ANNEX D
ADAPTIVE MANAGEMENT AND MONITORING PLANS FOR THE LOXAHATCHEE RIVER WATERSHED RESTORATION PROJECT

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D INTRODUCTION TO ANNEX D: THE LRWRP ADAPTIVE MANAGEMENT AND MONITORING PLANS

The LRWRP PIR Annex D contains four plans: Adaptive management plan, hydrometeorological monitoring plan, water quality monitoring plan, and ecological monitoring plan. The annex begins with the adaptive management plan required by USACE implementation guidance for WRDA 2007 Section 2039[1], the 2003 Programmatic Regulations for the Comprehensive Everglades Restoration Plan (CERP), and CERP Guidance Memorandum 56[2]. The annex then contains three monitoring plans required to address various laws, regulations, and permits necessary to implement LRWRP. The items identified in this annex are based on knowledge formed from extensive scientific work on Everglades ecology and restoration, some initiated several decades ago, as well as USACE guidance and regulatory agency permit requirements. In particular the long-term, system-wide monitoring and modeling conducted by Comprehensive Everglades Restoration Plan's (CERP) interagency science group (the REstoration COordination and VERification group, or RECOVER) informed the planning of LRWRP and the development of the adaptive management plan. *The overall objectives of the adaptive management and monitoring plans in this annex are to: (1) identify the primary areas were restoration efforts will benefit from monitoring and assessment and specify the monitoring and assessment resources needed; (2) define how the monitoring and assessment can be used to refine LRWRP implementation to improve restoration performance in the face of inevitable uncertainties, using existing knowledge complimented by LRWRP's monitoring and assessment, and (3) meet regulatory and permit objectives to understand whether constraints are avoided and/or minimized.*

The monitoring plans contained in Annex D were guided in part by two principles. First, they needed to be complete from a LRWRP perspective by providing all monitoring required to address LRWRP-specific needs. Second, they must be integrated with other Everglades monitoring to take advantage of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and insure cost-effectiveness. These two principles have been accomplished in the adaptive management plan, hydrometeorological monitoring plan, water quality monitoring plan, and the ecological monitoring plan. It is expected that document reviews and future reassessments of LRWRP monitoring needs will identify additional monitoring to address regulatory and consultation needs, as well as additional efficiencies that can be gained. Where possible, LRWRP monitoring described here relies on existing monitoring resources including physical instrumentation, stations, locations, servicing, and analysis efforts funded by RECOVER, CERP sponsors, and partner agencies and assumes these other monitoring efforts will continue at least for the period required by LRWRP. Therefore the monitoring requirements described and budgeted in the LRWRP monitoring plan are limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LRWRP-specific questions. Cost estimates for Annex D monitoring are provided in Table D.1.1. A table and diagram of *leveraged* monitoring is provided in the implementation section of Part 1, the Adaptive Management Plan.

Part 1: Adaptive Management Plan – The Adaptive Management Plan, provides the strategies to address prioritized project uncertainties that will be faced as LRWRP progresses toward achieving restoration goals

[1] USACE. 2017. USACE HQ Implementation Guidance on Section 1161 of 2016 Water Resources Development Act. **http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll5/id/1212**

[2] USACE and SFWMD 2011. CERP Guidance Memorandum 56: Integration of Adaptive Management into Program and Project Management. http://www.cerpzone.org/documents/cgm/CGM_56_Adaptive_Management.pdf

and objectives while remaining within constraints. Each strategy follows a scientific approach that uses performance measures, monitoring, triggers, and/or thresholds to inform restoration progress and support decisions regarding the need to adjust LRWRP to improve restoration performance.

Per CERP's adaptive management guidance, the management options included in the LRWRP Adaptive Management Plan can be described as the following:

1. *Informing LRWRP Implementation* - results of monitoring a project component may inform design, construction, and/or operation of subsequent project components,
2. *Informing Project Operations* - results inform project operations or system operating manuals,
3. *LRWRP Adaptive Management Contingency Options* – monitoring results may suggest a need to implement additional restoration actions, called adaptive management options, pending all required and applicable coordination, policies, and permitting.

Management option matrices (MOMs) are provided as a quick reference to the adaptive management options. They provide a crosswalk of the monitoring, triggers and thresholds, and the management options. The descriptions and MOMs are intended to inform decision-makers, LRWRP partner agencies, and the public on potential actions to improve restoration performance. ***Implementation of adaptive management options is not automatic; the options are suggestions that capture current understanding of potential future issues and solutions. While the AM Plan and its suggested options are considered part of the LRWRP recommended plan, all applicable policies, permitting, and coordination requirements apply to implementing AM Options.***

The monitoring identified in the adaptive management plan is considered part of the adaptive management strategies and for measuring ecosystem restoration success, as per the 2003 Programmatic Regulations for the Comprehensive Everglades Restoration Plan, CGM 56, and the USACE CERP Adaptive Management Integration Guide (RECOVER 2011b), in accordance with WRDA 2007 and its subsequent implementation guidance. The monitoring is specific to uncertainties raised during LRWRP planning that require refined data to address, and which will inform feasible options to adjust LRWRP as identified in the LRWRP Adaptive Management Plan. Per USACE planning guidance ER- 1105-2-100 Appendix E, the intent of focusing on the uncertainties is to address questions and reduce the uncertainties. For LRWRP in particular, doing so helps to ensure that LRWRP water infrastructure investments continue to be good investments over the long time span of the project, potentially avoid expending funds if detailed data collection shows reductions in construction needs, and helps to avoid exceeding Section 902 cost increases by incorporating the best new knowledge into design, construction, and operations.

The adjustments and options identified in this adaptive management plan are part of the recommended plan, except for the few "future opportunities" suggestions that may apply to future restoration projects. These are clearly demarcated in the plan and would require separate authorization if they are pursued. These suggestions of future opportunities are provided to capture the best current understanding (i.e. to capture institutional knowledge) of measures that may be needed to achieve Everglades restoration beyond LRWRP, with recognition that LRWRP provides a significant increment but not complete restoration.

The summary in **Table D-1** shows the monitoring associated with chronological phases of the LRWRP project, per monitoring plan and per funding type. The Adaptive Management Options are a

potential project cost associated with improvement of the project based on knowledge gained from monitoring and analysis. Adaptive Management Options may or may not be implemented, as needed. Due to the large scale and complexity of LRWRP the post- construction adaptive management and ecological success monitoring shown here occurs in 10-yr windows, coordinated with implementation phases and locations of LRWRP but is shown here as a worst case scenario of one 10-year window. Cost estimates for Annex D monitoring are provided in Table D.1.1 for hydrometeorological and water quality monitoring. Ecological monitoring will be updated based on completion of required trust resource consultations in the Final PIR/EIS. Ecological monitoring cost is based on ecosystem restoration success and adaptive management monitoring identified in the adaptive management plan. A project-wide contingency of 30% has been added to these estimates to reflect need for any baseline monitoring; it should *not* be assumed that the full contingency will be available for use in monitoring. This table is also presented in the PIR Section 6.

Table D-1. Intro: Annex D Adaptive Management and Monitoring Costs.

Construction Costs – Construction General Funding (FY18)	–
Adaptive Management Contingency Costs (2016 WRDA Guidance)	**Total Costs**
Adaptive Management Options	$**3,831,000**
Pre-Construction Engineering and Design	**Annual Costs**
Pre-construction Data Investigation (PED) - Adaptive Management	$50,000
Pre-construction USFWS BO Ecological Monitoring[3]	$TBD
Sub-Total PED Monitoring and Adaptive Management	$50,000[4]
Construction Phase Monitoring	**Annual Costs**
Adaptive Management and Ecological Monitoring	**$731,0000**
Water Quality	**$20,000**
USFWS BO Ecological Monitoring[3]	$TBD
Sub-Total Construction Phase Monitoring	$TBD
Operational Testing and Monitoring Period(OTMP)	**Annual Costs**
Water Quality Monitoring	$620,000/$400,000
Hydrometeorological Monitoring	$200,000
USFWS BO Ecological Monitoring	$TBD
Sub-Total OTMP Monitoring	$820,000
Monitoring and Adaptive Management First Cost (rounded)	–

[3] FWS Biological Opinion costs will be based on any monitoring requirements identified in any biological opinion provided by the FWS and reflected in the final draft project implementation report and environmental impact statement (PIR/EIS).

[4] Cost will be updated by Final PIR/EIS

Total Monitoring And Adaptive Management First Cost (rounded)	$TBD
Post Construction Costs – Operations and Maintenance Funding	–
Post Construction Monitoring Costs – cost per year for a 10 year cycle	–
General Adaptive Management and Ecological Monitoring	$731,000
Post Construction Monitoring Costs – average annual cost in perpetuity (life of project including the period of analysis)	–
Hydrometeorological	**$200,000**
Water Quality	**$400,000**
USFWS BO Ecological Monitoring[3]	**$TBD**
Sub-total Post Construction OMRR&R ($ average annual)	$1,310,000 first 10 years; $600,000/year 11 to 50 years.

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PART 1. LRWRP ADAPTIVE MANAGEMENT PLAN

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D.1 LRWRP ADAPTIVE MANAGEMENT PLAN EXECUTIVE SUMMARY

LRWRP's planning process and recommended plan were based on extensive existing scientific knowledge of the Loxahatchee River and Estuary, understanding of the problems and opportunities, and the evaluation of alternatives and estimation of the potential project restoration performance. While the LRWRP PIR is based on this wealth of knowledge, this adaptive management plan is provided to help address uncertainty that exists as in every natural resource management and restoration effort. Several sources of agency guidance exist regarding such uncertainties, including the U.S. Army Corps of Engineers ER-1105-2-100 Section 3-5 and Appendix E, WRDA 2007 Section 2039 and its implementation guidance, the 2003 Programmatic Regulations for the Comprehensive Everglades Restoration Plan, and its subsequent guidance including CERP Guidance Memorandum 56 (CGM 56), the Adaptive Management Integration Guide (RECOVER 2011b) and the CERP Program-Level Adaptive Management Plan (RECOVER 2015). Per these sources, the concerns and uncertainties of coordinating agencies and stakeholders were taken into consideration throughout LRWRP planning. The uncertainties were addressed by several means that are part of the USACE planning process, and some uncertainties that could not be fully resolved during planning are described in this adaptive management plan. This plan specifies strategies and appropriate timing to address the uncertainties.

The adaptive management plan provides a screened and prioritized summary of specific uncertainties that can be addressed with efficiently structured approaches. The adaptive management plan describes the approaches (called strategies) and suggests management options for future consideration if needed. The adaptive management plan is a culmination of input from well-developed USACE planning procedures, extensive scientific and local knowledge developed over decades of experience, and input from the LRWRP PDT during planning and the LRWRP Value Engineering and Cost Risk Analysis workshop.

Every LRWRP uncertainty in the adaptive management plan was screened with criteria described in Section D.1.2 of this document to ensure their applicability to LRWRP and to adaptive management as it is described in the 2003 Programmatic Regulations for the Comprehensive Everglades Restoration Plan and its subsequent CERP guidance. The screening criteria were based on CGM 56 and criteria provided in the CERP Adaptive Management Integration Guide (RECOVER 2011b). Each uncertainty needed to: (1) potentially affect LRWRP's ability to meet its goals and objectives and remain within its constraints; (2) be at an appropriate LRWRP-scale spatially and temporally; (3) have options for adaptive management actions such as potential project adjustments; and (4) have a combination of high importance to LRWRP and high uncertainty that could be reduced by practical adaptive management means. As a result of the screening, some topics were routed to more appropriate venues for consideration, such as LRWRP's operating plan, the work plan for CERP's interagency system-wide science group (RECOVER), and/or the interagency modeling group that supports CERP.

The screened uncertainties were then considered by seven subteams who provided strategies and options for addressing them. Per CERP's adaptive management guidance, the management options included in this adaptive management plan can be described as the following:

1. *Informing LRWRP Implementation* - results of monitoring a project component may inform design, construction, and/or operation of subsequent project components,

2. *Informing Project Operations* - results inform project operations and/or system operating manuals,

3. *LRWRP Adaptive Management Contingency Options* - monitoring results may suggest a need to implement additional restoration actions, called adaptive management options, pending all required and applicable coordination, policies, and permitting.

The strategies and management options comprise the bulk of this adaptive management plan. The adaptive management plan also describes how adaptive management will be incorporated in the next steps of LRWRP, e.g., scheduling, design, construction, and throughout the life of LRWRP (CGM 56, RECOVER 2011b).

Adaptive management activities will be implemented during the coming phases of LRWRP, and the adaptive management plan will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions the adaptive management strategies and options proposed in this Plan may need refinement. Therefore, items included in this plan are not guaranteed to be funded as-is, but will be considered again when LRWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

It should be noted that cost estimates in this plan were provided using the best available information at the time of writing, and were provided before the LRWRP project-wide contingency of 39% was added to the project cost estimate. Therefore several detailed estimates provided in this AM and monitoring plan may be lower than the amounts shown in the cost summary tables that include the contingency (Table 6-9 in Section 6, and Table D.1.1 in Annex D intro). The contingency percentage was based on a project-wide analysis and therefore it should not be assumed that the additional contingency amounts shown in the summary cost tables will be available specifically to fund monitoring.

D.1.1 LRWRP Adaptive Management Plan Background

LRWRP's planning and tentatively selected plan were based extensively on scientific knowledge of the Everglades ecosystem and associated estuaries, from understanding the problems and opportunities to evaluating alternatives and estimating potential project restoration performance (Drew and Schomer (1984); Duever et al (1984); Vince et al. (1989); Abrahamson and Harnett, 1990; Myers and Ewel, 1990; Mitsch and Gosselink, 1993; David, 1996; Smith, et al., 1996; Beier and Noss, 1998; Miller and Gunsalus, 1999; FDEP, 2003; Pringle, 2003; Bond, 2003; SFWMD et al. 2006; Hoctor, et al., 2008; McVoy, et al. 2011; and RECOVER 2011a; SFWMD et al., 2012; LRWRP PIR Appendix H) and U.S. Army Corps of Engineers and CERP guidance. However, uncertainty exists in every natural resource management and restoration effort due to the fact that many processes in the ecosystem are not linear; they work synergistically together; and they will unfold in a future climate that is likely different than the one used to formulate the LRWRP plan. The LRWRP Adaptive Management Plan will address the key uncertainties identified during LRWRP's planning that relate to achieving restoration success and making adjustments in LRWRP if determined to be necessary to improve performance.

Congress understood that there were uncertainties in the Comprehensive Everglades Restoration Plan and therefore required CERP to include adaptive management for its individual projects (WRDA 2000). The 2003 programmatic regulations (Pro Regs) outlined an adaptive management program that would provide the tools needed to gather new information from the RECOVER monitoring and assessment plan (MAP- RECOVER 2009) and incorporate these so that CERP could be adjusted to ensure restoration success. The National Research Council's Committee on the Independent Scientific Review of Everglades Restoration Progress (CISRERP) endorsed the CERP adaptive management program (NRC 2007) and concluded that "uncertainties remain about the degree to which a resilient, self-sustaining ecosystem can be restored under the dramatically changed environment of South Florida" (NRC 2008). The CISRERP noted that adaptive management is essential for "…designing management strategies for dealing with complex ecosystem projects for which probable ecosystem responses are poorly known and hence,

difficult to predict" (NRC 2007). The CISRERP further reinforced its view regarding the essentialness of adaptive management in CERP project planning and implementation by stating that, "Given the enormous scope and complexity of the restoration effort, the success of the CERP depends on strategic, high-quality, responsive, and sustained science and an effective adaptive management framework" (NRC 2010).

Per the 2003 Pro Regs, CERP produced guidance for project teams to develop adaptive management plans and integrate adaptive management activities into all phases of a project lifecycle, e.g., planning, design, construction, and operations (USACE and SFWMD, 2011; RECOVER, 2011b). These are appropriate to the large scale and complexity of CERP and its projects, with its changing context of new non-CERP water infrastructure projects, and the shifting nature of its ecosystems. The intent of the detailed guidance is to improve restoration performance and reduce costs by increasing certainty throughout project implementation. The CERP guidance is consistent with the Everglades adaptive management WRDA 2000 authorization, as well as follows the more general 2009 adaptive management guidance from U.S. Army Corps of Engineers (USACE) Headquarters on implementing Section 2039 of WRDA 2007.

In summary, there is extensive knowledge about the Everglades and there are uncertainties that arise during project planning that need to be addressed. Rather than delaying planning for the sake of further data collection or model development, the adaptive management plan provides a mechanism to systematically address uncertainties during LRWRP's implementation in order to confirm that project performance is on the right trajectory, to detect early if an adjustment is needed, and to provide sound data to inform operations and implementation decisions. The adaptive management plan identifies which areas to monitor to detect performance, and options for adjusting LRWRP if needed to remain on track with performance expectations, as well as suggesting future CERP options to meet overall CERP restoration goals.

Definitions that will help the reader in understanding the LRWRP Adaptive Management Plan include the following. The concepts and definitions are described in more detail in CGM 56 (2010) and in the CERP Adaptive Management Integration Guide (RECOVER 2011b).

- **Adaptive Management** – A scientific process for continually improving management policies and practices by learning from their outcomes; Adaptive Management links science to decision making to improve restoration performance, efficiency, and probability of success. In the context of Everglades restoration, adaptive management is a structured approach for addressing uncertainties by testing for best project designs and operations to achieve restoration goals and objectives, linking science to decision making, and adjusting implementation, as necessary, to improve the probability of restoration success.
- **Uncertainty** – A question faced during planning or implementation regarding the best actions to achieve desired goals and objectives within constraints, which cannot be fully answered with available data or modeling.
- **Management Options** – Potential structural, non-structural, and/or operational alternatives to be undertaken to improve restoration performance. Adaptive management plans contain potential management actions "options" to improve performance in meeting project/program goals and objectives.
- **Strategies** – A plan to address one or more uncertainties identified in the adaptive management plan. The adaptive management strategies fit into the following approaches:
    - *Active Adaptive Management* (See Figure D-1) – Multiple pilot projects or design tests are implemented to determine the most efficient and effective way to achieve desired goals

and objectives. Each design or operational action is monitored, assessed, and results are used to inform implementation of the best design for a project component or operations. Pilot projects or design tests are usually conducted before implementing the full project component that they are intended to inform.

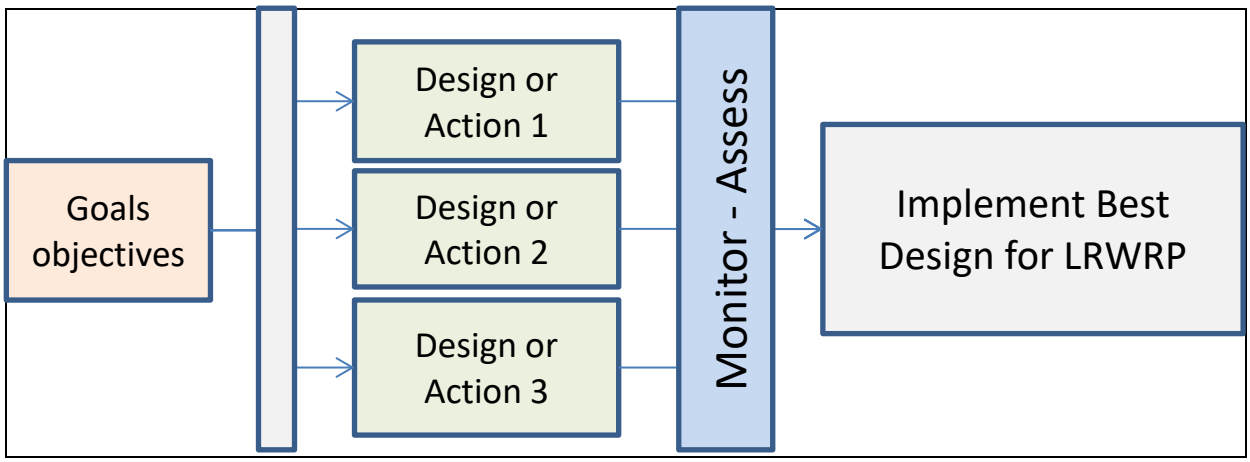

Figure D-1. Active Adaptive Management.

Project goals and objectives are used to determine multiple, alternate designs or management actions that could achieve the goals and objectives. These are tested by implementing them with associated monitoring. Assessment of the results indicates the best design of a particular component to move forward.

- *Passive Adaptive Management* (see **Figure D-2.**) – Most of the LRWRP adaptive management plan strategies are considered passive adaptive management approaches. One project component or set of operational criteria is implemented to test its ability to achieve desired goals and objectives. Results are monitored, assessed, and communicated to the appropriate participating agencies to determine how best to adjust project component designs, operations, LRWRP contingency options, or inform future CERP projects.

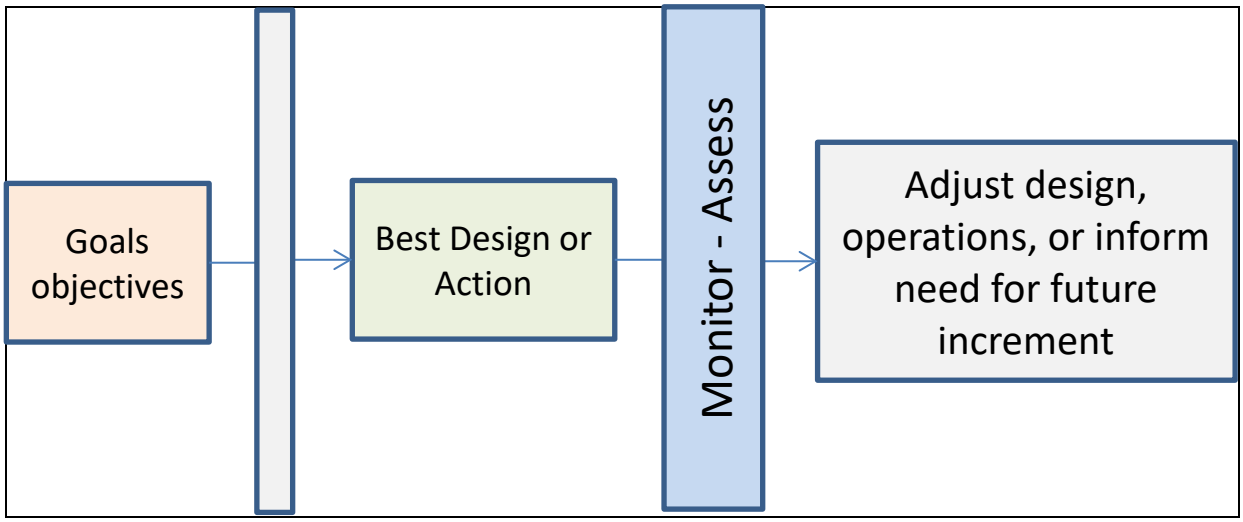

Figure D-2. Passive Adaptive Management.

Diagram illustrates that in Passive Adaptive Management, a design or management action is implemented to achieve project goals and objectives. Then, the associated monitoring and assessment produce documentation of successes and (potentially) shortcomings, that can be used as positive or negative lessons-learned to adjust other project component designs, adjust operations, and/or inform a future restoration increment.

Adaptive management activities will be implemented during the coming phases of LRWRP, and the adaptive management plan will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions the adaptive management options proposed in this Plan may need refinement. Therefore, items included in this plan are not guaranteed to be funded as-is, but will be considered again when LRWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

D.1.2 How the LRWRP Adaptive Management Plan Was Developed: Identification, Screening, and Prioritization of LRWRP Uncertainties

The LRWRP Adaptive Management plan development consisted of the following activities, consistent with the USACE planning guidance and CERP adaptive management guidance:

- PDT and stakeholder involvement;
- USACE planning and adaptive management principles were applied in the screening of project features that were used to create alternative plans and the recommended plan in order to increase confidence that LRWRP's components would have sufficient flexibility to continue to be good investments in a shifting environment (Section D.1.5.5 of this adaptive management plan);
- Identification and prioritization of key LRWRP adaptive management uncertainties, also referred to simply as "uncertainties" throughout this AM Plan (Section D.1.3 of this adaptive management plan) related to achieving LRWRP goals and objectives and avoiding constraints (Section 1 of PIR);

- Development of adaptive management strategies to address the uncertainties during LRWRP design, construction, and operations that consider existing Everglades conceptual ecological models, hypotheses, performance measures, and monitoring (Section 1.3 of this adaptive management plan);
- Identification of monitoring thresholds and/or triggers and associated management options to adjust, if necessary, based on feedback from assessments (Section 1.3 of this adaptive management plan);
- Development of an adaptive management implementation process to carryout adaptive management activities during design, construction, operations related to baseline and post-project construction monitoring, tests, analyses, and the process for communicating scientific findings to decision-makers, restoration partners, and the public (Section 1.5 of this adaptive management plan).

The identification of LRWRP uncertainties to be considered for inclusion in the LRWRP Adaptive Management Plan began with input from the LRWRP PDT and RECOVER. The outcome of this early effort, along with uncertainties identified through a multi-agency PDT process, produced a large list of LRWRP-related uncertainties to be considered for inclusion in the LRWRP Adaptive Management Plan.

The large list of uncertainties was screened using the following criteria:

1. Must be directly related to LRWRP goals, objectives, or 'constraints'. The constraints included but were not limited to the legal/USACE definition of constraints; they also included important considerations identified during LRWRP PDT and planning discussions.
2. Must be at project-scale. Although LRWRP is large, it is not system-wide scale. System-wide uncertainties were routed to appropriate groups.
3. Must have adaptive management options, i.e., ability to be addressed during implementation, improved by adjusting LRWRP. In some cases additional ability to address the uncertainty with a future increment of restoration was noted as a "future opportunity", but this feature was not sufficient in itself to pass this LRWRP AM criteria.
4. Must be an uncertainty. It should not include items that are already known. For example, questions should not ask "What are the effects of reduced fresh water discharges on oysters in the northern estuaries?" which is known. Instead they should ask, "Will LRWRP's reduction of fresh water peak discharges in the northern estuaries improve salinity conditions in x, y, z locations (specific locations related to LRWRP) enough to significantly improve conditions for oysters?"
5. The uncertainty needs at least one attribute that is measurable that will provide information to resolve the uncertainty, i.e. the attribute must be a trait able to change in the timeframe of the adaptive management plan, and one that is distinct from the 'background noise' of natural variability. Long-term changes need a faster responding surrogate-measure for the adaptive management plan.

Once a short-list of screened uncertainties was identified, the following criteria were used to prioritize them:

Risk: What is the risk (high, medium, low) of not meeting LRWRP restoration goals if this uncertainty is not addressed?

