin 2: 2007-present	Chlorophyll a, nutrients (nitrogen and phosphorus), water temperature, dissolved oxygen, pH, salinity, turbidity. Also records meteorological data including air temperature, precipitation, barometric pressure, relative humidity, and wind speed and direction.
City of Sanibel	12 (fixed)	Sanibel Island and Blind Pass	Monthly	2001-present	Total Suspended Solids: Turbidity; Ammonia; Total Nitrogen; Nitrate + Nitrite; Total Kjeldahl Nitrogen; Nitrate; Nitrite; Orthophosphorus; Total Phosphorus; Chlorophyll a; Conductivity; Salinity; Total Organic Carbon
FDEP-Charlotte Harbor Aquatic Preserve/Volunteer WQ Network	46 (fixed)	Lemon Bay, Charlotte Harbor southward to Estero Bay	Monthly	1998-present	Dissolved Oxygen; Salinity; Chlorophyll a; Turbidity; Color; Total Phosphorus; Total Kjeldahl Nitrogen;Nitrate/nitrite; Fecal coliform; pH; Temperature; Water Depth; Secchi Depth; Tide Stage; Wind speed; Wave height
FDEP-Charlotte Harbor Aquatic Preserve Data Sonde Program	2 (fixed)	Matlacha Pass	15-minute intervals	2005-present	Depth; Water temp; Conductivity; Salinity; pH; Turbidity; Dissolved oxygen
			Monthly	2005-present	Chlorophyll a; Total Kjeldahl Nitrogen; Nitrate/nitrite; Total Phosphorus; Red tide and other HABs; Secchi Depth; Water depth

4.3.2.10. Assessment

Sampling in most of the estuarine portion of the study area is sufficient to assess status and trends in water quality. However, the lower Caloosahatchee Estuary between Marker 66 and Shell Point is not covered adequately at this time. Sampling at the head of the estuary, just downstream of S-79, also is not covered adequately. During wet periods when the C-43 is flowing, water in this area will be very similar to that sampled upstream of S-79. However, in the dry season, intrusion of ocean water may cause water quality to be quite different. Organic forms of dissolved nitrogen are not currently sampled.

4.3.3. Oysters

The eastern oyster, *Crassostrea virginica*, forms important habitat in the Caloosahatchee Estuary. Because of the essential habitat it creates and its sensitivity to changes in salinity, environmental requirements of the oyster have been used to inform resource managers of impacts related to freshwater discharges. Oyster reefs comprise just 0.12% coverage or 7.4 hectares (18.4 acres) of the total surface area available in the estuary (Volety et al., unpublished results). Percent coverage of oysters reefs along various Gulf of Mexico estuaries ranges between 0 – 5.78% (data compiled by the USEPA). The lower percent coverage of oyster reefs in the Caloosahatchee Estuary is related to a combination of freshwater inflow discharge and lack of substrate, in part due to a combination of shell mining, dredging activities, and disarticulation of dead reefs. The restoration goal is to provide "approximately 400 acres of suitable oyster habitat with at least 100 acres of living oyster reefs" (RECOVER, 2007a).

Monitoring of oysters in the Caloosahatchee Estuary is currently conducted by the RECOVER Program (**Table 4.3-2**; RECOVER, 2007b) at six stations (**Figure 4.3-2**). Various aspects of oyster condition, life history and distribution are measured (**Table 4.3-2**). While most parameters are measured monthly or seasonally, the regional distribution of oysters will be mapped every five years (RECOVER, 2007a).

The information gained from the RECOVER program supported the development and optimization of a Caloosahatchee Estuary Habitat Suitability Index (HSI) model for oysters (Mazzotti et al., 2005; Volety et al., 2005; Volety, 2007). The HSI is an adaptation of the original model developed by Cake (1983) and modified by Soniat and Broady (1988) for Texas estuaries. The model has been, and will be used in the future, to predict oyster response to alternative freshwater inflow scenarios provided by large restoration programs (CERP and Southwest Florida Feasibility Study). Further refinement of the HSI will improve predictions, allow for real-time resource management decisions, and help identify areas that have the greatest potential for reef development. The Caloosahatchee Estuary lacks hard substrate suitable for larval settlement and hence growth of oyster reefs. With the placement of shell substrate in strategic places (as per the HSI model), reef growth is expected to accelerate, thus achieving or exceeding the previously stated RECOVER goal for area coverage.

4.3.3.1. Monitoring Assessment And Recommendations

The present oyster monitoring program is sufficient to detect long-term change in population size and physiological condition and to support adaptive management. A power analysis indicated that the present monitoring scheme can detect a change in oyster density of one and a half times the standard deviation of the long-term mean (RECOVER 2007b).

Table 4.3-2. Parameters measured in RECOVER's Oyster Monitoring Program, Caloosahatchee Estuary (Volety, 2007).

MEDIUM	PARAMETERS	STATIONS	FREQUENCY	COLLECTION
1. Water Quality	Dissolved Oxygen, pH, salinity, conductivity and temperature	All	Monthly	YSI/Hydrolab
2. Oysters-Adults	Density and size of living adults/sq. m.	All	Winter	Quadrat Counts and *in situ* measurements
3. Reproductive Condition	Gonadal Index, Gonadal conditions	All	Monthly	Histology and image analysis from collected samples
4. Recruitment	Oyster spat settlement and growth	All	Monthly	Count and measure spat on oyster settling apparatus
5. Oyster Juveniles	Juvenile oyster growth and survival	All	Monthly	Measure 50 random juvenile oysters from wire mesh bag: Examine % survival of all juvenile oysters.
6. Population (reef coverage)	Spatial coverage (acres)	Lower estuary and San Carlos Bay area	Minimum - Every 5 years	Aerial photography and ground truthing

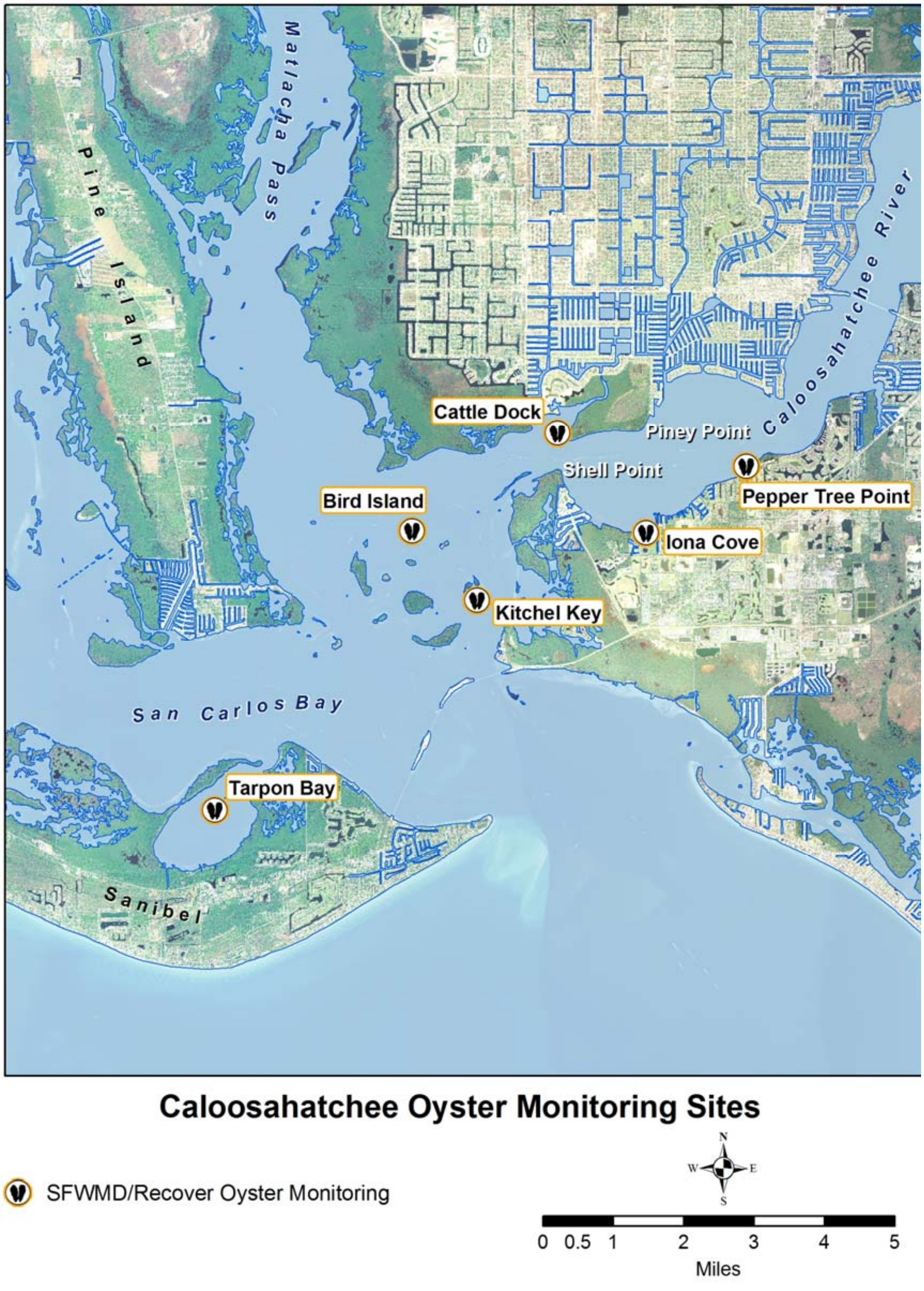

Figure 4.3-2. RECOVER's Caloosahatchee Oyster Monitoring Program Stations.

4.3.4. Submerged Aquatic Vegetation (SAV)

As described in Chapter 3, a variety of SAV species inhabit the tidal waters of the Caloosahatchee Estuary and downstream areas, including *Vallisneria americana* (tape grass) in the upper estuary and the seagrass *Halodule wrightii* (shoal grass) in the lower estuary and San Carlos Bay. The seagrass *Thalassia testudinum* (turtle grass) prominently mixes with shoal grass in San Carlos Bay, Pine Island Sound, and Matlacha Pass. Other species, for example, *Ruppia maritima* in the estuary and *Syringodium filiforme* in Pine Island Sound, can also make significant contribution to the overall species composition.

SAV are monitored in the Caloosahatchee Estuary because they are a general indicator of estuarine health and provide important habitat for a rich diversity of estuarine organisms. Their salinity requirements have been used to develop flow and salinity envelopes. In addition, seagrass light requirements will be used to develop a TMDL for nutrients. This section presents an inventory of existing SAV monitoring and the information to evaluate the ability of existing monitoring programs to detect changes in SAV and support adaptive management.

There are currently six SAV monitoring efforts in the tidal waters within the CRWPP boundaries. **Table 4.3-3** provides information regarding the organizations conducting the six programs and the purpose of the sampling. There have been five aerial photography surveys conducted since 1999. **Figure 4.3-3** depicts the survey boundary. Aerial survey information has been used by various organizations to evaluate incremental and long-term changes throughout the entire region and within major sections of the system.

4.3.4.1. Monitoring Assessment And Recommendations

The existing programs are sufficient for detecting trends and assessing the status of seagrasses in the CRWPP study area on multiple spatial and temporal scales. There is also sufficient overlap to provide program checks and ground truthing. The FDEP monitoring programs and the SFWMD hydroacoustic monitoring are conducted by in-house staff (minimum capital outlay). The working team concluded that the two-to-three year frequency of aerial photography surveys was sufficient to detect long-term large-scale changes, but not frequent enough to account for the impact of extreme drought or storm events. The working team also recommended that measurements (e.g. percent coverage) be standardized where possible.

Table 4.3-3. Identification of organizations conducting SAV monitoring and the purpose of their monitoring programs. A detailed list of station locations and parameters measured by each program is available upon request.

Organization Conducting Sampling	Sampling Program Name	Purpose of Sampling
RECOVER	Submerged Aquatic Vegetation Monitoring in the San Carlos Bay and Caloosahatchee River and Estuary	Typify changes in plant composition and abundance, range of aerial coverage, influence from freshwater inflow or water quality impacts, and provide support information for ecosystem model.
FDEP-South District – Environmental Assessment and Restoration (**EAR**)	Caloosahatchee/San Carlos Bay Quarterly Seagrass Transect Monitoring	(1) Determine changes over time in seagrass species composition, abundance, density, health and deep edge of bed; and (2) link monitoring results to water quality.
FDEP – Charlotte Harbor Aquatic Preserves (**CHAP**)	Charlotte Harbor Aquatic Preserves Seagrass Transect Monitoring	(1)Determine changes over time in seagrass species, abundance, density, health and deep edge of bed; and (2) link monitoring results to water quality.
FDEP – Estero Bay Aquatic Preserve (**EBAP**)	Estero Bay Aquatic Preserve Seagrass Transect Monitoring	(1) Determine changes over time in seagrass species composition, abundance, density, health and deep edge of bed; and (2) link monitoring results to water quality.
SFWMD	Hydroacoustic Monitoring of Submerged Aquatic Vegetation in the Caloosahatchee Estuary and Downstream Area	Quantify SAV spatial and temporal coverage along the salinity, depth, and water quality gradient of the estuary related to the influence of freshwater discharges.
SFWMD	Aerial Mapping of Lower Charlotte Harbor and Tidal Caloosahatchee	Detect trends in area wide (spatially contiguous) SAV coverage, depth, and distribution.

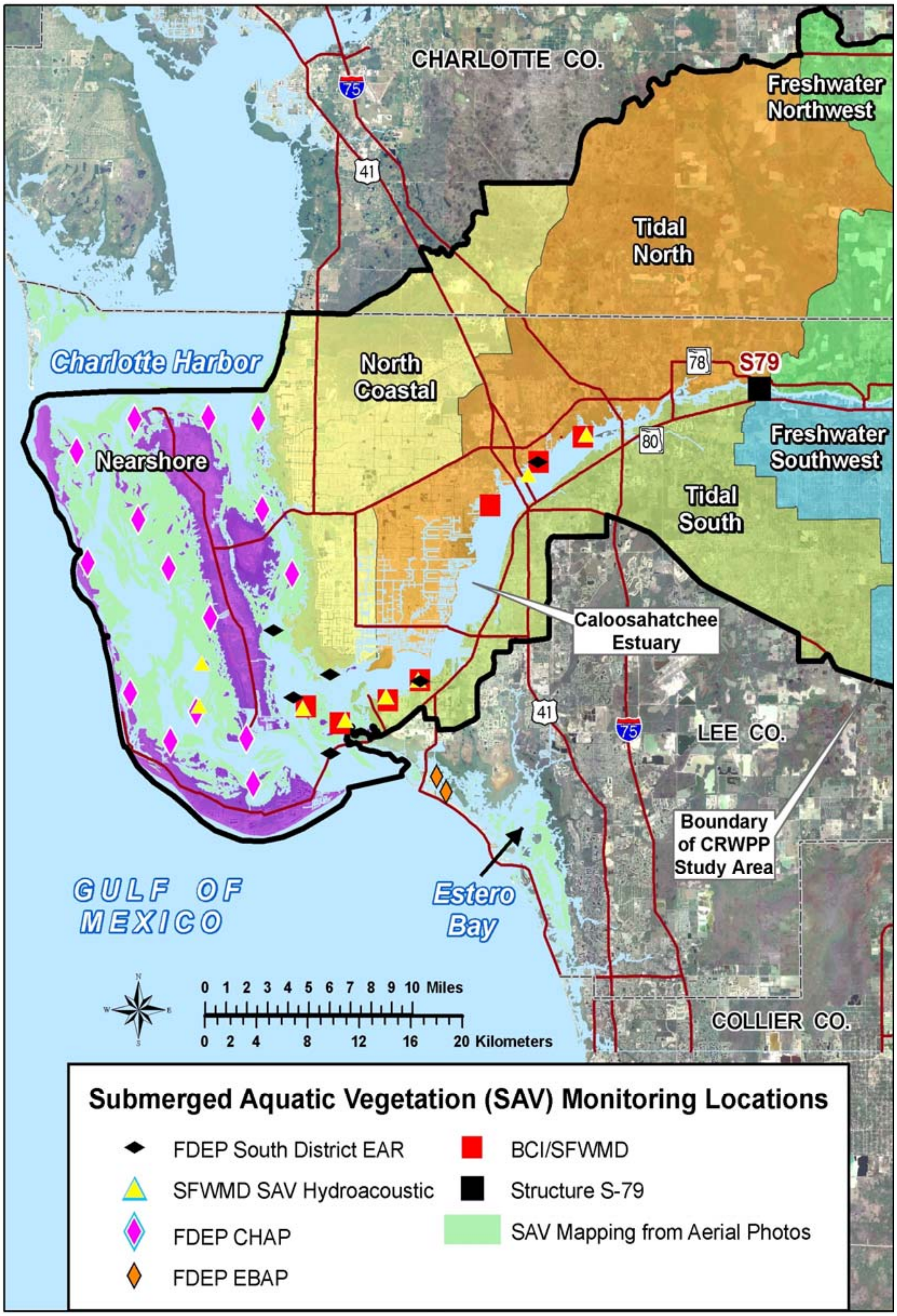

Figure 4.3-3. Caloosahatchee SAV monitoring stations for five monitoring programs and the general location of seagrass depicted from the aerial photography program.

4.4. Recommended Monitoring Program

The recommended monitoring program has been formulated to fulfill the goals and reporting requirements of the Caloosahatchee River Watershed Protection Program, as well as to support adaptive management. Therefore, the monitoring program provides the concentration and flow data necessary to calculate and track nutrient and other material loads from the watershed to the estuary. Salinity, water quality and aquatic habitat are monitored in order to quantify changes associated with anticipated reductions in flows and loads affected by the CRWPP. Additional water quality stations and parameters are recommended to support adaptive management.

4.4.1. Long-Term Water Quality and Flow Monitoring in the Watershed

The current flow monitoring and water quality monitoring conducted in the tidal basin west of S-79 by Lee County, USGS, and FDEP should continue as it is now planned (**Figure 4.2-1, Figure 4.2-3**). The limited-term flow monitoring conducted by USGS and FDEP will provide the data required to calibrate and verify watershed loading models. The extensive water quality monitoring conducted by Lee County and the Cities of Cape Coral and Ft. Myers will quantify changes over time, as well as support modeling and adaptive management. **Table 4.4-1** presents the list of water quality parameters recommended by the working group. All of the parameters listed are currently being measured, except BOD5 and dissolved Total Kjeldahl Nitrogen (TKN). Measurement of BOD5 will support modeling efforts and provide a measure of the labile organic loads to the receiving waters. Dissolved TKN allows the calculation of dissolved organic nitrogen (DON), which often constitutes most of the total nitrogen (TN) load.

Table 4.4-1. CRWPP recommended list of water quality parameters (Group A) to be measured for the in monthly grab samples.

Water Quality Parameters
1. TN (cal), NH4, NO2/ NO3, TKN, DTKN
2. TP, OPO4= SRP
3. BOD5 and TOC
4. Chlorophyll-*a*
5. TSS
6. Turbidity
7. Color
Physical Parameters (taken electronically)
8. Temperature
9. Specific Conductivity
10. DO
11. pH

The working group also identified a series of parameters that should be considered for inclusion in the monitoring program, based on the potential for possible impairments now or in the future **(Table 4.4-2).**

Table 4.4-2. Additional (Group B) Parameters that may be considered for inclusion in the monitoring program (specific location and frequency, responsible agencies- TBD).

1. Sediment Oxygen Demand
2. Fecal Coliform
3. Total Dissolved Solids
4. Total hardness
5. Iron
6. Copper
7. Lead
8. Arsenic
9. Zinc

Flow and water quality are monitored primarily at the three water control structures (S-77, S-78, and S-79). While useful, the existing spatial coverage was deemed too coarse to quantify loading on the scale required for tracking progress towards the TMDL, supporting adaptive management, and supporting development of a Basin Management Action Plan.

To improve upon existing spatial coverage, the addition of eight long-term water quality and flow monitoring sites along the reach of the Caloosahatchee River (**Figure 4.4-1**) are proposed. The existing S-79 and S-78 water control structures will require the addition of autosamplers on a permanent basis for on-going monitoring for collective source control program performance/ effectiveness. Along with existing structures, the eight stations sub-divide the Caloosahatchee River into reaches. Monthly water quality (**Table 4.4-1**) and continuous flow will be measured at each station, allowing calculation of loading to each reach of the river. Additional sites for flow-weighted measurement of nutrients may be needed for source control purposes in the future.

4.4.2. Short-Term Water Quality and Flow Monitoring in the Watershed

The assumption made for long-term monitoring is that the sum of the individual tributary loads in the contributing watershed will equal the load measured for the receiving reach. In order to test this assumption, four short-term water quality and flow monitoring sites in canal tributaries flowing into C-43 are also recommended (**Figure 4.4-1, 4.4-2**). The purpose of these stations is to test the hypothesis that the difference between loads from upstream and downstream long term stations is equal to the sum of the load calculated from tributaries. A three-year study, sampling one-to-two dry season months and one-to-two wet season months per year is contemplated. This study will also help identify hot spots and support calibration of watershed models. In future years, the sampling equipment may rotate to tributaries in different reaches or be replaced by SFWMD's

Caloosahatchee River Watershed Pollutant Source Control Program. The initial siting of these stations coincides with the proposed location of the Caloosahatchee River Water Quality Treatment and Testing Facility. Should the comparison of watershed/tributary monitoring to the associated river reach not substantiate the initial assumption, the adaptive management process provides for the reassessment of the proposed program to generate adequate watershed coverage.

4.4.3. Caloosahatchee River Watershed Pollutant Source Control Program

The SFWMD will expand its Pollutant Source Control Program within the boundaries of the CRWPP. Ongoing monitoring will be established at a regional level to assess the collective performance and progress of pollutant source control best management practice (BMP) programs, to support adaptive management within such programs, to identify priority areas of water quality concern and BMP optimization, and to provide data to evaluate and enhance performance of downstream treatment facilities. Monitoring will consist of flow weighted phosphorus (P) and nitrogen (N) concentrations and flow parameters measured daily during discharge. Because these will be long-term monitoring sites for regulatory purposes, every effort will be made to utilize existing sites where applicable. Once priority areas of concern are identified for BMP optimization activities using regional level monitoring data, a secondary level of local monitoring will be conducted by the SFWMD for a limited period of time to ascertain the most appropriate BMPs associated with the water quality concerns identified.

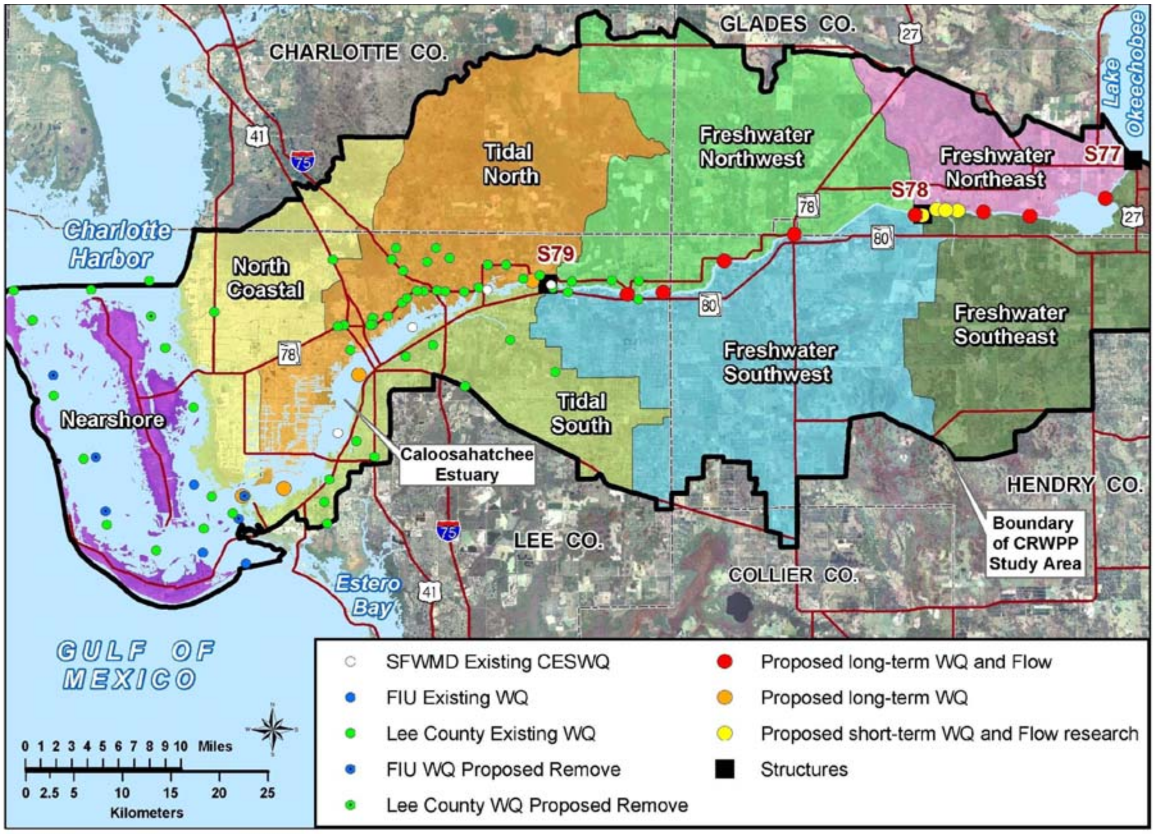

Figure 4.4-1. Proposed watershed and estuarine monitoring sites for the CRWPP. Black dots in station locations indicate potential for removal.

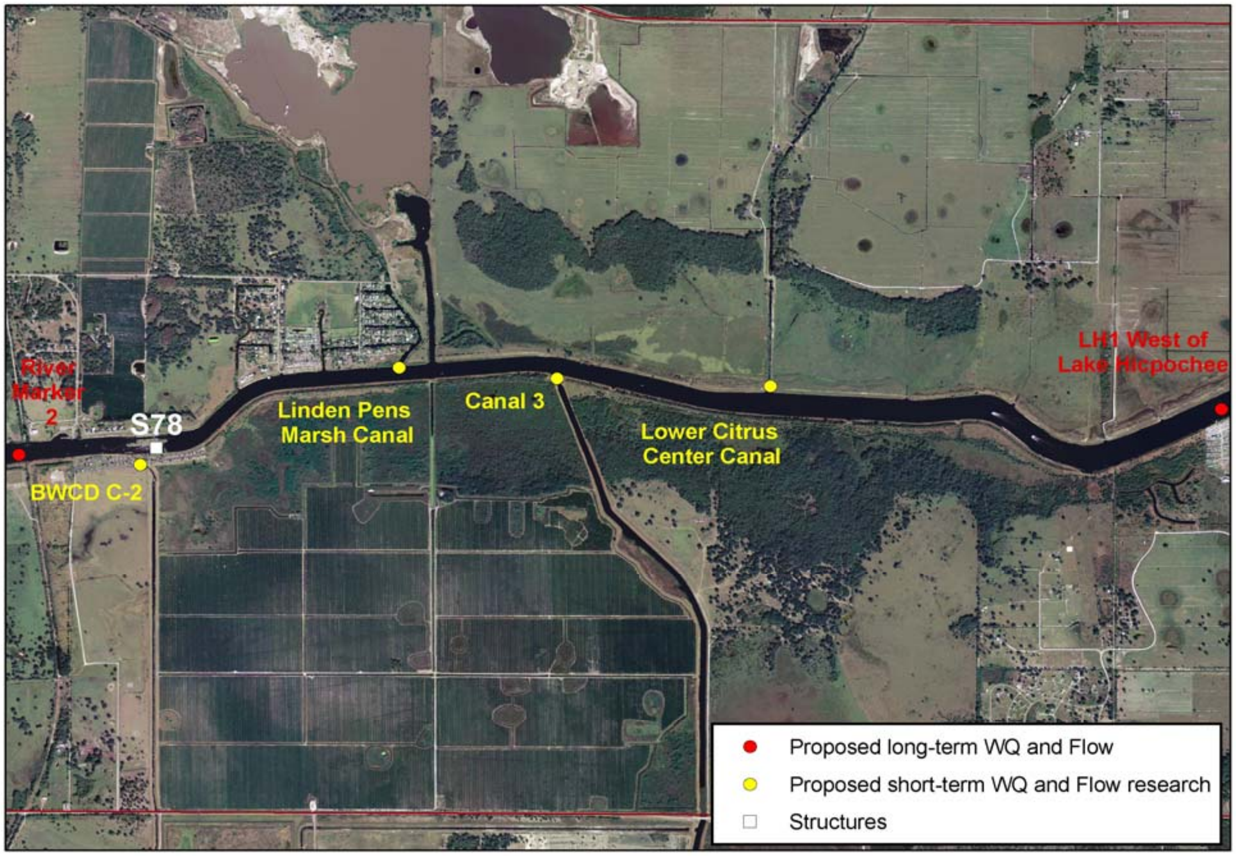

Figure 4.4-2. Proposed short-term monitoring sites on the tributaries of the Caloosahatchee River.

