

**ANNEX D
MONITORING PLANS FOR THE LAKE OKEECHOBEE WATERSHED
RESTORATION PROJECT**

Adaptive Management and Monitoring Plan

Water Quality Monitoring Plan

Hydrometeorological Monitoring Plan

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Table of Contents

D MONITORING PLANS	D-1
PART 1: ADAPTIVE MANAGEMENT AND MONITORING PLAN	D-3
D.1 Introduction to the LOWRP Adaptive Management and Monitoring Plan	D-5
D.1.1 Structure of the LOWRP AMMP	D-6
D.1.2 LOWRP Adaptive Management Plan Background	D-6
D.1.3 How the LOWRP Adaptive Management and Monitoring Plan was Developed: Identification, Screening, and Prioritization of LOWRP Uncertainties	D-12
D.1.4 LOWRP Adaptive Management Uncertainties, Strategies, and Management Options	D-15
D.1.5 LOWRP Monitoring Plan	D-52
D.1.6 Implementation of LOWRP Adaptive Management	D-67
D.1.7 LOWRP Adaptive Management Plan Cost Estimate	D-73
D.1.8 LOWRP Screened Uncertainties	D-79
D.1.9 Adaptive Management Plan References	D-84
ATTACHMENT 1: SUMMARY OF COMMENTS/RECOMMENDATIONS FROM THE NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES TO THE CERP ASR REGIONAL STUDY	D-87
PART 2: WATER QUALITY MONITORING PLAN	D-89
D.2 Introduction to the LOWRP Water Quality Monitoring Plan	D-91
D.2.1 Project Description	D-91
D.2.2 Water Quality Monitoring Objectives	D-93
D.2.3 Surface Water and Groundwater Quality Monitoring	D-93
D.2.4 Surface Water Quality Monitoring Cost Estimate	D-96
PART 3: HYDROMETEOROLOGICAL MONITORING PLAN	D-99
D.3 Hydrometeorological Monitoring	D-101
D.3.1 Data Quality Objectives	D-101
D.3.2 Rationale for Indicator Selection	D-104
D.3.3 Sampling Frequency and Duration	D-104
D.3.4 Assessment Process and Decision Criteria (Triggers and Thresholds)	D-105
D.3.5 Documentation	D-106
D.3.6 Quality Assurance and Quality Control	D-107
D.3.7 Data Analyses and Records Management	D-107
D.3.8 Adaptive Management Considerations	D-108
D.3.9 Groundwater Monitoring Plan and Cost: Operational and Regulatory ..	D-108
D.4 Total Adaptive Management and Monitoring Costs	D-111

List of Tables

Table D-1. LOWRP AM strategies: template and definitions.....	D-10
Table D-2. Lake stage management option matrix.....	D-21
Table D-3. ASR recovery efficiency management option matrix.....	D-25
Table D-4. Estuaries oyster and SAV management option matrix.....	D-31
Table D-5. Estuaries substrate management option matrix.....	D-34
Table D-6. ASR – methyl mercury (MeHg) management option matrix.....	D-38
Table D-7. ASR fish entrainment management option matrix.....	D-42
Table D-8. Invasive species management option matrix.....	D-45
Table D-9. Wetland vegetation management option matrix.....	D-48
Table D-10. Water supply management option matrix.....	D-51
Table D-11. LOWRP AM monitoring cross-walked with other monitoring programs.....	D-53
Table D-12. ASR annual mercury costs.....	D-59
Table D-13. LOWRP project-specific monitoring cross-walked with other monitoring programs...	D-63
Table D-14. Adaptive management and monitoring cost estimate.....	D-74
Table D-15. Total cost estimate for AM, project-level, water quality, hydrometeorological, and Biological Opinion.....	D-79
Table D-16. Uncertainties screened from the AM Plan.....	D-80
Table D-17. Summary of surface water quality monitoring costs.....	D-97
Table D-18. Monitoring gauges at existing structures in the LOWRP.....	D-102
Table D-19. LOWRP minimal gauging needs for the WAF and proposed wetlands.....	D-102
Table D-20. Example groundwater monitoring plan for ASR cluster associated with the WAF.....	D-109
Table D-21. Annual cost of groundwater monitoring required by permit for the WAF-assisted ASR clusters.....	D-110
Table D-22. Annual cost of groundwater quality analyses required by permit for watershed ASR clusters.....	D-111
Table D-23. LOWRP total cost estimate for AM, project-level, water quality, hydrometeorological, and Biological Opinion.....	D-112