- Low risk means that even if the uncertainty isn't addressed, it doesn't pose much risk to achieving LRWRP goals and objectives.
- Medium risk means that if the uncertainty isn't addressed it may or may not affect achievement of a goal/objective.
- High risk means that without addressing this uncertainty, there is a high risk of not achieving LRWRP's goals and objectives.

Knowledge: What is the level of (high, medium, low) understanding of this uncertainty (i.e., how much is known about this uncertainty)?

- Low understanding means little is known about the question/issue or how to address it;
- Medium understanding means some information is known in some geographical areas, but not all;
- High understanding means a lot is known about addressing this question in multiple geographical areas.

Relevance to Adaptive Management for LRWRP: What is the level of confidence (high, medium, low) that anything could be done to address the uncertainty? The team's preliminary identification of management options helped to determine this.

- Low confidence means that even if this uncertainty is addressed, LRWRP or operations will not be able to be modified given the results of LRWRP implementation.
- Medium confidence means if this question is addressed, a connection to future CERP project implementation is established/documented but future adjustments to the LRWRP may or may not be limited, especially if indicator response is longer than 10 years and is more relevant to RECOVER system-wide monitoring.
- High confidence means if this question is addressed, LRWRP design, implementation, and/or operations can be modified to improve restoration results.

The identification, screening, and prioritization process resulted in a final prioritized list of uncertainties. This list was used to develop strategies, management options, and costs in order to develop the Adaptive Management Plan.

D.1.3 LRWRP Adaptive Management Uncertainties, Strategies, and Management Options

The LRWRP uncertainties in this section consist of prioritized needs and opportunities to learn in order to make scientifically sound recommendations to refine LRWRP design, construction, and operations; the strategies and management options provided to address each uncertainty are intended to guide LRWRP performance in the face of inevitable uncertainties, with existing knowledge and knowledge that will be gained through monitoring and assessment. The strategies are focused on LRWRP, in order to maximize 'return on investment' for resources invested in pursuing the adaptive management activities. As with the other monitoring plans in Annex D, the monitoring proposed in the adaptive management strategies was guided in part by two objectives: to be complete from a LRWRP perspective by providing the monitoring required to address LRWRP-specific uncertainties; and to integrate with other Everglades monitoring to take advantage of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and insure cost-effectiveness. *Where possible, the*

LRWRP adaptive management strategies rely on existing monitoring resources such as physical instrumentation, stations, locations, servicing, and analysis efforts funded by RECOVER, CERP sponsors, and partner agencies like the Loxahatchee River District. Therefore the monitoring requirements described here are limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LRWRP-specific adaptive management questions. This point is discussed in the LRWRP Adaptive Management Implementation section of this plan, and a table is provided to show leveraged monitoring. In addition, it should be noted that the timing of the strategies is staggered throughout the design and implementation of LRWRP. Please see Section D.1.5, Implementation of LRWRP Adaptive Management, and the associated Figures and Tables for more detail on the estimated start- and stop-times for each adaptive management strategy.

The uncertainties, their strategies, and management options are organized in this Plan by the following categories: sheetflow, wetland vegetation, faunal species, invasive species, estuaries, and water supply.

The uncertainties, their identification numbers (ID#), and the LRWRP project objective and/or constraint are listed here for reference. The project objectives and constraints are described in detail in LRWRP PIR Section 1 (Introduction). A list of uncertainties that were screened out is provided in the final section of this adaptive management plan to show the array of ideas that were considered and brief notes from the screening process. As the LRWRP Project Team learns from LRWRP implementation, the list of LRWRP adaptive management uncertainties will be updated to identify which have been addressed and where the risks to achieving LRWRP restoration success have been lowered.

The remainder of this section of the adaptive management plan (Section D.1.3) provides strategies for addressing the following screened uncertainties.

Note: the uncertainty ID numbers below refer to the ID numbers assigned to each uncertainty during AM screening, and therefore may not appear sequential since those that did not pass screening are no longer included. The ID numbers were maintained for organizational purposes; future refinements of the LRWRP AM Plan may include re-numbering of the uncertainties.

Sheetflow

- Will there still be impediments to sheetflow in natural areas that were low impact agriculture after LRWRP is implemented? (ID#1; LRWRP Objective 4)
- Will there still be impediments to sheetflow in natural areas that were high impact agriculture after LRWRP is implemented? (ID#2; LRWRP Objective 4)

Wetland Vegetation

- Will wetland vegetation establish in areas that were high impact agriculture? Will LRWRP need to add seed or plant? (ID#4; LRWRP Objective 3/5)

Faunal Species

- How will LRWRP restoration enhance species abundance and diversity in the watershed (wading birds, prey, wetland indicator species)? (ID#9; LRWRP Objective 3)

Invasive Species

- Will the changes in hydrology from LRWRP facilitate the spread of invasive plant species? (ID#14; LRWRP Objective 5)
- How will new invasive faunal species affect the LRWRP restoration? (ID#15; LRWRP Objective 5)
- How will new invasive plant species affect the LRWRP restoration? (ID#16; LRWRP Objective 5)
- Is there potential for the LRWRP to transfer/expand invasive plants to other areas? (ID#18; LRWRP Objective 5)
- How will invasive species that are not managed on private property affect LRWRP restoration? (ID#19; LRWRP Objective 5)

Estuaries

- How does the timing in salinity changes and ranges affect oligohaline, seagrass and oysters? (ID#22; LRWRP Objective 2)
- As salinity ranges and locations change, is there proper substrate for oyster recruitment in the new salinity ranges/locations? (ID#23; LRWRP Objective 2)

Water Supply

- Based on future drinking water supply, will the ASR wells be able to deliver the proposed quantities and timing of water to the Northwest Fork? (ID#26; LRWRP Objective 1)
- Will there be unanticipated changes in water levels that impact existing levels of service to nearby residential areas? (ID#31; LRWRP Objective 4)

Adaptive management strategies are provided in this section to describe and address each LRWRP adaptive management uncertainty and inform LRWRP implementation based on the body of existing scientific knowledge in Everglades restoration. This section comprises the bulk of the LRWRP Adaptive Management Plan. It provides 1-2 page strategy descriptions for each uncertainty (sometimes combined, where appropriate) and summary tables of suggested management actions to improve restoration performance, as illustrated in **Table D-2**.

The strategy write-ups include information on drivers of the uncertainty, restoration targets and LRWRP targets for particular attributes of the ecosystem associated with the uncertainty (such as a key species or ecological features), how these attributes will be monitored to track progress toward the targets, the timeframe in which changes in these attributes will be measurable, and identification of a trigger or threshold that would give early warning that LRWRP performance is veering from restoration expectations. The "timeframe in which changes will be measurable" does not imply that changes will be *complete* in that timeframe; rather, the timeframes provide an estimate of time needed to *begin* to be able to distinguish LRWRP effects. For practicality, the LRWRP AM Plan screening criteria included the need to have attributes measurable within the time of the AM Plan, which in some cases necessitated a 'proxy' attribute to be measured that would represent expected changes on a longer time scale. In addition, the triggers and thresholds were identified with the best available information, but the AM team

recognizes that they should be updated to keep current with best available science. Second, following the strategies, tables of suggested management options are provided, called management options matrices (MOMs). These provide suggestions of paths forward and adjustments that can be made in order to keep LRWRP progressing toward the targets, based on specific decision-criteria, e.g., a trigger or threshold is crossed (reflecting unintended effects related to a constraint) or is not crossed (reflecting lack of restoration progress towards restoration goals and objectives). The purpose of the two formats is to provide A) background and detail of each strategy in the 1-2 page write-ups and B) a table reference summary and crosswalk that relates monitoring to specific decision-criteria and potential actions for multiple strategies in a specific area. The detailed write-up descriptions are referred to as the "strategies" and the summary tables are referred to as "management options matrices" (MOMs).

The strategies and MOMs provide synopses of the best available information, which in some cases is sparse and will need to be developed further as LRWRP moves toward implementation and the adaptive management plan is updated based on new information gained about the best project design and operations to achieve restoration goals.

Adaptive management activities will be implemented during the coming phases of LRWRP, and the Adaptive Management Plan will be updated accordingly. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge and answers to key questions the adaptive management options proposed in this Plan may need refinement. Therefore, items included in this Plan are not guaranteed to be funded as-is, but will be considered again when LRWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

The LRWRP adaptive management uncertainties and the strategies to address them are provided in the format shown in **Table D-2**. The uncertainties and strategies are presented by region, and each region's set is followed by an 11x17 pull-out table of suggested management options that can support LRWRP and potentially CERP refinement (Management Options Matrices, or MOMs). Please see further explanation in **Section D.1.3** above.

Table D-2. LRWRP Adaptive Management Strategies: Template and Definitions.

LRWRP AM Uncertainty and ID#. *The uncertainty is a question faced during planning or implementation regarding the best restoration actions to achieve desired goals and objectives within constraints, which cannot be fully answered with available data or modeling. Uncertainties were screened and prioritized to determine which to include in the AM Plan.*

LRWRP Objective or Constraint: *Uncertainties needed to be related to LRWRP objectives or constraints, among other criteria, to be included in the AM Plan. This rule helped to focus the scope of the AM Plan.*
Region(s). *Area of LRWRP footprint to which the uncertainty and strategy pertain.*
Associated LRWRP features: *Structures or measures to which the uncertainty and strategy pertain.*
Driver or uncertainty type: *Unlike most AM Plans, not all LRWRP AM uncertainties and strategies are ecological. Types such as Engineering and Operations are identified.*

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty? *Why the uncertainty needs to be addressed in LRWRP.*

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each. *A scientific approach begins with a well-informed, pointed, detailed statement that will be tested. For the purposes of LRWRP's AM Plan the statement can be referred to as an expectation or hypothesis. Approaching uncertainties scientifically is efficient because it is targeted; a properly identified hypothesis statement is the most important step to lead to effective, efficient methodology to address an uncertainty. It leads to proper identification of what to measure, how, how often, how to analyze, etc.*

More Information on attributes to be measured:

- **What is expected to be learned by measuring this attribute, i.e., *how will LRWRP benefit from knowledge gained about this attribute?***
- **What is the time frame in which changes to this attribute are expected to be measurable?**
- **Is this attribute complimented by other monitoring programs within and/or outside of LRWRP? If so, provide reference to other monitoring. Note the monitoring paid for by others in the LRWRP AM budget spreadsheet.**
- **When during LRWRP's life cycle should this monitoring begin and end?**

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting: *More information on what to measure, how, how often, how to analyze, and when and how to report results. PLEASE NOTE: the LRWRP AM Plan varies in the level of methodology detail provided; in several cases the details will be formed during LRWRP's detailed design phase. In ALL cases, methodology will be reviewed, updated and adjusted if needed by agency subject experts, before initiation, to best meet the intent of the AM Plan.*

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action. *Triggers or thresholds are a point, range, or limit that signifies when restoration performance is veering away from expectations and is trending toward an unintended outcome. Triggers/thresholds should be described <u>per attribute to be monitored</u> because each should result in an outcome that informs management decisions.*

Management options that may be chosen based on test results. *Management Options are provided in case a performance trigger or threshold is crossed, which would indicate that LRWRP performance needs to be adjusted. The Management Options are suggested paths forward and adjustments that can be made to keep LRWRP progressing toward objectives and within constraints. The Management Options are summarized in 11x17 pull-out tables after each region's strategies.*

D.1.4 Sheetflow and Flow Adaptive Management Strategies

Uncertainty ID, Related Restoration Objective, and Location:

Will there be Impediments to sheet flow in restored natural areas that were previously low impact agricultural areas such as Culpepper (CP), Nine-Gems (PM 1), and Cypress Creek (CC 4, 2 1) (**Figure D-3**). This uncertainty (#1) is related primarily to Objective #4 (Restore connections between natural areas to improve hydrology, sheet flow, hydroperiods, natural storage, and vegetation communities). It anticipates potential management actions that could be used to offset a reduced amount of improvement because of impediments to flow that prevent full restoration. This uncertainty is specifically related to those areas that were previously used for low impact agricultural activities, such as cattle grazing. Restoration activities in these areas will include such activities as plugging ditches and or removing berms, but large scale grading is not anticipated.

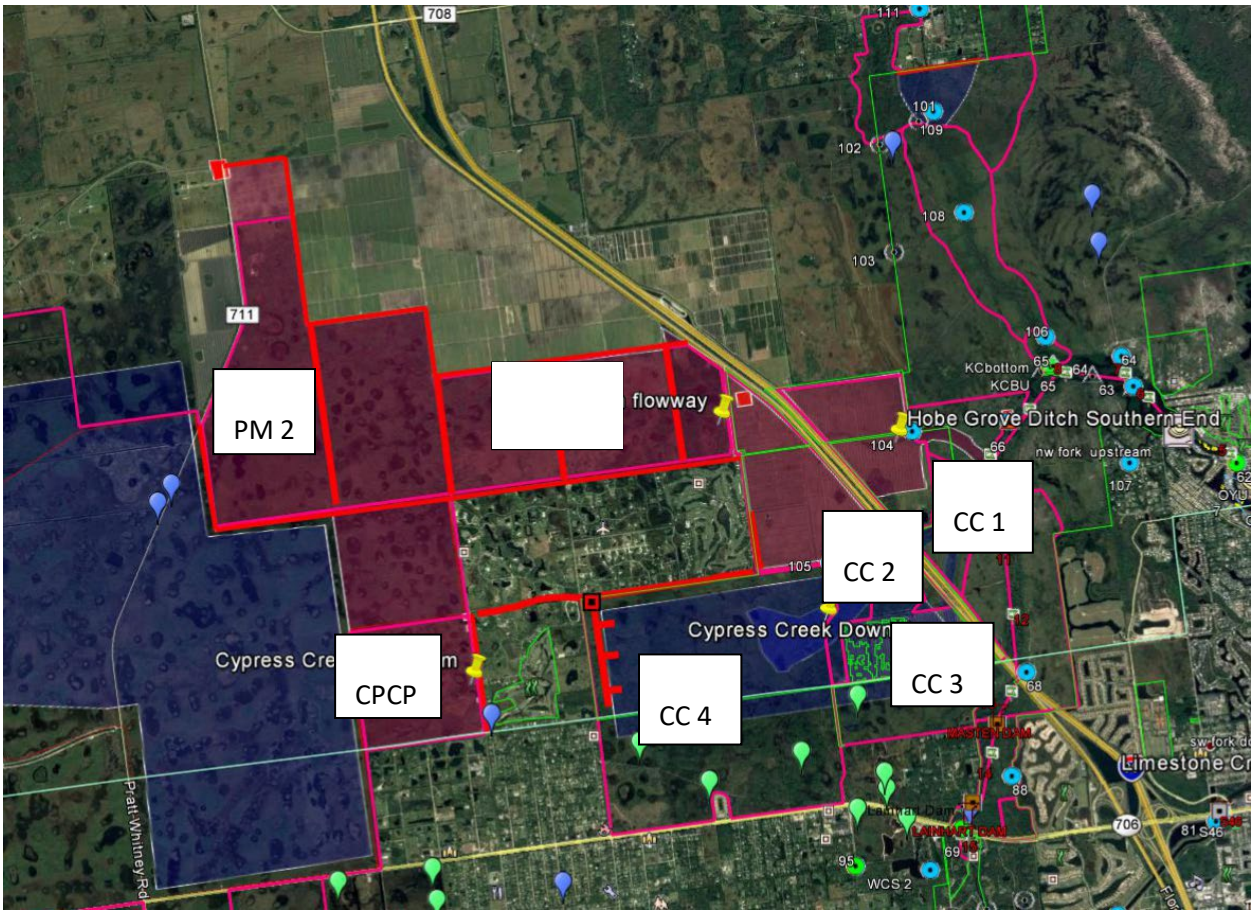

Figure D-3. Map of Nine-Gems (PM 1 and 2), Cypress Creek (CC4, CC2, CC1), and Culpepper Indicator Regions where flow is impeded.

Will there be impediments to sheet flow in restored natural areas that were previously high impact agricultural areas [Gulfstream East (GS 1) and West (GS 2), Shiloh Farms Pepper Farm (CC3) (**Figure D-4**)]? This uncertainty (#2) is related primarily to Objective #4 (Restore connections between natural areas to improve hydrology, sheet flow, hydroperiods, natural storage, and vegetation communities) and anticipates potential management actions that could be used to offset a reduced amount of improvement

because impediments to flow prevent full restoration. This uncertainty is specifically related to those areas that have been used previously for high impact agriculture such as row cropping or citrus, with significant land altering activities. The areas are expected to be graded to more natural contours during design and construction. Gulfstream West is included in this uncertainty even though it is not being restored to the original target of a depression marsh; it will function as a deep freshwater marsh slough.

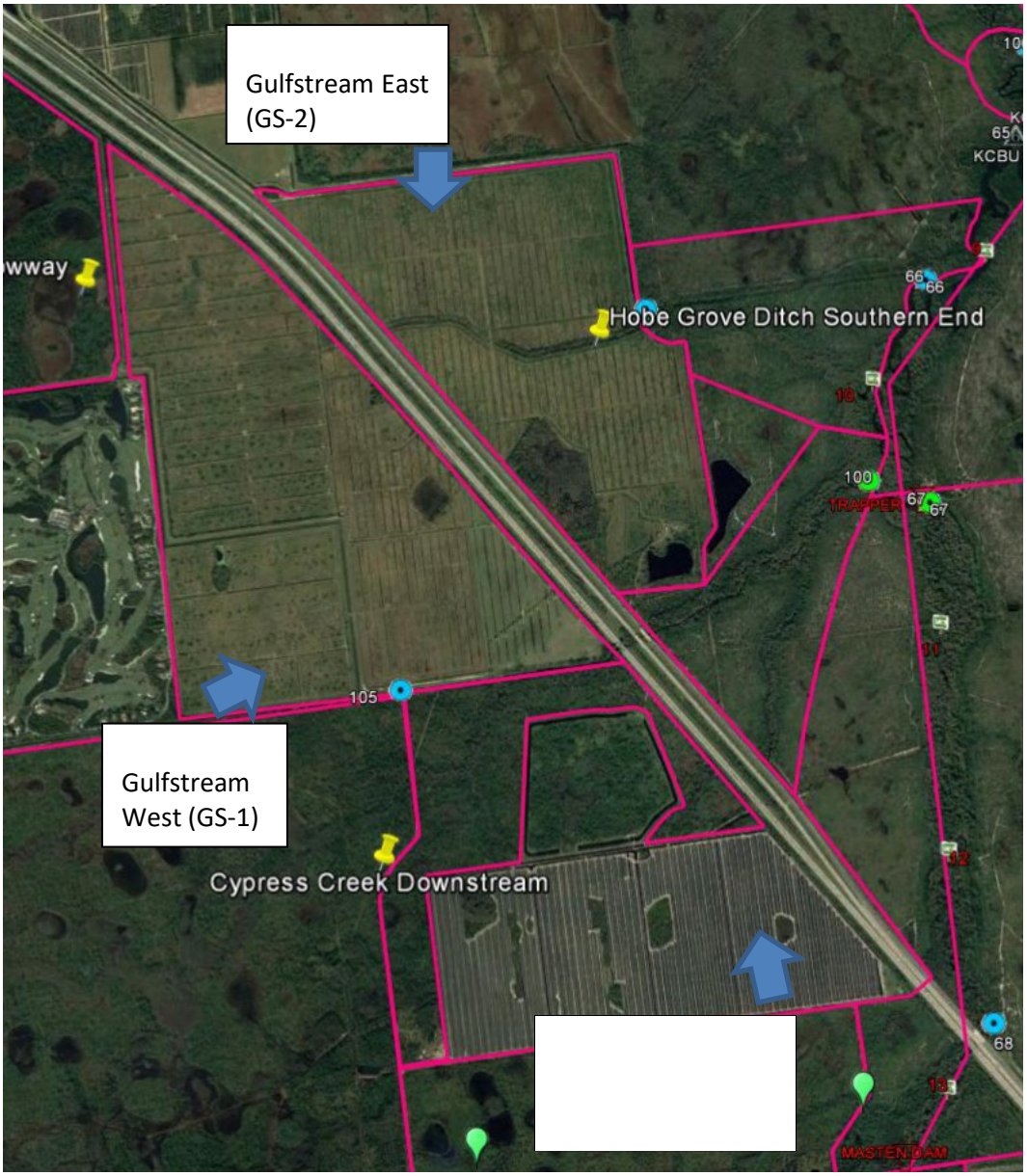

Figure D-4. Map of higher impact agricultural areas to be restored (Gulfstream West, East, and Shiloh Farms).

LRWRP adaptive management Uncertainty #1/2: Will there be Impediments to sheet flow in restored natural areas that were previously low impact agricultural areas (Culpepper, Nine-Gems, Cypress Creek,)?

Will there be impediments to sheet flow in restored natural areas that were previously high impact agricultural areas [Gulfstream East, Shiloh Farms Pepper Farm, and Gulfstream West]? (Driver or type: Hydrogeology)

This uncertainty is related to the LRWRP objective of restoring connections between natural areas to improve hydrology, sheet flow, hydroperiods, natural storage, and vegetation communities.

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty? Addressing this uncertainty will help the team determine the success of the management measures that are implemented with respect to restoring wetland character and modifying the timing and distribution of flows to the river, and particularly to the tributaries. Information gleaned with respect to impediments to sheet flow can inform decisions regarding whether additional measures may be necessary to encourage flow (surface and base flow) and timing of flows.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. Several hypotheses are to be tested to address Uncertainties 1 and 2. The project assumes that, as a result of restoring hydrology and improving the hydrologic connections in the watershed, that groundwater base flow to Cypress Creek and other tributaries will be increased while direct structure flows will be decreased, thus improving the timing and distribution of flows to the river. Groundwater recharge is dependent upon maintaining adequate wetland elevations within the watershed, which are also dependent upon the movement of water from the west to the east via historical sheet flow connectivity. This hypothesis can be tested by measuring flows at strategic structures (Cypress Creek Weir, flow through marsh, Culpepper culverts) and comparing those flows to baseline (pre-project) flows. If flows via surface water discharges are reduced, while base flows are increased, the project is successful. The attributes to be measure are: flow over the Cypress Creek Weir, flow from Culpepper Ranch to the Cypress Creek Canal, and groundwater levels adjacent to Cypress and Moonshine Creeks. For example, the project expects that, as a result of removing the impediment (ditch and berm) to flows moving northward from Culpepper to Nine Gems (Palmar East), less water will discharge through the Culpepper Culverts. If there is no reduction in discharge, it could be that flow is impeded and a management action taken to reduce the impediment.

Table D-3. Expected Flows and Total Percentage Project Flows:

Flow Tributary	*% Total Tributary Flow (CFS average dry season)*
Moonshine Creek (Hobe Grove Ditch)	10% (3)
Cypress Creek	64% (19)
Kitching Creek	26% (8)
NorthWest Fork (Lainhart)	N/A (69)

If flow volumes are consistent with expected results but there is an indication that flow is being intercepted and water levels are variable within the marsh, then measures to mitigate flow interception will be considered. These measures include recontouring the marsh elevations via scraping or other means, exploring plugging of ditches to discourage flow interception, or incorporating spreader swales to even out flow in marsh area.

Follow-up WRAP assessments (consider in monitoring plan) will be used as an index to determine success and hydrologic improvement of the associated wetland systems. **Table D-4** identifies the expected average annual hydroperiods improvement for various Loxahatchee River Watershed Restoration indicator regions, which include Pal Mar (Nine-Gems – PM 1 and 2), Culpepper (CP), Gulfstream West (GS1) and East (GS2), Shiloh Farms (CC3), Cypress Creek (CC1, 2, 4).