4.4.4. Long-Term Monitoring in the Caloosahatchee Estuary

4.4.4.1. Salinity

Salinity monitoring in the Caloosahatchee Estuary and adjacent waters is adequate to meet the goals of the CWRPP. It is recommended that continuous monitoring stations maintained by SFWMD and SCCF be continued.

4.4.4.2. Water Quality

In general, the water quality monitoring conducted by all agencies in estuarine and marine waters of the study area are adequate to meet program goals and should continue. However, there was some redundancy among programs and some areas were not receiving adequate attention. The R&WQMP Working Group identified redundancies and recommended the removal of some stations (**Figure 4.4-1**). Because the Caloosahatchee Estuary was under-sampled spatially, it is recommended that four stations from the CESWQ Program be reinstated (CES02, CES05, CES07 and CES08). **Table 4.4-2** presents the list of water quality parameters recommended by the working group that should be monitored in estuarine and marine waters. All of the parameters listed are currently being measured, except BOD5 and dissolved TKN. Measurement of BOD5 will support modeling efforts and provide a measure of the labile organic loads to the receiving waters. Dissolved TKN allows the calculation of DON, which often constitutes most of the TN load.

Table 4.4-2. CRWPP recommended list of water quality parameters (Group A) to be measured for the monthly grab samples taken from marine and estuarine waters.

Water Quality Parameters
1. TN (cal), NH4, NO2/ NO3, TKN, DTKN
2. TP, OPO4= SRP
3. BOD5
4. Chlorophyll-*a*
5. Phaeophytin
6. TSS
7. Turbidity
8. Color
Physical Parameters (taken electronically)
9. Temperature
10. Salinity
11. Specific Conductivity
12. DO
13. pH
14. Photoynthetically Active Radiation (PAR)

4.4.4.3. Aquatic Habitat

The current oyster monitoring program conducted by RECOVER should continue. It is further recommended that mapping of oyster beds by RECOVER also continue, at a frequency of at least every five years, with the next effort being completed in 2009 (no cost has been determined).

The current multi-agency approach to seagrass monitoring in the study area should also continue. However, to be able to compare programs and improve system-wide analysis, this plan also encourages standardizing (when possible) the collection methods of seagrass abundance measurements (e.g., species percent composition). The working team also recommends that SAV aerial photography surveys continue at the historical sampling frequency of every two-to-three years.

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5.0 WATERSHED AND ESTUARINE RESEARCH AND MODELING PROGRAM

5.1. Introduction

Three major goals of the Caloosahatchee River Watershed Protection Program, as stated in Section 373.4595, F.S. are: (1) achieve pollutant load reductions based upon adopted total maximum daily loads (TMDL), (2) establish salinity envelopes and freshwater inflow targets, and (3) reduce the frequency and duration of undesirable salinity ranges while meeting other water–related needs in the region. The Caloosahatchee River Watershed Protection Plan (CRWPP) will be updated every three years. Three research themes support these program goals: TMDL, Salinity Envelopes and Freshwater Inflow Targets, and Environmental Operations.

5.1.1. TMDL

A goal of the research program is to provide robust scientific support to reduce the uncertainty in the estimate of the TMDL. The program aims to quantify (1) the relationship between the biological resources upon which the TMDL may be based (e.g. seagrass) and aspects of water quality that the TMDL seeks to improve, and (2) the roles of nutrient loading and biogeochemical processes in controlling TMDL water quality parameters (e.g. Chlorophyll-*a*, dissolved oxygen (DO), and nutrients).

5.1.2. Salinity Envelopes and Freshwater Inflow Targets

These envelopes and targets provide the basis for management of the quantity of freshwater discharged to the St. Lucie and Caloosahatchee Estuaries. The goal of the program is to reduce the uncertainty in these resource-based targets and to quantify not only what are undesirable flows and salinities, but also to identify critical periods when meeting targets is most ecologically beneficial.

5.1.3. Environmental Operations

To improve environmental conditions in both estuaries, protection plans will call for the construction of facilities designed to help meet TMDLs and flow/salinity targets by attenuating and storing stormwater runoff and reducing nutrient loads. Operation of these facilities will be vital to their success. Monitoring and short-term studies will be required to adaptively manage these facilities to meet environmental objectives.

Research conducted within the context of an environmental protection program supplies information applied in adaptive management. Adaptive management is the iterative and deliberative process of applying the principles of scientific investigation to the design and implementation of a program to better understand the ecosystem, predict its response to implementation, and to reduce key uncertainties. The basis of adaptive management is the use of feedback loops that iteratively feed new information into the decision-making process for planning, implementation, and assessment of project components. The triannual assessment, specified in the legislation, provides this feedback loop and ensures the incorporation of adaptive management into the River Watershed Protection Plans (See Chapter 2).

Research for adaptive management (**Figure 5.1-1**) uses a combination of observational and experimental studies to reduce uncertainty in the TMDL and salinity /flow targets, improve the operations of water storage and water quality projects, and increase predictive capability. Models (numeric and conceptual) are used to synthesize the information and inter-relationships derived from research to specify new hypotheses, conduct preliminary testing, and enhance predictive capability.

This chapter describes the research and modeling program that supports the CWRPP. Research projects are intended to reduce or eliminate key uncertainties in the TMDL, as well as flow and salinity envelopes. Four research projects are presented in order of priority. Each project is accompanied by a table of project elements or components along with an assessment of how information will be obtained (e.g. new measurements, existing data or estimates from a model). The section on modeling describes existing watershed, estuarine, and ecological models and summarizes additional modeling requirements.

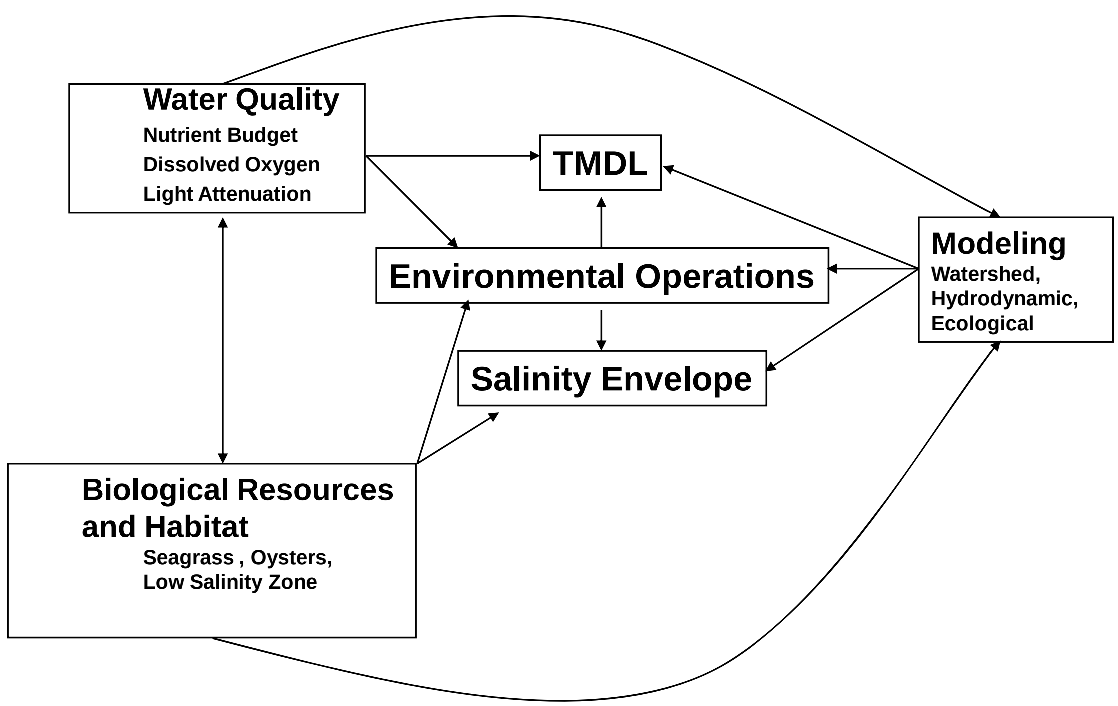

Figure 5.1-1. Relationship between applied research and modeling programs, driven by adaptive management, TMDLs, salinity envelopes, and environmental operations.

5.2. Estuarine Nutrient Budget

5.2.1. Project Overview and Background

Over-enrichment of estuaries with nutrients from urban and agricultural sources is both a local problem for the Caloosahatchee Estuary and a problem for most estuaries worldwide (DeGrove, 1981; Gray, 1992). In the 1980s, the Florida Department of Natural Resources determined that the Caloosahatchee Estuary had reached its nutrient loading limits, based on high Chlorophyll-*a* (phytoplankton biomass) and DO concentrations (DeGrove, 1981). More recently, blue-green algae blooms, red tides, and massive accumulation of drift algae (Lapointe and Bedford, 2006) have been taken as an indication that nutrient loads to the Caloosahatchee Estuary are too high and that the system suffers from eutrophication.

The scientific foundation for the management of over-enrichment rests on the concept of nutrient limitation (Smith, 1999): the nutrient that is present in the environment in the least quantity relative to plant demands will limit growth. Controlling the effects of over-enrichment should be accomplished by restricting the loading of this key nutrient to the ecosystem (Smith, 1999). As a rule of thumb, nitrogen (N) most often limits algal growth in marine systems, while phosphorus (P) is limiting in fresh waters (Smith, 2006). While dissolved inorganic forms of N and P are readily available for plant growth, some organic forms can be taken up directly or converted to forms that can be taken up (Seitzinger et al, 2002). Therefore, the distribution of the nutrient load among available inorganic and organic forms and unavailable organic forms is an important consideration in quantifying the load to be controlled or restricted.

A well-constrained nutrient budget is critical to understanding the origin, magnitude, and management of problematic nutrient loads. A nutrient budget is simply an accounting or summing up of nutrient inputs, outputs, and permanent losses (e.g. Nixon, 1995). Internal cycling terms are often included. For N, inputs include storm water runoff and atmospheric deposition. Outputs include, among others, export to the Gulf of Mexico. Burial in the bottom sediments is an example of a permanent loss term and the flux of nutrients out of the bottom sediments constitutes an internal cycling term.

5.2.2. Management Objective

This project supports the CRWPP goal of achieving the nutrient TMDL for the Caloosahatchee Estuary. The budget itself constitutes a tool that can be used to quantify nutrient loads from various sources and guide prioritization for load reductions.

5.2.3. Application of Results

Nutrient budgets assist with determining appropriate nutrient reduction approaches and with evaluating and optimizing project effectiveness. Meeting the TMDL relies on reducing nutrient loads that can be controlled. The relative magnitude of controllable and uncontrollable sources limits the extent of improvement achievable through best management practices (BMP). Since a nutrient budget is comprised of both types of sources, it provides the basic information required to quantify this limit. The inclusion of internal cycling terms, such as the regeneration of nutrients by bottom sediments, allows estimation of the time scale of system response to external load reductions. Results of this project can be used to support water quality modeling efforts that will reduce the uncertainty of the TMDL and increase the capability to predict effects of various management measures, including BMPs.

5.2.4. Methodological Approach

This project will construct nutrient budgets of N and P for the Caloosahatchee Estuary. Terms in the nutrient budget will be determined by a variety of methods. Some of the terms in the budget can be derived from existing information (i.e. nutrient load at the Franklin Lock and Dam). Others, such as storm water runoff from the Tidal Caloosahatchee Basin, may require a modeling effort. Still others, such as the flux of nutrients out of the bottom sediments, may require direct measurement (**Table 5.2-1**).

Priorities for evaluating the terms in the budget were determined. Terms that can be calculated without further data collection or new modeling efforts received high priority. Terms for which data collection was partially complete, also received high priority.

Table 5.2-1. Input, Internal Cycling, and Output Terms included in the Nutrient Budget for the Caloosahatchee Estuary. Also given is the status of data required for each term.

INPUTS	STATUS
Franklin Locks	Data Available
Tidal Basin	
Surface Flows	Require Modeling Project
Ground Water	Require Modeling Project
Wastewater Treatment Facilities	Data Available
Gulf of Mexico	Modeling Project
Atmospheric Deposition	Lee County Data for Estero Bay
Nitrogen Fixation	Require New Measurements
INTERNAL CYCLING	STATUS
Primary Productivity	Require New Measurements
Water Column Respiration	Require New Measurements
Benthic Nutrient Flux	Dry Season Data, Need Wet Season
Re-suspended Sediment Exchange	Require New Measurements
OUTPUTS	STATUS
Export to Gulf	Require Modeling Project
Burial in Sediments	Some Sedimentation Rate Data Exist
Denitrification	Dry Season Data, Need Wet Season
Biomass	
Migration	Data Needed
Harvesting	Data Needed

5.2.5. Progress This Year

5.2.5.1. Nutrient Limitation of Phytoplankton Growth in the Caloosahatchee Estuary

Although indirect evidence suggests that N is limiting in the Caloosahatchee Estuary, no recent studies have experimentally determined whether N or P limits algal production in the estuary. Measurements from monitoring programs indicate that much of the N load is organic and the extent to which this organic fraction can support algal production is not known.

This project examines nutrient limitation of algal growth at four stations in the Caloosahatchee Estuary through nutrient addition and dilution bioassays. The project also examines the availability of organic N. This information supports development of water quality targets, indicates which nutrient (N or P) needs to be controlled, and thus guides the development of TMDLs and the nutrient load reduction strategies required to achieve it.

This project began in 2006 and includes sampling for a two-year period. The final report is due in 2008. Preliminary results indicate N limitation.

5.2.5.2. Degradation of Riverine Dissolved Organic Nitrogen in the Caloosahatchee Estuary

Monitoring data indicate that approximately 80% of the N load at S-79 (a major freshwater source to the estuary) is organic and must be remineralized before becoming available to micro-algae (phytoplankton). Most of the organic nitrogen is dissolved organic nitrogen (DON), and how much can become available to support phytoplankton production is unknown. The amount that can become available will determine whether control of DON will be required to achieve the N TMDL for the estuary.

The South Florida Water Management District (SFWMD) has funded a project to examine how much of the DON in the downstream estuary can be remineralized (see above). There are many possible sources of DON to the downstream estuary, including tidal creeks, septage, decaying phytoplankton, and effluent from waste water treatment facilities. This study builds on previous work by characterizing the largest source, DON from the freshwater Caloosahatchee River, and determining how much can become available to phytoplankton. Experiments on the role of bacteria and photolysis follow those of Seitzinger and Sanders (1997) and Vahatalo and Zepp (2005).

Experiments were conducted in January, February, and March of 2008 (during the dry season of a drought year) when fresh DON input was expected to be minimal. Although some photolysis was detected in laboratory experiments, DON did not appear to be converted to inorganic N by bacteria and did not form particulate aggregates upon mixing with seawater. Further studies during wet conditions are required.

5.2.5.3. Benthic Nutrient Fluxes

In shallow coastal estuarine systems such as the Caloosahatchee Estuary, the water column and sediments can be tightly coupled with respect to the biogeochemical cycles of N and P. Sediment can function as a sink (i.e. permanent burial) or a source (i.e. inputs of nutrients to the estuary) through the transfer, or flux, of nutrients between the water column and sediments. Inorganic nutrients are produced during the microbial remineralization of organic matter within the sediments. Loads of nutrients from sediments can contribute significantly to the total nutrient load in subtropical estuaries. A recent study of benthic fluxes in an estuary in northwestern Florida identified sediments as a substantial source of inorganic N and P to the water column, relative to inputs from the main freshwater source during drought conditions (DiDonato, 2006).

Due to a lack of information on benthic nutrient fluxes available for this system, two studies were conducted in February 2008 to estimate benthic fluxes of N and P in the Caloosahatchee Estuary, "The Characterization and Quantification of Benthic Nutrient Fluxes in the Caloosahatchee River and Estuary" (Howes, 2008) and "An Assessment of Processes Controlling Benthic Nutrient Fluxes in the Caloosahatchee River and Estuary and the St. Lucie River and Estuary" (Cornwell, 2008).

The goals of the first study were to (1) provide estimates representative of system-wide benthic nutrient flux rates in the Caloosahatchee Estuary, (2) identify "hot spots" of benthic nutrient, and (3) provide data in support of current and future water quality modeling efforts. System-wide estimates were based on measurements from sediment cores collected from 50 sites distributed throughout the estuary.

The goals of the second study were to identify the contribution of diffusive and advective fluxes in the Caloosahatchee Estuary, by comparing fluxes measured from cores in the laboratory with fluxes measured in the field with chambers. Chambers in the field may capture the effects of groundwater seepage, while fluxes measured on cores in the laboratory did not. The results will guide future research and monitoring efforts in the application of appropriate methodology for measuring benthic nutrient fluxes.

Initial measurements were taken in February 2008, during the dry season in a drought year. Additional measurements are required to determine the relative contribution of the sediments to the total nutrient load.

5.3. Dissolved Oxygen Dynamics

5.3.1. Project Overview and Background

Low oxygen concentrations are often associated with excess nutrient loading (Gray, 1992) and have been a recognized problem in the Caloosahatchee Estuary since the 1980s (DeGrove, 1981). Oxygen concentrations less than the state standard of 4.0 milligrams per liter (mg/l) occur most often in the upper estuary during the warmer months of the year (see Chapter 3). The Caloosahatchee Estuary has been listed as impaired for DO and nutrients. Causative agents for the DO impairment were both a high biochemical oxygen demand (BOD) and high levels of Chlorophyll-*a* (http://www.dep.state.fl.us/water/tmdl/adopted_gp3.htm). The two causative agents suggest different origins for the DO impairments. The high BOD suggests that loading of labile organic matter from external sources might cause low concentrations of DO. By contrast, high levels of Chlorophyll-*a* suggest that excess nutrient loading leads to internal production of algae, which fuel a high oxygen demand when they die. The two scenarios lead to different management actions.

5.3.2. Management Objective

This project supports the CRWPP goal of achieving the TMDL for the Caloosahatchee Estuary and improving DO conditions in the Caloosahatchee Estuary.

5.3.3. Application of Results

This project will identify the factors causing the DO impairment in the Caloosahatchee Estuary. Once causes are known, appropriate management solutions can be implemented. The results of this study will provide critical information that will guide the selection of these management solutions.

5.3.4. Methodological Approach

To determine if proposed TMDLs for nutrients will improve DO concentrations in the Caloosahatchee Estuary, it is necessary to quantify the relative importance of factors that control DO and how they interact to exert that control. This study will examine the role of internal and external factors in determining the concentration of DO (**Table 5.3-1**). These factors include stratification, algal blooms, sediment oxygen demand, and BOD loading. Emphasis will be on measuring diel fluctuations of DO in surface and bottom waters in different seasons and over a range of freshwater inflows and algal bloom conditions. The interpretation of these observations will be aided by measurements of sediment oxygen demand and BOD in the water column.

Table 5.3-1. Sinks, Sources, and other measurements required to quantify the dynamics of dissolved oxygen in the Caloosahatchee Estuary.

SINKS	STATUS
External BOD Load	Monitoring Planned
Benthic SOD	Require New Measurements
Water Column Respiration	Require New Measurements
SOURCES	STATUS
Primary Productivity	Require New Measurements
Re-aeration	Modeled
PHYSICS	STATUS
Stratification	Require New Measurements
CONCENTRATION TIME SERIES	STATUS
Dissolved Oxygen	Require New Measurements
Chlorophyll-*a* Biomass	Require New Measurements
Light Extinction	Require New Measurements

5.3.5. Progress This Year

5.3.5.1. Benthic Oxygen Demand

Measurements of sediment oxygen demand were taken along with the nutrient flux measurements described above. These measurements were obtained during the dry season of a drought year (2008). Further measurements are required.

5.3.5.2. Dissolved Oxygen Time Series

In February 2008, continuous measurements of DO were initiated in the Caloosahatchee Estuary. One upper-estuary site is in an area normally occupied by the freshwater aquatic grass, *Vallisneria americana*. Two sites are located in shoal grass beds (*Halodule wrightii*) in the more marine lower estuary. Data have not yet been analyzed.

5.4. Low Salinity Zone

5.4.1. Project Overview and Background

One of the goals of the CWRPP is to minimize the occurrence of undesirable salinity ranges in the Caloosahatchee Estuary. In general, low flow and high salinity are a concern for the plants and animals living in the upper portions of an estuary. High flow and low salinity are troubling for the more saline regions. The low flow requirements of the northern estuaries have been based on salinity tolerances of organisms living in low salinity region located near the head of these systems.

The low salinity zone of an estuary (0-10 parts per thousand (ppt)) (Holmes, 2000) is also a highly productive one, serving as a nursery area for early life stages of economically important fish and shell fish (Day, 1989). Survival of these economically important fish stocks is dependent on survival of juveniles within these low salinity nursery habitats that depend on sufficient freshwater inflow. Whether the low flow targets determined from physiological salinity tolerances are sufficient to maintain the nursery function has not been determined.

Estuaries are characterized by high productivity (Nixon, 1986; Nixon 1988). It is generally agreed that freshwater input maintains this production (Fisher, 1988; Day, 1989; Montagna and Kalke, 1992). This paradigm regards the nutrients carried to estuaries by freshwater inflows as beneficial, with higher freshwater inflows leading to higher yields of desirable species (Loneragan and Bun, 1999). Yet the relationship between freshwater input and estuarine productivity is not completely understood (Livingston et al., 1997). While productivity is often positively correlated with the quantity of freshwater discharge, both reductions and increases in discharge can result in reduced productivity (Wilbur, 1992; Livingston, 1997; Turner, 2006).

In a recent review of recruitment of fish and other nekton, Petersen (2003) unifies the dynamic-stationary habitat overlap hypothesis of Browder and Moore (1981) with Cushing's (1990) match/mismatch hypothesis. Peterson (2003) notes that successful recruitment depends first on larvae approaching their physiological optima (salinity, temperature, DO) in the surrounding water (dynamic habitat) and then having available the appropriate habitat structure (e.g. grass bed, sediment type - stationary habitat) for other life requirements. Chief among these other requirements is the overlap between fish larvae and their prey. Annual variation in temporal and spatial overlap (match/mismatch) is reflected in subsequent recruitment. The dual role of freshwater inflow in positioning larvae, with respect to physical habitat, food and supplying the nutrients to grow the food, is evident here.

An important dynamic habitat in the low salinity zone is the estuarine turbidity maximum. Estuaries typically trap sediment in high concentrations at localized regions within the low salinity zone called the estuarine turbidity maximum (ETM). The ETM is a unique dynamic habitat that provides protection and nutrients to planktonic and larval fish (North and Houde, 2003; Roman, 2005). In Southwest Florida, estuarine-dependent fish such as Perch and Bay Anchovy spend the juvenile phase of their life cycle foraging in the ETM (Peebles, 1996). While the ETM is crucial to the ecosystem within the estuary, during high freshwater discharge it may be flushed outside of the river mouth into San Carlos Bay, thereby introducing large pulses of suspended sediment that can adversely affect seagrasses and filtering organisms, such as oysters. Despite its importance to the ecology of the estuary, little or no work has been done to examine the dynamics of the ETM.

5.4.2. Management Objective

Much of the work that supports estimates of minimum and maximum freshwater inflow requirements to the Caloosahatchee Estuary is based on the salinity tolerances of freshwater and marine organisms that inhabit the system. Inflow targets are primarily based on providing tolerable physiological conditions (see above). The relationship between freshwater inflow and estuarine productivity has not been described in the Caloosahatchee Estuary. It is not known whether freshwater inflow and salinity envelopes, based on physiological tolerances, also adequately support estuarine productivity.

This project examines elements of the estuarine food web, including planktonic and benthic algae, as well as zooplankton and fish larvae within the ETM of the Caloosahatchee Estuary. The ultimate goal of this program is to understand the role of freshwater discharge and production of fish larvae in the estuary. The project supports SFWMD's mission to improve natural systems and the establishment of water quantities that are protective of fish and other wildlife. Results can be applied to establishing water reservations, to refining flow and salinity envelopes, and to providing guidelines for delivery of freshwater to the Caloosahatchee Estuary.

5.4.3. Methodological Approach

The study area consists of the lower Caloosahatchee River and Estuary (**Figure 5.4-1**). A total of seven zones will be sampled from San Carlos Bay to just below the Franklin Lock and Dam. The locations for plankton sampling (both phytoplankton and zooplankton) will be fixed (nonmoving) for all collections. Collection locations will be located using a Global Positioning System (GPS). The collection vessel's position will be recorded using GPS chart plotters, providing quality assurance officers with records of the collection locations visited by the vessel during individual collection efforts.

Sampling and data collection will be conducted at night. In comparable studies, flood tides have been used as the standard condition for plankton-net sampling. Dates for plankton-net sampling will be determined according to the presence of flood tides to reduce variability caused by organisms' reactions to differences in tide direction. Existing data indicate that during flood tides, the estuarine water column tends to contain more organisms that are moving upstream or are trying to maintain position within the estuary, whereas ebb tidal waters tend to contain more organisms that are in the process of leaving the estuary. Transects will be conducted on two consecutive nights, if necessary, to ensure that sampling and data collection fall within a similar tide.

The following samples and data will be collected within each zone of the study area:

- Zooplankton (plankton net)
- Phytoplankton (plankton net)
- Benthic microalgae (Diving PAM: pulse amplitude modulation fluorometry; greased plates)
- Water-column Chlorophyll-*a* (in situ fluorometry)
- Estuarine turbidity maximum (location and strength)

- Colored dissolved organic matter (CDOM fluorometry)
- Standard water quality measurements (i.e., salinity, conductivity, temperature, DO)

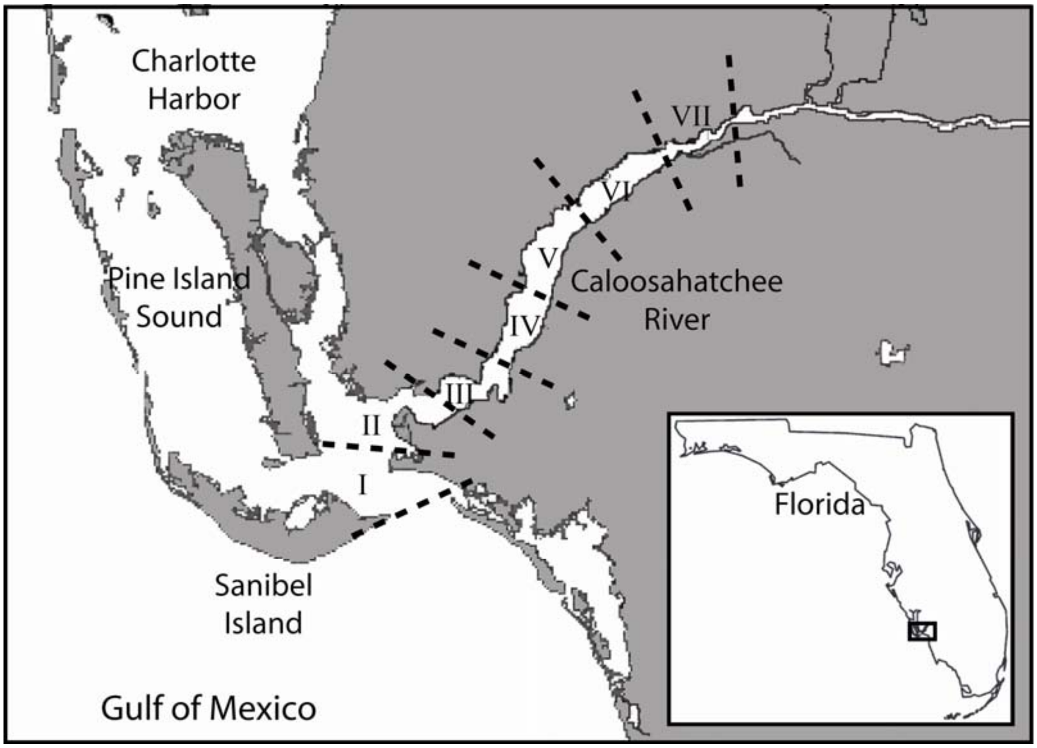

Figure 5.4-1. Map of the study area indicating zones selected for biological and water quality sampling.