List of Figures

Figure D-1. Adaptive management strategies and project implementation diagram.....	D-69
Figure D-2. LOWRP footprint map.....	D-92
Figure D-3. Recommended Plan Features.....	D-95
Figure D-4. WAF with proposed structures.....	D-103

D MONITORING PLANS

This annex contains 3 monitoring plans:

1. Adaptive Management and Monitoring Plan
2. Water Quality Monitoring Plan
3. Hydrometeorological Monitoring Plan

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PART 1: ADAPTIVE MANAGEMENT AND MONITORING PLAN

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D.1 Introduction to the LOWRP Adaptive Management and Monitoring Plan

The primary objective of the Lake Okeechobee Watershed Restoration Project (LOWRP) Adaptive Management and Monitoring Plan (AMMP) is to identify the monitoring necessary to inform the decision-makers, LOWRP partner agencies, and the public on achieving restoration success, as well as address uncertainties related to project performance that can be addressed with efficiently structured approaches. The AMMP follows the Comprehensive Everglades Restoration Plan (CERP) Guidance Memorandum 56 on the Integration of Adaptive Management into Program and Project Management. The monitoring plan specifies what monitoring is necessary to measure and detect the benefits of capturing, storing, and redistributing water entering the north part of Lake Okeechobee to improve lake stage levels for both environmental restoration and water supply purposes; improving flows to the Caloosahatchee and St. Lucie estuaries (collectively, the “Northern Estuaries”); restoring wetland habitats; and reestablishing connections among natural areas that have become spatially and/or hydrologically fragmented. The LOWRP’s planning process and Recommended Plan selection were based on extensive existing scientific knowledge of Lake Okeechobee, the Lake Okeechobee watershed, and the Northern Estuaries; understanding of the problems and opportunities; and the evaluation of alternatives and estimation of the potential project restoration performance. While the LOWRP Project Implementation Report (PIR) is based on a wealth of knowledge, the AMMP is provided to help address uncertainty that exists as in every natural resource management and restoration effort.

While the ecological monitoring focuses on the LOWRP’s success at meeting project objectives (per Water Resources Development Act (WRDA) 2016 guidance), the adaptive management (AM) monitoring focuses on addressing project uncertainties (per U.S. Army Corps of Engineers (USACE) Implementation Guidance on Section 1161 of 2016 Water Resources Development Act.; USACE 2017) that may be more specific in their location and/or scale than the overall project objectives. Because most of the ecological monitoring helps address project uncertainties as well as document project success, the ecological monitoring plan and AM plan have been combined in this document. The AM monitoring focuses on addressing project uncertainties that might not already be covered by the ecological monitoring. The AMMP will monitor ecosystem responses to changes in lake stage, created wetlands, and flows into the estuaries that are expected to provide ecological conditions suitable for expanded and intensified plant and wildlife utilization through improvements. Monitoring described in the plan will address specific AM questions to determine the need for project adjustments that would improve ecosystem restoration performance. The AMMP will also contain the monitoring and associated costs required under the U.S. Fish and Wildlife Service’s Biological Opinion (BO) and other agency permits that are needed to protect and conserve natural resources. The BO and associated monitoring information for LOWRP will be found in **Annex A**, Fish and Wildlife Coordination Act and Endangered Species Act Compliance. Cost estimates for monitoring associated with the BO, including a project-wide contingency cost, are included in **Section 6** and **Annex D** of the Final Integrated Project Implementation Report and Environmental Impact Statement (PIR/EIS).