Table D-4. Expected Inundation Duration Days Over Period of Record 14975 Days Based on Modeling of TSP Compared to ECB

Indicator Region	WRAP Cell Name	LECSR CELL ID	Acres	Dominant Vegetation	Target Inundation	ECB Inundation (est.)	Model 2014 ECB (APR 2018)	Model Alt5r (APR 2018)	Model Hydro-period Average Annual Difference
C-1	C-1	203,288	1,642	DM	9,840	6560	7296	8074	19
CC-1	CC-1A	123,349	202	FS	7,380	2460	108	493	9
CC-2	CC-2	125,342	557	FS	7,380	1230	102	9560	231
CC-3	CC-3A	–	394	WP	4,920	4100	1213	2914	41
CC-4	CC-4.1	127,335	2,542	DM	9,840	4920	32	7052	171
CM-1	CM-1.1	192,295	1,381	DM	9,840	1640	3	13271	324
CM-2	CM-2	183,310	3,191	DM	9,840	1640	11656	13252	39
pal mar	CP-1	122,316	642	DM	9,840	4920	1018	1926	22
GS-1	GS-1	117,339	543	DS*	9,840	1640	0	12288	300
GS-2	GS-2	–	737	DM	9,840	1640	0	6623	162
GWP-10	GWP-10	240,354	1,107	DS	10,455	10455	14436	14609	4
GWP-1	GWP-1A	205,354	42	DS	10,455	5228	13305	13928	15
GWP-2	GWP-2	201,348	397	DS	10,455	6970	7788	13483	139
GWP-3	GWP-3	195,340	308	DS	10,455	6970	14227	14799	14
GWP-4	GWP-4	202,340	755	DS	10,455	10455	12457	13468	25
KC-1	KC-1.1	95,349	658	FS	7,380	3690	3817	4681	21
KC-1	KC-1.2	95,353	658	FS	7,380	3690	5068	7621	62
KC-2	KC-2.1	105,352	585	FS	7,380	4920	382	1069	17
LS-10	LS-10.1	–	1,981	DM	9,840	–	6594	6963	9
LS-10	LS-10.2	–	1,981	DM	9,840	–	9060	9541	12
LS-2	LS-2	176,343	3,849	DM	9,840	6560	8980	10789	44
LS-3.1	LS-3.1	173,324	1,451	DM	9,840	4920	3288	3411	3
LS-3.1	LS-3.2	–	1,451	DM	9,840	–	4574	4720	4
LS-4	LS-4	193,348	772	DM	9,840	4920	8035	13166	125
LS-5	LS-5	164,354	1,782	DM	9,840	4920	6090	4463	-40
LS-6	LS-6A	177,348	405	DM	9,840	6560	3205	11140	194

Indicator Region	WRAP Cell Name	LECSR CELL ID	Acres	Dominant Vegetation	Target Inundation	ECB Inundation (est.)	Model 2014 ECB (APR 2018)	Model Alt5r (APR 2018)	Model Hydro-period Average Annual Difference
LS-7	LS-7A	179,351	426	SS	10,455	6970	3074	9356	153
LS-8	LS-8.1	192332	1670	DM	9840	6560	12143	14319	53
LS-9	LS-9	192341	576	DM	9840	6560	10476	12596	52
MC-1	MC-1	117,350	266	FS	7,380	1230	0	0	0
PM-1	PM-1	112,312	2,177	DM	9,840	4920	994	3680	66
PM-1	PM-1.1	–	2,177	DM	9,840	4920	1901	5876	97
PM-10	PM-10.1	116,302	7,181	DM	9,840	8200	7378	10679	81
PM-1	PM-11.2	114,306	2,181	DM	9,840	4920	446	6022	136
PM-2	PM-2	114,334	1,452	DM	9,840	3280	8210	13087	119
PM-2	PM-2.2A	111,321	709	DM	9,840	3280	2798	7593	117

Table D-4 Coloring:

Yellow	Areas where we had to make adjustments to model output or topo
Orange/peach	Consistent lack of results, although might expect improvements
Dark gray	Extra model cell for indicator region to check on different hydrology questions. Not part of habitat units calculations.
*GS-1	Modified restoration target due to altered wetland function to support restoration of moonshine creek flow

Attributes to be measured:

Flow and stage at key discharge points in the marsh and stage to identify the hydroperiods **(Figure D-5).**

1. Flow and stage at the Cypress Creek Weir
2. Flow and stage at the Culpepper Discharge Locations
3. Flow and stage into the flow-through marsh
4. Flow and stage on the discharge of the flow-through marsh
5. Staff gauges in key wetland locations
6. Groundwater elevations adjacent to Cypress Creek and Moonshine Creek

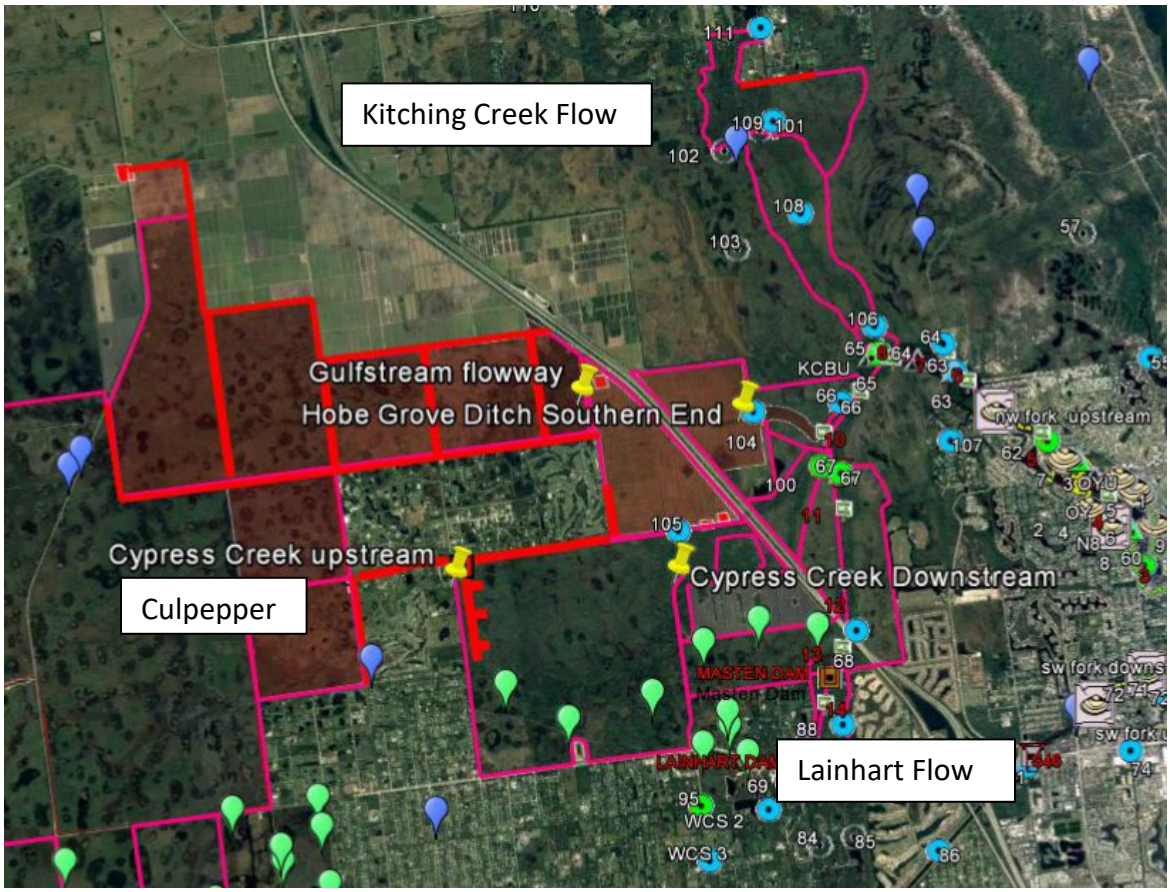

Figure D-5. Key Areas to Measure Flow Hydrologic Performance

What is expected to be learned by measuring this attribute, i.e., how will LRWRP benefit from the knowledge gained about this attribute:

Measuring flow and stage at specific locations (both surface water and groundwater) will allow an assessment of how well the project is performing to deliver water (by sheet flow or groundwater flow) Success of deliveries to the river is specifically tied back to improving base flows to the tributaries. Wetland stage information at key locations can be used to determine if hydrology is appropriate to the expected wetland function.

What is the time frame in which changes to this attribute are expected to be measureable?

The changes should be measurable within a 3 to 5 year time frame. This allows for natural variation with respect to weather patterns.

When during LRWRP's life cycle should this monitoring begin?

Flow and stage monitoring should be concurrent with the completion/construction of project features. Some baseline monitoring should be initiated prior to construction so that comparisons can be made regarding pre and post project flows.

Methodology for testing each expectation or hypothesis (included frequency of monitoring):

A Before and After Control Impact (BACI) design will be used to measure long-term improvements in flow to tributary creeks via gulfstream flow-way for Cypress Creek, Hobe Grove Ditch for Moonshine Creek, and Shiloh Farms for Cypress Creek. In addition, BACI design will be used to confirm flow to Kitching Creek. The following monitoring is recommended to measure stage, hydroperiods and flow. Control sites will be in identified during AM plan design in PED but will likely be areas where flow between marsh sites is not expected to change at all, e.g., Pal Mar indicator region 5.

Flows

Flow-way 3:

4 Stage (surface and groundwater) and 4 Flow gages will be installed before project construction to measure before and after changes in stage and flow. Stage gages are in center of each major indicator region (PM 10, PM 1, PM 2, Cypress Creek). Flow gages will be installed associated in locations up and downstream of the following areas: Cypress Creek Spreader, Cypress Creek, Gulfstream flow-way, Hobe Grove Ditch. See **Figure D-6**.

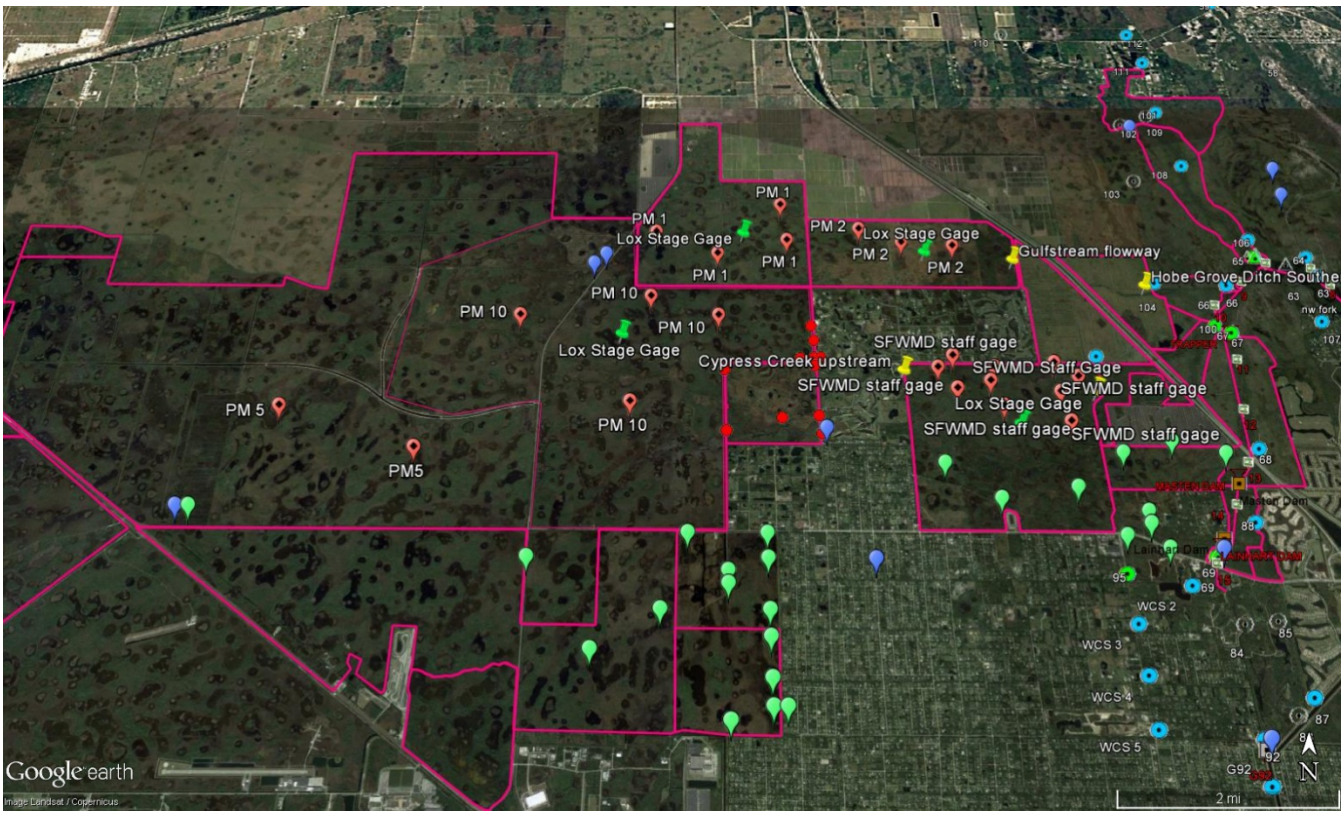

Figure D-6. Map of Currently Active and Proposed Hydrology Gages in Flow-way 3.
(green balloons – Palm Beach County staff gages; red circles – Martin County staff gages; red balloons – SFWMD and LRWRP Project staff gages [SFWMD in Cypress Creek]; blue balloons – SFWMD wells; green and blue doughnuts – River Keeper District; green and yellow Pins – LRWRP Project wells and flowmeters)

Flow-ways 1 and 2:

4 flow gages will be installed associated with project structures on C-18 impoundment, C-18 weir, G-160, G-161 to measure flow changes towards the river. Existing flow data will be utilized to measure changes at Lainhart, G-92, S-46, and Control 2 and 4. See **Figure D-7**.

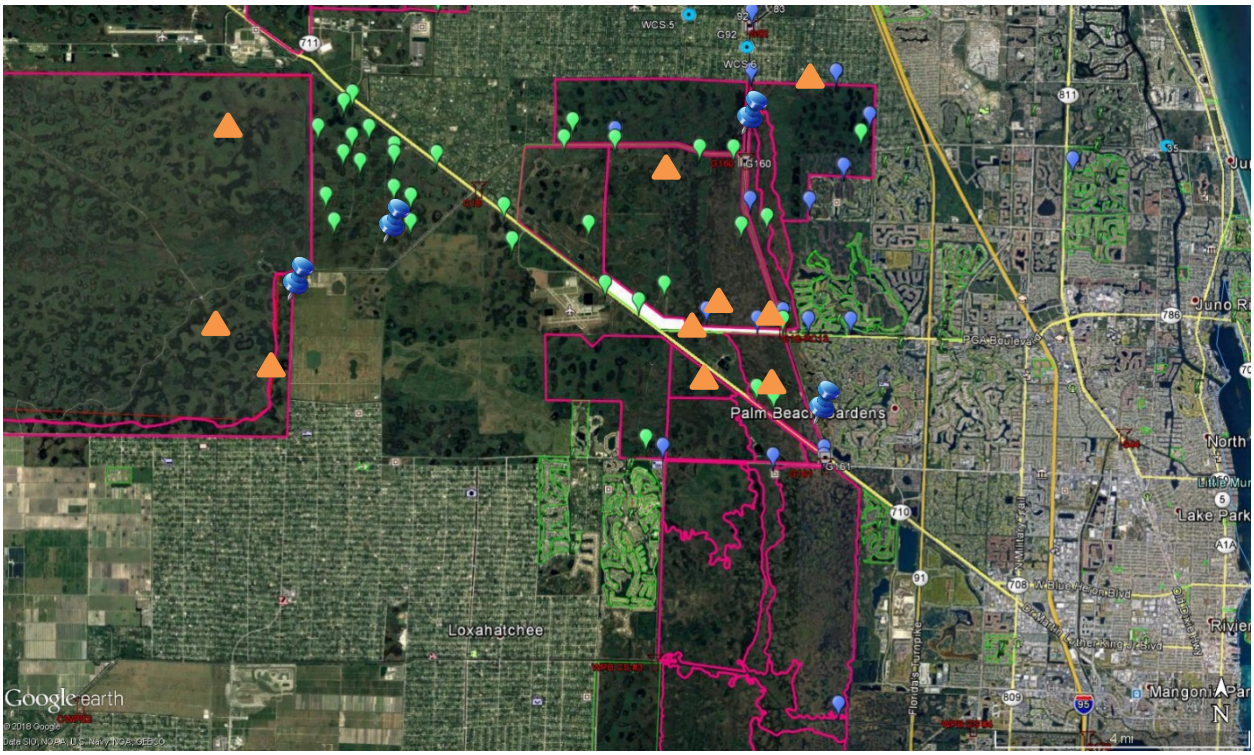

Figure D-7. Map of Currently Active and Proposed Hydrology Gages in Flow-way 1 and 2.
(green balloons – Palm Beach County staff gages; blue balloons – SFWMD wells; Blue Pins – LRWRP Project wells and flowmeters -blue pins; orange triangle – LRWRP Project staff gages)

Hydroperiods

Flow-way 3: 13 additional staff gages will be installed in the Nine Gems/Pal-Mar area. Existing staff gages will be utilized in Cypress Creek (SFWMD and Palm Beach County) and Culpepper wetlands (Martin County). River Keeper gages will be utilized in Kitching and Moonshine creeks and Loxahatchee River for stage and flow.

Flow-way 1 and 2: Monitoring will be leveraged from Palm Beach County and existing SFWMD project culverts 15 and 17, staff gages lox east and lox west and Hungryland will be used to measure improvements to Loxahatchee Slough and ensure maintenance of stages in Hungryland Slough. 10 additional staff gages will be installed in Corbett wildlife management area, Loxahatchee Slough, and northern Grassy Waters Preserve. Existing SFWMD/Palm Beach County wells and in Loxahatchee Slough and at G-160 and G-161 will be utilized for improvements to Loxahatchee Slough. Existing city of West Palm Beach wells in Grassy Waters Preserve will be used to ensure maintenance of stages in Grassy Waters Preserve (GWP).

How results will be reported, and the triggers/thresholds that indicate good LRWRP performance or need for adaptive management action:

Before and after measurements of stage will be used to assess hydro period improvements. LECSR modeling data will be used to assign initial targets for indicator regions expected to be improved by this project (Pal Mar, Cypress Creek, Gulf Stream, Kitching Creek, Culpepper, and Loxahatchee). Statistically significant changes compared to baseline should be achieved 3 years out from project features constructed and operated associated with flow-way changes. In addition, flow will be measured to determine statistically significant changes compared to baseline data. Existing gage information from dbhydro will be used to establish baseline values.

The Management Options Matrix (MOM) shown (**Table D-5** and **Table D-6**), and those throughout the adaptive management plan, help link monitoring identified in specific adaptive management strategies to decision criteria and suggested management options to consider for adjusting LRWRP if monitoring reveals performance issues related to LRWRP operations. *The "timeframe to detect changes…" does not imply that changes will be complete in that timeframe; rather, they provide an estimate of time needed to begin to be able to distinguish effects of LRWRP. These time frames are indications of response speeds, not limits on how long the monitoring will be conducted.

Table D-5. Impediments to Sheetflow Due to Low-Impact Agricultural Areas Management Options Matrix.

Uncertainty ID	Time Until changes are measureable	Indicator or Attribute	Specific Property to be Monitored, and frequency	Decision Criteria: Confirmation of LRWRP Performance or Trigger(s) for Management Action	Management Action Options
#1	3 years*	Variance in flow (< or >) predicted	Flow rate, water depth and velocities (avg. monthly in wet/dry season, storm events	• No Significant Change in flows to Creeks. • Flows to creeks meet Loxahatchee Restoration Plan Targets • Longer flow into dry season	• Scrape a Flow-way by several inches to encourage sheet flow (vegetation or earthwork) • Adjust control structure elevations • Construct seepage barriers to offset water losses • Plug additional ditches/other earthwork adjustments
N/A	N/A	Increase in Water dependent wildlife usage	N/A	N/A	

*Time frame could be shorter or longer depending upon prevailing weather patterns.

Table D-6. Impediments to Sheetflow Due to High-impact Agricultural Areas Management Option Matrix.

Uncertainty ID	Time Until changes are measureable	Indicator or Attribute	Specific Property to be Monitored, and frequency	Decision Criteria: Confirmation of LRWRP Performance or Trigger(s) for Management Action	Management Action Options
#2	<3 years*	• Variance in flow through structures > or < than predicted(C-18 weir, flow through marsh outflow) based on rainfall • Increase in water dependent usage	Flow rate, water depth and velocities (avg. monthly in wet/dry season, storm events)	Flow into Cypress Creek and Moonshine Creek is not occurring adequately to effect movement of water into floodplain	Scrape areas to facilitate sheet flow, reduce impediments

*Time frame could be shorter or longer depending upon prevailing weather patterns. Variance measured by double mass curves of rainfall and flow or other analysis to control for rainfall variation.

D.1.5 Wetland Vegetation Strategies and Management Options

Will wetland vegetation establish in areas that were high impact agriculture, or will we need to seed or plant? This uncertainty is related to Objectives #3 (Increase natural area extent of wetlands) and #5 (Restore native plant and animal species abundance and diversity) and anticipates potential management actions that could be used to offset a reduced amount of improvement as a result of a reduction or failure of wetland vegetation to become established in areas that were formerly managed in high impact agricultural production. This would include former Gulfstream Citrus property east and west of I-95 and the Turnpike and potentially the flow-through marsh. Vegetation species diversity and types of vegetation within the flow-through marsh are depth dependent, as well as the Shiloh Farms in Cypress Creek headwaters.

LRWRP Adaptive Management Uncertainty #4: Will wetland vegetation establish in areas that were high impact agriculture, or will we need to seed or plant? (Driver or uncertainty type: Ecological)

This uncertainty is related to LRWRP objectives to increase the natural area extent of wetlands and to restore native plant and animal species abundance and diversity.

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty? Addressing this uncertainty will provide input into the degree of effort that is needed to ensure restoration of native habitat in this area and for other CERP projects. Greater coverage with desirable wetland and upland species will provide more appropriate and productive habitat (greater foraging space, better nesting habitat, etc.) which ties into and enhances the LRWRP goal for restoring native species diversity and abundance.

Expectations and hypotheses to be tested to address uncertainty #4, and attributes that will be measured to test each: It is expected that restoring topography and hydrology in high-impact agricultural areas (e.g., Gulf Stream east and west and Shiloh Farms area) will result in recruitment of desirable wetland species if invasive species is controlled. The plan should establish a target to encourage 80% or greater coverage by desirable species in both wetland and upland areas. Assuming the appropriate hydrology and topography have been realized, this is further dependent upon limiting coverage of invasive species, as well as seed source availability within the soils of the areas that have been restored.

Attributes to be measured: The attributes to be measured include percent coverage of native desirable species vs percent coverage of invasive exotic or undesirable species. If greater than 15% of the areas where hydrology and topography have been restored are colonizing with invasive or undesirable species, or less than 25% of the area colonizes with desirable wetland species management action options will be implemented.

What is expected to be learned by measuring this attribute, i.e., how will LRWRP benefit from the knowledge gained about this attribute: By measuring this attribute, the team will be able to determine the amount of effort needed to restore wetland character in areas that have previously been used for agricultural purposes, and determine the degree of success with respect to meeting LRWRP objectives.

Time frame in which changes are expected to be measurable: It is expected that these changes will be observable within 6 months of site grading and the restoration of the appropriate hydrology. Prevailing weather patterns (e.g., extended dry periods following restoration) may increase the time period over which changes will be observable.

Methodology for testing each expectation or hypothesis: Visual observation of species diversity and coverage using vegetation. Vegetation transects will be conducted twice a year (wet and dry season) at baseline and then after project features restore high impact agricultural areas. Intervals for vegetation transect monitoring will be before project (-2, -1,) and after project (1, 2, 5, 10).

Low Impact Agricultural Areas and Natural Areas

WRAP: Vegetation monitoring associated with G-160 and G-161 has already been completed to demonstrate restoration improvements in Loxahatchee slough. The WRAP procedure will be repeated prior to project construction (wet and dry season) and then twice a year after project construction in IRs in Flow-way 1 (GWP triangle), Flow-way 2 (Corbett near C-18 impoundment, Loxahatchee Slough), and Flow-way3 (Pal mar, Nine Gems, Gulf stream, Shiloh Farms, Kitching Creek, Cypress Creek, Loxahatchee River Flood plain).

Aerial Photo Interpretation: Remote sensing photo interpretations of vegetation change will be conducted at baseline for the whole project and then after constructed project features restore areas in flow-way 1, 2, and 3 in 5 and 10 years post-construction.

High impact Agricultural Areas

WRAP assessment for high intensity agricultural areas and natural areas, include more information on vegetation species, in addition to hydrology. In addition, groundtruthing points for remote sensing of high impact agricultural sites would be conducted in years 1 and 2 to inform adaptive management decisions.

How results will be reported and the triggers/thresholds that indicate good LRWRP performance or need for adaptive management action: The results will be reported as percent coverage of desirable vegetation and invasive or non-desirable vegetation. After 6 months - 1 year, if native species fail to colonize these restoration areas, action shall be triggered. With respect to invasive species, action shall occur as soon as practicable to ensure that native vegetation is not outcompeted and is further addressed in the invasive species management plan.

The Management Options Matrix (MOM) shown (**Table D-7**), and those throughout the adaptive management plan, help link monitoring identified in specific adaptive management strategies to decision criteria and suggested management options to consider for adjusting LRWRP if monitoring reveals performance issues related to LRWRP operations. *The "timeframe to detect changes…" does not imply that changes will be complete in that timeframe; rather, they provide an estimate of time needed to begin to be able to distinguish effects of LRWRP. These time frames are indications of response speeds, not limits on how long the monitoring will be conducted.

Table D-7. Establishment of Vegetation Management Options Matrix.

Uncertainty ID	Time Until changes are measureable	Indicator or Attribute	Specific Property to be Monitored, and frequency	Decision Criteria: Confirmation of LRWRP Performance or Trigger(s) for Management Action	Management Action Options
#4	6 months 2-3 years	Visual observation (photo points) of establishing vegetation (native vs. exotics)	Coverage of Invasive species vs. desired wetland and/or upland species coverage	>15% of area establishing with invasive and/or exotic species <25% of area where hydroperiods have been restored has desirable vegetation	Sweep (burn or herbicide applications) for exotics to keep under control so native vegetation has opportunity to establish and/or Introduce desired vegetation seed or plantings to the area
–	<3 years*	Visual observation (vegetation obstruction, impounding, wetland indicators)	Vegetative species composition (obligate vs. facultative spp.) Aerial extent of wetland coverage	<25% spatial extent of expected wetland coverage or type	–
–	<5 years*	Visual observation (vegetation obstruction, impounding, wetland indicators)	5 year WRAP Assessments Vegetative species composition (obligate vs. facultative spp.) 5 year Landscape Assessment with Ground Truthing	Hydroperiods 25% < expected for 3-5 year period 25% < or > spatial extent of wetland coverage or type	–

D.1.6 Faunal Species Strategies and Management Options

Faunal species play an important role in determining success of ecological restoration within a project area. Certain fauna serve as ecological indicators for specific conditions associated with restoration objectives. Indicator species may only be present under certain environmental conditions. Other species are keystone species, which have a profound effect on their environment either through trophic interactions or habitat manipulation (ecosystem engineers). The uncertainty related to fauna for the Loxahatchee River Watershed Restoration Plan (LRWRP) is, "How will restoration enhance species abundance and diversity in the watershed (wading birds, prey, and wetland indicator species?" To address this uncertainty, species were selected that represent different trophic levels ranging from primary consumers to top predators. Monitoring of the selected species groups will provide a more distinct picture of the effects of ecological restoration throughout the food web as it pertains to the project area. Due to the abundance of species found within these groups, representative species may be selected to represent each group. LRWRP is generally broken into two general ecosystem types; those being floodplain and estuarine. Given the process of wetland restoration, the timeframe to detect change will be slightly different between these two ecosystem types **(Table D-9 below**). The period of time for detection of change within the estuarine ecosystem is expected to be less than that for the floodplain ecosystem.

Restoration should have a positive effect on faunal species abundance and diversity. In order to determine if goals and objectives of LRWRP are being achieved, specific species or groups of species can be monitored to provide detail as to the progress and/or success of restoration over time. The faunal species and species groups determined to provide such data are: birds (wading birds/raptors), Anurans (frogs and toads), alligators, small mammals, and fishes. These groups (indicator) will have their own metrics to measure status and adaptive management strategies.