5.4.4. Application of Results

Results of this study will be used to refine salinity and flow envelopes and to provide guidelines for delivery of freshwater to the Caloosahatchee Estuary.

5.4.5. Progress This Year

5.4.5.1. Low Salinity Zone Demonstration Project

A demonstration project was initiated this year. The work is being conducted by investigators from Florida Gulf Coast University and the University of South Florida. Sampling was limited to two events: one event during a seasonally dry month (April or May) and one event during a seasonally wet month (September) in 2008. The sampling frequency is being increased, using funding that the principal investigators were able to obtain from other sources.

5.4.5.2. Estuarine Turbidity Maximum

A short-term preliminary study of the Caloosahatchee ETM was initiated in 2008. The goal of this study was to identify and evaluate the vertical and horizontal density and turbidity structure(s) with respect to DO, salinity, and/or Chlorophyll-*a* stratification. The results of this project can be used for the calibration of a numerical sediment transport model to evaluate light conditions in the estuary. The project also has implications in environmental operations for better management of freshwater releases to improve ecosystem health in the Low Salinity Zone and for refinement of salinity and flow envelopes.

Four longitudinal transects were made during two trips on February 7, 2008 and March 16, 2008. This project produced some of the first high spatial resolution, contemporaneous measurements of turbidity, DO, and Chlorophyll-*a* in the Caloosahatchee River. During low discharge periods, the ETM is located upstream around 14-18 km from the Franklin Locks.

5.5. Light Attenuation in San Carlos Bay

5.5.1. Project Overview and Background

A resource-based method (Corbett and Hale, 2006) is being considered to establish nutrient TMDLs in the Caloosahatchee Estuary. Nutrient load reductions would be based on achieving water clarity in San Carlos Bay that allows enough light for seagrasses to grow to a depth of 2.2 meters. McPherson and Miller (1994) identified three major water quality constituents that attenuate light in the Southern Charlotte Harbor: turbidity, colored dissolved organic matter (CDOM), and Chlorophyll-*a*. The major assumption of this resource-based approach is that nutrient load reductions will result in reductions in Chlorophyll-*a* sufficient to achieve the water clarity goal.

While there has been no comprehensive investigation of light attenuation in San Carlos Bay, existing evidence suggests that in some years CDOM may account for most of the light attenuation, while in other years, Chlorophyll-*a* may dominate (Dixon and Kirkpatrick, 1999; Doering, 2006). This evidence suggests that in some years a TMDL might meet its resource goal and in others it would not.

5.5.2. Management Objective

The management objective is to reach a water clarity goal through nutrient load reduction. This project tests whether this objective is achievable.

5.5.3. Application of Results

Information from this study will better define controls on light attenuation in San Carlos Bay and the relationship between the TMDL and its resource goal. Results can be used to determine when and under what conditions resource light attenuation goals may be met.

5.5.4. Methodological Approach

This study will determine how the relative contributions to total light attenuation of Chlorophyll-*a*, CDOM, and turbidity vary with season and freshwater inflow in San Carlos Bay. Water quality samples will be taken at several stations in the estuary and San Carlos Bay, where the light extinction coefficient (Kd) will be measured (**Table 5.5-1**). Light attenuation will be modeled following McPherson and Miller (1994). The model will allow calculation of the contribution of each constituent to total light attenuation under different seasonal and flow conditions. The estuarine mixing behavior of CDOM from various sources will also be investigated.

Table 5.5-1. Elements of the Light Attenuation Project in San Carlos Bay.

INPUTS	STATUS
Franklin Locks	
Flow	Data Available
Color	Data Available
Turbidity	Data Available
Chlorophyll-*a*	Data Available
TSS	Data Available
Tidal Basin	
Surface Flows	Require Modeling
Color	Project/Measurements
Turbidity	Data Available
Chlorophyll-*a*	Data Available
TSS	Data Available
INTERNAL CYCLING	STATUS
Mixing Behavior	Require New Measurements
Sediment Resuspension	Require New Measurements
CONCENTRATION TIME SERIES	STATUS
San Carlos Bay	
Color	New Measurements
Turbidity	New Measurements
Chlorophyll-*a*	New Measurements
TSS	New Measurements
PAR (Kd)	New Measurements

5.5.5. Progress This Year

Routine monitoring data useful to the project has been collected during the past year, but no specific research has been initiated. The Charlotte Harbor National Estuary Program is re-evaluating the optical model employed by Corbett and Hale (2006).

5.6. Research Projects and Priority order

Each major project (e.g. Nutrient Budget) can be broken down into several component parts. These parts are given in separate tables (e.g. **Table 5.2-1**). Examination of the component parts of each project shows that several projects may have common components. The commonalities between components of the various projects are summarized in **Table 5.6-1**. As in the individual project tables, the source of data for each component is given (existing data, new measurements, model, etc). The components funded in any given year may be prioritized according to the number of projects to which they belong.

Table 5.6-1. Major research projects in the Caloosahatchee River Watershed and Estuary: their components and commonality

Research Component	Research Projects				Source
	Nutrient Budget	DO Dynamics	Low Salinity Zone	Light Attenuation	
INPUTS					
Franklin Lock Loads (S-79)	√	√	√	√	Monitoring
Tidal Basin Loads					
Surface Flows	√	√	√	√	Model/Measurements
Ground Water	√	√	√	√	Model/Measurements
Waste Water Treatment Facilities	√	√	√	√	New Measurements
Gulf of Mexico	√				Model for Flow Literature Concentration
Atmospheric Deposition	√				Literature/ Data Analysis
INTERNAL CYCLING					
Primary Productivity/ Water Column Resp	√	√	√	√	New Measurements
Organic Matter Decomposition (incl DON)	√	√			New Measurements
Benthic Nutrient Flux	√	√			New Measurements
DO Time Series		√	√		New Measurements
INTERNAL CYCLING					
San Carlos Bay Times Series					
Color				√	New Measurements
Turbidity				√	New Measurements
Chlorophyll-*a*				√	New Measurements
TSS				√	New Measurements
PAR (Kd)				√	New Measurements
OUTPUTS					
Export to Gulf	√				Model

Research Component	Research Projects				Source
	Nutrient Budget	DO Dynamics	Low Salinity Zone	Light Attenuation	
Denitrification	√				Benthic Flux Project
BIOMASS					
Larval/ Juvenile Fish				√	New Measurements
Zooplankton				√	
Benthic microalgae				√	
Phytoplankton (species/groups)				√	

5.7. Integrated Modeling and Assessment Framework

5.7.1. Introduction

Anthropogenic and natural changes originating within coastal waters and their watersheds can influence both ecosystem structure and function. However, direct impacts are often difficult to predict using cause and effect relationships from observation or monitoring programs alone. The observed changes are usually the result of not one, but multiple variables or stressors under the compounding effects of various physical driving forces. This complexity makes the evaluation of water resources management and its impact on the coastal ecosystems difficult.

An integrated modeling framework combining the resource-based Valued Ecosystem Component (VEC) approach and linked watershed and estuarine models has been proposed to meet water management objectives for the protection and restoration of coastal ecosystems (SFWMD, 2008). Integrated or linked models are used to simulate the effects of changes in population, land use or management practices in the watershed on estuarine physics, chemistry, and ecology (Chesapeake Bay Program and IAN, 2005; Wan, 2002; 2006). Specifically, the watershed model estimates the quantity, timing, and quality of freshwater inflow to the estuary. The estuarine hydrodynamic, sediment transport and water quality models, in turn, simulate the estuarine conditions in terms of salinity, water quality, and sediment transport. Finally, the ecological models simulate the responses of estuarine resources and processes to the estuarine conditions. SFWMD has been using this approach for several years in the Minimum Flows and Levels (MFL) Program, and in CERP-related projects, both for feasibility studies (Indian River Lagoon South, Southwest Florida Feasibility Study) and at the project level (Caloosahatchee River (C-43) West Basin Storage Reservoir).

During the past several years, numerous modeling efforts were conducted for the Caloosahatchee River and its watershed. Some of these models have been used in the protection plan efforts to date and may be used in the plan refinement phase. Modeling tools make a critical contribution to achieving the goals of the CRWPP through simulation of present conditions and prediction of future responses. For example, one of the primary goals of the CRWPP is to meet the TMDL through nutrient load reductions. Modeling not only aids in calculating loads that presently exist, but can also aid in estimating future load reductions required to meet TMDL concentration or ecologically based targets. In practice, the TMDL will be achieved through a combination of management measures, ranging from BMPs for urban and agricultural lands to large filter marshes and reservoirs. Models can help formulate and evaluate various combinations of these measures to arrive at a preferred plan. Other modeling tools presented here will be used to optimize operation of reservoirs and other facilities. The contribution of models to the adaptive management process is also critical. Here, models can be used to synthesize information and generate testable hypotheses that will refine the TMDL and the plan to achieve it.

The intent of this section is not to review the theory and numerical coding of each model developed in the area. Instead, an overview of the existing models and an assessment of modeling needs for future applications are given. This overview and assessment covers both hydrology/hydrodynamic and water quality aspects of modeling for the watershed and the receiving waterbody. In the future, a comprehensive modeling framework for the Northern Everglades domain (Kissimmee River and Watershed, Lake Okeechobee and Watershed, integrated with St. Lucie and Caloosahatchee Rivers, Estuaries and Watersheds) will be evaluated and developed.

5.7.2. The Caloosahatchee River Watershed Hydrology and Water Quality Models

5.7.2.1. The AFSIRS/WATBAL Hydrologic Model

The AFSIRS/WATBAL hydrologic model is a basin scale, simple water budget model based on the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) model (Smajstrla, 1990). All major components of the hydrologic cycle are determined in AFSIRS/WATBAL: demands from groundwater and surface waters, demands for the major irrigated and non-irrigated land uses, and runoff from land irrigated with groundwater, from land irrigated with surface water and non-irrigated lands. The water budget modeling for a given basin has three primary separate components: AFSIRS, AFSIRS Water Budget, and WATBAL, as well as a central location for common data (RF_PET_LU_inputs). AFSIRS calculates irrigation requirements for cropland. The AFSIRS Water Budget spreadsheet was developed to calculate and route runoff and ground water components for AFSIRS. The WATBAL spreadsheet calculates the hydrology of non-irrigated land.

The Caloosahatchee River implementation of the AFSIRS/WATBAL model is conceptualized as a four basin model covering the lands between S-77/S-235 and S-79 that influence the regional system. These basins are defined as East Caloosahatchee irrigated with groundwater, East Caloosahatchee irrigated from C-43(ecal-d), West Caloosahatchee irrigated with groundwater, and West Caloosahatchee irrigated from C-43. The break between the “East” and “West” basins is considered to occur at S-78. The multi-basin conceptualization of the model requires the addition of spreadsheets to handle the routing between basins. In addition to this need, the Caloosahatchee River Basin has the supplementary consideration of public water supply withdrawals from the C-43 Canal (Lee County and Ft. Myers) and deliveries from the regional system (Lake Okeechobee, C-43 Reservoir, ASR, etc…) to supplement agricultural and public water supply withdrawals. The model was calibrated for the period of 1991-2000. The model provides basin runoff and irrigation demands to the Northern Everglades Regional Simulation Model (NERSM) for alternative evaluation.

5.7.2.2. The Northern Everglades Regional Simulation Model

5.7.2.2.1. Hydrology component

The Northern Everglades Regional Simulation Model (NERSM) is a basin budget/link node implementation of the Regional Simulation Model (RSM) developed by SFWMD. The NERSM uses a lumped hydrologic approach to model water levels. It assumes that water in each water body is distributed in level pools. Local-scale features within a watershed, e.g. stages at specific gauging stations and flows across specific transects, are not simulated. The model domain captures all of the Northern Everglades, including the Lake Okeechobee Watershed, the Caloosahatchee River Watershed, and the St. Lucie River Watershed. These watersheds have been sub-divided into modeling sub-watersheds as follows:

- Lake Okeechobee Watershed (Upper Kissimmee, Lower Kissimmee, Lake Istokpoga, Fisheating Creek, and Taylor Creek/Nubbin Slough)
- Caloosahatchee River Watershed (East and West Caloosahatchee)
- St. Lucie River Watershed (C-44, C-24, C-23, Ten Mile Creek, North Fork/South Fork/Basins 4,5, and 6)

The period of simulation is 1970-2005, using a 1-day time step. For the St. Lucie River Watershed, basic hydrology, runoff, and supplemental irrigation requirements were obtained from the WaSh (<u>Wa</u>ter<u>sh</u>ed) model. Alternatives were evaluated by comparing model output to pre-established performance measures. The OPTI6 model (described below) provided operation criteria and simulation targets for the Indian River Lagoon-South preferred alternative. Violations in the high discharge criteria (2,000 cubic feet per second (cfs) and 3,000 cfs mean monthly flow) and the salinity envelope criteria are the two main performance measures used to evaluate alternative scenarios.

5.7.2.3. The MIKESHE Hydrologic Model

The Caloosahatchee River Basin Integrated Surface Water-Groundwater Model (MIKESHE) was developed as part of the Caloosahatchee Water Management Plan (SFWMD, 1999) for the Caloosahatchee River Basin. The model is based on the MIKESHE modeling system. The model domain stretches from Lake Okeechobee upstream to the S-79 downstream. The model area encompasses approximately 1,050

mi^2 (2,720 km^2). The model includes subsurface flow in terms of groundwater and unsaturated zone flow, surface water in terms of overland and canal flow, and a fully dynamic coupling between the components of the model. Meteorological data, topographical data, soil physical data, land cover data, vegetation data, hydrogeological data, canal and hydraulic structure data, and irrigation permit data were used to establish the model. The model was calibrated against surface water discharges and groundwater heads in the upper and lower aquifer, respectively, for the period of 1986-1990. Furthermore, the model was validated with data collected from 1994-1996. The Caloosahatchee River Basin MIKESHE model was used as a modeling tool to predict watershed flows discharged to the estuary under various alternative conditions for the Caloosahatchee River (C-43) West Basin Storage Reservoir project (West Reservoir) and the Southwest Florida Feasibility Study (SWFFS).

The Tidal Caloosahatchee Basin Model (SFWMD, 2002) is an application of the MIKESHE code developed in 2002. This model is an integrated, surface water, and groundwater model intended to simulate hydrologic process in the watershed including evaporation, runoff, storm water detention, river hydraulics, stream water management, groundwater withdrawals and recharge, etc. The model was calibrated and validated against measured data in the rivers and aquifers in the period of 1990-2000. Since MIKESHE results were available only for a short simulation period, an empirical, linear reservoir (LinRes) model was developed for the tidal basin to provide flow data over a thirty-year period. The linear reservoir model was constructed by deriving a regression relationship between rainfall and tidal basin runoff results from the MIKESHE, using the same rainfall and PET data (Konyha, 2002). The output from the linear reservoir model is the total daily flow from the tidal basin watershed. The total flow was distributed to 10 segments, based on the ratio derived from the MIKESHE model. The Tidal Caloosahatchee Basin MIKESHE model was applied to the update of the Caloosahatchee MFL. The limitation of the tidal Caloosahatchee River MIKESHE model and the LinRes model is the lack of a water quality module to quantify the pollutant load produced in the watershed.

5.7.2.4. HSPF Model for Caloosahatchee River Basin TMDLs

5.7.2.4.1. Hydrology and Water Quality Components

To provide a technical tool for the development of TMDLs of the tidal Caloosahatchee River, Florida Department of Environmental Protection (FDEP) funded a model development effort for a series of models for the Caloosahatchee River and Watershed (Dynamic Solutions and Camp Dresser & McKee, 2008). The model framework included watershed runoff and pollutant loading using HSPF (Hydrological Simulation Program—Fortran); hydrodynamic transport using EFDC (Environmental Fluid Dynamics Code); and receiving water quality using EFDC/WASP. The HSPF model simulates flow and water quality in the Upper Caloosahatchee River Watershed (C-43 Basin) and the Tidal Caloosahatchee River Watershed (downstream of S-79). The model simulates flow and water quality constituents such as temperature, BOD5, N, P, Chlorophyll-*a*, and DO. The hydrologic component of the HSPF model was calibrated using data from 2001 through

2005 and validated using data from 1997 through 1999. The water quality component of the model was calibrated using the ambient water quality data from 2004 through 2005 and validated using data from 2002 through 2003. The HSPF model provides pollutant load as input to the estuarine hydrodynamic (EFDC) and water quality model (EFDC/WASP).

5.7.3. Estuarine Hydrodynamic and Water Quality Model

5.7.3.1. The CH3D Hydrodynamic/Salinity Model

SFWMD has developed a CH3D hydrodynamic and salinity model of the Caloosahatchee River and Estuary to predict circulation and the distribution of salinity as these variables are influenced by tide, wind and fresh water inflows. The CH3D model predicts the spatial and temporal distribution of salinity in the estuary and provides salinity and velocity outputs for input to ecological and habitat suitability models. More specifically, the model simulates time-dependent circulation in estuaries, lakes, and coastal waters and solves the three-dimensional equations of motion with given computational domain, initial conditions, and boundary conditions. It uses a horizontally boundary-fitted curvilinear grid and a vertical sigma grid, and is suitable for application to surface waters with a complex shoreline and bathymetry. The non-orthogonal grid enables CH3D to accurately represent the complex geometry of a riverine system. The model contains a robust turbulence closure model (Sheng and Chiu, 1986; Sheng and Villaret, 1989), which enables accurate simulation of stratified flows in estuaries and lakes.

The model domain includes the entire estuarine system, including Caloosahatchee River, Charlotte Harbor, Pine Island Sound, San Carlos Bay, Matlacha Pass, Matanzas Pass, Estero Bay, a large offshore region, and all the major tributaries. The fine model grid permits the representation of the numerous islands, including the islands of the Sanibel Causeway and Estero Bay. The original development of CH3D in Charlotte Harbor and adjacent areas began in 1999 for the Charlotte Harbor National Estuary Program. The purpose for the model development was to assess the impact of removing the Sanibel Causeway on water currents (Sheng, 2001). SFWMD extended the model calibration of salinity to the Caloosahatchee River portion using 16-months of time series data (Qiu, 2003). The calibrated model was used during the 2003 update of the Caloosahatchee River MFL to investigate the salinity distribution in the Caloosahatchee River. In 2005, the Caloosahatchee and Estero Bay portions of the model were further calibrated with a three-year period of record (Sheng and Zhang, 2006). The CH3D model also supports the evaluation of various alternative plans arising from the SWFFS.

5.7.3.2. EFDC/WASP Model for Caloosahatchee River Basin TMDLs

5.7.3.2.1. Hydrodynamic/salinity component

The Caloosahatchee EFDC hydrodynamic model is being developed by FDEP in support of establishing TMDLs for the Caloosahatchee River and Estuary. EFDC is a general-purpose modeling package designed to simulate 1D, 2D, or 3D flow, transport, and biogeochemical processes in surface water systems, including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf scale coastal regions. The model domain covers the Caloosahatchee River and Estuary, portions of Matlacha Pass, San Carlos Bay, and the southern tip of Pine island Sound. The upper boundary is at S-79. To resolve the requirement of boundary conditions, a separate coarse-grid model of the near ocean portion of the Gulf of Mexico, extending from Clearwater to Naples, was developed to simulate the effects of meteorological phenomena and tidal interactions between the Caloosahatchee River and its receiving water – the Gulf of Mexico. Four layers were implemented into the EFDC grids to represent temperature and density profiles. The calibration period for the hydrodynamic/salinity component of the EFDC model is from January 1, 2003 to December 31, 2003. The watershed model (HSPF) provided flow input to the hydrodynamic (EFDC) model. Then the output of EFDC was used to drive the water quality model.

5.7.3.2.2. Water quality component

The water quality component of the EFDC model and a WASP7 model are both being development by FDEP to help establish TMDLs for the Caloosahatchee River and Estuary. The water quality component of the EFDC simulates eutrophication processes involving phytoplankton growth, nutrient cycling, and DO dynamics. The EFDC water quality model used water quality data collected in 2003 for calibration and 2004 for validation. The EFDC modeling results were compared with WASP7 model results to evaluate the similarities and differences in the kinetics employed in each model.

5.7.4. Estuarine Ecologic Response Model

5.7.4.1. The Tapegrass Model

Submerged aquatic vegetation (SAV) is frequently identified as an important resource in coastal ecosystems and used as an ecological indicator of condition. A numerical model for tape grass (*Vallisneria. americana)* was developed to integrate both field and laboratory data and to predict the effect of environmental variables on growth, survival, and re-establishment in the upper Caloosahatchee Estuary (SFWMD, 2003; Hunt and Doering, 2005). The density is estimated based on responses to light, salinity and temperature at two sites within the upper estuary. Monthly field monitoring of *V. americana* density and water quality parameters has been conducted at these sites since 1998. The model was calibrated based on measured *V. americana* densities, water temperature, and transparency at each station for the period 1998-2001. Data collected from January 1, 2002 through October 1, 2003 was used for validation and encompassed a period of re-growth following near extirpation by drought conditions in 2001. The model was applied to the update of MFL in 2002 by helping meet management challenges associated with altered quantity of freshwater delivery in a South Florida estuary (SFWMD, 2003).

5.7.4.2. The HSI Models

Habitat Suitability Index (HSI) models for multiple species were developed in the Caloosahatchee Estuary for evaluations of changes in estuarine communities resulting from alternative scenarios of water releases and storage in the Caloosahatchee River Watershed. Species selected for modeling are ecologically, recreationally or economically important and have a well-established linkage to stressors of management interest. The Caloosahatchee Estuary HSI models include three SAV species, *Vallisneria americana*, *Halodule wrightii* and *Thalassia testudinum*, as well as the eastern oyster, *Crassostrea virginica*. Salinity, temperature, depth, substrate, and high flow frequency were chosen as the particular requirements for determining habitat suitability for each species in the estuary. The models calculate habitat suitability monthly, as the weighted geometric mean of the environmental variables identified as important for each model.

5.7.5. Modeling Needs and Recommendations

Although substantial progress has been made in the Caloosahatchee River and Estuary modeling efforts, an overall assessment of the needs of each modeling component is necessary to plan future work with budget-limited resources and to provide the needed technical support for adaptive management and implementation of the CWRPP. The integrated modeling and resource assessment framework is recommended and can be applied at different levels of complexity to provide the information required for sound, science-based management. Such a well-calibrated and validated modeling system can be implemented as an essential tool to quantify the impacts of watershed modification. It can also be used to evaluate restoration alternatives, such as BMP projects, and to assess management targets, such as TMDLs.

The modeling needs described below are based on an examination of both simulations with long time steps that take a short time to run and more comprehensive models with short time steps that take longer to run. On the one hand, there will always be a need to furnish solutions for pressing management needs in a short time. On the other hand, more comprehensive and complex models are required to synthesize knowledge and to fully understand and simulate coastal ecosystems. In both cases, solutions built upon sound and defendable science are needed to sustain peer reviews in scientific and academic arenas. In the future, a comprehensive modeling framework for the Northern Everglades domain (Kissimmee River and Watershed, Lake Okeechobee and Watershed, integrated with St. Lucie and Caloosahatchee Rivers, Estuaries and Watersheds) will be evaluated and developed.

5.7.5.1. Watershed Hydrology and Water Quality Modeling Needs

Effective management that can protect water quality must occur at the watershed-scale. Watershed models provide the necessary links for this purpose, particularly when it comes to understanding how nonpoint sources of pollution interact with point sources, and how these jointly affect the downstream water quality.

Regarding watershed hydrology and water quality simulation, modeling tools are needed that are capable of (1) simulating the hydrologic interaction of the Caloosahatchee River Watershed with other components of the Northern Everglades Program (Lake Okeechobee and St. Lucie River Watersheds), (2) watershed loading simulation, and (3) optimizing operations and sizing of features. Existing tools include the NERSM, MIKESHE model, AFSIRS/WATBAL, and HSPF model. The NERSM model can serve as a regional hydrological model to simulate the hydrologic interactions across the Northern Everglades watersheds, but would require additional refinements and integration with a water quality component and optimization component. The MIKESHE model, AFSIRS/WATBAL, and HSPF model can be used as the sub-regional models to simulate the detailed hydrology of the watershed. These models will need to be further evaluated and refined with additional calibration to better simulate nutrient cycling and DO dynamics in major canals. A longer period of calibration and validation is also needed. Data collected by the monitoring activities described in Chapter 4 can be used for this purpose. A user-friendly graphic user interface (GUI) is also necessary for management of the geo-spatial data, such as land use change and irrigation demands. To manage freshwater discharge by implementing the C-43 West Basin Storage Reservoir, it is critical to have a reliable operation model to meet the salinity envelope target in the estuary.

5.7.5.2. Estuary Hydrodynamic and Water Quality Modeling Needs

One of the major objectives of the CRWQMP is to identify and answer the priority science questions to reduce the uncertainties of the CRWPP. One priority question is how the change in the quantity, quality, timing, and distribution of watershed inflows will improve the water quality condition and aquatic habitats in the estuary. The estuary hydrodynamic, water quality and ecological models, when integrated with the watershed models, will serve as a critical tool to evaluate the many hydrodynamic and water quality issues such as stratification, nutrient cycling, and DO dynamics in response to the implementation of the CRWPP.

Regarding estuary hydrodynamic and water quality simulation, modeling tools are needed that are capable of (1) simulating the impacts induced by the watershed loading; (2) estuary hydrodynamics; (3) estuary water quality processes. Existing tools include SFWMD's Caloosahatchee Estuary CH3D model (CE-CH3D, hydrodynamic component), FDEP's EFDC model (hydrodynamic and water quality component), and FDEP's WASP model. The hydrodynamic component of the CE-CH3D model has been fully calibrated against 5 years of field data (2000 through 2004) that includes both dry years and wet years. It has been successfully applied in several critical initiatives, such as the C-43 West Basin Storage Reservoir PIR and the Southwest Feasibility Study. However, to apply the CE-CH3D model in this area would require additional refinements with groundwater seepage data and sediment transport scheme and integration with a water quality component. The FDEP's EFDC model and WASP7 model for establishing Caloosahatchee River and Estuary TMDLs are being developed and should be available in FY2009. The calibration period for the hydrodynamic/salinity component of the EFDC model is from January 1, 2003 to December 31, 2003. This EFDC model has a much shorter calibration period and was not used in the major SFWMD projects. The water quality component of the EFDC model and the WASP7 model used water quality data collected in 2003 for calibration and 2004 for validation. To simulate the impact in the estuary from watershed loading for adaptive management, the water quality model will need to be updated with newly collected data that includes benthic flux, diurnal DO concentrations, and sediment and turbidity data. Calibration and refinements on nutrient cycling process, stratification, and DO dynamics need to be done when such data are available. The empirical relationships of important water quality processes and the control factors need to be explored further. The simulation period also needs to be extended to cover a longer time period, such as 2000-2008. To develop a better integrated modeling system for the Caloosahatchee River and Estuary, these models will be evaluated and assessed in the future.