The AMMP will be closely coordinated with the CERP Restoration Coordination & Verification (RECOVER) Monitoring and Assessment Plan (MAP) to ensure that measures and targets selected by the project team are consistent with system-wide measures and leverage existing monitoring to avoid duplication of efforts. Furthermore, the AMMP will ensure temporal and spatial coverage of monitoring parameters that are appropriate to detect changes at the project level. The AMMP will fill gaps in the MAP monitoring parameters to address LOWRP-specific needs by adding additional project-level parameters not included in the MAP. Thus, the LOWRP AMMP will cover the LOWRP regions within Lake Okeechobee and the Northern Estuaries with greater spatial and temporal resolution to detect ecological changes resulting from project-level implementation in order to evaluate project success.

D.1.1 Structure of the LOWRP AMMP

The LOWRP AMMP is organized by project objective. For each LOWRP project objective, monitoring parameters have been identified to measure progress toward success of meeting the objective. Uncertainties for each objective were identified through a robust process described below in **subsection D.3**. The AMMP provides a screened and prioritized summary of specific uncertainties that can be addressed with efficiently structured approaches. The AMMP describes the approaches (called strategies) and suggests management options to adjust project implementation for future consideration if needed. The AM 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 LOWRP Project Delivery Team (PDT) during planning and the LOWRP Value Engineering and Cost Risk Analysis workshop. **Table D-1** summarizes the (1) AM uncertainties, (2) monitoring attributes, (3) monitoring methodology and frequency, (4) monitoring cost estimates, (5) LOWRP monitoring locations, (6) Current MAP monitoring component, (7) Current monitoring by other agencies/universities and (8) Performance Measures and ecological indicators. The AMMP's main goal is to detect the expected improvements from LOWRP features and operations as well as specify strategies, timing, and appropriate monitoring to address the LOWRP uncertainties.

D.1.2 LOWRP Adaptive Management Plan Background

The LOWRP's planning and Recommended Plan selection were based extensively on scientific knowledge of the Everglades ecosystem, Lake Okeechobee, and associated estuaries from understanding the problems and opportunities to evaluating alternatives and estimating potential project restoration performance (Davis and Ogden 1994; Department of Defense 2003; RECOVER 2004; Ogden 2005; RECOVER 2009; McVoy et al. 2011; RECOVER 2011a; LOWRP PIR/EIS Appendix H) and the USACE 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 LOWRP plan. The LOWRP AM Plan will address the key uncertainties identified during LOWRP's planning that relate to achieving restoration success and making adjustments in the LOWRP if determined to be necessary to improve performance.

Conceptual Ecological Models (CEM) were used to guide the planning of the LOWRP ecosystem restoration project. Conceptual ecological models provide a key link between early planning (e.g., an effective statement of problem, need, opportunity, and constraint) and later evaluation and implementation (USACE, EAB 2006). Conceptual ecological models are key components of an Adaptive Management Program that is described in the Programmatic Regulations for the Comprehensive Everglades Restoration Plan. The LOWRP was developed using the Total System CEM developed by Ogden et al. (2005). The total South Florida ecosystem encompasses all natural areas that were once interconnected and embedded within the vast Everglades basin that originally extended from coast to coast and from the Upper Kissimmee Basin headwaters to Florida Bay, Biscayne Bay, the Gulf of Mexico, and the Caloosahatchee, St. Lucie, and Indian River Lagoon estuaries. Restoration of this system will be successful once defining characteristics of the pre-altered system are recovered. Defining characteristics of the ecosystem are: 1) abundant large vertebrates and aquatic prey bases, 2) animals with large spatial requirements, 3) healthy, dynamically sustainable estuaries, 4) oligotrophic freshwater wetlands, and 5) complex landscape mosaics and interactions. These defining characteristics have been altered by three external drivers that create stressors on the system: water management, land-use management and development, and climate change and sea level rise. Stressors on the South Florida ecosystem include loss