LRWRP AM Uncertainty #9: How will restoration enhance species abundance and diversity in the watershed (wading birds, prey, and wetland indicator species)? (Driver or uncertainty type: Ecological)

This uncertainty is related to LRWRP overall project goals of enhancing ecological values; improving habitat and functional quality; as well as, improving native plant and animal species abundance and diversity. This uncertainty is, also, related to project restoration goals of increasing natural area extent of wetlands; restoring connections between natural areas; and restoring native plant and animal species abundance and diversity. The project specific objectives (developed by the PDT) relative to this uncertainty are:

- Restore freshwater forested wetlands in the Northwest Fork of the Loxahatchee River closer to 1940's conditions
- Provide or improve hydrologic connections within the contiguous greenway and the regional water management system to increase water management options for maintaining or enhancing the existing natural areas
- Optimize quantity, quality, timing and delivery of surface water to/from areas to achieve ecological and water supply enhancement purposes
- Capture, store, and treat excess surface waters and supplement water deliveries to areas to achieve ecological and water supply enhancement purposes

The Management Options Matrix, or MOM, is shown in **Table D-8** below. The MOM for the faunal uncertainty shows the adaptive management thought process that will be used to assess restoration

status as well as details on action items to address any deficiencies that may arise during the restoration process.

D.1.6.1 Bird Strategy

Wading Birds

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

Wading birds are long-legged water birds that typically include species within the avian families *Ardeidae* (bitterns, herons and egrets), *Ciconiidae* (storks), *Phonicopteridae* (flamingos), and *Threskiornithidae* (ibises and spoonbills). Birds in these four families forage in shallow water (depths < 50 cm) and typically nest either above motionless and slowly moving bodies of water or near these areas. Wading birds are considered top predators in south Florida and their reproduction is dependent on prey availability. Prey primarily consists of aquatic animals such as amphibians, aquatic reptiles, fishes, and aquatic invertebrates. Flamingos will also consume algae. Prey availability can be affected by nutrients in the system, microtopography, vegetation type, vegetation cover and density, and hydrology. Nesting occurs during the annual dry season in south Florida and receding water levels help concentrate prey into the deeper locations. When annual water level recessions do not occur or are not synced with the nesting periods then this can greatly affect wading bird nesting success because prey may not be available in great enough amounts for chicks to grow and fledge from nests. Changes to south Florida's natural hydrology have had detrimental impacts on many species of wading birds; thus, wading birds have been a primary focus of the Everglades restoration efforts throughout the ecosystem.

The majority of wading birds in south Florida can be separated into two foraging types: tactile and visual foragers. Tactile foragers such as ibises, spoonbills, and wood storks require shallower water levels (5 to 25 cm) to help concentrate prey and make it more available, while most visual feeders can forage within a greater range of water levels (5 to 45 cm). Tactile foragers have become less common (several have been listed by the state of Florida as threatened species) and therefore are considered a more vulnerable group of wading birds. All wading birds can be affected by the timing of the annual water recession and any recession reversals that occur during dry season. If the recession of water happens too soon, too late, or not at all then nesting success for that year can be greatly reduced. Additionally, if water levels are ideal, but prey is still not available because of a lack of open water areas to forage within (*e.g.*, dense vegetation), then this too can cause reduced nesting success.

The presence of wading birds serves as an indicator of wetland habitat with the presence of tactile foragers serving as an indicator of ideal water levels to make prey available for most species. Understanding the population dynamics of wading birds within a wetland system, including species diversity, species richness, and other population dynamics not only gives an understanding of how the restoration is progressing within LRWRP, but also serves as a methodology to quantify restoration results. The proposed adaptive management activities will increase the probability for successful recruitment of many foraging wading bird species into the LRWRP project area. Some of these wading birds may choose the site for nesting as well, if other non-prey related conditions are adequate, such as the presence of woody vegetation nesting substrates within the project area.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each.

The presence of foraging wading bird species within the project area can be considered an ideal indicator to determine the success of this restoration. Restoration of freshwater inputs into the Loxahatchee River Watershed should increase the amount of wetland acreage, permanent and temporary, throughout the project area. Increase in hydrologic patterns altering upland dry communities into wetland communities should result in an increase in the number of wading birds and wading bird species attracted to the project area; especially during the annual nesting period. Species richness and abundance of individual wading birds serve as measurable indices to evaluate restoration success. A large and diverse mix of foraging wading bird species will indicate a diversity of shallow water levels that are ideal for making prey available for both visual and tactile foraging wading birds. The presence of only a few wading bird species or only visual foraging wading birds may indicate reduced prey availability for some if not all wading bird species. It is expected that wading birds will show an immediate response to ideal foraging conditions (prey availability). A measureable response may be possible as quickly as the first nesting season once the restoration activities have been completed. Conversely, wading bird numbers will also quickly decline in these areas if foraging condition deteriorate. Increases of successful wading bird nesting within the LRWRP area can also serve as a measurable response since wading birds typically do not initiate nesting or successfully fledge young without appropriate prey availability. This prey availability would include the amounts of prey, ideal water levels, and slow recession rates during the dry season.

In order for LRWRP to be considered successful in the conversion/creation of wetland habitat, there must be measurable data showing that there is wading recruitment into the project area. Regional wading bird nesting success should be taken into account. Since precipitation drives the hydrologic conditions throughout south Florida, regional and local rainfall should be taken into consideration when evaluating the success of the project based on wading birds. Recruitment occurs via (1) individuals (adults and juveniles) purposely moving into the project area, (2) displacement of individuals into the project area, and (3) nesting and survival of offspring.

More information on attributes to be measured:

While several aspects for measuring the presence of species may seem duplicate to each other, the differing methods for measuring species does provide important but specific information. All are methods for assessing biological diversity.

- Total number of wading bird counted is simply the number of wading birds documented during surveys.
- Species richness refers to the number of species per sample (community/habitat type).
- Species diversity refers to the number of species and their abundance (evenness) per sample.
- A simple estimate of nesting numbers for each species can be compiled from aerial surveys along with boat surveys if necessary.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Monitoring of wading birds falls into two (2) categories: biodiversity and reproduction. Both the biodiversity of wading birds and their nesting within the project area involves the commonly used technique of flying an aircraft or drones along transects over the project area observing for foraging and nesting birds. This methodology may not capture wading birds foraging under the canopy along stretches

of the river, so adjustments may be necessary to this methodology that include monitoring from boats along stretches of the river. Monitoring should occur at least monthly from February to June, during the dry season, each year.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action:

Restoration of freshwater inputs into the LRWRP project area will positively affect the recruitment and potentially nesting of wading birds on the project by increasing prey availability for residents and birds that fly to the project area during the annual dry season. Given this expectation, restoration targets will be above current baseline values. The metrics designed for trigger/threshold determination are: total wading bird count, species richness, species diversity, and number of wading bird nests observed within the LRWRP project area. Surveys should be performed annually and evaluations compare the current year to a three-year average (the three years prior to the year being evaluated) while controlling for rainfall variation.

- Total Wading Bird Count: Total number of wading birds present each month within an area of study. In order to assess usage of the project area, a number (X) of survey transects will be identified for surveys within the LRWRP project area. At each of these locations, surveyors will fly along the transects and observe all visible wading birds. The trigger/threshold value will be X value below the established target value based on the best available science and expertise.
- Species Richness: Species richness is simply the total number of species present within an area of study. In order to assess species richness of wading birds within the project area, a number (X) of survey transects will be identified for survey within the LRWRP project area. At each of these locations, surveyors will fly along the transects and observe all visible wading birds. The trigger/threshold value will be X value below the established target value based on the best available science and expertise.
- Species Diversity: Species diversity takes into account species richness and species evenness. Species richness is described above. Species evenness is the variation of abundance of individuals per species within an area. There are several indices used to calculate species diversity, all with advantages and disadvantages. The preferred index to calculate wading bird species diversity is the <Shannon-Weiner?> Diversity Index. The trigger/threshold value will be X value below the established target value based on the best available science and expertise. - If the ratio of visual foragers to tactile forages falls below X ratio value established based on the best available science and expertise this should trigger an evaluation of water depths and recession rates within the LRWRP project area.
- Nesting: Nesting success should be evaluated separately from the presence of foraging wading birds because wading birds may travel into this area from nesting colonies not on the LRWRP project area. A simple count of the number of visible nests by each species can be compared annually. The trigger/threshold point will be X value below the target value based on the best available science and expertise.

Management Options that may be chosen based on test results:

If measurable data falls below the trigger/threshold value, there are several management actions that can or should be undertaken depending on what threshold is not being met.

- Prey availability: Prey availability should be evaluated via checking the timing of water recessions, the recession rate, survey prey concentrations during the wet season, exploring if prey is becoming isolated and concentrated during the annual drydown, and exploring if emergent or submergent vegetation is too dense for wading bird foraging.
- Disturbance: Check if the area experiences disturbances that might drive wading birds away from locations within LRWRP project area.
- Make adjustments to the hydrology: Lack of wading bird species presence and reproduction may be a result of hydrological influences. Hydrological factors including duration/persistence of ephemeral wetlands, water levels, and flow of water (rate) may need to be adjusted to provide more ideal conditions for wading birds foraging.

D.1.6.2 *Anuran* Strategy

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

Anurans are species of amphibians, frogs and toads, within the order Anura. Amphibian populations are dependent on the availability of water to survive. Frogs and toads possess porous skin that is susceptible to drying out. In order to reproduce, these species require a body of water, permanent or temporary, as they do not produce a productive barrier to retain moisture within the embryo. Given these characteristics, Anurans are great ecological indicators of wetland conditions and habitat.

Anurans are also an important species within the wetland food chain. As a secondary consumer, they are pivotal in the transference of energy. They aid in keeping primary consumer populations in check, while providing a significant energy source for top predators such as wading birds and the American alligator. With any restoration project, specific components are necessary to avoid both top-down and bottom up trophic cascades. *Anurans* serve both as an indicator of wetland habitat but also as an indicator of trophic health of a wetlands system. Understanding the population dynamics, including species diversity, species richness, and other population dynamics provide, not only an understanding of how restoration is progressing within LRWRP, but methodology to quantify restoration results. The proposed adaptive management activities will increase the probability for successful recruitment population longevity (age structure to confirm population is surviving year to year) of *Anurans* within the LRWRP project area.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each:

Restoration of freshwater inputs into the Loxahatchee River Watershed should increase the amount of wetland acreage, permanent and temporary, throughout the project area. Increase in hydrologic patterns altering upland dry communities into wetland communities should result in an increase in the number of anuran species present within the project area. Species type and duration of presence serve as measurable indices to evaluate restoration success. A large mix of Anuran species will indicate a diversity in wetland types. The presence of a few Anuran species may indicate conversion to a more monotypic

wetland type resulting in less richness and ultimately less diversity (which takes into account evenness as well as richness).

For restoration to be considered successful, the presence of Anuran species isn't the only factor to assess. The presence of these species may not mean there is a residential population. In order for LRWRP to be considered successful in the conversion/creation of wetland habitat, the must be measurable data showing that there is Anuran recruitment into the project area. Recruitment occurs via (1) individuals (adults and sub-adults) purposely moving into the project area, (2) displacement of individuals into the project area, and (3) reproduction and survivability of offspring.

More information on attributes to be measured:

While several aspects for measuring the presence of species may seem duplicate to each other, the differing methods for measuring species does provide important but specific information. All are methods for assessing biological diversity.

- Species richness refers to the number of species per sample (community/habitat type).
- Species diversity refers to the number of species and their abundance (evenness) per sample.
- Species occupancy, also referred to as the occupancy-abundance relationship, refers to a measure of abundance of species related to the size of their ranges (total area occupied within a designated area of study) within an area.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Monitoring of *Anurans* falls into two (2) categories: biodiversity and reproduction. Measuring the biodiversity of *Anurans* within the project area involves commonly used techniques of recording audible calls to determine species presence throughout the project area as well as use of open-ended PVC pipe placed in the ground throughout the project area. Another method to use for measuring species biodiversity is to dipnet in waterbodies to identify species and abundance. Reproductive activity, also monitored via dipnet sampling, can be quantified by identifying and summing the number of temporary wetlands, tidal pools, and permanent water bodies containing tadpoles (verification of breeding) as well as calculating total acreage of those areas to provide assessment for the ability/capacity for reproduction within the project area. All aspects of Anuran monitoring shall occur three (3) times a year, during the wet season, in years 0, 3, 6, and 9. The overall monitoring strategy will be updated during pre-construction engineering and design (PED) when detailed monitoring scopes of work are developed.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action:

Restoration of freshwater inputs into the LRWRP project area will positively affect the recruitment and sustainability of *Anuran* populations by increasing preferred habitat for residents as well as reproduction. Given this expectation, restoration targets will be above current baseline values. The metrics designed for trigger/threshold determination are: species richness, species diversity, species occupancy, and # of water bodies used for breeding versus those available.

- Species Richness: Species richness is simply the total number of species present within an area of study. In order to assess species richness of *Anurans* within the project area, a number (X) of survey areas will be identified for survey. At each of these locations, surveyors will utilize acoustic recorders to record/document audible frog and toad calls. Due to typical *Anuran* behavior, audible

surveys will be conducted in the evening and/or during the night. Species of *Anurans* will be identified based on unique calls documented upon playback of the survey recordings. The trigger/threshold value will be X value below the established target value based on the best available science and expertise.

- Species Diversity: Species diversity takes into account species richness and species evenness. Species richness is described above. Species evenness is the variation of abundance of individuals per species within an area. There are several indices used to calculate species diversity, all with advantages and disadvantages. The preferred index to calculate *Anuran* species diversity is the part of the suite of Simpson's Diversity Indices (Simpson's Index and Simpson's Index of Diversity). Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. Simpson's Index of Diversity, calculated as (1 – D), provides the same information from a different view point. Instead of calculating the probability that two individuals are from the same species, the Simpson's Index of Diversity calculates the probability that two individuals are from different species. Both of these indices have an end value between 0 – 1. The trigger/threshold value will be X value below the established target value based on the best available science and expertise.
- Species Occupancy: Species occupancy is a model based application to solve problems that result from deficient detectability of target species. Detection of *Anuran* species is no different. Survey data is compiled from PVC pipe surveys and transect surveys. Species occupancy is a mark/recapture process without actually marking specimens. For more information on what species occupancy is and how it is calculated refer to: https://fresc.usgs.gov/products/fs/fs2005-3096.pdf. Occupancy values will be between 0 and 1. The trigger/threshold value will be X value below the established target value based on the best available science and expertise.
- Water Bodies for Breeding: Population sustainability requires reproductive success. In order to assess *Anuran* species within the project area, all potential breeding locations need to be identified. All *Anuran* species require a body of water (in some form) to successfully reproduce. As stated above, frogs and toads do not encase their embryo in any type of protective feature which would prevent desiccation. As such, all embryos develop in water. Surveys throughout the project area during the wet season will identify all potential bodies of water that could be used for breeding as well as those that are being used. A target value will be established off best available science and expertise. The calculated value will simply be number of used water bodies divided by number of potential breeding water bodies. All end values will be between 0 and 1. The trigger/threshold point will be X value below the target value based on the best available science and expertise.

Management Options that may be chosen based on test results:

If measurable data falls below the trigger/threshold value, there are several management actions that can or should be undertaken depending on what threshold is not being met.

- *Facilitate an increase in ephemeral wetlands (marshes, ponds, pools, etc.)*: Lack of Anuran success within the project area may be dependent on predation at the juvenile/sub-adult phase. The lack of ephemeral wetlands suggests a reliance on permanent water bodies within the project area for use as refugia and breeding. Typically, permanent water bodies contain a host of predator species that may prey on adults, young, and embryos. These permanent water bodies may possess predator fish, harbor more predator birds, and contain alligators, all of which may prey on the various life-stages of *Anurans*. Ephemeral wetlands provide temporary

water sources that do not contain predatory fish and are not big enough or long-lived enough to provide a significant threat from alligators and their young. There still may be a threat from wading birds but the threat should be reduced when compared to a permanent wetland. Depression marshes are targeted in Pal Mar indicator regions and Cypress Creek.

- *Assess water quality*: Due to the biology of *Anurans* including their porous skin, toxins in the environment can have a profound effect on their populations. If the threshold limits are not being achieved, the assessment of water quality could provide essential information as to the source for failure to maintain or achieve the threshold value. Water quality data will be analyzed from the WQ monitoring plan to determine whether this stressor may be impacting anuran success.
- *Make adjustments to the hydroperiod*: Lack of *Anuran* species presence and reproduction may be as a result of hydroperiod influences. Hydroperiod factors including duration/persistence or ephemeral wetlands, water levels, and flow of water (rate) may need to be adjusted to provide more ideal conditions for recruitment of *Anurans*.
- *Remove exotic plant and animal species*: Exotic flora and fauna provide aspects of ecosystem unknown to native species. Exotic plants can alter the vegetative landscape of a community resulting in less niche space for native Anuran species. Exotic flora may alter the water chemistry resulting in less favorable conditions to reside or breed in. Exotic fauna may out compete native *Anuran* species for similar resources including food and shelter. There may be a direct impact including predation as well. Eradication of exotic flora and fauna results in a more natural native landscape for native *Anuran* species to flourish.

D.1.6.3 Fish Adaptive Management Strategies

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

Along the Northwest Fork of the Loxahatchee River, many ecological factors combine to influence the presence, abundance, and movements of freshwater and marine fishes. Such ecological factors include: freshwater inputs, freshwater flow rates, tidal cycle, vegetation type, salinity, and precipitation patterns, all which come together to support a wide variety of fish species. Fish are an important part of the food chain within the Loxahatchee River Watershed, providing sustenance to wide assemblage of predators including other fish, amphibians, reptiles, birds, and mammals. Fish, also, serve a human dimensions' role in terms of subsistence (jobs/livelihood) and recreation (fishing).

Over time, the development of water control structures has reduced the spatial extent of freshwater wetlands throughout the Loxahatchee River Watershed. In the northwest fork, the reduced amount of freshwater flowing into the fork has resulted in salt-water intrusion further inland throughout the northwest fork. This intrusion has shifted the freshwater influence farther upstream converting more of the river to brackish water thus altering the types of vegetation and species present. As freshwater flows are restored, monitoring of fish species frequency, composition, abundance, individual length, and movement will provide essential details into the success of shifting the freshwater boundary of the fork seaward and increasing the amount of freshwater via the expansion of freshwater habitat (i.e. freshwater wetland communities) within the Loxahatchee River Watershed.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each.

Restoration of freshwater inputs into the Loxahatchee River Watershed Project (LRWRP) should increase the amount of wetland acreage, permanent and temporary, throughout the project area. An increase in freshwater supplied to the watershed should reverse the pattern of salt-water intrusion shifting the mixing zone farther seaward (closer to the predevelopment period). More freshwater flows should also result in a transition to more freshwater wetland communities linked to the northwest fork of the Loxahatchee River further providing freshwater input into the river. As freshwater influences shift seaward, suitable habitat for freshwater fish should increase, thus resulting in increased freshwater species diversity, recruitment, and movement. It is unclear how the increase in freshwater inputs and adjusted flows will react with salt-water intrusion, tidal action, and sea level rise on the size of the "brackish zone", which is important for recruitment and reproduction of certain fish species.

Expansion of freshwater habitat in the watershed should favor shorter hydroperiod aquatic fauna (crayfish, mosquitofish, shrimp). Because wetlands are somewhat ephemeral in depression marshes, large fish predation of smaller aquatic prey should be limited, resulting in concentrating pools of fish for wading birds at the mid to late phases of the dry season.

More information on attributes to be measured:

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Monitoring of fishes falls into two (2) categories: biodiversity and movement. Measuring the biodiversity of fishes within the Northwest Fork of the Loxahatchee River and its tributaries involves the commonly used techniques utilizing fish sampling gear such as seines, dip nets, electroshockers (non-lethal), drop traps, and cast nets. Monitoring and survey protocols should replicate fish studies on the northwest fork between 2007 and 2010. Those studies include:

- 2007 Loxahatchee River Watershed Fish Survey
- 2008 Fish Assemblages and Dry Season Flow and Stage Levels
- 2008-2009 Snook Behavior in Relation to Freshwater Inflows
- 2007-2010 Snook and Largemouth Bass Habitat Utilization and Resource Partitioning
- 2005-2007 Aquatic Fauna and Periphyton Status Demonstration

These studies provided a much-needed baseline for comparison with data collected during and after the implementation of the Loxahatchee River Watershed Restoration Project. **Figure D-8** represents sampling from the Aquatic Fauna and Periphyton monitoring funded by RECOVER in 2005-2007.

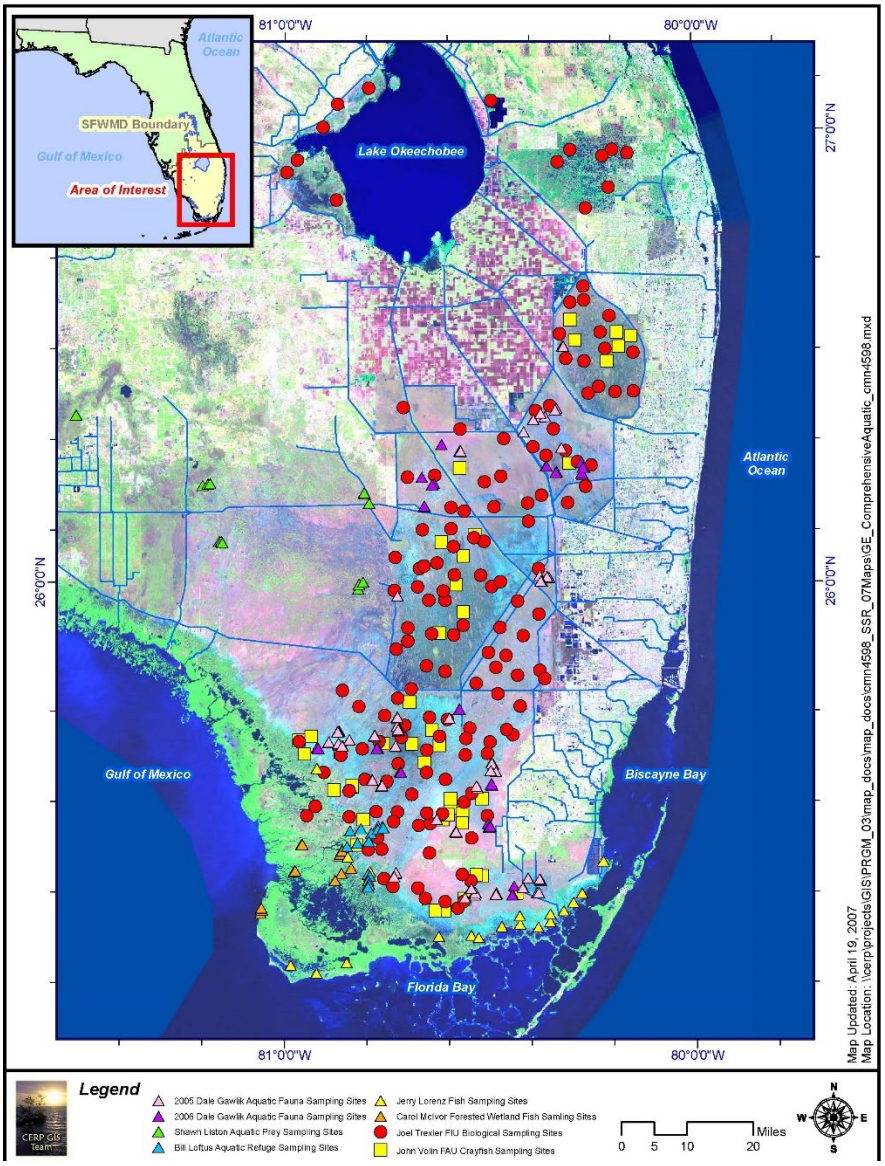

Figure D-8. Map of Aquatic Fauna Sampling in Greater Everglades.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action:

- Restoration of freshwater inputs into the LRWRP project area will positively affect the recruitment and sustainability of fish populations (fresh, marine, catadromous, etc.) by increasing preferred habitat resulting from a change in water conditions (salinity/freshness). Patterns of fish movement provides a good metric as to the current conditions at various points along the river and its tributaries. Given this expectation, restoration targets will be above current baseline values. Assessing length of fish within the river and its tributaries will provide important metrics on population dynamics and how the river is being utilized. The metrics designed for trigger/threshold determination are: species richness, species diversity, and age/size class. *Age/Size Class*: Size class shows the population breakdown of age and importance within a fish population. The presence of smaller fish may reveal stronger recruitment into the system which

indicates positive ecological response due to the restoration of the Loxahatchee River Watershed. Larger fish are important due to their potential to reproduce. Larger fish are also more ideal for recreation as well. Restoration success may be indicated by the ability for the river to sustain larger population sizes containing larger, more fecund individuals. For this metric, total fish length will be measured for each individual and age will be determined via counting growth zones of annuli. This data will show population structure for species of fish present. Von Bertalanffy growth curves can be created for each species present throughout the Northwest Fork of the Loxahatchee River (and its tributaries).

Management Options that may be chosen based on test results:

If measurable data falls below the trigger/threshold value, there are several management actions that can or should be undertaken depending on what threshold is not being met.

- *Assess salt water intrusion*: Salt water intrusion will affect the presence and assemblage of fish species present as well as other ecological pertinent issues such as type, variety, and density of vegetation along and in the river. If salt water intrusion continues to be a problem, adjustments to how much freshwater is released into the system, how fast it flows, and duration and timing of flows into the river will need to be evaluated and adjusted.
- *Evaluate vegetation present along and in the river*: Vegetation in and along the river will be influenced by salinity and flow rates. Fish presence may be determined by the amount and type of cover provided by vegetation along shore and in the river itself. Vegetation will also influence the flow and current through the river creating eddies, low energy areas or increased areas of flow (channeling) which may need to be addressed for preferred conditions.
- *Hydroperiod adjustments:* As mentioned previously, one of the targets for the Loxahatchee River Watershed Restoration Project is to shift the boundary between fresh and brackish/salt water seaward of its current position along the river which will provide a greater extent of freshwater and possible a larger mixing zone (brackish) creating a more diverse assemblage of fish throughout the entire river system. If species diversity is low or shifted to marine/brackish species, the amount of water, timing of release, duration of release, etc., may need to be adjusted to provide the proper water conditions for freshwater species to thrive. If wetlands surrounding depression marshes have shorter hydroperiods than desired, then habitats might not be conducive to aquatic prey.

The Management Options Matrix, or MOM, is shown in **Table D-9**. The MOM for the faunal uncertainty shows the adaptive management thought process that will be used to assess restoration status as well as details on action items to address any deficiencies that may arise during the restoration process. The MOM includes monitoring attributes recommended to assess status, placeholder decision criteria to trigger management action, and management action option suggestions to improve performance if needed.