5.7.5.3. Estuarine Ecologic Response Modeling Needs

Future efforts in estuarine ecologic response modeling should simulate the habitats for seagrass, oyster, and fish larvae to represent the entire spectrum of the valued ecosystems in the estuary. These VECs may serve as the performance measures for future environmental operation during different climatic and seasonal conditions. To achieve this goal, a set of ecological performance measures representing different habitats for fish larvae, oysters, and seagrass will be needed to direct operation for both the dry season and the wet season. These performance measures will also need to be integrated into an index-type model, along with a Graphical User Interface (GUI) to aid in future applications. Eventually, a community-level ecological response model should be developed to predict ecosystem change with the anticipated improvement in the habitats. A GUI will also need to be developed to provide explicit linkage between management objectives and predicted improvements with restoration actions. Spatial maps and temporal dynamic graphics demonstrate system-wide visual comparisons and enhance effective communications. These GUI tools could be applied to showcase modeling results with maps, time series plots, animation, and movies.

5.7.5.4. Habitat Suitability Index Models

Existing HSI models are static parameter-based models that do not contain dynamic processes. These models provide an overall assessment of whether estuarine conditions are favorable for SAVs or oysters. The HSI models should be incorporated into ArcGIS to portray responses spatially and temporally to facilitate policy decisions. The HSI models were developed principally with literature, expert knowledge, and currently available field data. They are deterministic indices that combine independent variables without explicit consideration of variable interactions or dynamic processes. The models need to be further validated with comprehensive monitoring data. A comprehensive assessment is also necessary to evaluate the model for both long-term and short-term applications. The advantage of HSI models is that they can be developed in the early stages of a project with relatively low demand for data. When validated, HSI models, can be used as a forecasting tools for ecosystem assessment. Such an approach fits well into an adaptive management framework for the evaluation and refinement of alternative plans.

5.7.5.5. The SAV Models

The existing Vallisneria Model for the Caloosahatchee Estuary was developed using Stella® (acronym for Structural Thinking Experiential Learning Laboratory with Animation), an icon-based software package specifically designed for dynamic systems modeling. The model should be converted to a common platform such as a FORTRAN program, with linkages to Microsoft Excel or another user-friendly interface to increase computation efficiency. For broader applications, the SAV model needs to be expanded to include other SAV species such as *Halodule wrightii* and *Thalassia testudinum*. A numeric ecological model will need to be set up for each species and calibrated with field monitoring data. A broad range of tests will also need to be conducted under different salinity, light and water temperature conditions. Additionally, there are no current water quality linkage applications with SAV models, and these links would need to be established.

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APPENDIX F

PLAN OPERATIONS & MAINTENANCE, PERMITTING, AND MONITORING

F1.0 PLAN OPERATIONS, MAINTENANCE, PERMITTING, AND MONITORING

F1.1 Operations & Maintenance

With very few exceptions, the majority of projects features included in the CRWPP are likely to require some level of operation and maintenance (O&M). Consideration of operations and maintenance needs from the outset of planning is important to insuring that the project goals and objectives are achieved in the most efficient, effective, and safe manner. The term "operations and maintenance" collectively refers to the following five major elements:

Operations – ongoing activities required to operate the management measure to achieve the project objectives – includes water control, fuels and materials, monitoring, etc.

Maintenance – ongoing activities required to maintain system in an operable condition – includes machinery maintenance, mowing, inspections, etc.

Repair – periodic repair of machinery or other structural elements as needed to restore complete operability of the management measure – includes machinery repair, filling scour holes, repairing erosion, etc.

Replacement – periodic replacement of project elements that have reached or exceeded their functional life – includes pump replacement, stop-log riser replacement, etc.

Rehabilitation – major rehabilitation of a project component may be required under the following circumstances:

- When the component has exceeded its functional life and continued repair and replacement activities are no longer cost effective,
- When there are substantive changes in conditions at the facility or associated components of the water management system that preclude meeting the project objectives or result in other undesirable impacts, or
- Changes in design or safety standards.

Funding and labor requirements for O&M can vary dramatically, depending on the type of management measure and its physical setting. For example, a wetland restoration element that is composed of a fixed crest weir constructed in an existing stream to flood the wetland during wet conditions might require very little O&M beyond periodic inspections. On the other hand, a wetland restoration project that calls for pumped inflows to an area impounded by levees or berms with a water control structure to manage water levels might require substantial funding and labor resources for O&M.

As a result, O&M requirements cannot be fully determined until a significant level of design has been completed for elements of the Plan.

General O&M requirements for different types of project features are described below. Note that O&M requirements will have to be tailored for each individual facility based on site-specific conditions and project objectives.

F1.1.1 Reservoirs O&M Requirements

Operations – Hydrologic, water quality, and meteorologic data is monitored to guide water control operations. In many cases, water control operations are performed remotely from the SFWMD headquarters. Where remote operational capability does not exist, field personnel perform gate changes and other water control activities based on guidance from SFWMD headquarters. Operational activities are required on an ongoing basis to provide proper inflows, water control in the reservoir, and discharges. This includes operation of pump stations, water control structures, and culverts. Costs include hired labor, fuel, and materials. Inflow pump stations require a particularly high level of operational activities and associated costs. Power costs for pump stations can be a large part of O&M.

Maintenance – The O&M Manual will establish preventative maintenance requirements for machinery at pump stations, water control structures, and culverts. These activities will include inspections, lubrication, cleaning, etc. Regular inspections of levees and channels are required to identify scouring or erosion problems. Periodic mowing of levees is also required.

Repair – Even with proper maintenance, occasional repairs will be necessary. The types of repairs that might be necessary for operation of a reservoir include machinery repair, levee erosion, channel scouring, etc.

Replacement – Pump motors, bearings, stop logs, etc., will require eventual replacement when the frequency and/or the nature of required repairs becomes cost prohibitive or unsafe.

Rehabilitation – Levees and canals will be designed and constructed to be functional indefinitely. Major rehabilitation to levees and canals should only be necessary if there is a significant change in design and/or safety standards, such as changes that occurred following the New Orleans levee failures caused by Hurricane Katrina. The most significant long-term requirements for major rehabilitation will be for the inflow pump stations.

F1.1.2 STAs O&M Requirements

Operations – Water control operations for STAs require careful maintenance of water levels and flows to optimize TP reduction performance. Moreover, STAs are typically composed of multiple cells and/or treatment chains. Each individual STA cell will require control of water levels and flows. Monitoring of hydrologic, water quality, and meteorologic data is performed to guide water control operations. In many cases, water control operations are performed remotely from the SFWMD headquarters. Where remote operational capability does not exist, field personnel perform gate changes and other water control activities based on guidance from SFWMD headquarters. Water control operations will include operation of pump stations, water control structures, and culverts. Costs include hired labor, fuel, and materials. Inflow pump stations require a particularly high level of operational activities and associated costs. Power costs for pump stations can be a large part of O&M.

Maintenance – Relative to reservoirs, the increased infrastructure (levees, canals, water control structures, culverts, etc.) associated with STAs will generally require a greater level of effort for maintenance. The O&M Manual will establish preventative maintenance requirements for machinery at pump stations, water control structures, and culverts. These activities will include inspections, lubrication, cleaning, etc. Regular inspections of levees and channels are required to identify scouring or erosion problems. Periodic mowing of levees is also required. Within the STA cells, some reshaping of the bottom or levee modifications may be necessary after long periods of operation, due to the soil accretion. Soil accretion in the STAs may create non-uniform depths and flows that could reduce TP reduction efficiency. Additionally, soil accretion may require levee modifications to prevent overtopping.

Repair – Even with proper maintenance, occasional repairs will be necessary. The types of repairs that might be necessary for operation of an STA include machinery repair, levee erosion, channel shoaling or scouring, etc.

Replacement – Relative to reservoirs, the increased infrastructure (levees, canals, water control structures, culverts, etc) associated with STAs will generally require a greater level of effort for repairs. Pump motors, bearings, stop logs, etc., will require eventual replacement when the frequency and/or the nature of required repairs becomes cost prohibitive or unsafe.

Rehabilitation – Relative to reservoirs, the increased infrastructure (levees, canals, water control structures, culverts, etc) associated with STAs will generally require a greater level of effort for rehabilitation. Levees and canals will be designed and constructed to be functional indefinitely. Major rehabilitation to levees and canals is unlikely at an STA. The most significant long-term requirement for major rehabilitation will be for the inflow pump stations.

F1.1.3 Wetland Restoration Project O&M Requirements

Operations – In general, wetland restoration projects are designed to be low maintenance, passive systems. A wetland restoration project that consists of simply plugging an existing drainage ditch may require virtually no operational activities beyond periodic inspections. Projects that involve berms or levees to protect adjacent land and downstream control structures will require additional operation activities. Hydrologic data would be collected and used to guide water control operations of the downstream control structure. Periodic inspections of the berms or levees would be required. For wetland restoration projects that include pump stations and conveyance canals, labor, fuel, and materials will be required for operations.

Maintenance – For passive wetland restoration projects, maintenance requirements may be negligible. However, for those projects that contain mechanical components (pumps or control structures) maintenance will be required. Mowing levees would be required.

Repair – For passive wetland restoration projects, repairs would be limited to potentially correcting erosion or scouring problems. For projects that involve mechanical components, such as pumps or control structures, there would be an increased need for repair. Erosion or sedimentation problems may be required.

Replacement – For passive wetland restoration projects, replacement requirements would be negligible. For projects that involve mechanical components, repairs will be necessary – even with proper maintenance.

Rehabilitation – For passive wetland restoration projects, there will be no need for rehabilitation. For projects that involve mechanical components such as pumps or control structures, major rehabilitation will be required.

F1.1.4 O&M Requirements for BMPs

The components of BMPs are quite diverse. Some BMPs are entirely operational in their nature – feeding practices, fertilization, crop rotation, etc. Virtually all BMPs have some element of O&M that is required to insure that the objectives are being met. However, because the number and diversity of BMPs are so great, it is beyond the scope of this document to summarize these BMP O&M requirements.

F1.1.5 O&M Requirements for Alternative Water Storage Facilities

Operations – Operational requirements for these projects will vary as a result of the variation in infrastructure required for each individual project. At one extreme, the operational requirements will be the same as a reservoir. At the other extreme, the project feature may be limited to a sheet pile weir constructed in an existing channel to retain floodwater runoff. In other cases, berms or levees or existing agricultural pump stations may require maintenance. Water control operations would be driven by onsite water elevations so that adverse flood impacts to adjacent areas would be avoided.

Maintenance – Maintenance requirements would vary with the extent of infrastructure involved in each individual project. Normal maintenance activities would involve periodic inspections of levees, ditches, and water control structures. If pumps are used, maintenance would include compliance with the O&M Manual or manufacturer's guidelines.

Repair – In most cases, repairs would be minimal. However, when pump stations are included, repairing mechanical components would be necessary.

Replacement – With the exceptions of pump stations, requirements for replacement should be negligible.

Rehabilitation – With the exception of pump stations, major rehabilitation requirements should be minimal.

F1.2 Permitting

Construction and implementation of the Plan features will require a variety of permits and regulatory approvals. Types of permits and approvals needed are likely to vary with feature type and location.

Obtaining all required federal, state, and local permits for implementation and operation of a project often requires an intensive level of effort. Permitting can result in significant project delays if it is not adequately considered early in project development. However, specific permit requirements and/or issues may not be evident until a substantial level of detail has been developed during planning and design.

The types of permits and level of effort required during the permitting process may vary greatly for similar or identical measures, depending on the physical conditions that exist at the project site and surrounding area. During the PD&E process, continuing consideration will be given to the types of permits required and the potential permitting issues that must be addressed. In this way, the level of effort and time requirements can be factored into the planning and design process to minimize the potential for significant permit-related project delays.

Federal and state permits that are likely to be required for the types of project features contained in the Plan are described below. Local permit requirements will vary from site to site and will have to be addressed on a site-specific basis.

F1.2.1 Federal Permits

Section 404 Dredge and Fill Permit – This permit is required by the Clean Water Act of 1972, as amended, and is administered by the U.S. Army Corps of Engineers. A Section 404 Permit is required prior to discharging dredged or fill material into the waters of the United States. Waters of the United States (33 CFR Part 328) include essentially all surface waters, including all navigable waters and their tributaries, all interstate waters and their tributaries, all impoundments of these waters, all wetlands adjacent to these waters, and certain isolated wetlands.

The term "wetlands" means those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. A number of federal requirements are addressed during the permitting process under Section 404. These include the following:

> **National Environmental Policy Act (NEPA) of 1969 –** This law requires federal agencies to study and consider the environmental impacts of their proposed actions. For actions that do not have any significant impact on the human environment, preparation of an Environmental Assessment (EA) is required. For projects that will have a significant impact, preparation of an Environmental Impact Statement (EIS) is required.
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> **Coastal Zone Management Act –** The federal consistency requirement of the CZMA (Section 307) requires that federal actions (including permit approvals) that are likely to affect any land or water in the coastal zone (within 3 miles landward or seaward of the coast) must be consistent with the state's coastal management program.
>
> **Endangered Species Act –** The Endangered Species Act (ESA) requires that permit applicants take no action that might adversely affect certain listed species. In addition, species that are under stress may become listed species if adverse impacts continue to their population or habitat. To help ensure that permitted projects do not contribute to further endangerment of a species, it may be required to modify or condition a permit where a species of concern is present.
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> **Magnuson-Stevens Fishery Management Act and Essential Fish Habitat –** This act requires that actions minimize, to the extent practicable, the adverse effects of fishing on

essential fish habitat, and identify other measures to promote the conservation and enhancement of essential fish habitat. Coordination with the National Marine Fisheries Service (NMFS) is required.

National Historic Act – If the proposed activity would involve any property listed or eligible for listing in the National Register of Historic Places, coordination with the State Historic Preservation Officer will be required to determine the required course of action.

Section 401 Certification – Issuance of a 404 Permit requires that water quality certification (Section 401 of the Clean Water Act) be obtained by the applicant or waived by the regulatory agency. In Florida, authority for water quality certification has been delegated to the Florida Department of Environmental Protection (FDEP).

Section 10 Permit – This permit is required by the Rivers and Harbors Act of 1899 and is administered by the U.S. Army Corps of Engineers. Approval of a Section 10 Permit is required prior to any work in, over, or under navigable waters of the United States, or which affects the course, location, condition or capacity of such waters. Processing Section 10 Permit applications is generally subject to the same procedures and requirements as the Section 404 Permits. Applications under Sections 10 and 404 are processed together. For the purpose of a Section 10 permit, navigable waters (33 CFR Part 329) are defined as waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation.

Corps of Engineers Consent to Easement Permit – A Consent to Easement Permit will be required for any action that requires access to, or modification of, Corps of Engineers' right of way for works of the Central and Southern Florida (C&SF) Project.

US Coast Guard Approvals – In general, if a proposed project impacts a bridge or a navigation aide in a navigable waterway of the U.S., then Coast Guard approval will be required.

Federal Aviation Administration Guidelines – Construction of Plan project features in the vicinity of public airports would potentially require compliance with two FAA guidelines:

- Unsafe wildlife attractants near public airports, and
- Obstructions to navigable airspace.

Construction of facilities that might attract wildlife that would create unsafe conditions for landings and take-offs would be performed only beyond specified distances from the airport boundary. The specified distances vary based on the airport capacity. To ensure compliance with this guideline, management measure sites closer than 10,000 ft from any airport were eliminated from consideration. FAA notification of an obstruction to navigable airspace is required by law for construction that would penetrate an imaginary plane that rises 1 foot vertically for every 100 ft of horizontal distance from the runway.

F1.2.2 State Permits

Environmental Resource Permits – An Environmental Resource Permit (ERP) is required before beginning any construction activity that would affect wetlands, alter surface water flows, or contribute to water pollution. The permitting program is authorized by Part IV of Chapter 373, F.S. The ERP process is administered by the SFWMD. However, for an action proposed to be implemented by SFWMD, FDEP administers the permitting process. Exemptions from the requirement to obtain ERP permits are authorized for implementation of many agricultural BMPs. Environmental Resource Permits are recognized by the U.S. Army Corps of Engineers as water quality certification for Section 404 Permits. A joint ERP and 404 permit application is used, and the state and federal review processes proceed in parallel.

The Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) was enacted by the Florida legislature (Chapter 373.1502 F.S.) for the purpose of providing efficient and effective permitting of CERP project components. CERPRA permits are in lieu of all other permits required in Chapters 373 and 403, except for permits that are under any delegated authority. For elements of the Plan that are included in CERP, the CERPRA permit would take the place of the ERP.

National Pollution Discharge Elimination System Stormwater Permitting Program – Federal law prohibits the point source discharge of pollutants to the waters of the United States without a National Pollution Discharge Elimination System (NPDES) Permit. The U.S. Environmental Protection Agency (USEPA) has delegated authority to FDEP to implement the NPDES stormwater permitting program in the State of Florida.

- **Stormwater Pollution Protection Plan –** This program regulates point source discharges of stormwater runoff from large (> 5 ac) and small (between 1 and 5 ac) construction sites. The applicant must implement appropriate pollution prevention techniques to minimize erosion and sedimentation and properly manage stormwater.

Title V Air Quality Permit – These permits are required by the Clean Air Act. Administration has been delegated by the USEPA to FDEP. Permits are required for construction and operation. The extent of required permitting varies with the magnitude of the impact of the proposed action.

Dewatering Water Use Permit – SFWMD manages the water use permitting process within its boundaries under authority of Chapter 373, State Statutes, 40E-20 F.A.C. A water use permit allows a user to withdraw a specified amount of water, either from the ground, a canal, a lake, or a river. The water can be used for a public water supply; to irrigate crops, nursery plants or golf courses; or for industrial processes. Short-term dewatering required during the construction of elements of the Plan would also require a water use permit. For features being constructed by the SFWMD, the permit application would be processed by FDEP.

F1.2.3 Permitting Issues

Key permitting issues likely to be encountered during permitting of STA and Reservoir Plan features are described in **Table 1.2-1** below. Many of the other Plan features may encounter similar permitting issues.

Table 1.2-1 Key Permitting Issues

Land Requirements SFWMD needs to demonstrate ownership of lands prior to obtaining federal and state permits.	Lands will have to be purchased prior to applying for 404 and 373.1502 permits.
Existing Permits Projects that are currently permitted within the proposed project footprints will have to be researched. Such existing permitting requirements, if any, may impact design criteria.	Research existing permits for within proposed project footprints and if applicable, identify owners/operators of permitted projects.
Federally Listed Threatened & Endangered (T&E) Species	Many federally listed plant and animal species exist in the Caloosahatchee River Watershed and Estuary. Information on occurrence of T&E species within proposed project footprints and specific project affected regions will have to be determined. This information will help determine species that will be impacted, mitigation strategies, construction schedules, design criteria, management protocols, etc. Biological surveys will have to be conducted at all sites proposed for locating Plan features that are not already permitted.
State Listed T&E Species	Information on occurrence of T&E species within proposed project footprints will have to be determined. This information will help determine species that will be impacted, mitigation strategies, construction schedules, design criteria, management protocols, etc. Biological surveys will have to be conducted at all sites proposed for locating Plan features that are not already permitted.
Water Resources	Proposed projects that directly impact the C-43 Reservoir and the Caloosahatchee River may require U.S. Coast Guard navigation permit in accordance with ***23 CFR 650, Subpart H.***

Table 1.2-1 continued Key Permitting Issues

Transportation and Other Infrastructures Coordination with agencies such as FDOT, FP&L, airports, cell towers, railroad crossings, etc. may be required.	Determine likely impact of proposed project features on existing transportation and other infrastructure. This information will be needed for design criteria, easement access, right-of-ways, etc.
Archaeological/Historical Resources Numerous pre-Columbian and post-Columbian archaeological sites, as well as a large number of historic structures and districts, have been recorded at various locations in the Caloosahatchee River Watershed.	Cultural resource surveys will have to be conducted within all proposed project feature footprints. If such sites are present, it may impact design and probably also require monitoring during construction.
Wetlands/Uplands Presence of jurisdictional wetlands (JD) within proposed project footprints will have to be addressed.	Extent of JD within proposed project footprints will have to be determined. This information is needed to determine federal and state JD impacts. UMAM analysis will need to be conducted to evaluate existing functional values and determine compensatory mitigation for these impacts.
Contamination Presence of contaminants within project footprints will have to be determined and appropriately addressed.	Phase 1 assessment will be required for all proposed project footprints. This information is needed to determine potential contamination that may require corrective actions/ remediation; and, their impacts to endangered species such as the snail kite.
Geotechnical Information This information will help in understanding the soil composition within the project footprints (i.e. if soils would need to dry out prior to use for construction, if soil materials can be used or if they need to be hauled offsite, etc.) and design of the various features; determine blasting protocols for endangered species, road traffic, and safety protocols.	Soil profiles for seepage, embankment materials, ability to retain water, etc. will have to be developed.
Pump Type Benefits of diesel vs. electric pumps will have to be evaluated.	If a diesel pump is selected, and depending on its size, a Title V Air Permit may be required.
Water Quality	Effluent discharge will have to meet water quality standards and avoid impacts to downstream water bodies and ecological health of the natural system.

F.1.3 Monitoring

Monitoring is required to determine if individual project features within the plan are performing as intended. A comprehensive monitoring and information system will be utilized to provide the data necessary to measure the performance and effectiveness of planned projects in meeting restoration goals and objectives of the subject plan. SFWMD will utilize the existing water quality monitoring information, in addition to monitoring proposed in the Caloosahatchee River Watershed Research and Water Quality Monitoring Plan. This monitoring will provide project specific measurements needed to document the effectiveness of nutrient control efforts in meeting Caloosahatchee River Watershed TMDLs, once established, and to assure future compliance.

Monitoring requirements for individual regional projects (STA, reservoirs) are established during the permitting process to ensure that there is a water quality improvement as a result of the facility. Therefore, specific monitoring requirements (parameters, frequency, and locations) for regional Level 1 and 2 features have already been permitted and the information is available. Water quality information is not available for local Level 1 and 2 projects (stormwater retrofits, Ag and urban BMPs and permitted ERP projects) as a presumption of compliance is given based on implementation of water quality and quantity BMPs or facilities. No information is currently available for water quality monitoring associated with Level 3, 4, and 5 features. However, since the two primary objectives of the Plan are storage and water quality improvements, it can be expected that performance of all structural and non-structural project features included in the Plan will have to be monitored for flow and phosphorus and nitrogen load reductions. Project-level assessment will also focus on estimating the performances of both regional projects (i.e. STAs) and local projects (i.e. stormwater retrofits) located throughout the Caloosahatchee River Watershed. Results of the project-level assessment will provide important water quality reduction information including the assessment of the size of the sub-watershed vs. the size of the treatment facility, residence time/pollution removal efficiencies and will assist in evaluating specific nutrient reductions from different types of treatment systems. The overall temporal performance (life cycle) of these facilities over time will also be estimated through this effort. This information will ultimately be used in the adaptive management process to improve the overall performance of treatment facilities of various sizes (i.e. regional and local scale). In addition, safety monitoring will be required for features such as reservoirs and STAs.

To ensure the overall efficiencies of implemented BMPs, periodic inspections and monitoring will need to be conducted to determine if expected BMP performances are achieved. The Plan also recognizes and recommends a SFWMD-sponsored source control monitoring program, which is under development. At the sub-watershed level, monitoring activities associated with this new program will assess the collective success of pollutant source control BMPs, compliance with pollution reduction targets, and the need for additional BMPs or optimization of existing BMPs. At the local level, it will identify priority areas of water quality concern such as those with elevated non-point source loading (i.e. hot spots) and provide data to enhance performance of downstream treatment facilities.

Known monitoring requirements for the more common types of features included in the Plan are described below:

Reservoirs – Reservoirs that have been previously permitted in South Florida are required to monitor some or all of the following parameters: water level, discharge through spillways and outlet works, DO, nutrients, rainfall, water quality, algae blooms and vegetation changes, sediment in reservoir, downstream sediment, and concrete safety (horizontal alignment, vertical deflection, variations in foundation). The majority of the monitoring is to be conducted at locations within the reservoir and at the discharge point. Frequency of monitoring varies depending upon the parameter.

STAs – Water quality monitoring permitting required at recently permitted STAs includes parameters such as total phosphorus, mercury (total and methyl), vegetation, temperature, specific conductance, DO, pH, total nitrogen, and sulfates. Monitoring is typically conducted at inflow and outflow locations; some internal stations may also be monitored to provide data for performance optimization. Monitoring is generally conducted weekly or bi-weekly.

APPENDIX G

POTENTIAL FUNDING SOURCES

Potential Funding Sources

Program	Purpose
FEDERAL	
U.S. Army Corps of Engineers	
Comprehensive Everglades Restoration Plan	CERP projects are eligible for 50:50 cost sharing per WRDA, 2000.
Small Navigation Projects	To provide the most practicable and economic means of fulfilling the needs of general navigation, through projects not specifically authorized by Congress.
U.S. Department of Interior - federal land acquisition programs	
Land and Water Conservation Fund – Federal Land Acquisition	Acquisition for various federal agencies [U.S. Fish and Wildlife Service (USFWS), National Park Service, Bureau of Land Management, and Forest Service].
Migratory Bird Conservation Fund (USFWS)	Receipts in this account allow USFWS to acquire important migratory breeding areas, migration resting places, and wintering areas. Areas acquired become part of the refuge system.
Grant programs strictly for land acquisition by non-federal entities	
Cooperative Endangered Species Conservation Fund Act Program (USFWS)	To provide grants to states for Recovery Land Acquisition. (There is additional funding for Habitat Conservation Fund Land Acquisition Grants.)
Grant programs that may be used for land acquisition and other purposes by non-federal agencies	
State and Tribal Wildlife Grants (USFWS)	To help states and tribes implement comprehensive wildlife conservation plans and activities.
Land and Water Conservation Fund State Grant Program (National Park Service)	To provide matching grants to states and local governments for the acquisition and development of public outdoor recreation areas and facilities.
Sport Fish Restoration – Grants to States (USFWS)	To provide funding for fisheries recreation and conservation efforts in the United States. Non-competitive apportionment-based program.
Federal Aid and Wildlife Restoration – Grants to States	This program apportions funds to states and territories for use in restoring and protecting wildlife.
Grant programs that may be used for land acquisition and other purposes by federal and non-federal agencies	
North American Wetlands Conservation Act (USFWS)	May fund the acquisition of habitat for waterfowl and migrating birds in support of the North American Waterfowl Management Plan.
Sport Fish Restoration - Coastal Wetlands Grants (USFWS)	To acquire, restore and enhance wetlands in coastal states (FDEP/Nature Conservancy used this program for a project in Hendry Creek to buffer Estero Bay).
Federal Aid Wetlands Conservation (USFWS)	May fund the acquisition of habitat for waterfowl and migrating birds in support of the North American Waterfowl Management Plan.
Other partnership programs supporting non-land acquisition conservation activities	
Private Stewardship Grants Program (USFWS)	To provide grants for on-the-ground conservation projects on private lands benefiting federally listed, threatened, endangered species or other at-risk species.
Landowner Incentive Program (USFWS)	Establish or supplement existing landowner incentive programs that provide technical or financial assistance, including habitat protection and restoration, to private landowners to benefit species at risk.