of spatial extent; loss of connectivity; altered geomorphology and topography; altered volume, timing, and distribution of regional hydroperiods; input of nutrients; altered fire patterns; and introduction and spread of exotic plants and animals. The Total System Conceptual Ecological Model links stressors to changes in the defining characteristics through major working hypotheses of cause-and-effect relationships. The linkages (ecological effects) relate to hydroperiod and depth patterns, sheet flow, salinity gradients, nutrient status and dynamics, fire patterns, habitat availability, and marsh aquatic fauna prey bases. For each defining characteristic, key ecological indicators are identified to collectively track the decline and restoration of the ecosystem (Ogden et al. 2005). The Total System CEM provided the framework for the LOWRP and was used to inform the uncertainties and develop the AM strategies for the aquifer storage and recovery (ASR), invasive species, water supply, and wetland categories in this AMMP. Region-specific CEMs were used to inform the uncertainties and develop adaptive management strategies for Lake Okeechobee and the Northern Estuaries in this AMMP.

The Lake Okeechobee CEM (Havens and Gawlik 2005) was used to develop the Lake Okeechobee uncertainties and adaptive management strategies described in this AMMP. The main stressors on Lake Okeechobee are: (1) large inputs of nutrients from agricultural and other anthropogenic land uses in the watershed, (2) unnatural variation in water levels due to channelization of inflows and dike containment, and (3) rapid expansion of non-native plants. Ecological effects are complicated due to three distinct in-lake zones with different water chemistry, physical properties, and biota. A central pelagic zone has turbid, nutrient-rich water and phytoplankton dominance; a shallow south, western, northwestern and north near-shore zone has submerged plant or phytoplankton dominance (at low vs. high water levels, respectively); and a western and northwestern littoral zone is dominated by emergent wetland plants. Changes in water level influence the flow of nutrients between zones, thereby creating a synergistic effect between stressors. Under high water conditions, there is considerable advective transport of nutrients from the pelagic zone into the nearshore and littoral zones. Under low water conditions, the littoral zone is cut off hydrologically and is a rainfall-driven oligotrophic wetland. Low water also facilitates drying and wildfires in the littoral zone, which in turn has an influence on expansion of non-native plants and recovery of native plants from buried seed banks. All of these factors influence fish, wading birds, and other animals, which depend on littoral and near-shore plant communities for nesting and foraging habitat (Havens and Gawlik 2005).

The Caloosahatchee Estuary CEM (Barnes 2005) was used to inform the uncertainties and develop the AM strategies for the Caloosahatchee estuary. In the Caloosahatchee, changes in estuarine salinity, flows, and nutrient inputs, along with physical alterations, can affect estuarine fishes, dolphin and manatees, as well as benthic communities including bivalves, and submerged aquatic vegetation. As a result, these estuarine attributes can be used as indicators of restoration success (Barnes 2005). The other CEM used to inform the uncertainties and develop the AM strategies was the St. Lucie Estuary and Indian River Lagoon CEM (Sime 2005). External drivers that result in ecological stressors in the St. Lucie Estuary and Indian River Lagoon include agricultural and urban land use and development and ensuing construction and operation of water management systems, both in local watersheds of the estuary and lagoon and in the larger drainage basin of Lake Okeechobee. Sea level rise is also a factor that affects the ecology of these systems that should be considered during restoration efforts. These drivers result in major stressors: Lake Okeechobee high-volume freshwater flows, basin flood flows, and basin water withdrawals that alter freshwater flow volume and timing, which in turn, alters estuary salinity and increases turbidity and color. Physical alterations to the estuaries and adjacent tributaries have resulted from construction and maintenance of inlets and development of shoreline and adjacent wetlands. Boating and fishing pressure is also a stressor to the system. The key ecological attributes that are affected by these stressors include submerged aquatic vegetation (SAV), oyster communities, estuarine fish communities, sport and

commercial fisheries, estuarine benthic communities, shoreline habitat, and nearshore reefs. The critical linkages between stressors and attributes/working hypotheses described in the CEM were used to inform the estuary uncertainties in the LOWRP and develop the AM strategies in this AMMP (Sime 2005).