Table D-8. Faunal Species Management Option Matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#9	Floodplain Ecosystems species – 7-10 years Estuarine Ecosystems species – 5-7 years	• Birds • Anurans • Alligators • Small Mammals • Fishes	<u>Bird Monitoring</u> • Wading Bird Foraging during the annual nesting season (November to April) ○ River to be surveyed either aerially (generally preferred – however they may not capture foraging under the canopy along regions of the river) or via boat on a weekly to monthly basis through the nesting season • Wading Bird Nesting during the annual dry season ○ River to be surveyed either aerially (preferred) or via boat on a weekly to monthly basis through the dry season <u>Anuran (Frog/Toad) Monitoring</u> Species Diversity/Abundance/Occupancy: Wet season sampling (3x/year, years 0, 3, 6, 9) • Diversity/Richness	<u>Bird Monitoring</u> *Wading Bird Monitoring* • 20% increase in number of individual wading birds based on three-year average of observed wading birds within the LRWRP project area *(placeholder)* • Increased species richness diversity value <u>Anuran (Frog/Toad) Monitoring</u> • 20% increase in species richness and diversity • 25% species occupancy value below reference sites (Pal Mar west <u>Fishes Monitoring</u> • 20% increase in species richness and diversity value below restoration target • ? increase in biomass from baseline • Trend towards reference site biomass	<u>Bird Monitoring</u> 1. Assess prey concentrations within known foraging spots 2. Evaluate disturbance to any foraging and nesting birds by boating activities 3. Hydroperiod adjustments (flow, water levels, period of inundation) 4. Keep isolated floodplains free of exotic/invasive emergent vegetation that can reduce foraging by raptors and large wading birds <u>Anuran (Frog/Toad) Monitoring</u> 1. Facilitate increase in ephemeral ponds (avoid relying on permanent wetlands which increase fish predation) 2. Assess water quality (WQ monitoring plan)

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
			○ Evening/night audible call surveys (acoustic recorders) • Population ○ PVC pipe monitoring ○ Transect surveys • Larval/Juvenile Survey ○ Dip Net (tadpole id) Reproduction/Recruitment Monitoring: Wet season sampling (3x/year, years 0, 3, 6, 9) • Breeding Pool/Ephemeral water body ○ ID/Map locations (GPS/GIS) <u>Fishes Monitoring</u> • Under 2x's/year scenario: fish surveys should be conducted 1 time at end of the wet season and 1 time at end of the dry season. Species Richness/Diversity: measured 2, every year for 5 years.		3. Hydroperiod adjustments (flow, water levels, period of inundation) 4. Removal of exotic species (exotic fishes, exotic veg [especially melaleuca], exotic amphibians and reptiles) due to predation and competition, resource depletion (i.e. water loss) 5. Innoculation with desired species to establish breeding populations. <u>Fishes Monitoring</u> 1. Evaluate water quality (in terms of salinity) 2. Evaluate vegetation present along river and in river 3. Hydroperiod adjustments (flow, water levels, period of inundation)

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
			• Methods for Richness and Diversity include capturing with seine nets, dip nets, cast nets, drop traps, non-lethal electoshockers. Age/Size Class: measured 2 times a year, every year for 5 years. • Each specimen caught (or set number of each species) measured and evaluated for statistical analysis.		

D.1.7 Invasive Species Strategies and Management Options

LRWRP adaptive management uncertainties number's 14, 15, 16, 18 & 19 (see below for description of each uncertainty that was identified).

These uncertainties are related primarily to LRWRP Objective #5 (Restore native plant and animal species abundance and diversity), which pertains to restoring a natural mosaic of upland and wetland habitat within the watershed, as well as restoring the appropriate hydrologic regime to support the NW Fork floodplain and the restoration of flows to the Moonshine Creek, Kitching Creek and Cypress Creek tributaries.

The introduction and expansion of invasive and nuisance plant and animal species has the potential to alter the predicted LRWRP restoration species composition and community structure and reduce habitat quality through competition and displacement of native species and alteration of fire frequency and intensity. This in turn can result in impacts to listed (threatened and endangered) species, and alter trophic dynamics and food webs. These uncertainties consider management options to offset a reduced amount of improvement that might occur if invasive and/or nuisance plant and animal species (either currently recognized or newly recognized) affect the integrity of the ecological systems that are restored. Impacts to the landscape resulting from particularly aggressive floral and faunal invasives (e.g., Old-World Climbing Fern, Melaleuca, Brazilian pepper, and feral hogs) are well documented. These species, however, are only a fraction of the invasive and nuisance species in the Loxahatchee watershed, and many of the other species' life histories, ecosystem impacts, and responses to disturbance and restoration are not well understood.

These uncertainties are applicable to all areas of the LRWRP where ecological improvements are expected. Invasive species responses may be greater in areas where ecological responses are less certain (specifically, where ecological function is proposed to be returned to areas that were previously devoted to high impact agriculture).

The LRWRP adaptive management invasive species strategy described here focuses on consolidating species data that is existing and proposed to be collected. This, in turn, will improve the ability to target species management resources most effectively in the specific conditions that will be created by LRWRP, and thus minimize or prevent invasive and nuisance species impacts on the performance of LRWRP. This adaptive management strategy has been coordinated with the LRWRP Invasive and Nuisance Species Management Plan (INSMP).

The following uncertainties are considered:

LRWRP adaptive management uncertainty #14. Will the changes in hydrology facilitate the spread of invasive plant species? (Driver or type: Ecological)

LRWRP adaptive management uncertainty #15. How will new invasive faunal species affect the restoration? (Driver or type: Ecological)

LRWRP adaptive management uncertainty #16/XX. How will new invasive plant species affect the restoration? (Driver or type: Ecological)

LRWRP adaptive management uncertainty #18. Is there a potential for the project to transfer/expand invasive plants to other areas? (Driver or type: Ecological*) (Species such as Azolla pinnata, Mimosa pigra)*

LRWRP adaptive management uncertainty #19vi. How will invasive species that are not managed on private property affect the restoration? (Driver or type: Ecological)

The Management Options Matrix, or MOM, is shown in **Table D-10** for the invasives species management. The MOM for the invasive species management uncertainty shows the adaptive management thought process that will be used to assess restoration status as well as details on action items to address any deficiencies that may arise during the restoration process. The MOM includes monitoring attributes recommended to assess status, placeholder decision criteria to trigger management action, and management action option suggestions to improve performance if needed. Further details on invasives species management is addressed in the invasive species management plan.

Table D-9. Invasive Species Management Option Matrix.

Uncertainty ID	Time until changes are measurable*	Indicator or Attribute	Specific property to be Monitored, and Frequency	Decision Criteria: confirmation of LRWRP Performance or Trigger(s) for Management Action	Management Action Options
#14	< 1 year	Extent and density of current species, identify species likely to expand in response to hydrologic changes	% of total project area covered or impacted Ratio of invasive/native species in specific areas	Species dependent, presumption of routine mgmt. sweep (on cycle)	Adding new species that invade the area to the management list Identify and incorporate New Control Strategies as they are identified
#15	<1year	Hog rooting Movement of freshwater fish species downstream Northward colonization by Pythons and/or exotic apex predators	Wetland restoration areas (depending upon alternative selected)	>x% of area affected by hog rooting	Incorporate trappers to reduce # hogs
#16	N/A	Extent and density of new species(not previously	Wetland restoration areas (alternative dependent)	Species dependent, presumption of routine management sweep (on cycle)	Adding new species that invade the area to the

Uncertainty ID	Time until changes are measurable*	Indicator or Attribute	Specific property to be Monitored, and Frequency	Decision Criteria: confirmation of LRWRP Performance or Trigger(s) for Management Action	Management Action Options
		present in the area) Improved species profiles			management list Identify and incorporate New Control Strategies as they are identified
#18	N/A	Extent and density of current species Control strategies relative to species known	Western areas (Mecca, Avenir) Cypress Creek (pepper farm restoration)	Track presence of species in waterway and floodplain, species dependent, presumption of routine land management sweep	Early Detection, rapid response monitoring to identify species movement
#19	N/A	Type and presence of invasive species on adjacent private parcels	All project areas	???	Maintain private landowner interaction via CISMA and FISP

Expectations and hypotheses to be tested to address uncertainties numbers 14, 15, 16, 18 and 19 and attribute(s) that will be measured to test each

No new monitoring is proposed in this adaptive management strategy to improve predictions and risk assessment. Rather, data from the LRWRP INSMP and other CERP INSMPs and individual property land management plans, historic and current databases, and aerial photos may be used to develop and/or refine risk assessment tools that will aid in directing invasive and nuisance species management decisions. Existing regional aerial monitoring and low strata monitoring (essentially relying on land manager observations and alertness with respect to rapid detection and early response to identify new species and potential problems should continue. These adaptive monitoring activities consider that the majority of properties within the LRWRP area are currently in a maintenance level condition with respect to invasive species management.

Before LRWRP implementation these data should be consolidated in the CERPZone and needed species profiles and tools should be developed. It is recommended that the causal relationship between invasive or nuisance species to restoration activities and outcomes should be considered as the data are consolidated. For example, the following LRWRP questions may be pursued: What is the impact of invasive faunal species such as coyotes or pythons on the nesting success of wading birds or ground nesting birds

in the watershed? How can the development of relationships and communication with adjacent private landowners, including utility and roadway rights-of-way aid in reducing the impact of invasive species on restoration success. Will changing salinities increase the distribution of freshwater invasive faunal or floral species? Will restoration of specific areas increase the dispersal of invasive plant species (seed source)? Can the removal of canal berms reduce the spread of those species that use these as primary travel corridors?

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

There is an awareness that invasive species both exist, and new species can invade the watershed, and that these species should be tracked and monitored, using the current monitoring approach (primarily land manager alertness, annual property sweeps, etc.). It is expected that addressing this uncertainty will improve the understanding and ability to predict how invasive and nuisance floral and faunal species influence the ecosystem function and structure within the footprint of the LRWRP, and how they might potentially influence the outcome of the LRWRP restoration activities. Improved species profiles and prediction/risk assessment abilities can help target resources to the most effective species management activities, and can inform future design and operations of LRWRP and other restoration project to avoid expensive trial and error attempts to reduce the impacts of invasive and nuisance species. The proposed activities will reduce the possibility of invasive and nuisance species from hindering the success of the LRWPR in achieving its restoration objectives.

There are three categories that are germane to, and drive the tracking, targeting and management of invasive species. The first is related to those species that are well studied, where biologists are familiar with the history of invasion, how the species impact the environment and what control methodologies are most effective. For these species, it is relatively easy to predict what to expect with certain restoration scenarios, including the rate at which the plant(s) become an issue and how they can be most effectively controlled. The second category includes those species for which some information is known, however, there is not a clear understanding of where they are on the invasion curve, whether or not they are about to become a huge problem and how these plants may respond in restoration scenarios. The final category are those species that are just appearing on the landscape, and for which there is little or no information. Biologists can use the University of Florida/IFAS Non-Native Plant Assessment Tool, a research based approach to conduct status and predictive assessments to determine a low or high risk of invasion, or determine if further evaluation is warranted. This tool can bring together the rather loose network of invasive species biologists to aid in identifying current distributions, and allow a rapid assessment of emerging species. If the rapid assessment identifies a new species as a high risk, it can justify a rapid response action in an attempt to eradicate or contain the species. Management teams can also currently utilize, and should continue to utilize the early detection/rapid response funding provided by the Florida Fish and Wildlife Conservation Commission (FWC) and tie into the reporting aspects of the Early Detection and Distribution Mapping System (EDDMAPS) that has been built via a collaborative effort and is a way to share data on locations and distributions. Consideration should be given to the development of a system wide management program. Additionally, with respect to invasive faunal species, consideration should be given to expanding the Everglades Invasive Reptile and Amphibian Monitoring Program (EIRAMP) to include the Loxahatchee Watershed. There is a recognition that there is a perennial issue with respect to invasive species management in that there are generally reasonable budgets for management, however funding for science to conduct risk assessments is limited.

What is the time frame in which changes to this attribute are expected to be measurable?

In general, impacts from invasive species for newly constructed features or newly restored properties should be measureable within a year of construction ((i.e., return to appropriate hydrologic conditions). However, this is species dependent and there are some species that might not respond unless favorable weather conditions prevail.

When during LRWRP's life cycle should this monitoring begin?

This monitoring is ongoing on most of the lands that have been acquired for incorporation into the LRWRP, and should continue during implementation, construction and operation.

How will results, and the triggers/thresholds that indicate good LRWRP performance or need for adaptive management action, be reported?

Lessons learned will be provided as feedback to various stages of the LRWRP design, construction and implementation by the invasive species biologists during interaction with the LRWRP design team, operations and land managers as appropriate. There are a number of forums available for sharing this information, similar forums should be available as the project is implemented. Additionally the LRWRP INSMP is a living document and will be updated with lessons learned.

Management Options that may be chosen to reduce the impacts of invasive species.

Suggested adaptive management options listed below are not in any particular order and can be implemented simultaneously, as appropriate. Details of the management actions are listed in the LRWRP INSMP.

- Continued refinement of existing, or development of new Invasive Risk Assessment Tools
- Implementation of Invasive and Nuisance Species Management Plans to immediately identify and eradicate/minimize new, opportunistic highly invasive species on active construction sites, or within newly restored areas
- Suppression of established invasive or nuisance species to the lowest possible level to minimize ecosystem impacts by regular coordination between land managers and Statewide groups such as CISMAs, FLEPPC and FISP
- Continued regular sweeps of restored and adjacent properties for reduction and control of invasive and nuisance species
- Redesign existing or planned features, based on lessons learned, to make them less likely to support invasive species colonization, or movement

D.1.8 Estuaries Strategies and Management Options

D.1.8.1 Estuaries – Submerged Aquatic Vegetation (SAV) Strategy

How does the timing in salinity changes and ranges affect SAV?

Note that within and between years there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to SAV between these short-term conditions and restoration. Uncertainties exists with respect to how the project's increased restoration flows will meet species-specific salinity regimes for SAV. Some measurable parameters may be limited by species (e.g. productivity measurements for *Vallisneria americana* and *Thalassia testudinum* due to blade size and width). However, all seagrasses in the estuary and freshwater species such as *Vallisneria* in the Northwest Fork will be monitored. The decision criteria and management action options consider both whether the intended changes in salinity timing are met, and what other actions may be required if salinity conditions are met but effects to SAV cause decline or no change without also mediating other environmental conditions (i.e. substrate limitation).

LRWRP AM Uncertainty #22. How does the timing in salinity changes and ranges affect SAV? (Driver or uncertainty type: Ecological)

LRWRP Objective or Constraint: *Restore and/or maintain estuarine communities (oysters, fish, seagrass)*.

Region(s). *Loxahatchee River and Estuary*

Associated LRWRP features: All features that promote flow to the river.

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

Submerged aquatic vegetation (SAV) plays a critical role in influencing the population, community, and ecosystem dynamics of estuarine environments. Altered hydrologic activity (e.g., restorative freshwater flows) may influence the abundance, density, and distribution of seagrass. Additional flows provided by this project are not expected to negatively impact estuarine and marine SAV but will be monitored to provide assurances that this is the case. These additional flows into the Northwest fork should have marked positive effects on SAV with a lower salinity tolerance, such as *Vallisneria*. Elucidating how restoration performance may influence SAV in the Loxahatchee River is imperative so that adaptive management actions can be undertaken, ensuring restoration success.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each.

A change in the volume, timing, and duration of freshwater flows may shift seagrasses from upstream of RM 4 downstream between RM 0 and 4. Adaptive management will be needed if there is a 20% or greater decrease in SAV acreage from the best mapping year (2007) and/or there is a 20% or more loss in SAV abundance. Submerged aquatic vegetation distribution, abundance and productivity will be monitored to discern potential changes to SAV in the river. Please note that 20% is a place holder value to be updated during PED.

Additionally, increased (sustained) freshwater flows are expected to maintain or increase *Vallisneria*, which is found roughly between RM 15 and RM 8. If restoration scenarios are not met (i.e., flows are variable or do not meet minimum restorative flows), adaptive management will be needed if *Vallisneria* acreage doesn't increase from the best mapping year (2013) and/or there is a 20% or more loss in *Vallisneria* abundance.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

SAV abundance and productivity will be monitored during the growing season in April, June, and August according to seagrass patch scale sampling methodologies outlined in the Loxahatchee River District's seagrass sampling program (see www.loxahatcheeriver.org/river/seagrass). The following parameters will be monitored:

- Presence/absence of SAV
- Percent SAV cover
- SAV shoot densities
- SAV productivity
- SAV canopy height
- SAV biomass (below-and aboveground tissue)

SAV distribution will be assessed during the summer growing season every 3-5 years using the Loxahatchee River District's Quadzilla method, a $9m^2$ quadrat that is placed throughout the river.

Vallisneria monitoring will also be initiated using similar or newly developed methodology as those used by the RECOVER program and/or LRD.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action, and subsequent management options:
To assess the LRWRP performance or whether there is a need for adaptive management action as it pertains to SAV in the river, the following management options may be applied:

- Optimize freshwater flows to obtain salinity in locations in which SAV is or should be present.
- Remove fine-grained sediment (e.g., muck) that may accumulate, so SAV can expand and grow.
- Assessing water quality to ensure that abiotic conditions are suitable for SAV growth.
- SAV restoration in areas in which SAV should be present or is present but at low densities.
- Implementing structures such as breakwaters or sediment traps to reduce possible sedimentation issues and/or shear stress on SAV.

D.1.8.2 Estuaries – Oyster Strategy

How does the timing in salinity changes and ranges affect oysters?

Note that within and between years there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to oysters between these short-term conditions and restoration. Inherent uncertainties for oysters include restoration activities which meet the salinity envelopes, and benefits may be limited if there is also substrate or spat limitation (also see Uncertainty #23 (**Table D-11 below**). The decision criteria and management action options consider both whether the intended changes in salinity timing are met, and what other actions may be required if salinity conditions are met but effects to oysters cause decline

or no change without also mediating other environmental conditions (i.e. substrate limitation; spat limitation).

LRWRP AM Uncertainty #22. How does the timing in salinity changes and ranges affect oysters? (Driver or uncertainty type: Ecological)

LRWRP Objective or Constraint: Restore and/or maintain estuarine communities (oysters, fish, seagrass).
Region(s). Loxahatchee River and Estuary
Associated LRWRP features:

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?
Oyster communities in coastal estuaries have respective salinity envelope requirements to persist within a system. However, the timing and duration of altered freshwater flows due to restoration activities will affect the desired areal extent, abundance, and density of oysters. Depending on the location in the estuary, interactive effects in salinity and temperature may have beneficial or detrimental effects on the prevalence and intensity of disease (i.e. *Perkinsus marinus* infection, or "Dermo"), as well as predation by marine predators. Substrate and spat limitation have the potential to impede restoration performance despite meeting suitable salinity envelopes. By addressing these uncertainties in the LRWRP monitoring plan, performance goals and subsequent adaptive management actions are developed to ensure restoration success moving forward.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each.
With a change in volume, timing, and duration of freshwater flows, it is expected that oysters upstream of River Mile (RM) 6 will shift downstream between RM 3.5 and 6. If the proper salinity envelope is maintained more than 80% of the time between RM 3.5 and 6, it is expected that there will be no net loss of oysters, but mainly a shift in location. Because the estuary is wider at this more downstream location, if the proper substrate is available it is possible to see an increase in the overall areal extent/distribution of oysters post-restoration. It is realistic to estimate an additional 10-20 acres are possible downstream given the substrate is there to support spat settlement. Oyster extent/distribution (in acres) as well as percent living oysters will be mapped and/or monitored both prior to and after restoration implementation to ascertain the effects of the restoration activities.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Quarterly, the following monitoring will occur at existing RECOVER site and/or Lox sites (**Figure D-9**). Additional site locations will need to be added or relocated once salinity shifts are detected (descriptions of possible methods are available in the *Oyster Habitat Restoration Monitoring and Assessment Handbook* (http://ocean.floridamarine.org/CHIMMP/Resources/Oyster%20Habitat%20Restoration%20Monitoring%20and%20Assessment%20Handbook.pdf):

- Density/m^2
    - Including percent live/dead
- Growth

- Disease prevalence
- Predation
- Recruitment
- Mapping

The timeframe determined to detect change in oysters is five (5) years. Within and between years there will be seasonal and inter-annual conditions which may, in the short term, dampen the ability to detect changes to oysters between short-term conditions post-restoration, therefore mapping should occur pre-restoration, and then again five years after restoration implementation, and once every five years after to track long-term change and inform adaptive management.

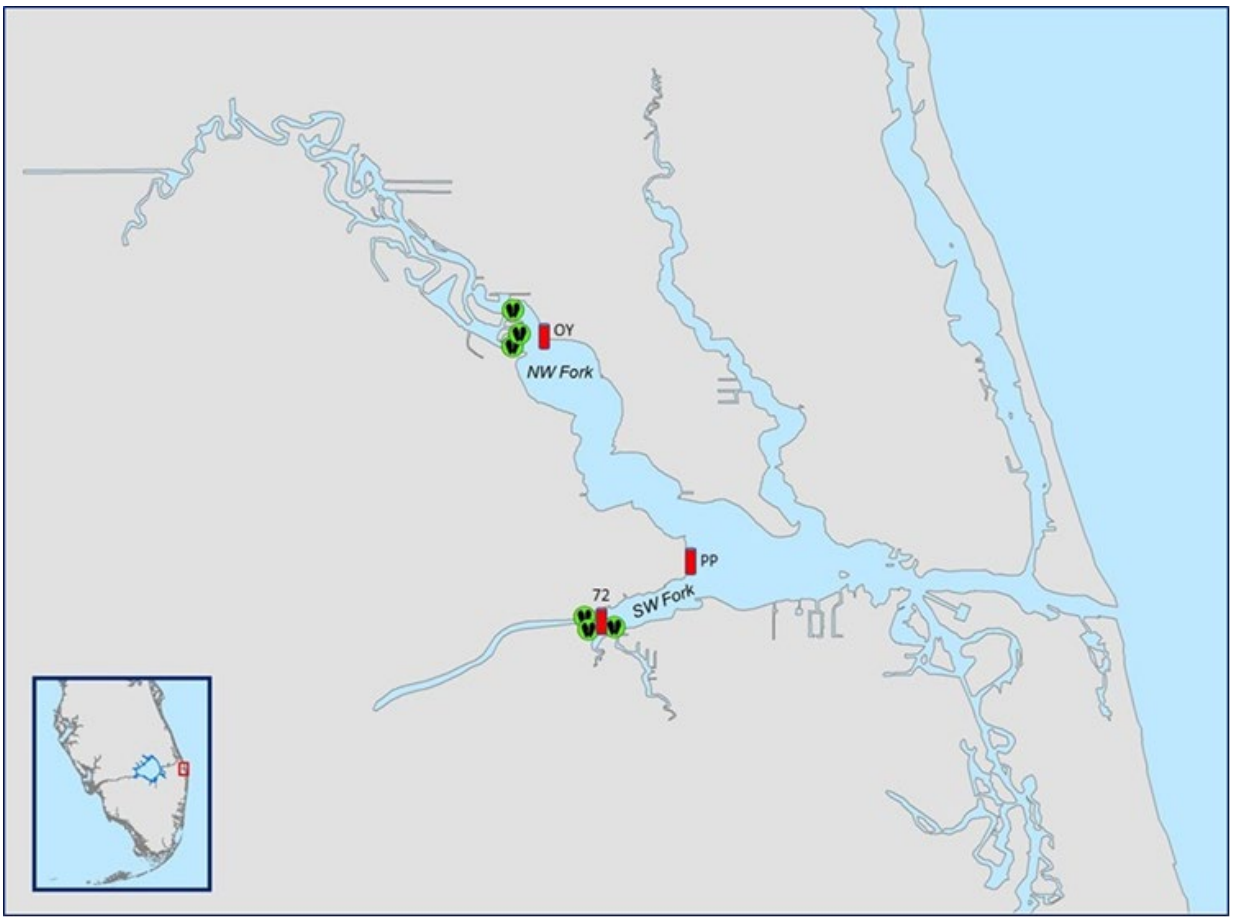

Figure D-9. Map of Current Oyster and SAV Monitoring

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action, and subsequent management options:

Triggers for adaptive management action varies depending on the metric, but any one of these triggers will be considered independently. Further, actions may vary in application depending on the management trigger observed:

- Salinity envelope – if the salinity envelope falls outside of the preferred range between RM 3.5 and 6 more than 20% of the time, changes in operations to increase or decrease flows would need to occur.
- Area – If the number of acres of oysters currently found upstream of RM 6 are not replaced by equal or greater number of acres between RM 3.5 and 6, this may be a factor of salinity envelope conditions, and/or other possible mechanisms related to either substrate or spat limitation. For substrate-limitation, cultch or travertine tiles may be added. From past restoration projects in the area the cost of cultch placement including planning, design, permitting, cultch acquisition, placement and public education is approximately $130,000/acre. For spat limitation, several options exist, including adding spat to the water column, transplanting mature oysters, or deploying seeded (with spat) cultch or travertine tiles.
- Abundance – if the acres of "replaced" live oysters does not increase or falls below 80% of the pre-restoration acreage, the information gained by the monitoring of disease, predation, and other parameters should be evaluated to elucidate what conditions might be driving these indicators of oyster health. Adaptive management actions that should be considered include change in operations, e.g. if current flows or salinity envelope conditions increase the susceptibility of disease.

Table D-10. Estuaries Oyster and SAV Management Option Matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#22	SAV: 5 years Oysters: 5 years (acres of live oysters)	SAV Oysters	SAV Monitoring: Growing season sampling (3x/year) Presence/absence Shoot density Productivity (Val and Thallassia) % Cover Canopy height SAV biomass (above and below ground) SAV distribution using Quadzilla Mapping (every 3-5 years)	SAV: A decrease of 20% or more of acres of SAV from best mapping year (2010) 20% or greater loss in SAV abundance Oysters: If the number of acres of oysters currently found upstream of RM 6 are not replaced by = or greater number of acres of oysters	SAV: Optimize flows to get the correct salinity in the correct locations Substrate issues – muck removal Assess water quality Seagrass plantings Structural changes – breakwater or sediment trap to reduce shear stress Oysters:

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
			Oyster Monitoring: Quarterly at existing RECOVER sites and/or Lox sites Density/m^2 Growth Disease Predation Live and dead counts Recruitment	between RM 3.5 and 6 If outside of the preferred oyster salinity envelope between RM 3.5 and RM 6 more than 20% of the time 20% or greater reduction of living oysters between RM 3.5 and 6	Change operations to increase or decrease flows if salinity envelope is not correct Add cultch to areas in RM 3.5-6 If spat is a limiting factor, add mature oysters to existing beds or add spat or seeded cultch to water column, add travertine tiles

D.1.8.3 Estuaries – Substrate Strategy

LRWRP AM Uncertainty #23. As we change salinity ranges and locations, do we have the proper substrate for the new salinity? (Driver or uncertainty type: Ecological)

If restoration activities meet intended changes to timing in salinity, SAV and oysters may otherwise be limited by the available substrate, as it relates to redistribution of different sediment types (e.g. fine-grained sediments, sand) as a result of increased flows or other conditions from the project. Specifically, areas susceptible to fine-grained sediment entrainment can limit productivity or result in sedimentation. For oysters, spat may be unable to locate suitable substrate on which to settle even if salinity regimes and sediment type are suitable. Benthic mapping will identify changes to substrate and benthic conditions following restoration and whether additional management actions are required to create suitable conditions for SAV and oysters (see **Table D-12 for Substrate Management Options Matrices)**. Change in sediment distribution or composition is possible as an effect of both natural or project-driven mechanisms (e.g. increased flows).