Program	**Purpose**
Partners for Fish and Wildlife Program (Fish and Wildlife Service)	To provide assistance to landowners to voluntarily restore wetlands, streams, grasslands, woodlands, and other important habitat that support fish and wildlife.
Coastal Program	To work with coastal communities and other partners to focus and leverage resources on high-priority coastal habitat issues by providing important technical and financial support to our existing and new partners, including the Everglades/South Florida Ecosystem.
National Park Service Challenge Cost Share	To increase the participation of neighboring communities and qualified partners in preserving and improving the cultural, natural, and recreational resources for which the National Park Service is responsible.
USFWS Challenge Cost Share	Foster innovative and creative cooperative efforts to restore natural resources and establish or expand wildlife habitat, with an emphasis on federal lands and resources.
Bureau of Land Management Challenge Cost Share	To leverage federal dollars with private and state funding for conservation efforts, benefiting resources on Bureau of Land Management administered public lands. The program solicits partnerships and partnership funding through a variety of resource management programs, including fisheries, wildlife, threatened and endangered species, cultural resources and recreation.
U.S. Department of Transportation	
National Scenic Byways Program	To provide grants in support of eligible projects, including protection of natural resources in an area adjacent to a scenic byway.
Federal Lands Highway Program	To provide funds for eligible projects to include acquisition of necessary scenic easements and scenic or historic sites.
High Priority Projects	To support member priority projects.
Transportation Enhancements	To provide reimbursement for 12 eligible activities that enhance the transportation experience, including acquisition of scenic easements and sites.
U.S. Department of Agriculture	
Conservation Reserve Enhancement Program (CREP)	To remove marginal agricultural lands from production and establish conservation practices to improve water quality and create wildlife habitat.
Conservation Innovation Grant	Conservation Innovation Grant (CIG) is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program funds are used to award competitive grants to non-federal governmental or non-governmental organizations, Tribes, or individuals. CIG enables Natural Resources Conservation Service (NRCS) to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with federal, state, and local regulations. NRCS administers CIG.
Forest Legacy Program	To help states acquire fees or easements for perpetual forest preservation.
Wetlands Reserve Program	To assist landowners in restoring wetlands and wetland functions.
Farm and Ranch Lands Protection Program (FRLPP)	To purchase easements on farm and ranch lands that will remain in agricultural production.

Program	**Purpose**
Wildlife Habitat Incentives Program (WHIP)	To encourage the creation of high quality wildlife habitats that support wildlife populations on wetland, riparian, upland and aquatic habitat on agricultural lands.
Federal Agriculture Improvement and Reform Act of 1996 (Farm Bill) Section 390	To provide $200 million to the Secretary of the Interior to conduct restoration activities in the Everglades ecosystem in South Florida, including the acquisition of real property.
National Oceanic and Atmospheric Administration	
Coastal and Estuarine Land Conservation Program	To provide matching funds to states to acquire land or easements to protect or restore coastal areas that have considerable conservation, recreation, ecological, or economic value and are threatened by conversion from their natural state to other uses or could be managed or restored to effectively conserve, enhance or restore ecological function.
OTHER	
Agricultural Water Enhancement Program (AWEP-formally RWEP)	Allows cooperative agreements between Secretary of Agriculture and partners on AWEP activities. Broadens list of eligible activities to include practices to mitigate the effects of drought, including the building of on-farm ponds and reservoirs. Removes priority consideration for projects that include multiple partners and that are most likely to improve the water quantity or quality issue of concern. Does not explicitly include non-governmental organizations (NGOs) as eligible partners. Allows monitoring, but does not require it to be a component of an AWEP project; no priority areas.
STATE	
Florida Forever Program/Board of Trustees (Department of Environmental Protection)	To fund the acquisition and restoration of environmentally sensitive lands and lands to protect water resource development and supply. To increase public access, public lands management and maintenance, and protection of land by acquisition of conservation easements. Florida Forever is the umbrella funding source for the state programs listed below.
Florida Forever Program Water Management Districts (Department of Environmental Protection)	To fund the acquisition of lands and capital project expenditures necessary to implement the water management districts' priority lists; $25 million of the annual Florida Forever allocation to the SFWMD is to be used exclusively for the acquisition of land needed to implement the CERP.
Florida Communities Trust (Department of Community Affairs)	To fund the state's land acquisition grant program for local governments and non-profits to acquire lands that promote outdoor recreation and natural resource protection needs identified in local government comprehensive plans.
Florida Forever Program In-holdings and Additions Programs (Department of Environmental Protection)	To acquire in-holdings and additions to existing conservation lands.
Florida Greenways and Trails (Department of Environmental Protection)	To fund the statewide initiative to create a system of greenways and trails connecting communities and conservation areas.
Florida Recreation Development Assistance Program (Department of Environmental Protection)	To fund the acquisition or development of land for public outdoor recreation and the acquisition of in-holdings and additions for state parks.
Save Our Everglades Trust Fund (Department of Environmental Protection)	To implement the CERP.

Program	Purpose
Florida's Rural Land Stewardship Program (Department of Community Affairs)	The intent of the program is to direct development of rural lands to preserve agriculture and protect the environment. Local governments designate stewardship areas within their Comprehensive Plans and credits are allocated to individual parcels, based on environmental and other values. The credits are recorded as a covenant or restrictive easement.
Florida Coastal Management Program (Department of Environmental Protection)	To implement 23 statutes that protect and enhance the state's natural, cultural and economic coastal resources, and to coordinate local, state and federal agency activities using existing laws to ensure that Florida's coast is as valuable to future generations as it is today.
Matching Aid to Restore States' Habitat Program (Florida Fish and Wildlife Conservation Commission)	Provides funding to acquire and enhance habitat for waterfowl.
Save Our Rivers (SFWMD)	Enables water management districts to acquire lands necessary for water management, water supply, and the conservation and protection of water resources.
TMDL Water Quality Restoration Grants (FDEP)	The Department receives documentary stamp funding for the implementation of projects (primarily stormwater retrofitting projects undertaken by local governments) to reduce urban nonpoint source pollution discharged to impaired waters. These funds are restricted to projects that reduce pollutant loadings to water bodies on the state's verified list of impaired waters or to water bodies with a FDEP proposed or adopted TMDL.
Florida Section 319 Grant Work Plans and Project Summaries (FDEP)	The Nonpoint Source Management Section administers grant money it receives from EPA through Section 319(h) of the Federal Clean Water Act. These grant funds can be used to implement projects or programs that will help to reduce nonpoint sources of pollution. Projects or programs must be conducted within the state's NPS priority watersheds, which are the state's SWIM watersheds and National Estuary Program waters. All projects must include at least a 40% nonfederal match.
NON-GOVERNMENTAL ORGANIZATIONS	
Green Horizon Land Trust, Inc.	To preserve environmentally valuable or sensitive lands and open space areas in and around the Central Florida Ridge for the benefit of the general public, and to educate the public as to the importance of such lands and their preservation.
National Fish and Wildlife Foundation	To award challenge grants that address priority actions promoting fish and wildlife conservation and the habitats on which they depend, work proactively to involve other conservation and community interests, leverage available funding, and evaluate project outcomes.
The Conservation Fund	To forge partnerships to preserve our nation's outdoor heritage, American's legacy of wildlife habitat, working landscapes and community open space.
The Nature Conservancy (TNC)	To preserve plants, animals and natural communities representing the diversity of life on earth. TNC works to increase public funding at the local, state and federal level and works with landowners to craft innovative land protection projects.
Trust for Public Lands (TPL)	To help agencies and communities create a vision for conservation, raise funds for conservation and complete conservation real estate transactions. TPL raises public, as well as private, funds and packages projects to funders and agencies.

Program	Purpose
Bureau of Land Management Challenge Cost Share	To leverage federal dollars with private and state funding for conservation efforts, benefiting resources on Bureau of Land Management administered public lands. The program solicits partnerships and partnership funding through a variety of resource management programs, including fisheries, wildlife, threatened and endangered species, cultural resources and recreation.

APPENDIX H

AGENCY AND PUBLIC COMMENTS AND RESPONSES

AGENCY AND PUBLIC COMMENTS

CHARLOTTE HARBOR NATIONAL ESTUARY PROGRAM
1926 Victoria Avenue, Fort Myers, Florida 33901
239/338-2556, Fax 239/338-2560, www.chnep.org

October 30, 2008

Ms. Carol Wehle, Executive Director
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Re: Caloosahatchee River Watershed Protection Plan Review

Dear Ms. Wehle:

The Charlotte Harbor National Estuary Program (CHNEP) has reviewed the Caloosahatchee River Watershed Protection Plan, October 2008 Draft (CRWPP). CHNEP commends the South Florida Water Management District and its partners for preparing this important plan that is critical to the long term restoration and sustainability of the Caloosahatchee River estuary. CRWPP provides an excellent scientific context for water quality, hydrologic, habitat, and stewardship issues within the Caloosahatchee basin. We commend the South Florida Water Management District on meeting the challenging schedule outlined by the Florida legislature.

CHNEP is a partnership program, created by Section 320 of the Federal Clean Water Act, to protect and preserve the Charlotte Harbor estuary, recognized as an estuary of national significance. The tidal Caloosahatchee is part of the CHNEP program area. Implementation of CRWPP will assist CHNEP in implementing its *Comprehensive Conservation and Management Plan* (CCMP) as provided for in section 320 of the Federal Clean Water Act..

Development and implementation of the CRWPP is consistent with many of our CCMP quantifiable objectives relating to water quality, hydrology and fish and wildlife habit, including:

- **WQ-1:** Maintain or improve water quality from year 2000 levels. By 2011, bring all impaired water bodies into a watershed management program….;
- **HA-1:** By 2015, identify, establish and maintain a more natural seasonal variation (annual hydrograph in the freshwater flows for the Caloosahatchee R;
- **HA-3:** By 2020, enhance and improve to more natural hydrologic conditions water bodies affected by artificially created structures throughout the Charlotte Harbor NEP study area, including Franklin Lock (S-79) in Lee County…:
- **HA-4:** By 2010, for each watershed, identify the linkages between local, water management district, state and federal government development permitting and capital programs affecting water storage, flood control and water quality….;
- **FW-1:** Meet the stated objectives for the target extent, location and quality of the following habitats in the Charlotte Harbor NEP study area: native submerged aquatic

vegetation should be maintained and restored at a total extent and quality no less than caused by natural variation…

Therefore, CHNEP supports the primary goals of the CRWPP to reduce nutrient loads from the Caloosahatchee River watershed and restore more natural salinity regimes in the river and its estuary. In addition, the plan appears to be technically sound and based on best currently available data and methodology.

We reviewed the CRWPP in relationship to our CCMP quantifiable objectives and suggest the following additional information be incorporated to enhance implementation of the plan:

- **Partner Management and Monitoring:** Include management and monitoring activities initiate by local governments, the Charlotte Harbor NEP and the River of Grass Initiative. **CHNEP - 1**
- **Economic Impacts:** Include economic and ecotourism impacts in Table 1-1 of Problems, Objectives and Constraints. **CHNEP - 2**
- **Reservoirs:** Include planned reservoirs and modifications associated with the River of Grass Initiative in calculations of water storage needs. **CHNEP - 3**
- **Impaired Waters:** Include the complete list of impaired waters and parameters in Chapter 5, specifically Table 5-2, including fecal coliform bacteria impairments. **CHNEP - 4**
- **Base Conditions:** Define River Watershed Protection Plan Base Conditions more thoroughly throughout the plan, clearly explaining which restoration projects are included in the baseline. **CHNEP - 5**
- **Sediment Nutrient Loadings:** Include nutrient loadings from sediment re-suspension in modeled loading and reduction calculations, as well as monitoring programs. **CHNEP - 6**
- **Freshwater Inflow from Wastewater Treatment Plants:** Explain how the percent of freshwater inflow originating from wastewater treatment facilities was calculated, in light of the increasing use of reclaimed water. **CHNEP - 7**
- **Monitoring Requirements:** Include a requirement for long term monitoring of water quality (including BOD_5), flows, submerged aquatic vegetation, and Fisheries Independent Monitoring (through the Florida Fish and Wildlife Commission) within the Caloosahatchee and its tributaries. **CHNEP - 8**
- **Lake Okeechobee Impacts:** Include Lake Okeechobee in flow, salinity and nutrient regime calculations. **CHNEP - 9**
- **Modeling Assumptions:** Include assumptions and selected values used for modeling low flows, nitrogen and phosphorus concentrations, land use proportioned "event mean concentrations", and effects of nutrient reduction methods, as well as minimum data requirements used to allow modeling spatial and temporally conditions. **CHNEP - 10**
- **Conservation and Restoration:** Include conservation and restoration activities within management actions, especially relating to modifications to Environmental Resource Permitting. **CHNEP - 11**
- **Low Flow Assumptions:** Include definition, references and explanation of how low flow adverse impact thresholds were determined. **CHNEP - 12**
- **Implementation Strategy:** Include implementation strategy with projects, BMPs, schedules, lead partners, potential funding sources, potential impediments and recognition for local projects. Specifically add lead agency and time period to Table 6.4-6. **CHNEP - 13**

If we can be of further assistance, or if you have any questions, please contact me at the Charlotte Harbor National Estuary Program office a (239) 338-2556 x 235 or via e-mail at lbeever@swfrpc.org.

Sincerely,

Lisa B. Beever, PhD, AICP
Director
Charlotte Harbor National Estuary Program

cc: Colonel Paul L. Grosskruger, District Engineer
Jacksonville District Corps of Engineers
U.S. Department of the Army
701 San Marco Blvd
Jacksonville FL 32207-8175

The Nature Conservancy

Protecting nature. Preserving life.

October 28, 2008 – hand delivery

South Florida Water Management District
c/o Pinar Balci, MS 7640
3301 Gun Club Road
West Palm Beach, FL 33406

RE: Caloosahatchee River Watershed Protection Plan

Ladies and Gentlemen:

The Florida Chapter of The Nature Conservancy respectfully suggests modification of Potential Management Measure CRE-LO 91 found on pages B-30 and 31 of the Appendices.

TNC-1

The suggested modification is attached. Please note that with the exception of **Location/Size/Capacity,** this revision is identical to Potential Management Measure SLE 56 proposed in the St. Lucie River Watershed Protection Plan dealing with the same subject matter.

CRE-LO 91 was taken verbatim from the Lake Okeechobee Watershed Technical Plan. The management measure was time and place specific for the Lake Okeechobee plan and, as such, the statements made in that measure do not apply to the Caloosahatchee. SLE 56 and the modified management measure attached are more generally worded to allow broad partnerships and application of both the Wetlands Reserve Program (WRP) and the Farm and Ranchlands Protection Program (now called Farmland Protection Program in the new Farm Bill). The easement acquisition and wetland restoration of WRP are self evident benefits to the Caloosahatchee Watershed and the objectives of the Protection Plan.

Accordingly, we suggest replacing CRE-LO 91 with the attached amended management measure, or a substantial equivalent, along with the appropriate revision to the Management Measure Description on page B-ii.

Sincerely,

John C. Winfree
Senior Field Representative

• 1501 Corporate Drive • Suite 210 • Boynton Beach • Florida • 33426
Phone (561) 732-6550 • Fax (561) 732-6680

Northern Everglades -Potential Management Measure

Project Feature/Activity: Farm and Ranchland Partnerships

Level: 4

General Description/Background: There are two USDA Natural Resources Conservation Service (NRCS) programs that help farmers and ranchers keep their land in agriculture: the Farm and Ranchlands Protection Program (FRPP) and the Wetlands Reserve Program (WRP). Both programs provide funds to purchase conservation easements. The proposal is that the NRCS, the District, local agricultural landowners, and other partners enter into agreements to contribute funding and resources toward a long-term partnership.

Purpose: The partnership would acquire easements on private lands to remain in agriculture and provide water quality and storage benefits in support of the Northern Everglades initiative.

Location/Size/Capacity: Caloosahatchee River Watershed

Initiative Status: FRPP and WRP are established programs and landowners are waiting to participate pending federal appropriations.

Cost: The proposal is that the NRCS, the District, and local agricultural landowners enter into agreements to contribute funding and resources toward a long-term partnership. The partnership would leverage existing federal and state funding.

Estimate of Water Quality Benefits

- Minimum: Unknown
- Maximun: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions: NA

Estimate of Water Quantity Benefits

- Minimum: Unknown
- Maximum: Unknown
- Most Likely: Unknown
- Level of Certainty: Unknown
- Assumptions:

Screening Criteria

- Proof of Concept: NA
- Other Impacts: NA

Contact: SFWMD

Final Water Quality Method and Summary: Undetermined
Final Water Quantity Method and Summary: Undetermined

Method: Water quality and quantity benefits are anticipated to occur as a result of this project; however, the magnitude of these benefits was not determined due to the nature of the project.

October 24, 2008

Ms. Carol Wehle
Executive Director
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

Re: Comments Regarding the Caloosahatchee River Watershed Protection Plan, October 2008 Draft

Dear Ms. Wehle:

It is with great pride that Lee County ("County") submits these comments concerning the Caloosahatchee River Watershed Protection Plan ("CRWPP") into the record. For over 2 years, the County has worked tirelessly, in concert with the South Florida Water Management District ("SFWMD"), to draft and promote the 2007 Northern Everglades and Estuaries Protection Act ("NEEPA"). A cornerstone of this legislation is the requirement for development of the CRWPP. Under NEEPA, Lee County is explicitly recognized as a coordinating government as it relates to the CRWPP. It is without question that the Caloosahatchee River and Estuary serve as the centerpiece of the County's precious natural resources.

After extensive review, and participation in the development of the CRWPP, the County supports the CRWPP. However, the County hereby requests that the SFWMD address the following comments before finalizing the CRWPP.[1] Our specific comments on the CRWPP are attached as Appendix "A".

Introduction

The CRWPP has three major components: Construction, Pollution Control, and Research and Water Quality Monitoring. Construction includes structural and non-structural options. Pollution Control is tied in large part to the pending Total Maximum Daily Load ("TMDL")

[1]The CRWPP is required by the NEEPA, Section 373.4595(4), F.S. It is part of a greater planning effort involving the tributaries of Lake Okeechobee, its two discharge points at the Caloosahatchee River and St Lucie Canal, and the river basins of the Caloosahatchee and St Lucie. The CRWPP is a collaborative effort, but the designated entity to produce the CRWPP for the Legislature is the SFWMD (Section 373.4595(4)(a), F.S.).

process. Research and Water Quality Monitoring aspects of the CRWPP draw upon the work already done, and acknowledges the "eastern river basins" need more monitoring.

Several alternatives were evaluated. The preferred alternative (Alternative 4), upon which the CRWPP is based and with which we concur, depicts the need for 400,000 acre-feet of water storage[2], proposes a reduction of approximately 40% in nitrogen and phosphorus discharges, and has an expected total Phase I cost of up to $971 million for construction, $813 million in water quality improvements and an additional $5 million in monitoring

General Comments

The County supports the key objectives of the CRWPP which are (1) reduce nutrient loads from Lake Okeechobee and the surrounding watershed and (2) reduce the frequency and duration of undesirable salinity ranges while meeting other water related needs of the region such as water supply and flood protection. To effectively accomplish these objectives, the following issues must be fully addressed:

I. Land Acquisition

The SFWMD's **"River of Grass" Initiative** presents a unique opportunity to acquire strategically important lands within the Caloosahatchee Watershed**.** As a part of the River of Grass Initiative, lands within the Disston Conservancy District, lands in and around Lake Hicpochee (the headwaters of the Caloosahatchee River), C-139 Basin, and the S-4 Basin should be targeted for water storage and treatment projects because of their strategic location. The County recognizes that the SFWMD has begun this evaluation process, but ongoing coordination between the River of Grass Initiative and the CRWPP is critical to the success of both efforts.

LC - 1

II. Water Quality Monitoring Program

To establish a meaningful body of data upon which TMDLs, or other pollution load reduction goals, can be established, it is essential that a comprehensive water quality monitoring network be in place within the Caloosahatchee River Watershed. The current state of affairs includes a patchwork of monitoring programs implemented by a multitude of agencies including the SFWMD, the Department of Environmental Protection, U.S. Geological Survey, the U.S. Army Corps of Engineers, Lee County, and other local governments. A more integrated and watershed-based approach is needed. The CRWPP is certainly making strides in the right direction, but more coordination is needed.

LC - 2

III. Environmental Resource Permitting Regulations

The SFWMD is empowered by law to develop basin-specific permitting criteria based upon the unique attributes of a particular basin or watershed. The Caloosahatchee Watershed

LC - 3

[2] This is in addition to the 900,000 acre-feet of storage contemplated in the Phase II Technical Plan for the Lake Okeechobee Watershed.

presents its own unique water quality and water quantity challenges. Expedited Environmental Resource Permit rulemaking is needed to address new and/or modified land uses within the watershed in order to enhance onsite storage and treatment for individual projects. This is a necessary compliment to the regional projects that are contemplated in the CRWPP.

LC - 3
Continued

IV. Implementation of Best Management Practices

In the context of the Caloosahatchee River Watershed Pollutant Control Program, a multi-faceted approach to reducing pollutant loads is mandated. Development and timely implementation of agricultural and non-agricultural Best Management Practices ("BMP") are needed to address a large portion of the existing land uses within the watershed. In fact, BMPs are, under NEEPA, to be implemented on an expedited basis to address nonpoint sources, among other contributing factors. A specific schedule for implementation is needed.

LC - 4

V. Implementation of the CRWPP and Operations

The County is concerned that the CRWPP does not specifically identify lead, and responsible agencies for each of the programs, initiatives and projects identified in the document. Moreover, implementation timetables are needed. There exist numerous well intentioned regional and watershed plans that have never been fully executed. The Caloosahatchee River and Estuary simply do not have the time to waist. Implementation plans must be initiated. Additionally, an operational component needs to specifically be developed and include information such as which agency is responsible for what structures/facilities and how such structures/facilities will be operated. Given that the CRWPP required a specific due date for submission to the Florida Legislature, the County understands that the details of these operational issues will need to be developed in the Process Development and Engineering phase.

LC - 5

VI. Other Restoration Efforts and Projects

Several ongoing restoration efforts and other relevant projects are listed in the document. Presumably, these are listed to provide a foundation for the CRWPP to build upon. This section leaves out several key efforts and projects such as the Charlotte Harbor National Estuary Comprehensive Conservation and Management ("CCMP") and the Lower Charlotte Harbor Surface Water Improvement and Management ("SWIM") Plan. County Restoration efforts and water resource projects are not noted in the CRWPP, but should be acknowledged as they can be utilized as a foundation for future projects and initiatives.

LC - 6

In conclusion, the County has provided significant leadership and support in the drafting, and passage, of the NEEPA. Realization of the CRWPP is a significant step forward. The need is clear, the objectives are clear. Now is the time for funding and implementation. While the County understands that implementation of the CRWPP is a function of the availability of funding, we stand ready to work with the SFWMD, the Florida Legislature, and Congress to obtain the necessary funding, a lack of which should not dictate or limit plan recommendations. A separate prioritization can be made later, based on availability of funds. At the same time, it is crucial that we define quantifiable success criteria, and measure progress made by the CRWPP.

The time has come for meaningful and quantifiable restoration of the Caloosahatchee River and Estuary Watershed.

The County looks forward to continued participation in this very important effort. As stated above, we have included detailed comments as an Attachment to this comment letter. For more information on these comments, please do not hesitate to call Kurt Harclerode at (239) 335-8146.

Sincerely,

Ray Judah, Chairman
Lee County Board of County Commissioners

c: BoCC, Dist 1, 2, 4, 5
Don Stilwell, County Manager
David Owen, County Attorney
Roland Ottolini, Natural Resources
Kurt Harclerode, Natural Resources
Wayne Daltry, Natural Resources
Tamara Pigott, VCB
Ken Ammon, SFWMD
Temperince Morgan, SFWMD
Pinar Balci, SFWMD
Janet Starnes, SFWMD
Phil Flood, SFWMD

Appendix “A”

The CRWPP needs to include a justification of why, how and to what extent the North Coastal and Nearshore Basins are included in the Caloosahatchee Watershed. Where is the separation from the Charlotte Harbor Watershed? The County understands the need to assess impacts to the Caloosahatchee Watershed’s surface waters from the coastal watersheds and barrier islands but we are not sure it is necessarily a Caloosahatchee issue. This seems to diminish the loading contributions from the C-43 Basin and Lake Okeechobee. **LC - 7**

Executive Summary, L 147-148: Has the funding been secured for the Northern Everglades Lake Okeechobee Watershed Protection Plan Construction Project, Phase II Technical Plan such that it should be included in the River Watershed Protection Plan Base Condition? **LC - 8**

Executive Summary, L 155: Is the completion of the modified water deliveries and C-111 projects a realistic assumption for the River Watershed Protection Plan Base Condition? **LC – 9A**

Figure 1-2: How can this figure show the proposed load reductions anticipated from Lake Okeechobee? **LC – 9B**

Section 1.4.3, L 215-219: What amount of water storage of the 1.3 million acre-feet identified in this section is likely to be situated on the River of Grass lands? Is there overlap between the initiatives and if so, does this reduce the overall water storage required (and thus the cost of same) for the CRWPP? **LC - 10**

Section 1.4.7: This section is describing the Charlotte Harbor basin. **LC - 11**

Section 1.5: This section fails to acknowledge local government efforts in pollutant control especially regarding fertilizer ordinances. **LC - 12**

Section 1.5, L 423-429: Submerged aquatic vegetation monitoring may be sufficient but only if the monitoring is continuous and uninterrupted over time. Historically it has been intermittent, subject to available funds and other competing priorities of the SFWMD. **LC - 13**

Section 1.6.1: Recommended language change: “measurement of freshwater flows east of I-75 is equally sparse”. **LC - 14**

Section 1.6.2: This section needs to include an overview of the Florida Gulf Coast University nutrient study. Is the light attenuation work referring to CHNEP initiatives? **LC - 15**

Table 1-1: Problem column should include impacts to eco tourism and environmental pollution. **LC - 16**

Table 1-4: Please correct the status of the Powell Creek Algal Turf Scrubber project, it is a pilot project that is underway, it is not completed. **LC - 17**

Section 1.7, L 549-561 & L 57-580: Which base condition is used for the determination of Preferred Plan benefits / Phase 1? **LC - 18**

Appendix "A"

Section 1.7.1, L 585-587: The CRWPP assumes that Comprehensive Everglades Restoration Plan ("CERP") projects will continue to be implemented through the "existing mechanisms or programs as originally intended." Given the rewrite of the Programmatic Regulations, the development of the new Integrated Delivery Schedule and the potential schedule changes associated with the River of Grass land acquisition, this may not be a reasonable assumption. This cost section also needs further elaboration. Only a fraction of urban the urban pollutant control program will be funded by the CRWPP. The rationale for this particular funding breakdown needs to be explained. **LC – 19A** **LC – 19B**

Section 1.7.1, Table 1-5: This Table should clearly reflect the total end range of costs for the entire implementation of the CRWPP. If there is overlap with the River of Grass land acquisition, then this should be noted in the Table, because the result may lower the costs of the CRWPP. **LC - 20**

Section 2.2 Purpose and Scope: The CRWPP needs to state the importantance of Lake Okeechobee in meeting suitable salinity regimes. These targets cannot be met without those flows and additional flows south. **LC - 21**

Section 2.3: Please see first general comment in this Appendix. The County continues to question the need to include the stated coastal waters. **LC - 22**

Section 2.4.2: Please make the correction that Matlacha Pass discharges into the Charlotte Harbor Watershed. **LC - 23**

Section 2.4.4.1: Please address backflows from the S-78 to Lake Okeechobee when the Lake's level is down. This has the effect of reducing the Caloosahatchee River Basin watershed area and flows during times of drought. **LC - 24**

Section 3.0: Please include a discussion on water reservations, and relationship of the CRWPP to same, in this Section. **LC - 25**

Section 3.1.3: Lee County Surface Water Management Master Plan should be identified under this section. **LC - 26**