Recommendations made by the National Research Council (NRC) of the National Academies of Sciences during their review of the CERP Aquifer Storage and Recovery (ASR) Regional Study (USACE 2015) were used to define uncertainties and inform development of the AM plan for ASR system implementation. A summary of those recommendation is provided as **Attachment 1** to Annex D, Part 1. The NRC recommended testing of ASR systems with respect to chemical and biological water quality with a seated, quarantined test of multiple years before proceeding with large scale implementation of ASR. Four years of successful cycle testing was completed at the Kissimmee River ASR system, as part of the CERP ASR Regional Study. This pilot project serves as a “seated, quarantined test of multiple years”, and has an extensive ASR water quality dataset. The testing demonstrated that the maximum lateral extent of the largest volume recharge event (1 billion gallons) was less than 2,350 ft from the ASR well. In addition, there is a significant amount of existing borehole data for this area (Paradise Run FAS wells, Brighton Reservation ASR and monitoring wells, OKF-105, and the ASR and associated monitoring wells at the Kissimmee River ASR system).

The Underground Injection Control (UIC) permitting process requires that recharge water be treated to drinking water standards. Wellhead disinfection and filtration technologies have advanced since those designed in 2005 for the ASR pilot facilities designs, and those advances will inform the pre-treatment design process during Preconstruction Engineering and Design (PED). It is likely that ASR implementation will benefit from “economies of scale”, where pre-treatment of recharge flows to well clusters can be developed. Four years of analyses of recovered water confirms that the only treatment required in recovered water was re-aeration to increase dissolved oxygen concentration prior to release into the Kissimmee River. During cycle test 4, the Florida Department of Environmental Protection (FDEP) was sufficiently convinced about the lack of impacts to surface water quality that the water quality monitoring requirements associated with the facility NPDES permit were reduced.

Uncertainty was also identified in the overall impacts to the aquatic resources, due to fishery impingement and entrainment. These impacts are currently unknown and have the potential to adversely affect aquatic resource population dynamics. Additionally, temperature and dissolved oxygen changes during ASR recovery events have uncertain effects on fisheries. The NRC also identified uncertainties related to the potential production of methylmercury from increased sulfate loads, thereby decreasing the overall water quality. The relationship between sulfate loading and methylmercury production was analyzed in the United States Geological Survey (USGS) Scientific Investigation Report 2007-5240 “An Assessment of Potential Effects of Aquifer Storage and Recovery on Mercury Cycling in South Florida”. The results of the study concluded that sulfate added from the release of recovered ASR water could contribute to additional methylmercury formation within the receiving waters.

As recommended in the findings of NRC review of the CERP ASR Regional Study, a local-scale simulation of the movement and displacement of groundwater within the aquifer during ASR operations would best be conducted after site-specific aquifer conditions are quantified during testing at each exploratory borehole. These simulations would be “calibrated” by actual multi-well operational testing and monitoring. Benefits from the ASR component of the project can be confirmed once additional knowledge of ASR recovery efficiencies is gained during operational testing. Based on findings from the CERP ASR Regional Study, the Recommended Plan modeling was conservatively constructed to assume that the ASR wells will have a combined recovery efficiency of 50% for wells completed in the UFA and the APPZ. By