LRWRP Objective or Constraint: *Restore and/or maintain estuarine communities (oysters, fish, seagrass)*.

Region(s). *Loxahatchee River and Estuary*.

Associated LRWRP features:

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty?

Both oyster and seagrass communities in coastal estuaries have substrate requirements to persist and recruit in a system. By changing the salinity regime in the system through restoration activities these

communities are expected to shift downstream. Shifting of these communities will require the appropriate substrate for recruitment in restoration areas in addition to the alteration of salinity regimes. This subject was included in the Adaptive Management Plan due to its level of uncertainty, uncertainty of project outcomes, and the ability to address undesired outcomes through adaptive management options.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each.

A change in the volume, timing, and duration of freshwater flows are expected to shift oysters from upstream of River Mile (RM) 6 downstream between RM 3.5 and 6 and seagrasses from upstream of RM 4 downstream between RM 0 and 4. This is dependent on the availability of the appropriate substrate for each of these communities existing in these river stretches following two years of restoration activities. Restoration activities may suspend and redistribute fine-grained sediments (e.g. muck) in the water column, which may affect the distribution of oysters and SAV. This redistribution can result in covering surfaces needed for oyster reef growth. Further downstream, successful restoration of SAV will aid in sequestration of sediments from the water column, providing smaller-grained substrate which is beneficial for rhizome growth in sandy sediments.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting:

Two years following the initiation of restoration, benthic mapping will be conducted to determine if the appropriate substrate exists for these communities. Following this initial mapping there will be additional mapping every ten (10) years.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action, and subsequent management options:

If the substrate within the indicated RMs is not appropriate for the species expected to be found in the area (i.e., hard bottom substrate such as rock and preferably oyster cultch for oysters; medium to small grained sediment for seagrass) or if muck starts to dominate areas which can be enhanced by appropriate substrates for either oysters or SAV, the following actions may be applied to provide the appropriate substrate:

- Adding cultch may be necessary for oyster recruitment and growth if existing hard bottom substrate is not present. Addition of cultch will replace or add to the available hard bottom substrate needed for oyster communities. From past restoration projects in the area the cost of cultch placement including planning, design, permitting, cultch acquisition, placement and public education is approximately $130,000/acre.
- Removing or capping fine sediments may be needed. Fine sediments that are suspended in the water column reduce the amount of light available to seagrasses and cover hardbottom substrate needed by oysters. By removing or capping fine sediment these communities will be aided by reducing the burying of hard bottom substrate and increasing light availability.
- Sediment traps may need to be installed to reduce sediment runoff into the system.
- Installation of breakwaters could assist in protecting areas from shear stress and/or promote sediment accumulation.

Table D-11. Estuaries Substrate Management Option Matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#23	5 years	Substrate type	Benthic mapping at 5 year increments	If substrate is not appropriate for the species expected to be found in the area (hard sediment/crunched shell for oysters or medium to small grained sediment for seagrass) If muck is present in the area neither oysters nor will SAV be able to expand into the area.	Substrate remediation: Adding cultch Removing or capping fine sediments Sediment traps Install breakwaters to protect areas from shear stress and/or sediment accumulation

D.1.9 Water Supply Strategies and Management Options

D.1.9.1 Water Supply – Aquifer Storage and Recovery Strategy

LRWRP AM Uncertainty #26: Will the Aquifer Storage and Recovery (ASR) wells be able to deliver the proposed quantities and timing of water to the Northwest Fork? (Driver or uncertainty type: Engineering and Operations)

LRWRP Objective or Constraint: *This uncertainty relates to the LRWRP objective of improved quantities and timing of water deliver to the NW fork*.

Region(s). *ASR wells*

Associated LRWRP features: *ASR wells.*

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty? We will learn more about our local hydrogeology. A better understanding of the hydrogeological characteristics of the aquifer at the ASR wells will inform design and operations of LRWRP features.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each. ASR at our specific project site will be able to perform as expected with regard to capacities of 5 MGD per well and 70% efficiency of long-term recovery of stored water from ASR.

More Information on attributes to be measured:

- **What is expected to be learned by measuring this attribute, i.e., *how will LRWRP benefit from knowledge gained about this attribute?*** Aquifer hydrologic characteristics will be determined during the exploratory borehole testing. This information will inform future operations and infrastructure needs. The exploratory borehole will then be converted to ASR well #1.
- **What is the time frame in which changes to this attribute are expected to be measurable?** <3 years
- **Is this attribute complemented by other monitoring programs within and/or outside of LRWRP? If so, provide reference to other monitoring. Note the monitoring paid for by others in the LRWRP AM budget spreadsheet.** SFWMD maintains the Regional Floridan Aquifer monitoring network. Several nearby FAS monitor wells are part of this network. ASR wells at the C-18W Reservoir will contribute additional hydrogeologic data to inform and update SFWMD's Upper East Coast groundwater flow model.
- **When during LRWRP's life cycle should this monitoring begin and end?** Monitor wells will be installed and monitored throughout the life of this project, though monitoring frequency and characteristics are expected to be reduced over time.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting: Several monitoring wells and monitoring protocols will be established Underground Injection Control (UIC) permit criteria. The analysis will proceed by standard requirements, and results will be reported to the appropriate regulating agency as required. Daily monitoring and totalizing of ASR inflow and outflow volumes will be measured daily, and ASR outflow operations will be constrained by a maximum chloride concentration of 250 mg/L, measured weekly, supplemented by daily measurements of specific conductance values. *The monitoring program will be developed during LRWRP's detailed design phase, and methodology will be reviewed, updated and adjusted if needed by agency subject experts, before initiation, to best meet the intent of the AM Plan.*

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action.

- UFA does not have suitable permeability for ASR.
- Significant decrease in well capacity.
- Percent recovery significantly below (for example, 30 percent) the target 70 percent by volume (higher groundwater salinity than expected).
- Arsenic concentrations that exceed the Safe Drinking Water Act criterion (10 µg/L).

Management options that may be chosen based on test results.

<u>Pre-construction measures</u>

- Utilize additional and deeper aquifers (for example, the Avon Park Permeable Zone) at the C-18W Reservoir site.
- Construct a second exploratory borehole farther south along the western embankment, or along the northern embankment west of the pump station.

<u>Post-construction Measures</u>

- Perform well rehabilitation, a typical component of ASR system maintenance.

- Perform longer, larger volume recharge events;
- Adjust schedule of recharge, storage, and recovery plan.
- Revise ASR and Reservoir operations to optimize ASR/Reservoir co-operations.
- Consider well infrastructure changes, such as plugging or changing the open interval of the aquifer to improve stored groundwater quality
- Potential addition of wells

D.1.9.2 Water Supply - Flood Risk Management Strategy

LRWRP AM Uncertainty and ID#31. Will there be unanticipated changes in water levels that impact existing level of service to nearby residential areas? (Driver or uncertainty type: Engineering and Operations)

LRWRP Objective or Constraint: *Constraint is flood protection assurances and septic system performance*.

Region(s). *Any agricultural or residential areas adjacent to LRWRP storage and restoration areas*.

Associated LRWRP features: *Impoundments, canals, wetlands, natural storage, flow-through marsh, and any other footprints that will store or detain water for this project*.

What is expected to be learned by addressing this uncertainty, i.e., how will LRWRP benefit from addressing this uncertainty? Gaining local acceptance and support for project.

Expectations or hypotheses to be tested to address the uncertainty, and attribute(s) that will be measured to test each. Seepage and conveyance features will not cause negative impacts to nearby property owners.

(Additional groundwater recharge will benefit nearby landowners without compromising flood protection or septic system performance.)

More Information on attributes to be measured:

- **What is expected to be learned by measuring this attribute, i.e., *how will LRWRP benefit from knowledge gained about this attribute?*** Measuring these attributes will indicate how the natural system responds to retaining more water with reduced flashiness and how increased groundwater levels will contribute to base flow while providing flood protection assurances. LRWRP will benefit by fine-tuning operations to optimize benefits while honoring this flood protection constraint.
- **What is the time frame in which changes to this attribute are expected to be measurable?** Less than 3 years.
- **Is this attribute complimented by other monitoring programs within and/or outside of LRWRP? If so, provide reference to other monitoring. Note the monitoring paid for by others in the LRWRP AM budget spreadsheet.** Yes, all monitoring data collected and used for flow calibration compliment this monitoring by allowing a historical perspective to compare project performance and impacts to nearby landowners.

- **When during LRWRP's life cycle should this monitoring begin and end?** This could be 10+ years. A couple of extreme events may be needed to confirm project performance.

Methodology for testing each expectation or hypothesis (including frequency of monitoring) and for reporting: Frequency will be event-driven, and documentation could be in the form of an after-storm report. Periodic inspection of facilities would occur consistent with standard practices used for similar existing infrastructure.

Triggers/thresholds that indicate good LRWRP performance or need for adaptive management action: Sustained increased stages in the areas of concern compared to similar historical situations;
Piping observed along project flow-ways, complaints on excessive and prolonged water levels; delayed recovery to pre-storm water levels compared to historical performance.

Management options that may be chosen based on test results: Management options to help address water supply performance issues include the following and are listed in **Table D-13**.

- Modify operations to avoid adverse impacts to level of service
- Expand seepage collection (deeper seepage collection, larger SC pump, extend length of SC canal)/reduction features (deepen/extend seepage barrier, or berm construction)
- Improve conveyance capacities (such as localized canal bank improvements or excavation)
- Periodic levee inspections
- Annual or otherwise periodic review of LOS performance compared to historical system response.
- Compare actual system performance with similar historical and modeled output scenarios & user complaint history

Table D-12. Water Supply- Flood Control Strategy Management Option Matrix

Uncertainty Tracking ID#	Uncertainty Description	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
26	Will the ASR wells be able to deliver the proposed quantities and timing of water to the NW Fork? Deliver performance expecting	<3 years	Exploratory well capacity, conductivity, source water quality, ASR recovery efficiency	Well hydrologic performance will be determined during the exploratory bore hole construction, Volume of daily recharge and recovered water,	Test borehole hydraulic conductivity or water quality substantial unfavorable compared to planning assumptions of same. Significant decrease in well capacity, Significant increase in	<u>Preconstruction measures</u> Utilize additional and deeper exploratory boreholes for improved siting Investigate the development of deeper aquifer Perform well rehabilitation <u>Post-construction Measures</u> Perform longer, larger volume recharge events; Adjust schedule of recharge, storage, and recovery plan.

Uncertainty Tracking ID#	Uncertainty Description	Timeframe to detect change of attributes*	Attribute or indicator	Specific Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
					recovered chlorides	Revise ASR and Reservoir operations to optimize ASR/Reservoir co-operations.
31	Will there be unanticipated changes in water levels that impact existing level of service to nearby residential areas? (team presumes a flood impact concern)	<3 years	Canal stages, Groundwater stages;	Monitor specific areas with LOS concerns	Sustained increased stages in the areas of concern compared to similar historical situations; Piping observed along project flow-ways, complaints on excessive and prolonged water levels; delayed recovery to pre-storm water levels compared to historical performance	Modify operations to avoid adverse impacts to level of service Expand seepage collection (deeper seepage collection, larger SC pump, extend length of SC canal)/reduction features (deepen/extend seepage barrier, or berm construction) Improve conveyance capacities (such as localized canal bank improvements or excavation) Periodic levee inspections Annual or otherwise periodic review of LOS performance compared to historical system response. Compare actual system performance with similar historical and Model output scenarios & user complaint history

D.1.10 How Adaptive Management Activities Will be applied during LRWRP Implementation

D.1.10.1 Project Management

RECOVER will work with the LRWRP project managers to develop workplans and monitoring scopes of work in coordination with other technical resource providers as needed to provide the budget, schedule, and details to execute the adaptive management strategies identified in the Annex D. At a minimum, one RECOVER scientist should be dedicated to overall all coordination of the LRWRP monitoring and adaptive management efforts. Additional technical expertise should be engaged as needed. Adaptive management activities will be implemented in sequence with the project components being implemented. Workplans will include all necessary activities, resources needed, and schedule for completion so that they can be resourced appropriately and tracked by the project manager for progress and execution as part of the project schedule and implementation plan during design, construction, and operations.

Project components will be implemented in a staggered fashion due to budget (amount of funds available each year), regulatory requirements (permits and compliance monitoring feedback), and LRWRP

dependency constraints (state and federal projects required prior to implementation of a specific LRWRP project component). Time needed to conduct certain adaptive management activities and tasks to inform subsequent project component is incorporated in the LRWRP implementation schedule and the Strategies section of the LRWRP Adaptive Management Plan. Each adaptive management strategy workplan will explain the timing needed to observe, understand, and report restoration performance results from any design tests, pilot projects, and/or response to phases of project components or full project components being implemented to inform LRWRP implementation (see **Figure D-10** for adaptive management strategies and project implementation diagram).

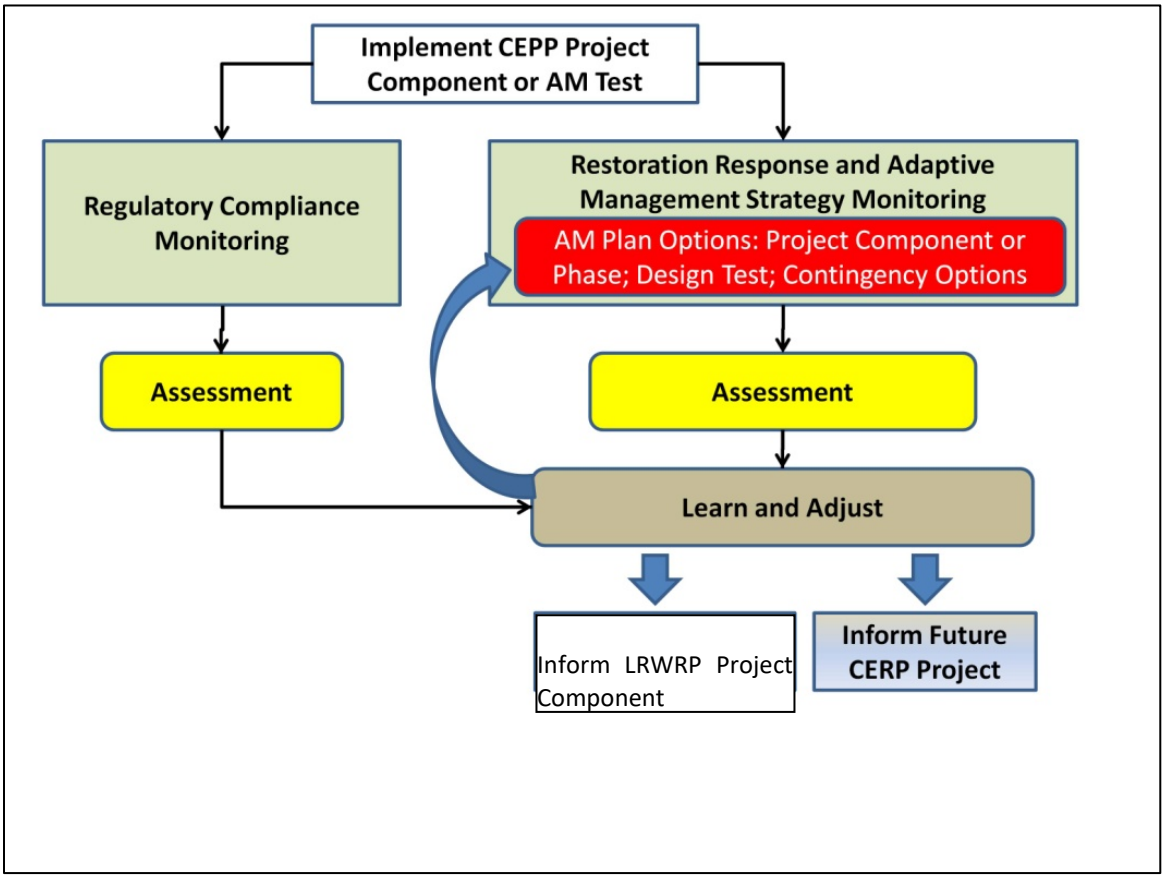

Figure D-10. Adaptive Management Strategies and Project Implementation Diagram.

Adaptive management can proceed associated with a full project component, phase, or test, with associated monitoring, to inform subsequent restoration actions. Monitoring should be implemented before and after implementation for regulatory compliance, restoration response, and adaptive management purposes, as described in the adaptive management and monitoring plans. The monitoring data assessed after construction, and any other current information, can then be coordinated with appropriate CERP agencies to determine progress or the need for adjustments. Adjustments are implemented as part of the adaptive management strategies or made to the next set of LRWRP project components. The information can also be used to inform future CERP projects.

Adaptive management during LRWRP's implementation will incorporate learning to reduce uncertainties and associated risk with some of the components, with the intent of achieving cost savings and providing the ability for certain project components to be implemented more efficiently. In order for this learning

to occur, adaptive management strategies will need to be implemented in sequence with the project schedule. LRWRP Project Component Schedule and Adaptive Management Implementation).

D.1.10.2 Design

Adaptive management activities will also be executed during the preconstruction engineering and design (PED) phase of the project. Adaptive management strategies that may involve pilot projects, operational tests, and phased implementation as described in this adaptive management plan will be discussed during value engineering and detailed design to determine the full scope of each test, project construction phase and implementation. RECOVER team members tasked with overseeing LRWRP adaptive management will coordinate with the LRWRP engineers and water managers to ensure project designs, tests, and project operations manual allow flexibility for adaptive management implementation, as well as ensure monitoring plan designs, thresholds-triggers, and reporting is consistent with engineering design and water management needs. Adaptive management strategies will also involve updates to monitoring and assessment plans to better develop experimental designs, monitoring locations, and analysis methods, as well as initiate baseline monitoring data. Some adaptive management activities will need to begin early enough to allow development of the monitoring plan design and to implement monitoring contracts to support establishment of a minimal baseline before construction of LRWRP project components is completed.

Monitoring and Experimental Design

RECOVER and other agency monitoring that is being relied upon to inform the LRWRP implementation as identified in the adaptive management plan will be reviewed to determine if changes in scope and frequency are needed to better capture LRWRP effects. The activities described here fall within the approved LRWRP adaptive management budget. LRWRP specific monitoring identified in the monitoring and adaptive management plan will require scopes of work, schedules, and assessment protocols to be developed and coordinated by RECOVER to determine monitoring location and experimental design details to update the monitoring plan. Data analysis and modeling may be needed to inform the statistical sampling design needed for monitoring to be able to test LRWRP project hypotheses. Before and after control designs will be specified in the monitoring plan update, consistent with the parameters identified in each strategy and within the constraints specified by regulatory permits. LRWRP monitoring plan design will use existing data where possible, e.g., RECOVER and other agency monitoring efforts. Adaptive management strategies maybe updated with more detailed decision trees to outline the decision-points associated with triggers/thresholds identified in each strategy. Decision trees will describe who receives reports, who provides guidance on decisions associated with the results, and what potential adjustments might occur. Updated monitoring plans will be coordinated for approval by implementing agencies and concurrence by participating agencies and Tribes.

Baseline Monitoring

In cases where there is not sufficient pre-project data monitoring, contracts will need to be initiated prior to construction of specific LRWRP components for illustration of baseline monitoring needs). Final assignment of agency monitoring responsibilities will be made after state and federal regulatory permits are issued for a component. RECOVER, USACE, and SFWMD monitoring points-of-contact will be identified to coordinate and implement monitoring with in-house agency resources or via contracts with CERP partner agencies and/or contracted universities or consultants to most efficiently and effectively execute the monitoring plan designs. Designated contacts will ensure that results are shared with the partnering

agencies and non-governmental stakeholders for the duration of the monitoring plan. In addition, prior to construction of any component and/or test, a baseline monitoring report will be developed by RECOVER and coordinated with the project team and stakeholders, as stated in the PIR monitoring and adaptive management plan. The report results will be presented during annual (or as frequently as needed) State of the Central Everglades technical meeting described below in the post construction and operations and maintenance section.

Pre-construction Engineering and Design (PED)

Project component designs will be developed and coordinated with RECOVER to ensure project component designs are consistent with the testing objectives identified in the adaptive management plan strategy. Further data analysis or review of other project design and monitoring information may be required to inform the design of LRWRP project components (e.g., ASR project components). In addition, monitoring locations that need to be installed prior to construction for baseline monitoring will be coordinated with the PED team to ensure they are aligned properly. The PED team will share project component plans and specifications with the RECOVER. Monitoring contract schedules will be aligned with project construction schedules and operating protocol as defined in the project component's operational strategy and consistent with the experimental design outlined in the adaptive management plan. RECOVER LRWRP point of contacts will also be responsible for conveying results from annual monitoring reports to the PED team to help determine options for improving project designs for additional project components when deemed relevant and necessary.

Project Operating Manuals

Project operating manuals are developed during design by water managers in coordination with engineers, and hydrologists to specify the operating criteria for each structure. Water managers and engineers will coordinate with RECOVER to understand what hydrologic analysis is needed to inform operational criteria to be used as part of adaptive management tests. In addition, RECOVER will work with water managers, planners, and hydrologists to ensure flexibility is incorporated into the project operational plan to allow for potential needed adjustments in the future consistent with regulatory constraints and NEPA analysis. RECOVER will work with water managers to identify the monitoring information, triggers and process to be included in the project operating manual that will inform operational adjustments. Project operating manuals should also include the process by which operational changes will be assessed throughout the year to integrate with assessments of monitoring data and report the effects of operational decisions as part of the annual State of the Central Everglades meeting, and/or similar relevant discussions. Draft project operating manuals will be reviewed by the RECOVER LRWRP points of contacts, as well as regulatory agencies, to coordinate with the adaptive management strategies outlined in the PIR monitoring and adaptive management plan and with regulatory permit requirements.

D.1.10.3 Construction

Construction schedules, construction contract language, and implementation progress will be coordinated with RECOVER to ensure that appropriate flexibility is included as needed to be effective in fulfilling the intent of the adaptive management plan. Schedules and implementation should include monitoring and operational tests consistent with the adaptive management strategies described in the adaptive management plan in order to learn from project component implementation. In some cases, when agreed to by the implementing agencies, adaptive management strategies may require adjustment to construction schedules to be able to learn from implementation of one phase to inform additional

phases. This logic will reduce uncertainty and risk, could reduce cost, and will need to be incorporated into the construction schedule and contracting approaches to ensure this flexibility. LRWRP Project Component and Adaptive Management Implementation, for specific adaptive management strategies that are intended to inform construction schedule.

D.1.10.4 Post Construction and Operations, Maintenance, Repair, Replacement, and Rehabilitation

Post Construction Monitoring

LRWRP specific project monitoring, RECOVER system-wide monitoring and other agency monitoring will be assessed by RECOVER to determine the restoration performance related to key project components or groups of components. The timing outlined in each strategy will determine when data analysis and reporting should occur based on the temporal and spatial scale of the parameters being assessed. The triggers and thresholds outlined in the management option matrices and adaptive management strategies will guide the frequency of reporting and whom the reports are intended to inform. For example, strategies developed to address higher risk uncertainties may require more frequent reporting to LRWRP implementing agencies and associated regulatory agencies to ensure constraints are addressed. Other strategies will have monitoring implemented after a particular project component is constructed for a specific timeline to report results to inform LRWRP operations or construction of subsequent project components.

Post Construction Assessment, Reporting, and Linking to Decision-Making

LRWRP assessment results will be reported to the implementing agencies and LRWRP partner agencies as part of the RECOVER system-status report, South Florida Environmental report, or more frequently if needed. The process for reporting results to decision-makers is provided in the CERP science feedback to decision-making diagram in the CERP Adaptive Management Integration Guide (Figure 3-9, RECOVER 2011b). The process has changed slightly since publication: 1) Senior-level decision-making/coordination bodies have been renamed from the Joint Project Review Board (JRB) to the Quarterly Executive Team (QET), and the Quality Review Board (QRB) to the Quarterly Agency Team (QAT).

As part of assessing and reporting LRWRP's performance, annual State of the Central Everglades meetings will be coordinated by RECOVER to discuss assessment results. Scientists, hydrologists, engineers and water managers will present results of structural and operational changes (Drivers) and corresponding hydrological (Stressors), ecosystem processes (Effects), and ecological response (Attributes) specific to LRWRP implemented project features, tests, and/or operational changes. The meeting goal will be to understand status and trends and potential causes of performance issues and/or success, as well as discuss the reality of what options (LRWRP and non-LRWRP related) are available to improve performance if needed. The meetings could occur in late summer or early fall after completing a water year (ending April 30). The meetings will be LRWRP performance focused. The meetings will require coordination among RECOVER entities overseeing monitoring (LRWRP project funded, RECOVER, and non-agency funded), and trained facilitation is recommended to ensure the technical meeting fulfills the LRWRP assessment reporting goals. RECOVER will work with the South Florida Ecosystem Restoration Task Force's Science Coordination Group to determine if that forum should host the technical meeting to encourage broader non-governmental stakeholder participation.

No later than 1-2 months after the annual State of the Central Everglades meeting, an environmental coordination meeting will be held with managers to discuss with managers any performance issues and to communicate success. This meeting will also be used to agree on the appropriate forum to make

decisions about options to adjust LRWRP implementation and operations, if determined to be needed, e.g., DCT, QET, or QAT.

Monitoring results will be reported in the context of the triggers/thresholds identified in the adaptive management strategies, e.g. if performance remains within the triggers/thresholds that are provided to indicate need for adjustments, then the operations may continue or the next project component may be constructed based on the demonstrated results. Constraint triggers/thresholds that are "triggered" will be reported to LRWRP implementing agencies and associated regulatory agencies with suggestions of management options to implement, as stated in the adaptive management plan management options matrices (MOMs), to be evaluated by the agencies to decide what action is needed. Results of multiple monitoring trends will be integrated as part of a multiple lines of evidence analysis (Burton, et al. 2002; RECOVER 2006) to inform the potential need for adjusting LRWRP implementation or documenting success.