Section 3.1.4.1: Please add to this Section a discussion of the local government fertilizer ordinance adopted by Sanibel and Lee County. **LC - 27**

Table 3-2: Lake Okeechobee is believed to be one of the sources of pollutant discharges to the river. Therefore, Lake Okeechobee should be identified as a line item on this table and performance measures and targets should be developed for Lake Okeechobee pollutant control. **LC - 28**

Section 3.3.2, L 723-724: As currently written, this objective is not clear. Monitoring does not implement a project. Monitoring programs verify, assess, corroborate, and validate but do not and cannot implement. **LC - 29**

Appendix "A"

Section 6.2.2.3: Target Flow Index: Not all flow regimes are at the "harm" level. Are those regimes within the harm range weighted more heavily? **LC - 30**

Section 6.3.1.1, L 70-71: Where did the assumed 1.65 mg/L TN concentration come from? How was it selected? Should include a citation. The reasoning behind the assumption of 1.65mg/L should be stated (average wetland land use values, agricultural land use values, etc). The current wording implies an arbitrary guess. **LC – 31**

Section 6.3, L 72-80: "Water quality analysis method" is not defined and if it is the same as the estimation method in previous text it should be stated that the "water quality is estimated because water quality data was not collected". "Water quality analysis method" precedes "data does not contain sufficient detail". Unfortunately, this is because there is little to no data being collected or planned to be collected in the watershed where there is a deficit of data. This leads to assumptions which cannot be verified and ultimately to insufficient information as the basis of future decisions, it also speaks to the need for tributary monitoring in the monitoring plan. **LC - 32**

The reasoning behind the assumptions used to determine the 1.65 mg/L for the TN concentration was stated. However, it uses the assumed land use EMCs and runoff coefficients combined with regional rainfall to calculate loads. The developed loads are then divided by the calculated flows used in the previous step to generate concentration. Thus, it is a calculated value which has no tangible link to the watershed, other than regional rainfall. With the amount of both effort and dollars being expended on the solutions developed from these calculated values, one would expect better confirmation of the relationship to values found in the watershed. **LC - 33**

Section 6.3, L 114-115: "Flow-weighted concentration" is an inappropriate term for this calculation. It is the land use proportioned EMC for the watershed. For all practical purposes, the number being used as load is calculated from the individual land use EMCs multiplied by the rainfall/runoff coefficient (flow) from the watershed land uses to generate load. The value calculated for concentration is developed from the total estimated load divided by the total calculated/estimated flow, it is not flow-weighted. By definition, flow-weighted concentrations vary over the hydroperiod with the flow. Thus, a better term may be "concentration is an approximation developed from the normalized annual load estimate to average annual flow relationship". River flows are used to calculate the concentration from the loads…which are calculated from land use and runoff coefficients applied to regional rainfall. The best-available values are available when there is watershed monitoring. **LC - 34**

Section 6.3.1.2, L 130-134: Were these assumptions based on any literature value? Where did they come from? The assumptions related to "concentrations entering Lake O and the lower lake level generating lower concentrations exiting" require further explanation. The input concentration does not automatically decrease because of lower lake levels. There must be another assumption made or rationale to generate the secondary reductions rather than lower lake levels. **LC - 35**

Section 7.1.1.1: ERP rules should be revised to promote restoration projects. At this time, the same rules and standards are applied to both developments and restoration projects. **LC - 36**

Appendix "A"

Section 7.1.3.1: The description of the stormwater updates and master planning should include local ordinances that are being promulgated to mitigate non-point source runoff. Structural Best Management Practices ("BMPs") are not only applied for pollution prevention. One example in many communities locally is the implementation of landscape and fertilizer BMP ordinances as well as the current Regional Planning Council proposal for an Onsite Sewage and Treatment Disposal System management program. This concept is again restated in Section 7.2. The section addresses state efforts and ignores the local government efforts in programs and planning. Many of these programs are carried out by local governments without support of state funds. **LC - 37**

Section 8.3.1, L 88-90 "...but decrease the frequency and duration of the damaging low flows that impact upstream, low salinity regions." The MFL below S-79 has been exceeded on many occasions. Please include a citation of where this comparison can be found. This issue is a key point in the estuarine system. It would seem a little more explanation is necessary. Dry weather has meant there are insufficient releases from S-79 to maintain estuarine health. **LC - 38**

Section 8.3.4, L 178-201: Please include a citation/citations from which these thresholds were selected for this section. **LC - 39**

Section 8.4.1: The planned monitoring modifications do not allow for differentiation (quality or quantity) of the contributing watersheds north and south of the river and is not covered by the amendments outlined in 8.4.3. This is a significant deviation from the current planned monitoring regime. If this is to be addressed via another district program, it should be described to acknowledge the need and that the issue is being addressed via another avenue. The information is critical in setting the Basin Management Action Plans (who does what, where, how and when) required for the total maximum daily load. Section 8.4.1 alludes to Chapter 4 in Appendix E. In Chapter 4 of A-E, the need for and absence of flow monitoring in the freshwater Caloosahatchee River basins is stated. Flow and water quality stations in the freshwater watersheds do not provide sufficient information to confirm the assumptions made for necessary modeling. Monitoring in the stem may reasonably be expected to provide an adequate wet weather estimate of the change in quality and quantity between stations. However, the likelihood of it failing to generate acceptable correlations in the dry season is not unreasonable. **LC - 40**

Section 8.4.3: This effort is much improved over the original monitoring. However, the same logic stated for 8.4.1 is true for the planned modifications. There is no mechanism to define the loads from north or south of the freshwater stem of the river. If this is being addressed by another district effort, it should be so stated. As an enhancement, this effort is much improved over the original monitoring. However, the same logic stated for 8.4.1 is true for the planned modifications. There is no mechanism to define the loads from north or south of the freshwater stem of the river. If this is being addressed by another district effort, it should be so stated. In order to adequately assess the effectiveness of any one portion of the planned features, a system of tributary monitoring should be established. **LC - 41**

Appendix “A”

Section 8.5.1.1, L 356 & 9.3.1.2 L 473: Recently much modeling work has been done on the Caloosahatchee with some models having used BOD5, some ultimate BOD and others CBOD5. If we are going to add BOD to support modeling efforts we must add the correct one for the models we will be using. **LC - 42**

Section 8.6.3, L 433: Has there been a determination by the modelers that there is enough data spatially and temporally to support the modeling tools we need to use to assess the system? If so, what is that assessment? **LC - 43**

Section 9.1.3.1: Lee County has many more projects than listed on this section targeting surface water management, restoration and improvement. **LC - 44**

Section, 9.1.3, L 154: Recommended language change to, “… land management, conservation and restoration…” **LC - 45**

Section 9.2: In 9.2, the referenced programs and activities ignore local efforts and ordinances. Specifically, Lee County and others have enacted fertilizer ordinances to provide more restrictive residential and commercial application schedules over those currently proposed by the state. Additionally, local staffing, education, certification and enforcement have been incorporated to assure compliance. The general message is to incorporate local efforts (general) into the text and give credit to local governments for their part in the overall plan. With that said, we are not going to provide a lengthy list of entity names, ordinance numbers or specific actions for inclusion, that would be beyond reason. General credit to local governments for their role in a successful plan and acknowledgement of local initiatives to achieve the common goal would go along way to having all entities recognized for commitment to a common goal. These comments relate to this and any other section which promotes government work efforts. **LC - 46**

Section 9.4.4, L 730-736: This section should note that the rate of implementation and funding will also be influenced by the River of Grass land acquisition. **LC - 47**

Section 9.45, L 743-744: This section should reflect the fact that the CRWPP will be specifically coordinated with the SFWMD River of Grass initiative. **LC - 48**

Monitoring Plan (App E), L 306: "...56% of the measured freshwater inflow came from wastewater treatment facilities." Much of the wastewater treatment plant flows are used as a reclaimed water source. The 56% flow rate appears to have been taken from the permitted flows not from the actual discharges. Much of the treated discharge in the basin is used in reuse, not wasted directly to tide. What is the basis for this assumption and is the 56% figure a treated or discharged wastewater number? **LC - 49**

Monitoring Plan (App E), L 583-585: There is a typographical error in that the page numbers are within the formula. **LC - 50**

Monitoring Plan (App E), L 361: Is the subject of potential nutrient resuspension from sediments to be included in the monitoring or research plan? If not, why? In the Nutrient **LC - 51**

Loading discussion, sediment as a source was ignored. If sediments are not an issue, they should be covered and the CRWPP should state that fact as well as the reasoning behind same. LC - 51 Continued

Plan Operations, Maintenance, Permitting, and Monitoring (App F): Although we understand that the Operations Plan will be developed later in the process and the CRWPP is a “framework” the County believes it is important to provide as much specificity as possible on the operations of the project features. Please provide more details on the operations of the CRWPP in Appendix F. LC - 52

Southwest Florida Regional Planning Council

1926 Victoria Avenue, Fort Myers, Florida 33901-3414
(239)338-2550 FAX (239)338-2560 SUNCOM (239)748-2550

October 31, 2008

Ms. Carol Wehle, Executive Director
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Re: Caloosahatchee River Watershed Protection Plan Review

Dear Ms. Wehle:

The Southwest Florida Regional Planning Council (SWFRPC) has reviewed the draft *Caloosahatchee River Watershed Protection Plan* (CRWPP), dated October 2008.

The Plan is the result of a multi-agency effort. The SWFRPC participated in the development of the plan and has partnered with the South Florida Water Management District in the preparation of this important plan that is critical to the successful restoration and long-term sustainability of the Caloosahatchee River and estuary. The CRWPP provides a useful scientific context for water quality, hydrologic, habitat, and stewardship issues within the Caloosahatchee River watershed. The SWFRPC understands the significant efforts made by the South Florida Water Management District and partners to meet the challenging fast schedule mandated by the Florida legislature.

The SWFRPC consists of elected city and county officials, regional and state agency representatives, and Governor Appointees. The SWFRPC "acts as a regional information clearinghouse, conducts research to develop and maintain area wide goals, objectives, and policies, and assists in implementing a number of local, state, and federal programs. The Council serves as an advocate for the Region with State and Federal agencies, including the Legislature and Congress" (SWFRPC 2004). The SWFRPC adopts a Strategic Policy Plan to guide its actions and decisions. The SWFRPC Strategic Policy Plan can be found at: http://www.swfrpc.org/srpp.htm.

The CRWPP is the plan required by the Florida Northern Everglades and Estuaries Protection Act for the Caloosahatchee River Watershed. It is part of a greater planning effort involving the tributaries of Lake Okeechobee, its two discharge points at the Caloosahatchee River and St Lucie Canal, and the river basins of the Caloosahatchee and St Lucie. The Plan does not include the Estero Bay Watershed. The Plan is a collaborative effort but the designated entity to produce the Plan for the Legislature is the SFWMD.

The Plan is coordinated with CERP, and assists in the SWFFS and with the Caloosahatchee River Phase II PIR and with the FDEP TMDL process.

The Plan has three major components: Construction, Pollution Control, and Research and Water Quality Monitoring. The "Construction" section includes built and non-structural options. Pollution Control is tied in large part to the pending TMDL process. Research and Water Quality Monitoring draws on the completed work in the tidal Caloosahatchee Estuary and existing monitoring stations, and acknowledges the eastern river basins need more monitoring. It should be noted that the S-4 connection to the Caloosahatchee River is included as a contributor of flow and water quality issues.

Several alternatives were evaluated. The preferred alternative (alternative 4) upon which the CRWPP is based depicts the need for 400,000 acre feet more storage, proposes a reduction of approximately 40% in nitrogen and phosphorus discharges, and has an expected Phase I cost of up to $971 million for construction, $813 million in water quality improvements and an additional $5 million in monitoring.

The Plan speaks to reporting and the entities described as relevant to implementation are FDEP, FDACS, and SFWMD. The advisory body is WRAC and the implementing agency for the Plan is SFWMD.

The SWFRPC supports the goals of the CRWPP to reduce nutrient loads from the Caloosahatchee River watershed and restore more natural hydrologic and salinity regimes in the river and its estuary. The CRWPP appears to be technically sound and based on best currently available data and methodologies.

Unfortunately while the CRWPP provides a valuable outline of needed restoration efforts, there are significant planning needs not yet addressed including an operational plan toward an implementation strategy, including an adaptive management component responsive to system changes and monitoring of project outcomes. The CRWPP also needs to identify the methods of funding the measures identified in the plan and the entities responsible for securing that funding. SWFRPC - 1A SWFRPC - 1B

The following information needs identified by the Charlotte Harbor National Estuary Program (CHNEP) technical reviews need to be incorporated into the CRWPP to enhance its effectiveness and likelihood of implementation.

Base Conditions: Define River Watershed Protection Plan Base Conditions more thoroughly throughout the plan, clearly explaining which restoration projects are included in the baseline. SWFRPC - 2

Conservation and Restoration: Include conservation and restoration activities within management actions, especially relating to modifications to Environmental Resource Permitting. SWFRPC - 3

Economic Impacts: Include economic and ecotourism impacts/benefits in Table 1-1 of Problems, Objectives and Constraints. SWFRPC - 4

Freshwater Inflow from Wastewater Treatment Plants: Explain how the percent of freshwater inflow originating from wastewater treatment facilities was calculated, in light of the increasing use of reclaimed water for public irrigation use and the shifting of unused reclaimed water to deep well injection. SWFRPC - 5

Impaired Waters: Include the complete list of impaired waters and parameters in Chapter 5, specifically Table 5-2, including fecal coliform bacteria impairments. SWFRPC - 6

Implementation Strategy: Include implementation strategies for projects, to include such items as BMPs, schedules, adaptive management, lead partners, potential funding sources, potential impediments and recognition for local projects. Specifically add lead agency and time period to Table 6.4-6. SWFRPC - 7

Incentives: Include a section compiling and summarizing incentives for agencies, land owners, research institutions, etc., similar to a "tool kit", which will encourage implementation of a wider variety of activities in a more expedient time period. SWFRPC - 8

Lake Okeechobee Impacts: Include Lake Okeechobee in flow, salinity and nutrient regime calculations. SWFRPC - 9

Low Flow Assumptions: Include definition, references and explanation of how low flow adverse impact thresholds were determined. SWFRPC - 10

Modeling Assumptions: Include assumptions and selected values used for modeling low flows, nitrogen and phosphorus concentrations, land use proportioned "event mean concentrations", and effects of nutrient reduction methods, as well as minimum data requirements used to allow modeling of spatial and temporal conditions. SWFRPC - 11

Monitoring Requirements: Include a requirement for long term monitoring of water quality (including BOD5), flows, submerged aquatic vegetation, and Fisheries Independent Monitoring (through the Florida Fish and Wildlife Commission) within the Caloosahatchee and its tributaries. SWFRPC - 12

Partner Management and Monitoring Activities: Include management and monitoring activities to be initiated by local governments, the SWFRPC and the River of Grass Initiative. SWFRPC - 13

Reservoirs: Include planned reservoirs and modifications associated with the River of Grass Initiative in calculations of water storage needs SWFRPC - 14

Sediment Nutrient Loadings: Include nutrient loadings from sediment re-suspension in modeled loading and reduction calculations, as well as monitoring programs. Re-suspension of nutrients bound to the sediment is important and should be considered appropriately compared to dissolved nutrients when considering bioavailability and resultant algal productivity. SWFRPC - 15

SWIM Plan: Reference the Lower Charlotte Harbor Surface Water Improvement and Management (SWIM) Plan and Reconnaissance Report within the text of the CRWPP. Ensure that projects referenced in the SWIM Plan are also included in the CRWPP. SWFRPC - 16

If you have specific questions about the content of this letter, please contact Mr. Jim Beever directly at (239) 338-2550, Extension 224, or via e-mail at jbeever@swfrpc.org.

Sincerely,

SOUTHWEST FLORIDA REGIONAL PLANNING COUNCIL

David Hutchinson
for Ken Heatherington
Executive Director

KH/dk

cc: Colonel Paul L. Grosskruger, District Engineer
Jacksonville District Corps of Engineers
U.S. Department of the Army
701 San Marco Blvd
Jacksonville FL 32207-8175

Dr. Lisa B. Beever, PhD, AICP
Director
Charlotte Harbor National Estuary Program
1926 Victoria Avenue
Fort Myers, Florida 33901

Starnes, Janet

From: Balci, Pinar
Sent: Saturday, November 01, 2008 6:57 PM
To: Morgan, Temperince; Starnes, Janet
Subject: Fw: CRWPP Comments
Attachments: CRWPPCmts1008.doc

Comments from SCCF.

Sent from my BlackBerry Wireless Handheld

SFWMD Wireless Email Solutions

From: Rae Ann Wessel
To: Balci, Pinar
Sent: Fri Oct 31 17:00:24 2008
Subject: CRWPP Comments

October 31, 2008

Pinar Balci, PhD

South Florida Water Management District

MS7640

3301 Gun Club Road

West Palm Beach, FL 33406

RE: Caloosahatchee River Watershed Protection Plan - SCCF Comments

Dear Dr. Balci:

The Sanibel Captiva Conservation Foundation (SCCF) appreciates the opportunity to provide these comments on the Caloosahatchee River Watershed Protection Plan (CRWPP).

Over the past year SCCF staff has participated with other stakeholders on the working team which has allowed us to bring issues and concerns forward during the process. These comments reflect our concerns about portions of the plan but also reflect our support of the plan which serves to move this process forward by identifying needs of the system to improve the public health, safety and welfare of the Caloosahatchee. Our goal is to support and enable restoration of the river to a functional fishable, swimmable river. We appreciate your consideration of these comments.

The Northern Everglades plans are designed to coordinate three interconnected watersheds; Lake Okeechobee, Caloosahatchee and the St. Lucie river with the objectives of maximizing the storage needs of the system to improve water quantity, quality, frequency and duration of water flows in order to address nutrient load reductions to meet TMDL goals currently being formulated.

The plan proposes to do this through three components: 1)Pollutant source control programs 2) Construction of structural elements and 3) Research and water quality monitoring programs.

Using models, a series of alternatives were developed to evaluate baseline conditions, water quantity needs and water quality objectives. The evaluation resulted in the selection of Alternative 4 as the basis of the CRWPP. The findings reveal storage needs in the Caloosahatchee watershed of 400,000 acre feet of storage - 170,000 ac ft would be in the C43 West Basin Reservoir - and an additional 900,000 – 1.4 million acre feet of storage north of Lake Okeechobee.

These storage figures are significantly higher than the previously determined 170,000 acre feet recommended with the C43 West Basin Reservoir (WBR)-project although they correlate with estimates that we have been working on independently. The disparity between the storage provided by the C43 WBR and the storage actually needed is one reason we have raised issues in the past about the cost effectiveness of the C43 WBR. The reservoir as it is designed would address only about 15% of the problem flows.

This experience in prior modeling efforts and their outcomes reinforces our continuing concern with the model assumptions used in the development of this plan. There are a number of very optimistic assumptions in this evaluation that will not be reflective of conditions in the near term and thus may continue to underestimate storage and treatment needs and over estimate nutrient reductions and flow optimization. SCCF - 1A

The modeled plan reflects significant water quality, quantity and flow improvements with nutrient reductions of 38% total nitrogen and 39% total phosphorus, reductions in high and low flow exceedence and an 84% improvement in achieving target flow distributions.

Unfortunately, the model assumes that all Lake Okeechobee Phase II projects, as well as the Caloosahatchee WBR and phase II water quality treatment are constructed and operational, it assumes that Lake Okeechobee discharges meet the 40 ppb TMDL for phosphorus and uses the old Lake Okeechobee regulation schedule -WSE- that allowed much more water to be stored in the Lake than the current LORS schedule allows. Given that these conditions will most certainly not be met during Phase I of the plan - that extends to 2012- and most likely will not be met by Phase III in 2018 we feel that these assumptions skew the outcomes to reflect benefits that will not be able to be realized. SCCF - 1B

Another problem caused by the optimistic but unrealistic assumptions in the modeling is that it may cause some alternative projects to be passed over because they would not achieve the reductions of Alternative 4 when evaluated in existing conditions. In other words, the modeling that has been done represents the best possible case for restoration. For comparison we recommend that alternative 4 be modeled with current conditions and the LORS regulation schedule to reflect more realistic conditions from which management decisions can be made. SCCF - 1B cont.

Recommendations

In addition to the above model run adjustments we would request the following projects and considerations be added to the plan.

To meet the plan goal of pollutant source reductions we recommend a dedicated effort to address the **Disston Island Conservation District**. A large portion of this area is located on or adjacent to US Sugar land and is adjacent to Lake Okeechobee and can be redeveloped into water storage and treatment systems thereby eliminating a major source of pollutant loading while providing distributed storage needed in the Caloosahatchee watershed. We urge the District to not swap this land away under the US Sugar land purchase and that plans be developed to create STA and storage in this area to treat water from Lake Okeechobee and the watershed. SCCF - 2

We highly recommend the addition of the **Caloosahatchee Alternative Riverway Betterment Plan** to the list of projects. This plan incorporates and connects Disston Island, Lake Hicpochee, BOMA and the C43 WBR into a multi-use, multi-function riverway system that can be created with much lower costs than traditional reservoir or STA systems. In addition, it has the potential for urban redevelopment of the inland Counties as well as ecosystem services. SCCF - 3

The cost of northern everglades restoration will restrict the number of engineered projects that we will be able to build. We encourage your active evaluation of alternatives that engage and utilize natural system components to achieve storage treatment and restoration. SCCF - 4

On the regulatory front we would recommend strengthening permitting requirements for both water quality and quantity by mandating BMP's in all permits and setting stringent pollution load reduction goals (PLRG) and mandating Low Impact Development features in all permits. SCCF - 5

As the Caloosahatchee restoration moves forward we encourage your commitment to restoration projects in all basins using the least amount of infrastructure that requires ongoing maintenance and operation cost to achieve the greatest return.

Thank you for your consideration.

Rae Ann Wessel

Natural Resource Policy Director

Sanibel Captiva Conservation Foundation

<<...>>

Rae Ann Wessel
Natural Resource Policy Director
Sanibel Captiva Conservation Foundation
Tel: ***239.731.7559***
Fax: 239.731.3779
Email: **rawessel@sccf.org**

Web: **www.sccf.org**

The review period is open from October 1 to October 31. A CRWPP Working Team meeting will be held on October 27 from 1:30 to 3:30 at the Lower West Coast Service Center and a Public Workshop the evening of October 27 from 6:00 until 8:00. From an email from Wayne: The Plan is required by the Florida Northern Everglades and Estuaries Protection Act. It is part of a greater planning effort involving the tributaries of Lake Okeechobee, its two discharge point at the Caloosahatchee River and St Lucie Canal, and the river basins of the Caloosahatchee and St Lucie. It does not include the Estero Basin. The Plan is a collaborative effort but the designated entity to produce the Plan for the Legislature is the SFWMD. It's coordinated with CERP and assists in the SWFFS and with the Caloosahatchee River Phase II PIR and with the FDEP TMDL process, which gets a significant jump start from the CRWPP. The Plan has three major components: Construction, Pollution Control, and Research and Water Quality Monitoring. The "Construction" section includes built and non-structural options. Pollution Control is tied in large part to the pending TMDL process. Research and Water Quality Monitoring draws on the work already done, and acknowledges the eastern river basins need more monitoring. It should be noted that S-4 connection to the Caloosahatchee River is included as a contributor of flow and water quality issues. Modeling is a key component, and the modeling effort is described in Appendix C. The modeling is important since it provides transparency into the evaluation and priority setting effort. Modeling also provides an analytical tool that 3rd parties can examine for relating effort to outcomes. Several alternatives were evaluated. The preferred alternative (alternative 4) upon which the Plan is based depicts the need for 400,000 acre feet more storage, proposes a reduction of approximately 40% in nitrogen and phosphorus discharges, and has an expected Phase I cost of up to $971 million for construction, $813 million in water quality improvements and an additional $5million in monitoring. The Plan speaks to reporting but the entities described as relevant are FDEP, FDACS, and SFWMD. The advisory body is WRAC and the implementing agency for the Plan is SFWMD.

<u>Review Comments from Wayne:</u> The Plan provides an important link to the science and how specified improvements in storage, and in management, are predicted to result in improvements to the outcomes desired—water quality, storage, and environment. The Plan does not have an "operational" component. Specifically, who really needs to do what, and when. Given the Plan required due date, such detail would
be difficult to negotiate and would likely detract from the Legislative review. However, an operational plan SCCF - 6
is still needed. The Plan does provide generic statements that could be redacted and replaced with a real
operational plan. The Plan does not speak to the role of the CHNEP Plan and the Lower Charlotte Harbor SCCF - 7
SWIM Plan. It may be a presumption that the outcomes of those two efforts are subsumed in the
CRWPP, but an independent conclusion is needed for that. The Implementation Program is weak. The SCCF - 8
Plan implementation needs a real coordination framework, akin to the MPO process, if not using an existing coordination entity. WRAC does not suffice, since the representatives are more samples of
designated interest groups, as opposed to a forum of implementation agencies and entities. Further, the SCCF - 9
funding needed for the program needs to a large degree come "up" from drawing upon existing sources who then reach for additional funding, or reprogram existing revenue sources. Depending upon a top down legislative appropriation, and a top down permit program, to ensure success will not work. Again, drawing upon the MPO process which has all functional providers of transportation at the table, as plan participants (and voters) AND as funding participants, the basin needs all functional providers of stormwater, water supplies, environmental investment and water quality at the table, enabled to speak for their organization. That said, I recommend supporting the Plan with whatever amendments can be made. It is a good first step—it is even a good second step. The operational plan should be a time specific required outcome, along with a time specific, agency specific coordinating council. Whether this latter is an existing entity or a new one, it cannot be held to the thinking, priorities, and time constraints of one single party.

Public Comments to the Caloosahatchee River Watershed Protection Plan:

Comments from the July 2008 WRAC presentation by Forest Michael are updated below with direct reference to the Southwest Florida Watershed Council's recommendations to the October 2008 SFWMD WRAC, and Lee Chairman Ray Judah's and Dr. Bill Hammond's comments from the District's Public Meeting Oct. 27, 2008.

FM-1

Request to prioritize affordable projects in CRWPP: (not in specific order)

- **Lake Hicpochee and Disston Island** (Natural storage and treatment and natural buffering of Okeechobee pulses)
- **4 Corners STA** (Natural storage and treatment)
- **Lake LaBelle** (Amendment to current C43 design for a more affordable naturalistic multiuse betterment)
- **Agricultural Lands** (Natural storage and quality in wetlands per historic practice with regulated releases during dry season)
- **Billie's Creek** (Continuation of positive progress)

These projects all provide multiple-use benefits to the following:

- Estuaries
- Communities
- Residents (Jobs quicker)
- Supporting businesses
- Local and State governmental revenues
- Ecotourism
- Ecosystems and Endangered Species
- Stormwater Management
- Recreation
- Civic Pride and Quality of Life

Comments respectfully provided by Forest Michael,
130 N. Center Street, #3, Winter Park, Florida, 32789,
michaelplanning@gmail.com

Town of Fort Myers Beach

Larry Kiker	*Herb Acken*	*Tom Babcock*	*Jo List*	*Bob Raymond*
Mayor	*Vice Mayor*	*Councilmember*	*Councilmember*	*Councilmember*

October 31, 2008

Janet Starnes
South Florida Water Management District
2301 McGregor Boulevard
Fort Myers, FL 33901

RE: Caloosahatchee River Watershed Protection Plan

Ms. Starnes:

Thank you for this opportunity to comment on the Caloosahatchee River Watershed Protection Plan (CRWPP). We respectfully submit this comment letter for your consideration.