doing so, a continuously expanding volume of water remains in the aquifer over the life of the project. While the assumption of a permanent low recovery efficiency is conservative, strict interpretation can falsely lead to a misleading extrapolation that this will result in an exponentially large volume of water emplaced within the aquifer during the life of the project. In fact, most operational ASR systems experience a gradual improvement in recovery efficiency over time, as the recharged freshwater “bubble” displaces the brackish water near the vicinity of the ASR wellbore. Numerous ASR systems within south Florida are now operating with recovery efficiencies in excess of 90 percent. It is expected that operation of the ASR wells proposed in the Recommended Plan will exhibit similar improvements over time. Additionally, local findings from the Kissimmee ASR system, operated for 4 years by the USACE, exhibited recovery efficiencies of nearly 100% during each test cycle. Results from this important system give some assurance that recovery efficiencies assumed in the model are somewhat overly conservative.

In order to systematically move forward with construction of ASR systems and address the remaining uncertainties in implementation of ASR on a large regional scale, a deliberate approach will be utilized. It is important to note that the locations proposed in the Recommended Plan are general. The final locations will depend on the results obtained at the watershed ASR systems to be constructed first. The locations could shift, contract, or expand depending on the testing results. The number of ASR wells at any one cluster location will be determined by the hydrogeologic testing results. Design studies will be undertaken to determine treatment facility sizing, well spacing distances, and the effects of vertically "stacking" storage zones within portions of the Floridan Aquifer System. The regional effects of ASR operation as conceptualized in the Recommended Plan have been based upon a detailed, calibrated groundwater flow and solute transport model developed during the ASR Regional Study and reviewed by the NRC. The groundwater model computational grid included an area encompassing nearly the southern half of Florida. When hydrogeologic information is available from all of the conceptual cluster locations, the groundwater model will be updated to better understand the effects of well implementation at the local and regional scale and will allow optimization of the number of wells at each site. This AMMP addresses the major remaining uncertainties identified in the NRC recommendations.

Table D-1. LOWRP AM strategies: template and definitions.

LOWRP 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.*

LOWRP Objective or Constraint: *Uncertainties needed to be related to LOWRP 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 LOWRP footprint to which the uncertainty and strategy pertain.*

Associated LOWRP features: *Structures or measures to which the uncertainty and strategy pertain.*

Driver or uncertainty type: *Unlike most AM Plans, not all LOWRP 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 LOWRP benefit from addressing this uncertainty? *Why the uncertainty needs to be addressed in LOWRP.*

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 LOWRP'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 LOWRP benefit from knowledge gained about this attribute?**
- **What is the timeframe in which changes to this attribute are expected to be measurable?**
- **Is this attribute complemented by other monitoring programs within and/or outside of LOWRP? If so, provide reference to other monitoring. Note the monitoring paid for by others in the LOWRP AM budget spreadsheet.**
- **When during LOWRP'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 LOWRP AM Plan varies in the level of methodology detail provided; in several cases the details will be formed during LOWRP'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 LOWRP 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 per attribute to be monitored 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 LOWRP performance needs to be adjusted. The Management Options are suggested paths forward and adjustments that can be made to keep LOWRP progressing toward objectives and within constraints. The Management Options are summarized in 11x17 pull-out tables after each region's strategies.*

Congress understood that there were uncertainties in the CERP and therefore required CERP to include AM for its individual projects (WRDA 2000). The 2003 Programmatic Regulations outlined an AM program that would provide the tools needed to gather new information from the RECOVER monitoring and assessment plan (MAP- RECOVER 2009) and incorporate new information 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 AM 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 AM 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 inclusion of AM 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 Programmatic Regulations, CERP produced guidance for project teams to develop AM plans and integrate AM 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 AM WRDA 2000 authorization and follows the more general 2009 AM guidance from USACE Headquarters on implementing Section 2039 of WRDA 2007.