Suggested options to adjust CERP implementation fall into several categories, listed here by level of effort required to implement:

1. Operational Decisions: Operations decisions are weekly/monthly, but get reported and summarized and reported at annual meetings. Annual meetings also are a forum to discuss potential upcoming operations decisions (e.g. , wet vs. dry years going into El Nino or La Nina years);

2. NEPA Covered Options, No Modeling Needed: LRWRP adaptive management plan options that are covered by NEPA and do not require additional modeling or analysis beyond what has been discussed by scientists and managers;

3. NEPA Covered Options, Requires Modeling: LRWRP adaptive management plan options that are covered by NEPA but may require model runs to determine best option;

4. Not NEPA Covered: LRWRP adaptive management options that have not yet undergone sufficient NEPA analysis and therefore require additional environmental review and public comment, and potentially additional modeling.

5. Not Included in LRWRP adaptive management plan: In some cases, the monitoring results may indicate the need for an option not identified in the adaptive management plan or PIR/EIS. This may result in agency-approved temporary adjustment to LRWRP implementation and operations to avoid the constraint while potential project adjustments are further scoped, analyzed, approved, and budgeted for implementation. If additional technical expertise is required in RECOVER, an ad-hoc team could be formed to identify performance issues and options in a post authorization change report or make suggestions for a future CERP project.

The USACE Jacksonville District in consultation with Federal and State resource agencies and the USACE South Atlantic Division (SAD) and the South Florida Water Management District will guide decisions on determining whether restoration success has been achieved or additional operational, structural, or other contingency options identified in the adaptive management plan MOMs need to be implemented.

D.1.11 LRWRP Adaptive Management Plan Cost Estimate

Identification of the LRWRP monitoring contained in Annex D was guided partly by two objectives. First, it must be complete from a LRWRP perspective in that it must provide the monitoring required to address LRWRP-specific needs. Second, it must be integrated with other Everglades monitoring to take advantage of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and insure cost-effectiveness. These two objectives guided development of the adaptive management plan, hydrometeorological monitoring plan, water quality monitoring plan, and the ecological monitoring plan. Where possible, LRWRP will rely on existing monitoring resources such as physical instrumentation, stations, locations, servicing, and analysis efforts funded by RECOVER, CERP sponsors, and partner agencies. Therefore the monitoring described in the LRWRP Adaptive Management and Monitoring plan is limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LRWRP-specific questions. It is assumed that the monitoring programs will continue for at least the time needed by LRWRP. The cost estimate for the adaptive management monitoring can be found in **Table D-14**.

LRWRP monitoring costs are shown here as if all monitoring will take place in one 10-year window. Therefore LRWRP costs here are a 'worst case,' whereas the actually monitoring schedule is expected to be staggered over the LRWRP implementation schedule as shown in and would therefore cost the project less per year. Dollar amounts shown here have not been updated with LRWRP project-wide contingency amounts. These costs were provided before LRWRP project contingencies were applied. *It should not be assumed that the added contingency amounts will be available specifically to fund monitoring efforts*. See **Table D-14** and **D-15** (this Annex) and PIR Section 6 for more information on final cost estimates for LRWRP. Please note that $ by itself represents an unknown cost by partner agencies, where we are leveraging existing ongoing monitoring

Table D-13. LRWRP Adaptive Management Monitoring Cross-walked with Other Monitoring Programs.

Category or Specific LRWRP Area	Uncertainty	ID#	Attributes to be Monitored	RECOVER 1-Yr Cost	Other Agency 1-Yr Cost	LRWRP 1-yr Cost*	Sampling Frequency	Notes
Watershed	Flow	1/2	Flow	$0	$0	$100,000	15 minute for operating structures; daily for non-operating	Six flow gages (either flow meters; or coupled Headwater Tailwater Gages associated with discharge). Analysis of 10 total gages
Watershed	Stage	1/2	Stage	$0	$0	$70,000	Monthly	Up to six additional Groundwater/Surface water wells in Pal Mar, Nine Gems, Cypress Creek, Corbett)
Watershed	Vegetation Restoration Success and	1/2	Vegetation WRAP	$0	$0	$30,000	2 x per year	Estimate based on two people (SFWMD/USACE) 5 sites a day/ 30 sites/ $1,000 per day.
Watershed	Wetland Vegetation	4	Remote sensing	$0	$0	$80,000	2 x per year	Baseline, 5, 10 years whole project ($150K) High impact ag (1, 2) ($80K)

Category or Specific LRWRP Area	Uncertainty	ID#	Attributes to be Monitored	RECOVER 1-Yr Cost	Other Agency 1-Yr Cost	LRWRP 1-yr Cost*	Sampling Frequency	Notes
Watershed	Flow Restoration Success	1/2	Flow	$0	$0	$5,000	60 minute for operating structures; daily for non-operating	Leverage existing gages Lainhart, G-92, S-46, C-18 W. Analysis of flow only
Watershed	Wetland Hydroperiod Restoration Success	N/A	Stage (inundation Duration)	$0	$0	$100,000	Monthly	Staff Gages (Install new in Nine Gems, Pal Mar, Lox slough, Northern GWP). 23 total. Monitor existing 10.
Watershed	Fish	9	Fish abundance, diversity, and biomass	$0	$0	$70,000	2 x per year	10 sites watershed 4 samples each, 6 downstream river/floodplain.
Watershed	Anurans	9	Frog diversity	$0	$0	$50,000	Years 0, 3, 6, 9	10 sites (Pal Mar, Cypress Creek, Lox Slough, GWP), 4 sample locations per site. watershed
Watershed	Wading Birds	9	Wading Bird Nesting and Abundance	$	$	$100,000	Annual	Method will be determine in future monitoring plan drafts (UAV, Fixed Wing sample)
Estuary	How will salinity changes due to increased flows in the NW Fork affect oyster populations	#22	Oysters	$54,000	$0	If additional site is needed $26,000	Monthly for all parameters and 4x/year for dead/live counts	Number of sites and their placement will need to be determined after salinity changes are evaluated post construction

Category or Specific LRWRP Area	Uncertainty	ID#	Attributes to be Monitored	RECOVER 1-Yr Cost	Other Agency 1-Yr Cost	LRWRP 1-yr Cost*	Sampling Frequency	Notes
Estuary	How does the timing in salinity changes and ranges affect SAV?	22	SAV Monitoring and Mapping	$0	$	$40,000 $60,000 per mapping year	Monitoring Monthly 3 months during the summer Quadzilla Mapping every other year	Leverage LRD monitoring; Design of Vallisneria monitoring will need to be determined post restoration
ESTUARY	As we change salinity ranges and locations, do we have the proper substrate for the new salinity?	22	Substrate Mapping	$0	N/A	$60,000	Once every five years	N/A
TOTAL AVERAGE	N/A	N/A	N/A	N/A	N/A	$731,000	N/A	Annual estimate.

Table D-14. Adaptive Management Costs.

Action	Location	Details	Cost
Plugs	Nine Gems	Up to 5 plugs in Nine Gems and/or Moonshine Creek/Cypress Creek to divert flow to desired flow path towards flow-way and creeks. ($23,000 per plug)	$115,000
Berm Removal	Nine Gems	up to 2,500 feet of additional Berm removal to reduce impediments to flow ($7.24 per cubic yard; 6 cy per linear foot)	$108,600
Regrade	GulfStream West/East/Shiloh	Up to 190 acres regrading ($1,168.48 per acre)	$222,000
Planting or Treatment	GulfStream west/East/Shiloh	Up to XXX acres treatment Up to 450 acres planting ($25,645 per acre)	$2,200,218
Cultch	Estuarine Mesohaline	$130,000 per acre. 10 acres.	$1,300,000
Total Adaptive Management Contingency Cost			**$3,831,000**

D.1.12 LRWRP Screened Uncertainties

Table D-15 lists the uncertainties screened out of the adaptive management plan. Reasons for screening out suggested uncertainties may have included lack of direct relevance to project object or constraint, low ratings in the screening criteria described earlier in this Plan, inappropriate scale for LRWRP (system-wide scale questions may be more appropriate to include in the RECOVER System-wide Adaptive Management Plan; very small scale questions may have scored low in the screening criteria), lack of ability to improve LRWRP performance by understanding more about the uncertainty, or simply that the uncertainty was already covered by another that had been suggested (duplicates). The suggested uncertainties are organized below by ID tracking number and geographic area. Refer to the brief LRWRP adaptive management sub-team meeting notes on rationale for screening are included.

Table D-15. Uncertainties Screened Out of Adaptive Management Plan.

Uncertainty ID #	Region	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
3	Wetland vegetation	Restoration of vegetation - will wetland vegetation establish in these areas? Will we need to seed or plant? - low impact ag	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
5	Flow	Ability to rehydrate wetlands due to water table fluctuations across the project area	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
6	Wetland vegetation	How will WQ affect our ability to restore natural vegetation? Downstream	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
7	Wetland vegetation	How will WQ affect our ability to restore natural vegetation? Flow-through Marsh	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
7	Process	Based on previous research and monitoring (2010 Lox River Science Plan) identify and overcome the deficit between what we want to do and what we need to pick up and reuse.	N/A	Process uncertainty - this will be addressed as we proceed in developing the AM and Monitoring Plan - Screened out as a project uncertainty
8	Wetland vegetation	How will WQ affect our ability to restore natural vegetation? Other areas	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
10	Estuaries	How will restoration enhance species abundance and diversity in the river (juvenile fish, species returning to the area)	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
10	Estuaries	What comes with a change of distribution of freshwater coming down the northwest fork? Will there be more nutrient-laden water? How would this affect species and natural communities downstream?	N/A	Added to Uncertainty #22 and it was expanded to include unanticipated habitat shifts

Uncertainty ID #	Region	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
11	Estuaries	How will restoration enhance species abundance and diversity in the estuary (fish, SAV, oysters, species returning to the area)	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
11	Estuaries	Are there or will there be unintended consequences that come from achieving targets?	N/A	Added to Uncertainty #22 and it was expanded to include unanticipated habitat shifts
12	Water Supply	How will future water withdrawals for potable water affect our ability to restore natural resources in that area?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
12	Estuaries	Seagrass decline/loss but may not be associated with restoration flows. There is a need to understand the complete picture of what has happened in the past and with what is occurring now in order to avoid the transference of success, or lack thereof, on the wrong attribute (current restoration project or previous/pre-existing environmental factor) if future restoration is not successful.	N/A	Screened Out
13	Invasive Species	Will the changes in hydrology facilitate the spread of invasive species? Fauna	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
13	Invasive Species	Understand what the status of invasive species are now in restoration/project area	N/A	The status of invasive species will be captured in the Project Invasive Species Management Plan. The uncertainties due to invasives are captured in Uncertainty #14. Screened Out
13	Invasive Species	Pal-Mar is in private hands with no land management and there could be an exotic species problem that comes into the project area.	N/A	Rolled into Uncertainty #14 on invasives

Uncertainty ID #	Region	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
13	Invasive Species	Is there potential for the project to transfer/expand invasives to other areas? Fauna	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
13	Invasive Species	Invasive issues on private lands in the project area – invasives not being managed on private lands, maintains a seed source for adjacent conservation lands	N/A	These uncertainties were rolled into Uncertainty #19 on invasives
20	Wetland vegetation/ Estuaries	How do habitat changes unrelated to the project affect restoration?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
20	Estuaries	How does the change in temporal and spatial aspects of the salinity regime affect the VECs we are trying to restore? Oysters, seagrass	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
21	Project Area	The Loxahatchee River Watershed boundaries - Revisions continue to be made to the attached map, but this particular map was adapted by the Loxahatchee River Management Coordinating Council	N/A	Screened out because it does not affect restoration
24	Cultural Resources	How will hydrological restoration affect cultural resources?	N/A	Screened out because the uncertainties will be addressed in plan formulation
25	Climate Change	Will project changes offset SLR effects? How will it affect what we are trying to do?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
27	Climate Change	How can the project counteract climate change affects that were not anticipated?	Not screened out initially, went through the prioritization process	Climate change uncertainties are going to be dealt with during the plan formulation process so they will not be addressed in the Adaptive Management Plan

Uncertainty ID #	Region	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
28	Climate Change	Will changing rainfall patterns affect the ability to deliver the quantity of water for the project?	Not screened out initially, went through the prioritization process	Climate change uncertainties are going to be dealt with during the plan formulation process so they will not be addressed in the Adaptive Management Plan
29	Species	Will STAs and/or FEBs affect nesting (breeding), foraging?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
30	Species	Will species impact our ability to manage the features for the benefit of the project?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
32	Cultural Resources	Cultural resources – some surveys complete	N/A	Screened out because the uncertainties will be addressed in plan formulation
33	Faunal Species	Threatened, endangered and species of special concern	N/A	Screened out because it is captured in Uncertainty #9
34	Engineering	Is there a need for additional operational changes to balance out stages and address flood control? (more water through C-18)	N/A	Screened out because it is captured in Uncertainty #1
35	Flow	Will there be more nutrient-laden water that was not anticipated?	Not screened out initially, went through the prioritization process	Tier 3 of prioritization so not carried forward
36	Engineering	There should be flexibility in the structures if they are installed? (adaptability)	N/A	Screened out because the flexibility of the structures is captured in plan formulation. Flexibility of operation of the structures is in the AM plan, but not the construction of the structures
37	Engineering	Operational changes already done – this project brings in more water – do we need to do additional operational changes?	N/A	Screened Out

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PART 2: HYDROMETEROLOGICAL MONITORING PLAN

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D.2 Hydrometeorological Monitoring

NOTE TO THE READER: THE HYDROMETEOROLOGICAL PLAN DESCRIBED HERE IS CONCEPTUAL AND WILL BE ADJUSTED ACCORDINGLY AS ADDITIONAL ANALYSES ARE PERFORMED DURING OPTIMIZATION OF THE TSP.

D.2.1 Data Quality Objectives

Developing Data Quality Objectives (DQOs) is an integral part of the planning process to ensure that final monitoring and testing data can be used for their intended purposes. Hydrometeorological data will be used to quantify project performance, evaluate water quality-related goals and objectives, and to comply with monitoring requirements of a variety of operational permits. The DQOs to be considered include accuracy, precision, sampling frequency, availability, completeness, reporting frequency, and timeliness. These objectives are addressed in CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010. The DQOs are further outlined in Section 3.1.1 of this document.

D.2.2 Monitoring Data Elements/Indicators/Cost Estimate

Hydrometeorological and hydraulic monitoring will collect, at a minimum, groundwater and/or surface water stages measured at each of the new or rehabilitated structures; gate openings at gated structures; and pump revolutions per minute (RPMs) at pump stations and Aquifer Storage and Recovery (ASR) wells to calculate flows. A list of currently active meteorological stations and surface water gages at main structures within the Loxahatchee River Watershed Restoration Project (LRWRP) project area can be found in **Table D-16**. All stations listed here currently are active. A list of currently active groundwater monitoring stations in the surficial aquifer and upper Floridan Aquifer are can be found in **Table D-17**. Structure designs proposed in the Tentatively Selected Plan (TSP) are still conceptual and locations will change as the recommended plan is developed. Labels and structure names will be provided after the optimization of the TSP.

A preliminary list of minimal gaging needs to be collected as part of LRWRP is described in **Table D-18**. These gaging parameters augment current monitoring stations that will be leveraged for LRWRP. The headwater and tailwater stage gages located directly upstream and downstream of the structures, respectively, along with the gate openings, are used to compute flows through structures, as well as controlling structure operation. ASR system monitoring requires wellhead pressures (in psi) and flow rates at each ASR well for monthly reporting requirements. The 15-minute measurement frequency is the USACE required standard for stage parameters at operable structures and flows at ASR wells. Breakpoint data are required for pump and are collected when changes to the RPMs are made, up to a frequency of 1-minute. The hydrologic and meteorological data collection equipment will be installed as part of a construction contract or as a separate task order with construction funding. Hydrometeorological parameters such as surface and groundwater stages require accurate estimates of the water elevation compared to a known reference. All new surface and groundwater monitoring installations will be surveyed to a first-order accuracy using the nearest geodetic benchmark. Reference elevations will be reported in both the NAVD88 and NGVD29 datums. Several of the structures are located in close proximity to each other and/or currently active gages, so that the final number of new gages can be reduced. The conceptual structures proposed for the northern portion of the project area (Pal-Mar, Nine Gems, Gulfstream West, and Ranch Colony Canal) are shown in **Figure D-11**. The conceptual structures proposed for C-18 west are shown in **Figure D-12**.

Table D-16. Currently Active surface water monitoring gages and meteorological stations at existing structures in the Loxahatchee River Watershed Restoration Project.

Basin	Structure	Parameter	Measurement Frequency	Location
C-18	C18-PC13-H	Stage, Headwater	BK, DA	PC-13 culvert north of PGA Blvd
	C18-PC15-H	Stage, Headwater	BK, DA	PC-15 culvert north of Bee Line Hwy
	C18-PC15-T	Stage, Tailwater	BK, DA	PC-15 culvert north of Bee Line Hwy
	C18W-H	Stage, Headwater	BK, DA	Weir north of Bee Line Hwy
	C18W-T	Stage, Tailwater	BK, DA	Weir north of Bee Line Hwy
	C18W-W	Flow	BK, DA	Weir north of Bee Line Hwy
	C18W-R	Rain Gage	BK, DA	Station on C-18W at Bee Line Hwy
	G160-H	Stage, Headwater	BK, DA	Spillway on C-18 at Lox Slough
	G160-T	Stage, Tailwater	BK, DA	Spillway on C-18 at Lox Slough
	PINEGLD_R	Rain Gage	BK, SUM	Pine Glades Natural Area
	PRATT_AN_R	Rain Gage	BK, SUM	Pratt and Whitney facility
	S46-H	Stage, Headwater	BK, DA	At S-46 structure on C-18 Canal
	S46-T	Stage, Tailwater	BK, DA	At S-46 structure on C-18 Canal
	S-46S	Flow at Gate	BK, DA	At S-46 structure on C-18 Canal
	G160-W	Flow	BK, DA	Spillway on C-18 at Lox Slough
	G160-T	Stage, Tailwater	BK, DA	Spillway on C-18 at Lox Slough
	G161-H	Stage, Headwater	BK, DA	Culvert beneath Northlake Blvd from GWP
	G161-T	Stage, Tailwater	BK, DA	Culvert beneath Northlake Blvd from GWP
	G161-C	Flow	BK, DA	Culvert beneath Northlake Blvd from GWP
Loxahatchee River Slough	LOXEST	Wetland Stage	BK, DA	Lox Slough east of C-18 Canal
	LOXWST	Wetland Stage	BK, DA	Lox Slough west of C-18 Canal
	LNHRT-T	Stage, Tailwater	BK, DA	Lainhart Dam
	LOX	Stage, Headwater	BK, DA	USGS gage upstream of Lainhart Dam
	LOX	Flow	DA	USGS gage upstream of Lainhart Dam
	LOX 8	Stage	DA	USGS gage on Lox River at FL Tpke
	LOX 8	Flow	DA	USGS gage on Lox River at FL Tpke
	LOX.91	Stage	DA	USGS gage on Lox River at HSLCD ditch discharge (RM 9.1)
	LOX.91	Flow	DA	USGS gage on Lox River at HSLCD ditch discharge (RM 9.1)
Kitching Creek	JDWX	Weather Station	BK, DA	J. Dickinson State Park at SE Kitching Creek Rd.
	LOX_KITC	Stage, Tailwater	BK, DA	Kitching Creek just upstream of Lox River
	LOX_KITC	Surface Water Temp	Min, Max, DA	Kitching Creek just upstream of Lox River
	LOX_KITC	Salinity	Min, Max, DA	Kitching Creek just upstream of Lox River
	LOX_KITC	Specific Conductance	Min, Max, DA	Kitching Creek just upstream of Lox River

Note: BK, breakpoint; DA, daily average; RPM, revolutions per minute; SUM, sum of precipitation over a given period; T, tailwater; H, headwater; RM, River Mile

Table D-17. Currently Active groundwater monitoring gages stations in the Loxahatchee River Watershed. Restoration Project.

Basin	Well	Parameter	Measurement Frequency	Aquifer	Location
C-18	PB-1525	GW level	BK, DA	Surficial	Lucky Tract north of C-18W Canal
	PB-689	GW level	Random	Surficial	Hungryland Slough off Indiantown Rd
	PB-875	GW level	BK, DA	Surficial	At G-92 Structure
	PGAW02	GW level	BK, DA	Surficial	Adjacent to G-160
	PGAW03	GW level	BK, DA	Surficial	Adjacent to G-160
	PGAW04	GW level	BK, DA	Surficial	Adjacent to G-160
	PGAW05	GW level	BK, DA	Surficial	Adjacent to G-160
L-8	PB-1615	GW level	BK, DA	Surficial	Corbett west of Mecca site
	PBF-15	GW level	BK, DA	Floridan Aquifer System	L-8 Tri-zone monitor well
Pal-Mar	M-1083	GW level	BK, DA	Surficial	Western Pal-Mar near Route 711
	M-1234	GW level	Random	Surficial	Old Indiantown Road

Note: BK, breakpoint; DA, daily average; Random, measured infrequently.

The USACE Jacksonville District receives data from various sensors and data collection platforms to monitor surface water flows and levels, and meteorological conditions. Automated timed processes provide provisional near-real-time data required for water management operations. Additional data are also received through an interagency data exchange program among the SFWMD, the USGS, and USACE.

As the recommended plan is optimized and further developed, estimates and contingencies for hydrometeorological monitoring during Operational Testing and Monitoring Phase (OTMP), and Operation, Monitoring, Repair, Replacement and Rehabilitation (OMRR&R) will be reported in Section 6 and in further Annex D sections.

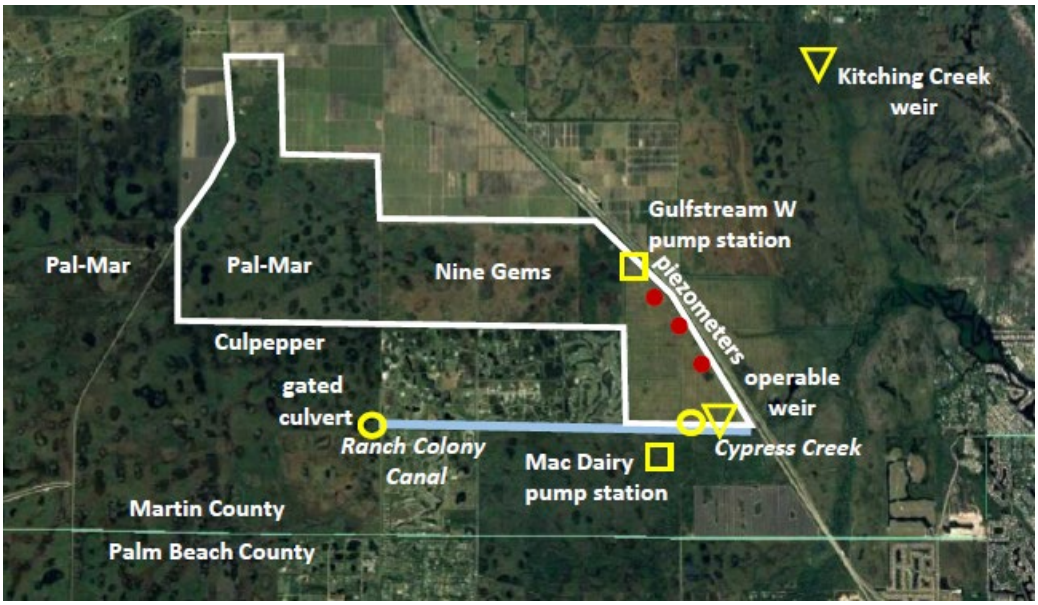

Figure D-11. Image showing approximate structure locations in the northern portion of the project area.

Table D-18. Minimum LRWRP surface and groundwater monitoring needs.

Management Measure	Component	Number of Structures	Parameters	Frequency
M-1 Canal	75 cfs pump station	1	Headwater, Tailwater Stage	15-min
M-O Canal	100 cfs pump station	1	Headwater, Tailwater Stage, pump RPMs	15-min
ASR System	Intake/Recharge pump at wet well	1	Stage at intake, pump RPM	15-min, BK
	Surface facility recharge/recovery piping	1	Flow, in MGD	15-min
	Recovery pump on each ASR well	4	Wellhead pressure in psi , pump RPM	15-min, BK
	Floridan Aquifer monitor wells	4	Wellhead pressure in psi	1 hour, DA
C-18 West Reservoir	Seepage pump	1	Headwater, Tailwater Stage	15-min
	300 cfs Inflow Pump Station	1	Pump RPMs	BK
	Inflow Structure	2	Headwater, Tailwater Stage	15-min
	Automated Dual 48-in Gated Culvert to C-18W Canal	1	Headwater, Tailwater Stage	15-min, BK
	Fixed-crest Corbett Weir	1	Headwater, Tailwater Stage	15-min
	Embankment piezometers along southern margin	15	Stage	15-min
	Basin level gages	4	Stage	15-min
	Weather Station	1	Rain, Wind	15-min

Management Measure	Component	Number of Structures	Parameters	Frequency
Ranch Colony Canal	Operable weir at Cypress Creek headwater	1	Headwater, Tailwater Stage, flow in cfs	15-min
	Operable twin 84-in culverts on Ranch Colony Canal	1	Headwater, Tailwater Stage, flow in cfs	15-min
Gulfstream West flow-through marsh	Inflow pump station (250 cfs)	1	Headwater, Tailwater Stage, flow in cfs pump RPM	15-min, BK
	Gated culvert for 200 cfs outflow to RCC	1	Headwater Stage	15-min
	Berm piezometers along eastern margin along FL Tpke	10	Stage	15-min
Nine Gems	Northern perimeter drainage canal	1	Stage (location to be determined)	15-min
Kitching Creek	Weir	1	Headwater, Tailwater Stage	15-min

Note: BK, breakpoint; DA, daily average; RPM, revolutions per minute; T, tailwater; H, headwater; RCC, Ranch Colony Canal.