Due to the fact that Fort Myers Beach depends primarily upon tourism, which can be affected by degraded water quality and environmental conditions, management of upstream watersheds is very important to the community of Ft. Myers Beach. As you are aware, Ft. Myers Beach is influenced by both Lake Okeechobee and the Caloosahatchee River, particularly during high basin and lake discharge events. In the past few years, some of these large events have caused degraded water quality within the Caloosahatchee River estuary and the nearshore environment. While further research is needed to determine if there are linkages between Lake Okeechobee and Caloosahatchee River discharge to red tide and red drift algae events, the prevalence of these events in the past few years (which have impacted tourism on Ft. Myers Beach) illustrate the need for lake and river management to be conducted on a landscape and watershed scale. The CRWPP is a positive step towards this end.

FMB - 1

Overall, the CRWPP is a well crafted approach to comprehensively describe, evaluate, and prescribe the problems and solutions to water management issues with the Caloosahatchee River watershed. However, the successful implementation of the CRWPP will depend on coordination with other watershed planning efforts, including the Caloosahatchee River TMDL program and the Lake Okeechobee Phase II Technical Plan. The successful implementation of this plan will also depend heavily on dedicated funding commitment and successful and timely development and construction of the management measures identified in Table 6.1-1. Constant revaluation of this plan, particularly during the first three year cycle, will also be critical to the long term success of this project.

The South Florida Water Management District should be commended for a developing the CRWPP in a relatively short time frame. Development of a plan of this scale in a short time frame may have lead to some oversights as performance measures are concerned. The CRWPP performance measures in Table 3-2 appear to be hydrologic indicators without well developed biological components. Hydrologic indicators alone without linkages to biological indicators may not be sufficient to monitor the success of any watershed plan. Specific targets for fish and shellfish, submerged aquatic vegetation, plankton, and most importantly, community structure should be paired with the performance measures stated in the plan. The increase in scientific research and monitoring by SFWMD, SCCF, FGCU, DEP and others over the past decade, would support the development of specific biological indicators.

FMB - 2

Thanks you again for this opportunity to comment on the CRWPP. If you have any questions, please do not hesitate to contact me at Keith@FortMyersBeachFL.gov or at 239-765-0202 ext 136.

Sincerely,

Keith Laakkonen

Keith Laakkonen
Environmental Sciences Coordinator

CC: Scott Janke, Town Manager

Watershed Council
Southwest Florida Watershed Council, Inc.
P.O. Box 61063, Fort Myers, FL 33906-1063
www.swfwc.org

October 30, 2008

Pinar Balci, Ph.D., Technical Program Specialist
South Florida Water Management District, MS 7640
3301 Gun Club Road
West Palm Beach, Florida 33406

Re: Southwest Florida Watershed Council Comments on the Draft Caloosahatchee River Watershed Protection Plan

Dear Dr. Balci:

The Southwest Florida Watershed Council appreciates the opportunity to participate in development of the Caloosahatchee River Watershed Protection Plan (CRWPP) and submits the following comments for your consideration. The Watershed Council is a multi-county coalition of individuals, organizations, agencies, and businesses that have come together to address issues affecting the Caloosahatchee and Big Cypress watersheds. The purpose of the Watershed Council is to ensure that the interests and concerns of all stakeholders are addressed and that long term management strategies balance the needs of the region's growth and the natural systems upon which our economy and quality of life depend.

The Northern Everglades and Estuaries Protection Program legislation, Sec. 373.4595 F.S., was developed to afford the Caloosahatchee and St. Lucie Estuaries the same protections as those given to Lake Okeechobee and its watershed. We strongly support the program's goal to restore the quantity, timing and distribution of water to the natural system and look forward to working with South Florida Water Management District staff on how to best implement the plan.

We feel that the overall plan does a good job of addressing water quantity and timing issues by significantly reducing the number times that the Caloosahatchee Minimum Flow and Level (MFL) rule is not met as well as the number of high flow events that exceed 2,800 cfs at Franklin Lock and Dam (S-79). Although it is clear that Alternative 4, the "Preferred Plan", will not reduce all of the low or high flow events it should significantly improve the overall health of the estuary. We are also glad to see that the proposed research and monitoring plan addresses the flow and nutrient data gaps in the eastern portion of the river and includes additional work on identifying Low Salinity Zone habitats important to local fisheries.

Overall we feel that the CRWPP is a good document, however we do have some concerns about several of the assumptions used in the modeling efforts. The model assumes that that Lake Okeechobee will be meeting its Total Maximum Daily Load (TMDL) of 40 parts per billion (ppb) of phosphorus. Since it is highly unlikely that the lake will meet its TMDL within the next 20 years, we suggest that future modeling runs use realistic nutrient loading values that will represent the actual loads discharged to the Caloosahatchee.

SWFWC - 1

The model also assumes the lake will be operated according to the Water Supply and Environment (WSE) lake release schedule rather than the newly adopted interim schedule (LORS08). Since rehabilitation of the Herbert Hoover Dike is not expected to be completed until 2030 we recommend that the interim lake release schedule be used in future modeling efforts. We believe that using the WSE schedule in your modeling efforts underestimates the amount of storage needed within the basin.

SWFWC - 2

All of the alternatives also assume that the Lake Okeechobee Phase II Technical Plan projects will be completed and that the C-43 West Reservoir will be constructed. Since these projects are the foundation of the plan and the west reservoir is the primary source of water for meeting the river's Minimum Flows and Level (MFL) it is critical that these projects get completed in a timely manner. It is also essential that Phase II of the C-43 West Reservoir project be completed and an STA or similar treatment facility be constructed to treat the water before discharging into the river.

SWFWC - 3A

SWFWC - 3B

Our final concern is the exorbitant cost of implementing the plan. While we agree that it is good plan, it estimated to cost over 1.2 billion to implement Phase I. At a time when funding is becoming increasingly limited we are concerned that the plan will never be fully implemented. As we move forward into the implementation phase we encourage you to conduct a cost-benefit analysis on all of the projects and prioritize those projects within the plan that will provide the greatest overall benefit in terms of water quality and water storage with the lowest associated costs and explore public-private partnerships.

SWFWC - 4

Thank you for considering our comments.

Sincerely,

John Cassani, Chair
Southwest Florida Watershed Council

Cc: Janet Starnes, SFWMD jstarne@sfwmd.gov
Pinar Balci, Ph.D., SFWMD pbalci@sfwmd.gov

Gulf Citrus Growers Assn. Inc.

Post Office Box 1319
LaBelle, Florida 33975
Phone: 863-675-2180
Fax: 863-675-8087
Website: www.gulfcitrus.org

October 29, 2008

Statement of Support
Caloosahatchee River Watershed Protection Plan

TO: South Florida Water Management District (SFWMD)

The Gulf Citrus Growers Association, representing citrus growers in the counties of Charlotte, Collier, Glades, Hendry and Lee, would like to go on record in support of the **Caloosahatchee River Watershed Protection Plan** as recently presented at the public meeting held October 27, 2008 at the South Florida Water Management District's office in Ft. Myers.

Citrus growers in the Caloosahatchee River Basin are inextricably linked to the river as a source of irrigation water supply, as well as for its other natural functions. As such, citrus growers have taken progressive and "pro-active" measures to address their water management protocols over the past several years. Central to our citrus growing activities in the Caloosahatchee River Basins has been the aggressive adoption and implementation of the Florida Department of Agriculture and Consumer Services' (FDACS) Gulf Citrus Best Management Practice (BMP) manual. This "manual/plan" was adopted by rule in February of 2006 under the Florida Watershed Restoration Act and serves as our industry's "operational" document and provides a valuable collection of the many useful and effective techniques directed at enhancing and protecting water quality in the basin. The Gulf Citrus Growers Association commends the South Florida Water Management District (SFWMD) and its coordinating agencies, the Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumers Services (FDACS) for including agricultural and urban BMPs as key components of the watershed pollutant control program within the plan. From our perspective, this inclusion links the Caloosahatchee River Watershed Protection Plan to the Florida Watershed Restoration Act (passed in 1999), which is the state's primary instrument for implementing Florida's Total Maximum Daily Load (TMDL) program.

We would like to take this opportunity to report to you, that along with our full support of this plan, to date... a total of 88,489 acres of citrus (out of a total of about 133,000 acres) have already enrolled to participate in the "Gulf Citrus" BMP manual program since its adoption in 2006. That is about 67% of the citrus acres in the region. Through our continual promotion of this program, we are encouraged that many of the additional acres will be enrolled and participating in a timely manner.

In addition, the Gulf Citrus Growers Association strongly urges the South Florida Water Management District, the Florida Department of Environmental Protection and the Florida Department of Agriculture and Consumer Services to collectively expand their efforts to develop and provide "dedicated" funding...targeted at "cost/share" and other programs specifically aimed at "on-farm/on-site" projects and protocols which have been proven to have the most positive results in achieving water management goals. One of the major concerns we have with the "proposed plan" is the lack of adequate funding at the "regional" and "state" levels to actually implement the plan, including the BMPs. The "cost/share" programs that have been used in the past to bring agriculturalists into the BMP program have worked well, but this funding is "drying up"! Something must be done to restore and enhance these funding sources.

GCGA-1

We look forward to working with the implementing agencies, as well as with our citrus growers to promote the implementation of the Caloosahatchee River Watershed Protection Plan, including the agricultural BMPs contained therein. We commend the SFWMD's staff for its leadership efforts in developing the plan, and stand ready to answer any questions regarding this statement.

Sincerely,

Ron Hamel, Executive Vice President
Gulf Citrus Growers Association

cc. Board of Directors
Governmental Relations Committee

DISTRIBUTED 10/28/08

City of Sanibel

800 Dunlop Road
Sanibel, Florida 33957-4096

www.mysanibel.com

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POLICE	472-3111
PUBLIC WORKS	[illegible]

October 27, 2008

Pinar Balci, Technical Program Specialist
South Florida Water Management District, MS 7640
3301 Gun Club Road
West Palm Beach, Florida 33406

Re: City of Sanibel Comments on the Draft Caloosahatchee River Watershed Protection Plan

Dear Ms. Balci:

The City of Sanibel submits the following comments on the Caloosahatchee River Watershed Protection Plan (CRWPP) for your consideration. I want to thank you and your staff for the opportunity to participate in the process as a member of CRWPP Working Team and to comment on the draft plan. We are pleased to see that the final draft incorporates our suggestions and the "Preferred Plan", alternative 4, includes several of the City's recommended projects.

Sanibel is a community that depends on good water quality and a healthy estuary to support its tourism-based economy. Over the last six years high freshwater discharges from Lake Okeechobee and urban and agricultural runoff from within the basin have adversely impacted our water quality resulting in losses in revenue to our local economy. These impacts include massive amounts of drift algae washing up on local beaches, filamentous algae smothering seagrass beds in Ding Darling National Wildlife Refuge, and the loss of seagrasses and oysters throughout the estuary.

The Northern Everglades and Estuaries Protection Program legislation, Sec. 373.4595, Florida Statutes, was designed to provide the Caloosahatchee and St. Lucie Estuaries the same protections afforded to Lake Okeechobee and its watershed. We strongly support the program's goal to restore the quantity, timing and distribution of water to the natural system and are encouraged that the Florida Legislature realizes the value of our coastal resources to the state's economy.

As a whole the plan is well thought out and does a good job of incorporating stakeholder input. However, we do have some concerns about some of the assumptions used in the model to evaluate the water storage and water quality efficiencies of the four plan alternatives. The first assumption that concerns us is that the model assumes the lake will be operated according to the Water Supply and Environment (WSE) lake release schedule rather than the newly adopted interim schedule (LORS08). We recommend that the interim lake release schedule be used in future modeling efforts since

SB - 1

rehabilitation of the Herbert Hoover Dike will not be completed until 2030. It is our belief that modeling the flows using the WSE schedule underestimates the amount of storage needed in the watershed. SB - 1 cont.

The second modeling assumption that we are concerned with is that the plan assumes that Lake Okeechobee will be meeting its Total Maximum Daily Load (TMDL) of 40 parts per billion (ppb) of phosphorus. Since it is highly unlikely that the lake will meet its TMDL in the next 50 years, we suggest that future modeling runs use realistic nutrient loading values that are more representative of the actual loads that we can expect to see from the lake. SB - 2

Our last concern is that all of the plan alternatives assume that the Lake Okeechobee Phase II Technical Plan projects will be completed and that the C-43 West Reservoir will be constructed. Since these projects are the foundation of the plan and the west reservoir is the primary source of water for meeting the River's Minimum Flows and Levels (MFL), it is imperative that we move quickly to secure funding with our federal partners to complete these projects in a timely manner. SB-3A We also feel that it is critical that a water quality treatment component be incorporated into the reservoir's design so that environmental releases aimed at meeting the river's MFL do not contribute nutrients to the estuary. SB-3B

The plan identifies the S-4 basin as having the highest average nutrient concentration of all of the sub-watersheds in the Caloosahatchee basin and contributes a load of approximately 93 metric tons of Nitrogen and 14 metric tons of phosphorus annually. The Preferred Plan does identify a Recyclable Water Containment Area (RWCA) in the S-4 (CRE 02); however there may be additional opportunities to restore areas like the S-4 basin and the Disston Water Conservancy District as part of the U.S. Sugar lands purchase further reducing nutrient loading from the east Caloosahatchee. SB - 4

Although it is clear that the preferred plan will not stop all of the damaging releases, it will significantly reduce the number of times that flows are above or below the flow targets established by the District's biologists. We feel that the proposed ecology-based discharge criteria of maintaining mean monthly flows at Franklin Lock and Dam (S-79) between 450 cfs and 2,800 cfs are suitable targets for achieving the plan's restoration goals. The water quality monitoring plan appears to be adequate for identifying nutrient loading hot spots and filling in the data gaps in the eastern portion of the basin. We are pleased to see the use of a more holistic approach to research and monitoring that incorporates additional work on estuarine fisheries as well as continued work on oysters and seagrasses.

As we move from the plan development stage into the implementation phase, we encourage you concentrate on those projects that provide the SB - 5 "biggest bang for the buck" and have low associated operation and maintenance costs. SB - 5 cont.

We appreciate being included in the process and we look forward to working with you during the plan implementation phase.

Sincerely,

Mick Denham, Mayor
City of Sanibel

Cc: Janet Starnes, Project Manager, SFWMD
Sanibel City Council
Judith A. Zimomra, City Manager
Kenneth B. Cuyler, City Attorney
Dr. Rob Loflin, Natural Resources Director

United States Department of the Interior

FISH AND WILDLIFE SERVICE
J. N. "Ding" Darling National Wildlife Refuge
1 Wildlife Drive
Sanibel, Florida 33957

November 6, 2008

Janet Starnes
South Florida Water Management District
Lower West Coast Regional Service Center
2301 McGregor Boulevard
Fort Myers, FL 33901

Dear Ms. Starnes,

The J.N. "Ding" Darling National Wildlife Refuge (Refuge) Complex has reviewed the October 2008 Draft Caloosahatchee River Watershed Protection Plan. The refuge complex is comprised of five national wildlife refuges (NWR), including the J.N. "Ding" Darling NWR, Matlacha Pass NWR, Pine Island NWR, Island Bay NWR, and Caloosahatchee NWR located within the Caloosahatchee river and Estuary including San Carlos Bay, Matlacha Pass, and Pine Island Sound. We support the primary goals of the CRWPP to reduce nutrient loads from the Caloosahatchee River watershed and restore more natural salinity regimes in the river and its estuary. The following comments are provided in accordance with the refuge system mission to manage lands and waters for the conservation, management, and restoration of fish, wildlife, and plant resources, and their habitat.

DDNWR - 1

The description of the Caloosahatchee River and Estuary in Chapter 3, Section 3.2.1.2 Oysters, lines 582 to 583, page 3-14 and in Appendix E Chapter 3, Section 3.1.1 River and Estuary, lines 36 to 40, page 3-2 and lines 66 to 71, page 3-3 does not match the description in Chapter 2, Section 2.3 Background, lines 149 to 153. Appendix E defines the estuarine portion of the Calooshatchee river system as extending from S-79 to Shell Point which only includes the tidal portion of the Caloosahatchee River. Chapter 3 expands that definition to include only San Carlos Bay. These sections should be revised to include San Carlos Bay, southern Matlacha Pass and portions of Pine Island Sound as described in Chapter 2. The Northern Everglades legislation includes reference to "...the tidal portions of the Caloosahatcee River and estuary" implying that the study area should include the tidal portions of the river (i.e., from S-79 to Shell Point) and the estuary which includes San Carlos Bay, southern Matlacha Pass and portions of Pine Island Sound. If the draft Caloosahatchee River Watershed Research and Water Quality Monitoring Program has decided to limit the focus of the research and monitoring program described in Chapter 8 and Appendix E to the tidal portion of the river, than the reasons for that decision should be included in the document and maps delineating the proposed focus areas for each component of the research and modeling program described in Appendix E, Chapter 5, pages 5-1 through 5-27.

DDNWR - 2

We are surprised and quite disappointed that the draft Caloosahatchee River Research and Water Quality Monitoring Plan does not include research or additional monitoring to adequately quantify impacts to San Carlos Bay, southern Matlacha Pass, and Pine Island Sound including the Ding Darling National Wildlife Refuge, Matlacha Pass National Wildlife Refuge, and Pine Island National Wildlife Refuge during high flows/releases at S-79. The legislation was passed following 2 active hurricane seasons resulting in extremely high freshwater flows at S-79 of which as much as 60% originated from Lake Okeechobee releases. Those flows contributed to poor water quality conditions, algae blooms, and decreased salinity in this area which has impacts on local commercial and recreational fisheries, waterbird popultaions, and tourism. Political and social pressure to improve local estuarine conditions and to reduce the need for above average releases from Lake Okeechobee contributed to passage of the Northern Everglades legislation.

DDNWR – 2 Continued

According to Chapter 8, Section 8.4.1.2 Existing Estuarine Monitoring Programs, lines 225 to 241, pages 8-6 and 8-7 and Appendix E, Chapter 4, Section 4.3 Estuarine Monitoring, lines 170 to 176 on page 4-9 and lines 257 to 264 on page 4-14, the existing salinity monitoring in the estuary is adequate to determine the frequency and duration of undesirable salinity ranges resulting from discharges at S-79 and the existing water quality monitoring is sufficient to assess status and trends throughout most of the estuary. However, existing monitoring efforts were not sufficient to establish cause and effect relationships between the above average releases at S-79 that occurred following the 2004 and 2005 hurrricane seasons and the coinciding poor water quality conditions, algae blooms, decreased salinity, and decline in seagrass productivity and commercial and recreational fisheries. Although the Sanibel-Captiva Conservation Foundation (SCCF) has recently established a salinity monitoring program that compliments the South Florida Water Management District's (District) program, a significant gap in data collection exists between the District's Sanibel salinity stations and the SCCF's Blind Pass station. The Water Resources Engineering Branch, U.S. Army Corps of Engineers - Jacksonville District (Corps), has proposed to establish a flow, salinity, and water quality monitoring station in this vicinity near the mouth of Tarpon Bay pending funding. A station is this vicinity would aid in determining the impact of flows at S-79 on fish and wildlife resources within and adjacent to refuge boundaries. We recommend that the District establish a permanent continuous salinity and water quality recorder in that vicinity either in cooperation with the Corps or independently. If a permanent station is not feasible, we recommend that the District: 1) increase the frequency of grab samples in relation to the magnitude of flows at S-79, particularly at FIU station numbers 472 and 476 and the Lee County station in the middle of those two stations (for example, as flows reach or exceed 2800 cfs at S-79, the frequency of sampling could be increased from monthly to weekly); and 2) add aditional WQ monitoring stations (grab sampling) in the vicinity of the Ding Darling Natioanl Wildlife Refuge during releases that exceed 2800 cfs at S-79. Likewise, additional monitoring is needed to determine the impact of releases at S-79 on seagrass beds. We therefore, recommend that the District add and an additional long-term seagrass monitoring station within or adjacent to the Ding Darling NWR boundary.

DDNWR – 3

We are opposed to the Caloosahatchee Area Lakes Restoration (Lake Hicpochee) Project described in Chapter 6, Section 6.4.3.3 Alternative 3 – Maximizing Water Quality Improvements, lines 271 to 275 on page 6.4-8. Lake Hicpochee is a diverse wetland complex comprised of short hydroperiod wetlands, emergent marsh, and forested wetland habitats that supports a variety of fish and wildlife resources including state and Federally-listed threatened and endangered species. The C-43 West Storage Reservoir project team, comprised of staff from the South Florida Water Management District, Corps of Engineers, Florida Fish and Wildlife Conservation Commission, and the U.S. Fish and Widlife Service, rejected this management measure as an alternative reservoir location due to the value of this wetland complex to Florida's fish and wildlife. For example, an abundance of apple snail eggs were observed in the spikerush habitat within Lake Hicpochee which is key food source for snail kites. We recommend

DDNWR – 4

this project be omitted from the proposed alternative. The West Lake Hicpochee Project described in Chapter 6, 6.4.3.2 Alternative 2 – Maximizing Storage, lines 180 to 187 on pages 6.4-5 and 6 could be combined with the East Caloosahatchee Water Quality Treatment Area project described in Chapter 6, Section 6.4.3.4 Alternative 4 – Optimize Storage and Water Quality Improvements, lines 300 to 305 on page 6.4-9 to maximize water storage and nutrient removal without negatively impacting Lake Hicpochee and the assocated fish and wildlife resources. Please contact the South Florida Ecological Services Office in Vero Beach at 772-562-3909 for more information on threatened and endangered species in the project area.

DDNWR – 4 Continued

Improvements in water quality and restoration of more natural salinity regimes will benefit estuarine habitats, improve their functional quality, and benefit fish and wildlife populations that utilize those habitats at a local, regional, and systemwide scale. We appreciate this opportunity to provide comments on the proposed plan and look forward to our continued participation as a stakeholder. If you have questions or comments, please feel free to contact Joyce Mazourek, Fish and Wildlife Biologist, at (239) 472-1100 x 231.

Sincerely,

Paul Tritaik
Wildlife Refuge Manager

LEWIS, LONGMAN & WALKER, P.A.
ATTORNEYS AT LAW

Reply to: *West Palm Beach*

November 18, 2008

VIA ELECTRONIC MAIL
and REGULAR U.S. MAIL

Pinar Balci,
c/o SFWMD, MS 7640
3301 Gun Club Road
West Palm Beach, Florida 33406

RE Comments Regarding the Caloosahatchee River (and St. Lucie River) Watershed Protection Plans, October 2008 Draft

Dear Ms. Balci:

Please accept these comments into the record, submitted on behalf of Consolidated Citrus/King Ranch ("CCKR") regarding the Caloosahatchee River Watershed Protection Plan ("CRWPP") and St. Lucie River Watershed Protection Plans ("SLRWPP") or collectively ("WPPs").

CCKR is a significant stakeholder in the implementation of both of these WPPs due to the size and location of its significant land holdings across the State. The water supply for these lands includes surface water withdrawals from both of the Caloosahatchee and St. Lucie basins, as well as the Lake Okeechobee Service Area, among other sources. Land holdings of CCKR are either within, or proximate to, the various nutrient reduction load areas as identified in the WPPs. Land holdings of CCKR could also be impacted by the construction of the various projects in the WPPs. Implementation of these Plans on some level will impact the water supply or the water quality regulatory requirements for the CCKR land holdings.

The WPPs have three major components in regard to substance: Construction, Pollution Control, and Research and Water Quality Monitoring. Construction includes structural and non-structural options. Pollution Control is tied in large part to the pending total maximum daily load ("TMDL") process. Research and Water Quality Monitoring draws on the work already done, and attempts to identify and fill gaps in existing programs. Modeling is a key component of the WPPs and it provides transparency into the evaluation and priority setting effort. Modeling also provides an analytical tool by which success of the WPPs can be measured.

CRWPP: The preferred alternative (Alternative 4), upon which the CRWPP is based, depicts the need for 400,000 more acre-feet of water storage, proposes a reduction of approximately 40% in nitrogen and phosphorus discharges, and has an expected Phase I cost of up to $971 million for construction, $813 million in water quality improvements and an additional $5 million in monitoring.

SLRWPP: The preferred alternative (Alternative 4), upon which the SLRWPP is based, depicts the need for 200,000 more acre-feet of water storage, proposes an approximately 55% reduction in nitrogen and phosphorous discharges, and has an expected Phase 1 cost of up to $709 million for construction, $481 million in water quality improvements and an additional $2.7 million in monitoring.

Water storage / water quality treatment lands. It appears as though the WPPs primarily build upon storage projects that are already planned or in the approval process. What additional water storage lands might be needed to implement the WPPs beyond C-43 West Reservoir, C-44, Indian River Lagoon South Natural Storage and Water quality Areas, and C-43 BOMA project? The WPPs should make the distinction between existing, planned projects or new water storage and water quality projects to achieve the requisite 400,000 and 200,000 acre-feet of storage targets. Where would these new water storage and water quality projects be located? CCKR - 1

Flows needed to make the plan a success. Where will the water flows come from that are planned to be captured by the water storage projects (combined 600,000 acre-feet of water storage for the WPPs)? Are these flows excess discharges that originate from the watershed basin and Lake Okeechobee? How will the capture of these flows affect water supply for users and will some of that captured water be available for agricultural consumptive use? Has there been any modeling of this plan for its impact on water supply? CCKR - 2

"River of Grass" initiative. Overall coordination between the WPPs and the River of Grass initiative must occur from both a cost and planning perspective. CCKR - 3

Water Quality Requirements. It appears as though most of the WPP waterbodies are impaired for total nitrogen, total phosphorous or biochemical oxygen demand. The reductions in nitrogen and phosphorous loading (for both WPPs) show improvement, but the loading CCKR - 4 performance will be "revisited" once the TMDL is adopted. Does this mean that the WPPs will be revised and if so, how and when? CCKR - 4 continued

Operations, implementation and further planning. CCKR is concerned that the WPPs, do not have an "operational" component. Specifically, this operational component needs to include information such as which agency is responsible for what structures/facilities and how those will be operated. The WPPs provide very generic statements that could be replaced with operational plans. Given that the WPPs had a specific due date for submission to the Florida Legislature, the CCKR understands that these operational issues will likely be developed in the Process Development and Engineering phase. However, an operational plan is still needed sooner rather than later. The WPPs also need a strong Implementation Plan addressing the specific of what will be constructed and when. Are Draft WPPs submitted to the Legislature in January 2009 or are those plans considered final? It appears as though most of the details of the WPPs (including operations and implementation) will be borne out in the Process Development and Engineering Phase which is slated to begin next year. These planning efforts must include the public, and in particular, landowners directly impacted by the further development of these WPPs. CCKR - 5 CCKR - 6

Rulemaking. There are several rulemaking efforts underway currently which will be included within the WPPs and will impact the implementation of the WPPs including:

- Rule 62-306.100, F.A.C. which will establish the procedures for water quality credit trading, including the process to determine how credits are generated, quantified, and validated; the process for tracking credits, trades, and prices paid; limitations on the use of credits, including eligible pollutants, minimum water quality requirements, and any adjustments for uncertainty or location; the timing, duration, and transfer of credits; and the mechanisms for determining compliance with trade provisions. The WPPs will need to be revised to incorporate this strategy into its implementation. CCKR - 7

- The Lake Okeechobee and Estuary Basin rule and Unified Statewide Stormwater rule: These two Rule processes will now be more coordinated, but depending on the final form of these rules, what changes may need to occur in the WPPs pursuant to their implementation? CCKR - 8

- What changes to the WPPs may be required after the TMDLs are finalized? CCKR - 9

Finally, CCKR is keenly aware of the legislative requirements driving the development and implementation of the WPPs. We do remain concerned, however, about the load reduction requirements and the actual location of some of the projects. The location of some of these features of the WPPs is not defined or subject to change. The SFWMD should be providing more certainty to landowners whose lands may be significantly affected by the WPPs about the location of project features and future revisions. We look forward to working with you in the CCKR - 10 future on the implementation of the WPPs. For any additional questions regarding these comments, please do not hesitate to call.

Sincerely,

Stephen A. Walker

SAW/ELD:kaa

cc: Mr. Mitch Hutchcraft
Mr. Paul Grose

RESPONSES TO AGENCY AND PUBLIC COMMENTS

Caloosahatchee River Watershed Protection Plan
Responses to Agency and Public Comments

Comment No.	Response
CHNEP - 1	The monitoring activities of state and local government agencies, CHNEP, and non-governmental organizations that are relevant to the goals and objectives of the CRWPP are summarized in Appendix E - Chapter 4, Tables 4.2-1 and 4.3-1. The River of Grass Initiative is under development and no monitoring plan has yet been developed.
CHNEP - 2	Table 1-1 of Problems, Objectives and Constraints identifies technical problems occurring within the watershed, all of which result in impacts to the economy and ecotourism. Therefore, the economy and ecotourism were not included. However, the Background Section of the Executive Summary and Chapter 2 discuss impacts to the economy and ecotourism.
CHNEP - 3	In regard to the River of Grass initiative, only broad concepts and objectives for restoration have been explored. Once the negotiation is complete, a public process will be utilized to develop definitive restoration project plans. Future CRWPP planning will incorporate this information, as appropriate. Additional text has been added in Section 3.1.2.3 to clarify.
CHNEP - 4	Table 5-2 in Chapter 5 was modified as requested.
CHNEP - 5	The River Watershed Protection Plan Base (RWPPB) condition is defined in Section 6.2.1.2 and does include a listing of the restoration projects that are included in the RWPPB.
CHNEP - 6	The nutrient load from resuspended sediments is best addressed by the research program described in Appendix E, Chapter 5. A short-term investigation as part of the larger Estuarine Nutrient Budget project (Appendix E, Chapter 5, Section 5.2) could provide enough information to support modeling and estimates of the magnitude of nutrient loading from resuspended solids. Table 5.2.1 was revised to include sediment resuspension as an internal source of nutrients. Both measured and modeled loads of TN or TP loading to the Caloosahatchee Estuary include nutrients carried on sediment particles. At present, rates of sediment resuspension in the Caloosahatchee and the partitioning of particle-bound and dissolved phases in the water column have not been quantified. Calculation of an internal nutrient load from resuspension is not yet possible. Appendix E, Chapter 5, Section 5.7.5 identifies sediment transport and its integration with a water quality component as a future modeling need.

Comment No.	Response
CHNEP - 7	The CRWPP does not account for any changes in flow or nutrient reductions resulting from increased use of reclaimed water. The reference in Appendix E to the percent of flows originating from wastewater treatment facilities was based on the Environmental Research and Design (Harvey Harper, 2002) report. The report references 2001, a dry year, when S-79 was closed. The discharge from the City of Fort Myers WWTP and Waterway Estates WWTP accounts for the 56% number.
CHNEP - 8	Long-term water quality monitoring is included in the CRWPP in Appendix E, the Research and Water Quality Monitoring Program. BOD_5 is one of the monitoring parameters. In addition oysters, benthic invertebrates, SAV and fish communities will be monitored as Valued Ecosystem Components.
CHNEP - 9	Lake Okeechobee was included in flow, salinity, and nutrient regime calculations, as discussed in Chapter 6, Sections 6.2.1.2 and 6.3.1.2.
CHNEP - 10	Chapter 6, Section 6.3 discusses in detail the assumptions and calculations included in the CRWPP Water Quality Spreadsheet. The Water Quality spreadsheet is based on loading rate coefficients derived from the information provided by Soil and Water Engineering Technology, Inc (SWET) and is included in Appendix D. Calculations for basins lacking sufficient historic data were based on best professional judgment and reviewed by the working team.
CHNEP - 11	Creation, restoration, enhancement, and preservation of wetlands and uplands are significant elements of the ERP program. The requirements for these subjects are discussed in detail in Chapter 4, Sections 4.3.2.1- 4.3.2.2, of SFWMD's Basis of Review for Environmental Resource Permits.
CHNEP - 12	The scientific basis for the low flow threshold of 450 cfs (mean monthly flow) to the Caloosahatchee Estuary is presented in Appendix E, Chapter 3, Section 3.4 <u>Salinity Envelope and Freshwater Inflow Targets for the Caloosahatchee Estuary</u>. The intention of the low flow threshold is to provide salinity conditions in the upper Caloosahatchee Estuary between Fort Myers and Beautiful Island that will support the growth of tape grass (*V. americana*). A combination of laboratory experiments, field observations, and review of the literature indicate that tape grass populations cannot sustain themselves over the long-term at salinities above 10 ppt. Hydrodynamic modeling indicates that a freshwater inflow of about 450 cfs is required to maintain 10 ppt or less in the upper estuary.

Comment No.	Response
CHNEP - 13	The Implementation Strategy includes a phased approach as described in Chapter 9, Section 9.4. More detailed information regarding lead partners and timetables for individual project implementation will be developed during program implementation and during the Basin Management Action Plan process. As developed, these details will be included in future annual reports and three-year plan updates. Specific project timelines will be dependent on funding, permitting, and other issues. Potential funding sources are discussed in Section 9.4 and Appendix G. Implementation challenges are discussed in Section 9.4.5. More detailed information will be included in future plan updates.
TNC - 1	Management Measure CRE-LO 91 has been revised as requested.
LC - 1	The River of Grass initiative planning process will take into consideration the objectives of the Northern Everglades and Estuaries Protection Program, as well as the projects that have been recommended by the LOP2TP and CRWPP, to determine the potential opportunities provided by the proposed acquisition.
LC - 2	There are many existing monitoring programs west of S-79, both within the tributaries and in mainstem of the Caloosahatchee River. Each of these monitoring programs has its own monitoring objectives, design and procedures for quality assurance, quality control, data management, assessment and reporting. While a more integrated and watershed-based approach is needed, care must be used when integrating and drawing conclusions across multiple data sets. The RWQMP working team has acknowledged the need for consistent methodologies in data collection, data sharing and management of the current monitoring plans in the watershed and will take this into account while implementing the proposed monitoring. East of S-79, SFWMD is moving toward a more integrated watershed approach and coordinating with the Source Control Program staff to identify overlapping needs. If any supplemental stations are needed to fully address the needs of this program in the watershed, the efforts will be coordinated with the working team.
LC - 3	FDEP has initiated rule development on a Statewide Stormwater Rule. This rule currently proposes that discharges of TP and TN from new development be equal to or less than that discharged from a pre-developed natural condition. SFWMD also has proposed a special ERP basin rule pertaining to water quantity for Lake Okeechobee and the St. Lucie and Caloosahatchee Estuaries that would ensure that there are no increases in discharge volumes. Currently applicants are required to demonstrate that their proposed projects will not contribute to the impairment of the water body.

Comment No.	Response
LC - 4	FDACS currently plans on implementing 100% of owner-implemented agricultural BMPs and 35% of cost-share agricultural BMPs within Phase I of the CRWPP, assuming that funding is allocated for that purpose by the Legislature. FDEP will develop a specific schedule for implementation of urban BMPs and other nutrient reduction measures as a part of the Basin Management Action Plan.
LC - 5	See response to CHNEP-13. A System-Wide Operating Manual will be developed that will identify many of the structures/facilities throughout the South Florida water management system (including the Central and Southern Florida project, CERP and other state projects). The manual will describe regulation schedules, water control, and operating criteria; and will reflect operating criteria used in the identification of the appropriate quality, timing, and distribution of water dedicated and managed for the natural system.
LC - 6	Additional information was included in Chapter 3, Section 3.1.2, <u>State and Local Efforts</u>.
LC - 7	The NEEPP Legislation defines the Caloosahatchee River Watershed as "the Caloosahatchee River, its tributaries, its estuary, and the area within Charlotte, Glades, Hendry, and Lee counties from which surface water flow is directed, or drains, naturally, or by constructed works, to the river, its tributaries, or its estuary." In addition, the watershed boundary was discussed by the working team and reviewed during the initial draft reviews by the working team. Furthermore, the boundary of the CRWPP study in this vicinity matches the standard basin boundary used for southwestern Florida, separating Upper and Lower Charlotte Harbor along a line extending eastward from Boca Grande Pass.
LC - 8	The funding situation for the LOP2TP is similar to that of the CRWPP and is as described in Section 9 of the LOP2TP.
LC - 9A	The RWPP base condition is intended to reflect conditions circa 2015. It is currently anticipated that the Modified Water Deliveries and C-111 projects will be substantially complete within this time frame. Base conditions and other assumptions will be reassessed and modified, as appropriate, in future plan updates.

Comment No.	Response
LC - 9B	The Figures in Chapter 1 have been removed.
LC - 10	The LOP2TP identified the need for 1.3 million acre-ft of storage to manage Lake Okeechobee stage and discharge. The River of Grass initiative will evaluate the relationship between storage needs and siting north and south of the Lake.
LC - 11	The reference has been corrected.
LC - 12	See response to LC-6.
LC - 13	Under the RECOVER Program, submerged aquatic vegetation has been monitored manually at seven sites in the Caloosahatchee Estuary and San Carlos Bay on a bimonthly basis since 2004 and is anticipated to continue. Tape Grass in the upper Caloosahatchee Estuary has been monitored since 1998. RECOVER will also produce SAV maps from aerial photographs of the study area every five years.
LC - 14	Chapter 1 has been revised.
LC - 15	While the FGCU study is noteworthy, it is currently underway and results are not available. It is not the purpose of the CRWPP to summarize all research that is currently going on in the Caloosahatchee River Watershed, rather, the CRWPP identifies future research projects that could fill gaps in our knowledge and contribute to meeting the CRWPP goals. The nutrient TMDL for the Caloosahatchee Estuary is based on providing sufficient water clarity in San Carlos Bay so that seagrasses can grow to a target depth specified by the CHNEP. The water clarity goal assumes that nutrient load reductions will lead to a reduction in chlorophyll-*a*, which in turn will lead to enhanced water clarity. Review of the literature indicates that color or chlorophyll may be the major attenuator of light, depending on the particular study. Therefore, a study is necessary to resolve conflicting evidence in the literature.
LC - 16	See response to CHNEP-2.
LC - 17	Table 1-4 has been replaced by Table 1-1, Phase I (2009-2012) Projects and Implementation Status Table. The completion column in this table shows a completion date of 2012 for the Powell Creek Algal Turf Scrubber project.

Comment No.	Response
LC - 18	Preferred Plan benefits/Phase 1 reflect improvement from current conditions, which are defined in Chapter 6, Section 6.2 and Section 6.3.
LC - 19A	This statement was in reference to the funding of various programs and projects, including CERP. It is still anticipated that CERP projects will be implemented through a 50:50 cost share between the federal and state government. Revisions to project schedules as currently reflected in the Integrated Delivery Schedule were captured in this planning process. Future schedule changes related to CERP or the River of Grass land acquisition will be incorporated as appropriate in future plan updates.
LC - 19B	An additional explanation of costs is included in Chapter 9, Section 9.4.4. The costs estimated in the plan reflect total costs to implement urban BMPs throughout the watershed in areas where they are not currently implemented. Areas of current implementation were not included. Due to the nature of urban BMPs, they have and will continue to be funded by individual owners, developers, local governments, and the state and federal government. More stringent regulatory criteria may result in a portion of these costs being covered by developers and landowners. In addition, the Basin Management Action Plan process may result in more specific information regarding costs and funding sources.
LC - 20	Cost estimates for Phase II and the subsequent phases will be developed in future updates of the plan, as described in Chapter 9, Section 9.4.3. Detailed cost estimates for each project will be developed as more detailed planning and design progresses. Since the River of Grass acquisition is still under negotiation, it is not possible to determine potential overlap or cost implications.
LC - 21	The suitable salinity ranges for the estuary are based on the needs of the identified Value Ecosystem Components and are not tied to a specific source.
LC - 22	See response to LC-7.
LC - 23	Text in Chapter 2, Section 2.4.2 was corrected.
LC - 24	During droughts or when the elevation of water in Lake Okeechobee falls below approximately 11 ft, S-78 is closed. Runoff from the East Caloosahatchee Basin then flows into Lake Okeechobee.

Comment No.	Response
LC - 25	There is no relationship between the CRWPP and water reservations. However, many of the projects included in the CRWPP are expected to improve low flow conditions in the estuary. Quantification of water to be reserved or allocated for the natural system is identified for individual projects as a part of the CERP Project Implementation Report process.
LC - 26	Reference to the Lee County Surface Water Management Master Plan has been added to Chapter 7, Section 7.1.3.1.
LC - 27	See response to LC-6.
LC - 28	Lake Okeechobee discharges are included in this table. In addition, impacts to the estuary from Lake Okeechobee discharges are discussed in the CRWPP. However, as stated throughout the document, management of Lake Okeechobee discharges was addressed in the LOP2TP.
LC - 29	Language in Chapter 3, Section 3.3.2 has been revised.
LC - 30	Flows that are within the “harm” region are weighted more negatively than flows that are not in the “harm” region.
LC - 31	Calculations for the S-4 Basin are based on the best available data and best professional judgment and reflect current accepted data for the basin. A citation has been added to the Water Quality Spreadsheet documentation to reflect sources.
LC - 32	The methodology is detailed in Chapter 6, Section 6.3. The best available data and best professional judgment were used as a part of the analysis and are included in the documentation for the water quality spreadsheet.
LC - 33	See response to LC-31.
LC - 34	“Flow-weighted concentration” is used correctly in this case. In response to an earlier review, the term “flow-weighted concentration” was deleted from several locations in the report. In this case “flow-weighted concentration” was the best descriptor and was explicitly defined as “computed by dividing total load by total flow.”
LC - 35	The text has been modified to clarify that the assumptions were based on the results of several modeling scenarios conducted utilizing the Lake Okeechobee Water Quality Model.

Comment No.	Response
LC - 36	See response to LC-3.
LC - 37	Additional information about local ordinances that are being promulgated to mitigate non-point source runoff has been added to Chapter 7, Section 7.1.3.1.
LC - 38	Chapter 8, Section 8.3.1 states that Lake discharges, "….decrease the frequency and duration of the damaging low flows that impact upstream, low salinity regions." See Appendix E, Chapter 3, Section 3.2 & Figures 3.2-6, 3.2-7, and 3.2-8. However, it is recognized that while discharges from Lake Okeechobee do reduce the frequency and duration of harmful low flows, the discharges do not always prevent exceedances of the MFL salinity criteria at Fort Myers.
LC - 39	A discussion of all these thresholds may be found in Appendix E, Chapter 3, Section 3.4.
LC - 40	While the recommended monitoring stations in the RWQMP do not distinguish between the north and south subwatershed, the Pollutant Source Control Program, as outlined in Chapter 7, will be able to make such a distinction once problem areas of the Caloosahatchee River Watershed are identified. See Appendix E, RWQMP, Chapter 4. While monitoring efforts in freshwater basins may not fulfill the current modeling needs, the monitoring efforts under the Pollutant Source Control Program and those recommended short-term monitoring stations in freshwater basins will provide modeling data. FDEP will initiate TMDL development in upper freshwater basin of the Caloosahatchee River in 2009 and short-term monitoring may be implemented to fill data gaps.
LC - 41	See response to LC-40.
LC - 42	BOD_5 was identified because measurement of BOD_5 will support water quality modeling efforts. BOD_5 is used to quantify the DO demand in oxidation of organic carbon and provide a measure of labile organic loads to the receiving waters. The most recent water quality modeling effort in the Caloosahatchee Watershed was undertaken by FDEP for TMDL development and includes BOD_5 as one of the water quality constituents: the EFDC model requires dissolved organic and total organic carbon (DOC and TOC) that is converted into BOD ultimate (BODU) and BOD_5. FDEP and SFWMD modeling efforts are being coordinated to ensure that laboratory analyses such as BOD are being performed in manner consistent with model data needs.

Comment No.	Response
LC - 43	An assessment of models and their needs is presented in Appendix E, Chapter 5, Section 5.7. In short, while interim models can be developed, there is not enough data to fully support all modeling tools. For example, the hydrodynamic/water quality model will need additional estimates of groundwater inflow, benthic flux measurements, diurnal dissolved oxygen data and sediment and turbidity data.
LC - 44	See response to LC-6.
LC - 45	Land conservation is already included in Chapter 9, Section 9.1.3.
LC - 46	See response to LC-6.
LC - 47	The impact of the potential River of Grass land acquisition on the rate of funding and implementation has not yet been determined.
LC - 48	Language has been added to Chapter 3, Section 3.1.2.3.
LC - 49	See response to CHNEP-7.
LC - 50	Correction has been made.
LC - 51	See response to CHNEP 6.
LC - 52	A System-Wide Operating Manual will be developed that will identify many of the structures/facilities throughout the South Florida water management system (including the C&SF project, CERP and other state projects). The manual will describe regulation schedules, water control and operating criteria and will reflect operating criteria used in the identification of the appropriate quality, timing and distribution of water dedicated and managed for the natural system. In addition, more details on operations of the specific CRWPP features will be included in future plan updates.

Comment No.	Response
SWFRPC - 1A	The Implementation Strategy includes a phased approach as described in Chapter 9, Section 9.4. More detailed information regarding lead partners and timetables for individual project implementation will be developed during program implementation and during the Basin Management Action Plan process. As developed, these details will be included in future annual reports and three-year plan updates. Adaptive management will be critical to the success of the Caloosahatchee River Watershed Protection Plan. The need for more detailed planning and design and for a process that incorporates and adapts to new information is recognized in the NEEPP legislation. The legislation specifically calls for a Process Development and Engineering (PD&E) component to ensure the Protection Plans are refined and updated periodically. A discussion of the PD&E component and associated monitoring is included in Section 9.4.6 and Appendices E and F.
SWFRPC - 1B	Potential funding sources are discussed in Chapter 9, Section 9.4 and Appendix G. More detailed information regarding funding scenarios for individual project implementation will be developed during program implementation and during the Basin Management Action Plan process. Detailed cost estimates for each project will be developed as more detailed planning and design progresses. As developed, these details will be included in future annual reports and three-year plan updates.
SWFRPC - 2	See response to CHNEP–5.
SWFRPC - 3	See response to CHNEP-11.
SWFRPC - 4	See response to CHNEP-2.
SWFRPC - 5	See response to CHNEP-7.
SWFRPC - 6	Table 5-2 in Chapter 5 has been modified as requested.
SWFRPC - 7	See response CHNEP-13.

Comment No.	Response
SWFRPC - 8	A variety of implementation and funding strategies will be used to move the Preferred Plan projects forward. Many of these projects are already included in other planning or restoration efforts (e.g., Comprehensive Everglades Restoration Project) and there may be other alternative funding strategies for these projects. The coordinating agencies will continue to maximize opportunities for federal and local government cost-sharing programs and opportunities for partnerships with the private sector and local government. For example, the Preferred Plan minimizes real estate acquisition requirements by promoting involvement of private landowners as partners in the restoration program (best management practices, Florida Ranchlands Environmental Services Project, Alternative Water Storage/Disposal projects) and emphasizing the use of state-owned lands. By reducing the amount of land that needs to be purchased and developing partnerships with local landowners, the potential for delayed implementation of the restoration projects can be minimized.
SWFRPC - 9	See response to CHNEP-9.
SWFRPC - 10	See response to CHNEP-12.
SWFRPC - 11	See response to CHNEP-10.
SWFRPC - 12	See response to CHNEP-8.
SWFRPC - 13	See response to CHNEP-1.
SWFRPC - 14	See response to CHNEP-3.
SWFRPC - 15	See response to CHNEP 6.
SWFRPC - 16	See response to LC-6.

Comment No.	Response
SCCF - 1A	Since the NEEPP legislation required development of plans for all three watersheds, it was necessary to ensure that the three plans were integrated and reflected the comprehensive benefits anticipated from implementation of the Northern Everglades and Estuaries Protection Program as a whole. The CRWPP does not assume that Lake Okeechobee discharges meet 40 ppb. As described in Chapter 6, Section 6.3.1.2., the plan assumes that flows into Lake Okeechobee are 40 ppb, but that due to internal lake loading, concentrations in discharges from the Lake to the estuary are only reduced from current conditions by 10% for TN and 20% for TP. Phosphorus concentrations in discharges from the Lake are therefore assumed to be 80 ppb, which can be compared to the current concentration of 87 ppb.
SCCF - 1B	Future plan updates will use updated Lake Okeechobee regulation schedules and other applicable operational changes. However, please note that LORS was developed as an interim schedule and will need adjustments to be compatible with additional storage features as they come online.
SCCF - 2	See response to LC-1.
SCCF - 3	The SFWMD is familiar with the Caloosahatchee Alternative Riverway Betterment Plan. Many of the components that are proposed in the Betterment Plan - such as Spanish Creek/Four Corners Environmental Restoration Phase I, C-43 Water Quality Treatment Demonstration Project, and Caloosahatchee Area Lakes Restoration (Lake Hicpochee) - are included in the CRWPP as management measures. A number of those management measures are scheduled for initiation in Phase I.
SCCF - 4	We concur and believe that it will be important to maximize the use of low intensity, lower cost projects.
SCCF - 5	Low Impact Development (LID) is a major component of the proposed Statewide Stormwater Management Rule. The rule proposes to allow credit for reductions to TP and TN through the use of LID features such as pervious pavement, green roofs, and cisterns. Additional credits will be allowed from the use of other BMPs. Credit will be offered for implementation of treatment trains and stormwater recycling. In addition, implementation plans for agricultural and non-agricultural BMPs to address nutrient (total phosphorus and total nitrogen) concerns for existing land uses are being considered under the CRWPP. These plans are detailed in Chapter 7, Sections 7.1.1.2, 7.1.2, and 7.1.3 of the CRWPP.

Comment No.	Response
SCCF - 6	See response to CHNEP-13.
SCCF - 7	See response to LC-6.
SCCF - 8	There will be a number of forums for coordination regarding implementation of the CRWPP, including the Northern Everglades Interagency Team, Lake Okeechobee Committee of the WRAC, WRAC, Governing Board, public meetings, and specific project working teams. Additional forums can be created if deemed necessary. In addition, the Basin Management Action Plan development process will also provide a forum for coordination regarding program and project coordination and will require involvement of all implementation agencies/entities, functional providers, etc.
SCCF - 9	We concur with the comment and feel that it will be necessary to utilize both existing revenue sources and also to maximize opportunities for cost-sharing, partnering, and grant funding in order to optimize use of fiscal resources.
FM - 1	See response to SCCF-3.
FMB - 1	We concur with the comment and note that the PD&E component and annual reports and three-year updates required by the legislation will ensure timely reevaluation.
FMB - 2	In the CRWPP, the hydrologic performance measures are directly linked to the Valued Ecosystem Components, SAV and oysters. The existing monitoring programs verify that improvements in water quality and the delivery of freshwater to the Caloosahatchee Estuary do have an effect on biological resources. In addition, RECOVER has established targets for oysters, benthic invertebrates, SAV and fish communities in the Northern Everglades estuaries. These may be found at http://www.evergladesplan.org/pm/recover/perf_ne.aspx
SWFWC - 1	The CRWPP does not assume that Lake Okeechobee discharges meet 40 ppb. As described in Chapter 6, Section 6.3.1.2, the plan assumes that flows into Lake Okeechobee are 40 ppb, but due to internal lake loading, concentrations in discharges from the Lake to the estuary are only reduced from current conditions by 10% for TN and 20% for TP. Phosphorus concentrations in discharges from the Lake are therefore assumed to be 80 ppb, which can be compared to the current concentration of 87 ppb.
SWFWC - 2	See response to SCCF-1B.

Comment No.	Response
SWFWC - 3A	We concur with the comment.
SWFWC - 3B	The need for additional water quality treatment facilities in the Caloosahatchee River Watershed has been identified in the CRWPP. The specific need for an STA at the location of the Caloosahatchee River West Basin Storage Reservoir has not been substantiated by the data that was collected during operation of the test cells on the site. Once the West Reservoir is operational, there will be ongoing monitoring to further evaluate the potential effect of the reservoir on water quality associated with releases from the reservoir.
SWFWC - 4	It is important to understand how the cost estimates in Chapter 9 were generated and what the individual estimates represent. Many of the projects in the CRWPP were already being planned and, in many cases, funded through other efforts or initiatives, Therefore, they do not represent new costs. Nonetheless, we concur that it will be important to understand the costs and benefits of various projects to ensure fiscal prudence. SFWMD will continue to work with agencies and the public to implement the projects that most cost effectively meet the objectives of the plan.
GCGA - 1	See response to LC-8.
SB - 1	See response to SCCF-1B.
SB - 2	See response to SWFWC-1.
SB - 3A	We concur with the comment.
SB - 3B	See response to SWFWC-3B.
SB - 4	See response to LC-1.
SB - 5	We concur that it will be important to understand the costs (including operation and maintenance costs) and benefits of various projects to ensure fiscal prudence. SFWMD will continue to work with agencies and the public to implement the projects that most cost effectively meet the objectives of the plan.
DDNWR - 1	Chapter 2, Section 2.3 is a general description that is consistent with NEEPA. Chapter 3, Section 3.2.1.2 and Appendix E, Chapter 3, Section 3.1.1 are discussing specific areas that are related to specific issues. Neither of these watershed descriptions takes away from the direction provided in NEEPA.

Comment No.	Response
DDNWR - 2	Appendix E (Research and Water Quality Monitoring Program) does cover both the tidal and riverine portion of the Caloosahatchee River Watershed.
DDNWR - 3	The CRWPP and RWQMP were assembled by a working team that included representatives from the coordinating agencies, Lee County, City of Sanibel, Fort Myers, Cape Coral, and others. The CRWPP was thought adequate to track changes in the study area to understand processes occurring within it. The RWQMP was thought adequate to monitor the changes that are occurring within the estuary and study area as a result of the CRWPP implementation.
DDNWR - 4	This project has not reached the Basis of Design Review (BODR) stage. These issues or any potential issues can be addressed during the Basis of Design Report phase of the project.
CCKR - 1	See response to SWFRPC-8 The management measures have not been geographically located in the CRWPP due to the need to complete the Process Engineering and Development phase for each of the reservoirs or water quality treatment facilities. A feasibility study will be completed for each management measure and each of those will be coordinated with those landowners that may be impacted.
CCKR - 2	The "excess" flows from the Caloosahatchee River Watershed will be captured in the water storage projects. Those "excess" flows will then be released to supplement low flows to the Caloosahatchee Estuary during the dry season when flows to the estuary fall below 450 cfs. When assessing the four alternatives in the CRWPP existing LOSA water supply demands were considered and modeled as a constraint to ensure that those permitted existing users were not impacted. See Chapter 6, Section 6.5.1.5 for more details and results.
CCKR - 3	See response to LC-1.
CCKR - 4	The CRWPP will be updated on a three year revisions cycle. Any impacts of the adoption of TMDLs and the associated Basin Management Action Plans will be incorporated during the three year revision cycle. See Chapter 9, Section 9.4.6 for more details regarding the plan update and revisions process. Also, see response to SCCF-8.

Comment No.	Response
CCKR - 5	See response to LC-5.
CCKR - 6	The submittal to the Florida Legislature on January 1, 2009 will be the final 2009 CRWPP. As discussed in Chapter 9, Section 9.4.6, there will be annual reports and three year plan updates which will be subject to a public process. Also, see response to CHNEP-13.
CCKR - 7	The CRWPP will be updated on a three year revisions cycle. Any rule revisions that impact the Plan will be incorporated during the three year revision cycle. Also, see response to SCCF-8
CCKR - 8	See response to LC-3. The rule changes and BMAP process will help further define the effectiveness, funding scenarios, and schedules for urban BMP implementation. These refinements and other changes resulting from rule adoption will be incorporated into future plan updates.
CCKR - 9	See Chapter 6, Section 6.4.1.2 for a discussion regarding this issue.
CCKR - 10	See response to SWFRPC-8 and CCKR-1.