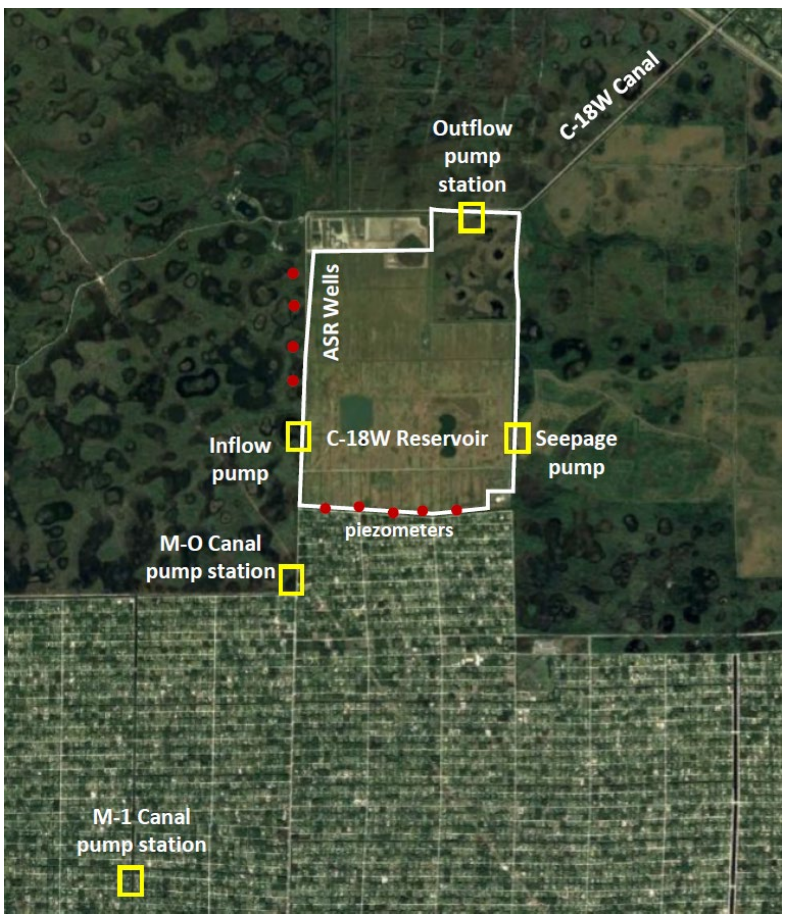

Figure D-12. Image showing approximate structure locations in the southern portion of the project area.

D.2.3 Procedures and Methods

Measurements will be recorded in the manner outlined in CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010.

To summarize, surface water stages will be measured using an SDI encoder at each monitoring location. The accuracy required is ±0.02 feet for critical sites and ±0.03 feet for non-critical site. The reported resolution will be 0.01 feet and the instrument range will be 0 20 feet. The precision will be ±0.01 feet. The sampling frequency will be 15 minutes, at 0, 15, 30, and 45 minutes past each hour (e.g., at 1500 hours, 1515 hours, 1530 hours, etc.).

Groundwater stages will be measured using an SDI encoder at each monitoring location. The accuracy required is ±0.03 feet. The reported resolution will be 0.01 feet and the instrument range will be 0 30 feet. The precision will be ±0.01 feet. The sampling frequency will be 15 minutes.

Rainfall will be measured with an accuracy of ±0.01 inches. The reported resolution will be 0.01 inches and the precision will be ±0.01 inches. The sampling frequency will be 15 minutes.

Gate positions will be measured using gate position indicators with an accuracy of ±0.05 feet, a reported resolution of 0.01 feet, and a gate position range of either 0-75 inches or 0-550 inches. The precision required is ±0.02% full stroke. The reporting frequency will be 15 minutes.

Pump RPMs will be measured with an accuracy of ±25 RPM and a reported resolution of 1 RPM. The pump RPM range will be 0-3,000 RPMs. The reporting frequency will be 1-360 samples per hour.

Computed flows will have an accuracy uncertainty limit of 95% C.I. The accuracy will be ±10% for inland spillways, ±15% for culverts, and ±15% for pumps. The velocity instrumentation will have a precision of ±0.01 feet/second. The reporting frequency will be 15 minutes.

The hydrologic and meteorological data collection instruments utilized for this project will be installed as part of the construction contract or under separate contract. Water stage measuring devices will be affixed to a platform in a manner to discourage vandalism and natural or unnatural intrusions (inclement weather, animals, etc.). Water surface elevation measuring devices will use SDI encoders for measuring values. Gate positions will be measured using gate position indicators. Flow calculation equations that are used to compute flow on site with certain instrument types, such as a programmable data logger, will be developed under the supervision of the sponsoring agencies hydrology and hydraulics monitoring units during the execution of this monitoring plan.

D.2.4 Rationale for Indicator Selection

The indicators selected for inclusion are required under CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010. The headwater and tailwater values are used, along with gate openings or pump RPMs, to determine the flow of water through the structure.

D.2.5 Sampling Frequency and Duration

The sampling frequency and duration is governed by CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010.

Surface water stages recording frequency will be 15 minutes, at 0, 15, 30, and 45 minutes past each hour 99 (e.g., at 1500 hours, 1515 hours, 1530 hour, etc.).

Groundwater stages recording frequency will be 15 minutes

Rainfall recording frequency will be 15 minutes.

Gate positions recording frequency will be 15 minutes.

Pump RPMs recording frequency will be by break point, with a minimum of one (1) recording per hour up to 360 recordings per hour.

Computed flows computing frequency will be 15 minutes.

D.2.6 Assessment Process and Decision Criteria (triggers and thresholds)

Trigger elevations for surface water will take into consideration the design headwater and tailwater at the gages' respective structures to ensure that design limits are not reached. In addition, the decision criteria will be further refined as the operations of LRWRP are developed.

D.2.6.1 Data Collection

D.2.6.2 Sample/Data Collection Standards and Ethics

No samples will be collected for hydrometeorological monitoring. Data will be collected following the required standards as described in this document.

D.2.6.3 Sample Submission

No samples will be collected for hydrometeorological monitoring.

D.2.6.4 Chain of Custody

No samples will be collected for hydrometeorological monitoring.

D.2.6.5 Quality Control Samples

No samples will be collected for hydrometeorological monitoring.

D.2.6.6 Data Validation

The Corps data validation process is subject to ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996, and ER 1110-2-249, *Management of Water Control Data Systems*, dated 31 August 1994. The Corps data validation methods may be accomplished by automated or manual means.

The SFWMD procedures are described in their 2008 South Florida Environmental Report, Appendix 2-1: Hydrological Monitoring Network of the South Florida Water Management District. The following paragraph is from a relevant section of that document.

"Several standard operating procedures (SOPs) were developed for data processing by the District…Many of these procedures and processes are automated. The Data Collection/Validation Preprocessing System (DCVP) database provides for the storage and extraction of preliminary time-series data for further inspection. Once data is extracted from DCVP, it is subjected to an initial QA/QC check in order to ascertain or improve data quality. This is accomplished through the use of the Graphical Verification Analysis (GVA) Program, a software tool which provides analysts with a graphical user interface in which to plot, edit, and apply quality tags and comments to data. The GVA application is used for the validation of the data. Once data has undergone analysis in GVA, it is uploaded into the DBHYDRO database, finalizing the preprocessing stage…"

D.2.6.7 Raw Data

Data collected by the SFWMD will be kept as raw archive files. The adjusted (QA/QCed) data will be stored as processed archive files. Data collected by the Corps is maintained in Oracle databases and further computations are applied to generate addition databases of computed data.

D.2.6.8 Data Processing

The Corps data validation process is subject to ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996 and ER 1110-2-249, *Management of Water Control Data Systems*, dated 31 August 1994.

The SFWMD procedures are described in their 2008 South Florida Environmental Report, Appendix 2-1: Hydrological Monitoring Network of the South Florida Water Management District.

Data processing should be approached with the same high accuracy standards for all sites/stations regardless of mandate or permit conditions. Flow and meteorological data must be summarized or derived through review, analysis, and interpretation before they can be placed in any meaningful context, then published. Data processing involves multiple steps: (1) data retrieval, (2) data review, (3) data verification and validation, (4) data analysis of raw time-series data to ensure data quality in support of environmental monitoring and assessment activities, (5) interpretation of analysis, and (6) archival.

D.2.6.9 Data Storage and Archiving

Data collected or obtained by the Corps will be stored and archived in accordance with ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996. The Corps maintains Oracle databases where all collected and computed Water Management data is stored/archived.

For the SFWMD, after the data validation process (generally with one week), all data are archived in a SFWMD database (DBHYDRO) and maintained so that end users can retrieve and review all information relative to a sampling event. If data are not suitable for DBHydro, they will be entered into the CERP Integrated Database (CID) on CERPZone through the Morpho interface. Field notes are maintained on an internal server either by scanning actual field note pages as PDFs (Portable Document Format) or by uploading narratives from field computers as CSVs (Comma Separated Values). All analytical data and field conditions are sent to a database designated by the sponsors for long-term storage and retrieval. The sampling agency or contractor maintains records of field notes and copies of all records relative to the chain of custody and analytical data. It is the responsibility of each agency or contractor to maintain both current and historical method and operating procedures so that at any given time the conditions

that were applied to a sampling event can be evaluated. For any contracted work, original documents are to be provided to the SFWMD by the project completion date.

D.2.7 Documentation

For all documents, the following standards should apply:

- Print text, do not use cursive handwriting.
- Dates should be recorded as MM/DD/YYYY.
- Time should be recorded in 24-hour format using local time.
- Logs and notes should be recorded on site and at the time of collection.
- Entries are to be made in waterproof ink.
- Samplers should be properly trained.

D.2.7.1 Field Notes

No field samples will be collected for hydrometeorological monitoring. Relevant field observations will be noted in a bound waterproof notebook that is project specific. The following information will be entered into the field notes: project name, frequency, trip type, date, collectors, responsibilities, weather, preservation/acids, labs submitted to, sample ID, site ID, time collected, and sample type. Additional comments on observations, equipment cleaning, maintenance, and calibration will also be recorded.

D.2.7.2 Field Instrument Calibration Documentation

Records of field instrument calibration will be kept and SFWMD or Corps SOPs for calibration will be followed.

D.2.7.3 Corrections

Corrections to header sheets, field notes, or calibration sheets will only be made by staff who participated in the production of the document. Changes will be made by striking through the error, writing the correction, initialing, and dating the change. On occasion, a detailed explanation of the error may be required.

D.2.8 Quality Assurance and Quality Control

D.2.8.1 System for assessing data quality attributes

The standards as set forth under the Corps and the SFWMD's respective requirements will be adhered to and followed. These are described and/or referenced under Section 2.3 of this document.

D.2.8.2 Data Quality Qualifiers

The data quality standards are outline in Section 2.2 of this document.

D.2.8.3 Field Audits

The data quality standards for hydrometeorological data are determined under the Corps and SFWMD's respective guidances and will be followed.

D.2.9 Data Analyses and Records Management

The Corps process is subject to ER 1110-2-8155, Hydrometeorological Data Management and Archiving, dated 31 July 1996 and ER 1110-2-249, Management of Water Control Data Systems, dated 31 August 1994.

The SFWMD procedures are described in their 2008 South Florida Environmental Report, Appendix 2 1: Hydrological Monitoring Network of the South Florida Water Management District.

Please refer to Section 2.3 of this document for further information.

D.2.9.1 Data Quality Evaluation and Assessment

The data quality standards for hydrometeorological data are determined under the Corps and SFWMD's respective guidances and will be followed.

D.2.10 Adaptive Management Considerations

Where possible, LRWRP hydrometeorological data will support adaptive management by contributing data needed to address LRWRP uncertainties and future project adjustments. The adaptive management strategies that will leverage hydrometeorological data include but are not limited to optimizing water deliveries from C-18 West and ASRs to the Loxahatchee River.

PART 3. LRWRP WATER QUALITY MONITORING PLAN

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D.3 LRWRP Water Quality Monitoring Plan

D.3.1 Introduction

This document serves as a preliminary reference for monitoring surface water and groundwater quality for the Loxahatchee River Watershed Restoration Project (LRWRP). Monitoring will be conducted to evaluate the LRWRP's performance with regard to restoration goals and regulatory compliance. Specifically, the project is intended to restore and sustain the quality, quantity, timing and distribution of water entering the federally designated "National Wild and Scenic" NWFLR. In addition, the project will restore, sustain, and reconnect the wetlands forming the historic headwaters of the river. The LRWRP areas of focus are the natural areas west of the C-18 Canal, east of the L-8 Canal, north of the C-51 Canal, and south of the C-44 Canal, located in central and northern Palm Beach County and southern Martin County. See **Figure D-13** for a map of the project footprint. This monitoring plan is conceptually organized to characterize the quality of the surface water in the three flow-ways used to provide surface water to the Loxahatchee River. Preliminary water quality assessment contained in appendix C.2 indicates the TSP is not likely to negatively affect water quality. This concerned was not identified in the original Adaptive Management Plan development process with the PDT. However, because the Loxahatchee River Northwest Fork is currently not meeting water quality standards for biology Category 4d, water quality monitoring of nutrients from projects structures will be assessed using this plan to confirm overall nutrient load to the river does not increase due to the project. If issues are identified, the monitoring and adaptive management plan will be updated to identify changes to project implementation to avoid contributions to increased nutrient load over the current conditions.

D.3.2 Project Description

The LRWRP project includes the following elements as shown in **Figure D-13**.

A. **Flow-way 1**: The southern-most flow-way.

   a. **Component 10**. Delivers Lower M-1 Basin water to the M -Canal and Grassy Waters Preserve (GWP)

   b. **Components 9** and **8**. Waters from the GWP are delivered via G-161 to the GWP Triangle and then to the Loxahatchee Slough.

   c. **Component 7**. Operation of control structure G-160 (on the C-18 Canal) improves hydroperiods in the Loxahatchee Slough before waters are discharged to the conveyance section of the C-18 Canal.

B. **Flow-way 2:** The central flow-way.

   a. **Component 6**. A connection from the M-O Canal supplies water to a 9,500 ac/ft above-ground C-18W Reservoir. Additional flow is provided to this feature from the C-18W canal, and from the J.W. Corbett Wildlife Management Area. This reservoir discharges via the C-18 West Canal to the C-18 Canal downstream of the G-160, mingling with waters from Flow-way 1 discharging from G-160.

   b. **Component 6**. At the C-18W Reservoir a total of 4 ASR wells will utilize the Upper Floridan Aquifer and the Avon Park Permeable Zone for storage and recovery increasing the capacity of the C-18W Reservoir.

C. **Waters from Flow-ways 1** and **2** can continue down the C-18 to the S-46 Control Structure and be discharged to the Southwest Fork of the Loxahatchee River. Alternatively, these waters can be routed from the C-18 through the G-92 structure into the Northwest Fork of the Loxahatchee River passing over both the Lainhart and Masten Dams.

D. **Flow-way 3**: the northernmost project flow-way has multiple hydrologic components, all of which are tributary to the Northwest Fork of the Loxahatchee River.

   a. **Component 1**. In portions of Kitching Creek, a spreader canal and a weir/plug improve hydrology.

   b. **Component 3**. Changes to weirs, culverts and grade, plus a small pump and spreader swale combine to reduce overdrainage of the Cypress Creek Canal and Ranch Colony area.

   c. **Component 5**. In Palmar East ditches are plugged, pipes removed, berms are improved and constructed. Sheet flow above control elevation is captured by the Nine Gems Canal and directed to the Gulfstream West flow-through marsh.

   d. **Component 4**. Restoration of area and creation of the Gulfstream West flow-through marsh. Drainage from the Hobe St. Lucie Conservancy District Unit 2 is collected and attenuated in the flow-through marsh.

   e. **Component 2**. Install weir in Hobe Grove Ditch (HGD) before it discharges to the main channel of the NWFLR. Connect HGD to Moonshine Creek, clear excess vegetation and grade adjacent areas to facilitate flow into Moonshine Creek channel

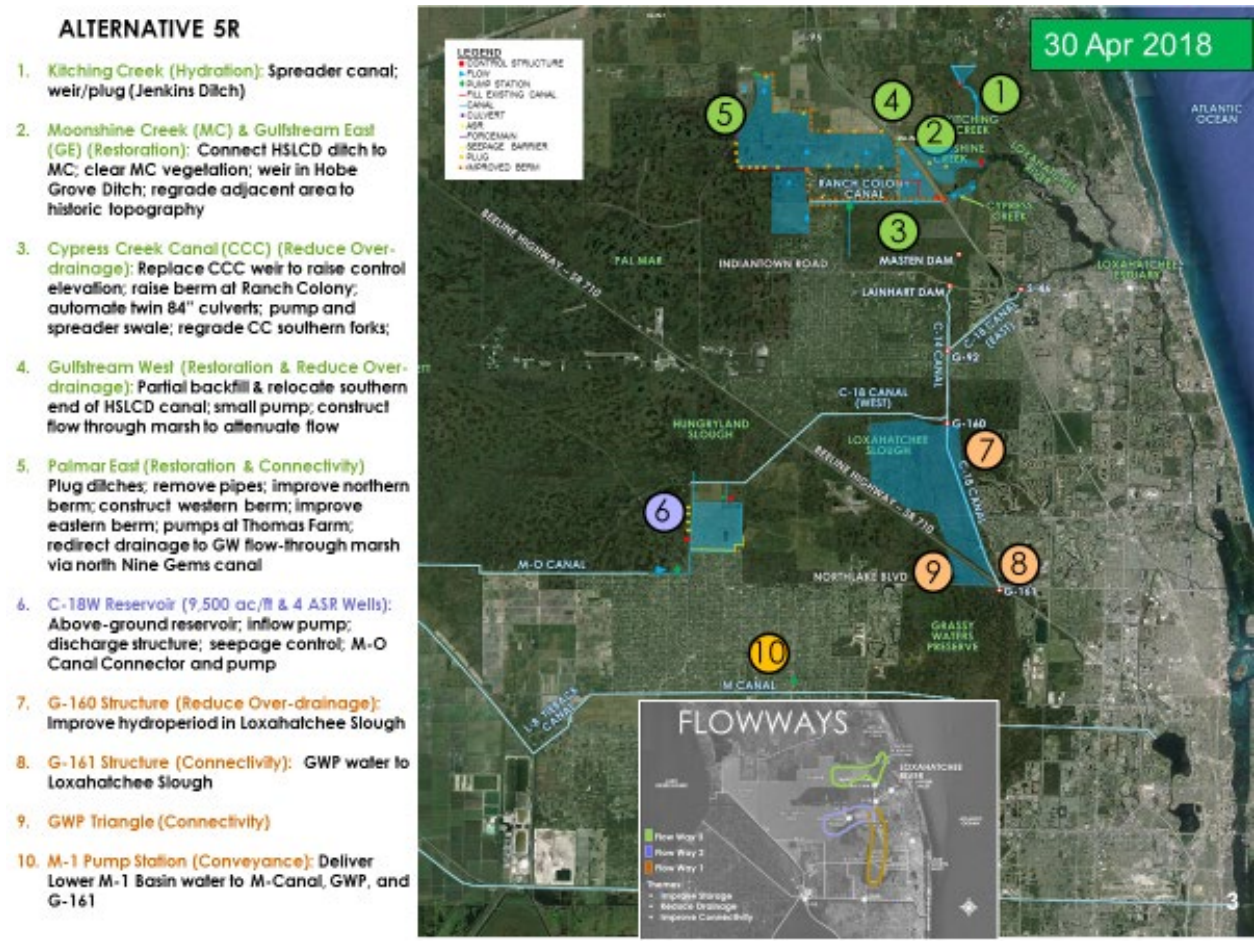

Figure D-13. Loxahatchee River Watershed Restoration Project Alternative 5R components.

D.3.3 Monitoring Objectives

This plan provides a preliminary outline for determining the quality of surface water entering, and downstream of, key project components for a period of ten years. However, as permits, land acquisition and required evaluations and environmental site assessments have yet to be completed this plan serves only as a placeholder for future refinements. This plan will be updated to meet permit monitoring requirements as necessary.

The monitoring described in this document has been developed to satisfy requirements of (issued or pending) Department of the Army 404 permits and/or State of Florida 373.1502 Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) permits for Start Up and Operational Phase Monitoring, as well as the Loxahatchee River Watershed Restoration Project.

The water quality data obtained under this program will be used to:

1. Evaluate water quality status and trends;

2. Assess compliance with federal and state water quality statutes, and applicable mandates and permitting vehicles;
3. Guide mid- and long-term resource management decisions as part of the adaptive management plan for the project.

The SFWMD has collected and analyzed surface water samples for multiple constituents and at various frequencies from stations adjacent to or near the project features. Similarly, the SFWMD has collected and analyzed groundwater quality data from wells open to the surficial aquifer system (SAS), the Upper Floridan Aquifer (UFA), and the Avon Park Permeable Zone (APPZ). These data are compiled in the District's DBHYDRO database and in the annual South Florida Environmental Report (SFWMD 2018), and in technical reports documenting exploratory borehole construction and testing in the Floridan Aquifer System (FAS). These data may serve as baseline information or as guidance for determining monitoring requirements.

Other organizations also collect surface water quality data in this region that may be relevant to the project as baseline data. Access to these data requires contacting the program manager at the appropriate organization.

D.3.4 Surface Water and Groundwater Quality Monitoring

The goal of surface water quality monitoring is to ensure surface water quality in the Loxahatchee River and its headwaters will not be negatively impacted by project components. The goal of groundwater quality monitoring is to ensure that aquifers are not negatively impacted by ASR activities, and that recovered water quality from the ASR systems is in regulatory compliance. The water quality monitoring plan presented is a conceptual outline for surface water and groundwater monitoring in relation to the operation of the three flow-ways, their components, and their subsequent discharges into adjacent waterways.

D.3.4.1 Surface Water Monitoring

The water quality in each flow-way will be monitored to determine trends, to ensure the project is not negatively affecting downstream receiving waters in the Loxahatchee River and estuary, and to validate model assumptions used during selection of the preferred restoration plan alternative. Specific monitoring stations, frequencies, and parameters, for each project component, will be determined during the permitting process pre-construction. Data from environmental site assessments (ESAs) generated prior to construction will be used to guide future monitoring decisions, as outlined in CERP guidance memoranda CGM-40 (Project Level Monitoring and Assessment) and CGM-42 (Screening Process for Mercury and Other Toxicants). Where possible, existing monitoring will be leveraged to achieve project monitoring goals. Surface water quality criteria are defined in the Clean Water Act and Florida Administrative Code (F.A.C.) Chapter 62-302 Surface Water Quality Criteria. Where practical, surface water quality collections will be targeted to occur during flow-related events at key features.

D.3.4.2 Groundwater (ASR) Quality Monitoring

Water quality at ASR systems is typically monitored during recharge, storage and recovery phases. The most intensive monitoring periods are during recharge and recovery. Water quality monitoring criteria for ASR systems are defined in the Safe Drinking Water Act and in F.A.C. Chapter 62-528 (Underground

Injection Control) during recharge and Chapter 62-302 (Surface Water Quality Criteria) during recovery. In the project area, 4 ASR wells are located within the footprint of the C-18W Reservoir.

When ASR systems are first constructed, there is typically an early period of "cycle" testing, when the wells are tested for pre-determined periods of recharge, storage and recovery, so that the operational efficiencies of the systems can be assessed, and permit compliance can be confirmed. After the cycle testing phase is completed (typically specified within the UIC permit), actual operation of the ASR systems will commence, with recharge, storage and recovery durations linked to watershed flows and water levels within the project area.

During recharge into the ASR wells water quality monitoring is performed to assure that the aquifer and potential underground sources of drinking water are not negatively impacted by operation of the ASR systems. Physical parameters such as flow rates, durations, volumes, water levels and pressures are measured. Water quality samples are collected and analyzed for ionic and chemical constituents, nutrients, and drinking water standards. During recovery, water quality monitoring takes place to assure that surface water quality is not negatively impacted by water discharged from the ASR to the surface. As with during recharge, parameters such as recovered water flow rates, durations, volumes, water levels and pressures are measured. Water quality samples are collected and analyzed for chemical constituents, nutrients, and applicable surface water standards. Actual sampling locations and frequencies for recharge, storage, and recovery are typically determined during the permitting process.

Table D-19. Estimated Costs for Water Quality Monitoring.

Budget Area	Year 1	Years 2-5	Years 6-10
Capital	**$ 135,000**	**$ -**	**$ -**
Fuel and Maintenance	**$ 10,000**	**$ 10,000**	**$ 10,000**
Consumables	–	–	–
SW Nutrients and Ions	$ 650	$ 650	$ 650
ASR Wells	$ 650	$ 650	$ 650
SW Hg and Toxins	$ 125	$ -	$ -
Small Fish Hg	$ 100	$ 100	$ -
Small Fish Toxicants	$ 25	–	–
Large Fish Hg	$ 25	$ 25	$ -
Sediment Hg and Toxins	$ 25	$ -	$ -
Annual Sums	**$ 1,600**	**$ 1,425**	**$ 1,300**
–	–	–	–
Analytical	–	–	–
SW Nutrients and Ions	$ 106,080	$ 106,080	$ 106,080
ASR Wells	$ 43,680	$ 43,680	$ 43,680
SW Hg and Toxins	$ 16,500	$ -	$ -
Small Fish Hg	$ 7,680	$ 7,680	$ -
Small Fish Toxicants	$ 14,208	–	–
Large Fish Hg	$ 19,200	$ 19,200	$ -
Sediment Hg and Toxins	$ 14,400	$ -	$ -
Annual Sums	**$ 221,748**	**$ 176,640**	**$ 149,760**

Budget Area	Year 1	Years 2-5	Years 6-10
–	–	–	–
Staff	–	–	–
SW Nutrients and Ions	$ 120,744.00	$ 120,744	$ 120,744
ASR Wells	$ 80,496.00	$ 80,496	$ 80,496
SW Hg and Toxins	$ 5,256.00	$ -	$ -
Small Fish Hg	$ 24,768.00	$ 24,768	$ -
Large Fish Hg	$ 12,000.00	$ 12,000	$ -
Sediment Hg and Toxins	$ 6,192.00	$ -	$ -
Annual Sums	**$ 249,456**	**$ 238,008**	**$ 201,240**
–	–	–	–
Annual Totals	$ 617,804	$ 426,073	$ 362,300
Number of years	1	4	5
–	$ 617,804	$ 1,704,292	$ 1,811,500
–	–	–	–
Grand Total	–	–	$ 4,133,596

PART 4. LRWRP ECOLOGICAL MONITORING PLAN

(To be developed based on trust resource consultation requirements before Final EIS. Ecosystem Restoration Success monitoring is contained in Part 1 – Adaptive Management Plan)