In summary, there is extensive knowledge about Lake Okeechobee but there are still uncertainties that were evident during project planning that need to be addressed. Rather than delaying planning for the sake of further data collection or model development, the AM plan provides a mechanism to systematically address uncertainties during the LOWRP'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 implement decisions. The AM plan identifies which areas to monitor to detect performance, and options for adjusting the LOWRP, 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 LOWRP Adaptive Management Plan include the following terms below. The concepts and definitions are described in more detail in CERP Guidance Memorandum (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 Lake Okeechobee watershed and estuary restoration, AM is a structured approach for addressing uncertainties by implementing one project component or operational criteria 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 AM plan. The AM strategies fit into the following approaches:
 - *Active Adaptive Management* – 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 during implementing the full project component that they are intended to inform.
 - *Passive Adaptive Management* – All of the LOWRP AM plan strategies are considered passive AM 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, LOWRP contingency options, or inform future CERP projects.

Adaptive management activities will be implemented during the coming phases of LOWRP, and the AM 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 as well as potential new monitoring requirements, the AM 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 LOWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time.

D.1.3 How the LOWRP Adaptive Management and Monitoring Plan was Developed: Identification, Screening, and Prioritization of LOWRP Uncertainties

The LOWRP Adaptive Management plan development consisted of the following activities, consistent with the USACE planning guidance and CERP AM guidance:

- PDT and stakeholder involvement.
- Identification and prioritization of key LOWRP AM uncertainties, also referred to simply as “uncertainties” throughout this AM Plan (**subsection D.1.4**) related to achieving the LOWRP goals and objectives and avoiding constraints (**Section 1** of PIR).
- Development of AM strategies to address the uncertainties during LOWRP design, construction, and operations that consider existing Everglades conceptual ecological models, hypotheses, performance measures, and monitoring (**subsection D.1.4**).
- Identification of monitoring thresholds and/or triggers and associated management options to adjust, if necessary, based on feedback from assessments (**subsection D.1.4**).

- Development of an AM implementation process to carryout AM 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 (**subsection D.1.6**).

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

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

1. Must be directly related to LOWRP 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 LOWRP PDT and planning discussions.
2. Must be at project-scale. Although LOWRP is large, it is not system-wide scale. System-wide uncertainties were routed to appropriate groups.
3. Must have AM options (i.e., ability to be addressed during implementation, improved by adjusting LOWRP). 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 LOWRP AM criteria.
4. Must be an uncertainty. It should not include items that are already known. For example, the question should not ask “What are the effects of reduced freshwater flows on oysters in the St. Lucie estuary?” which is known. Instead ask, “Will LOWRP’s improvements to salinity regimes be sufficient for recruitment of new oyster populations, or will supplemental habitat enhancement be required?”
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 AM plan, and one that is distinct from the ‘background noise’ of natural variability). Long-term changes need a faster responding surrogate-measure for the AM plan.

After 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 LOWRP restoration goals if this uncertainty is not addressed?

- Low risk means that even if the uncertainty is not addressed, it does not pose much risk to achieving LOWRP goals and objectives.
- Medium risk means that if the uncertainty is not 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 to not achieving LOWRP 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 much is known about addressing this question in multiple geographical areas.

Relevance to Adaptive Management for LOWRP: 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, LOWRP or operations will not be able to be modified given the results of LOWRP implementation.
- Medium confidence means if this question is addressed, a connection to future CERP project implementation is established/documented but future adjustments to the LOWRP 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, LOWRP 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.

The AMMP provides a screened and prioritized summary of specific uncertainties that can be addressed with efficiently structured strategies. The AMMP describes the called strategies and suggests management options for future consideration if needed. The AM 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 LOWRP Eco Sub-team during planning.

The screened uncertainties were then considered by six management action sub-teams that provided strategies and options for addressing them. Per CERP's AM guidance, the management options included in this AM plan can be described as the following:

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

The strategies and management options comprise the bulk of this AMMP. Adaptive management activities will be implemented during the coming phases of LOWRP, and the AMMP 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 AM strategies and options proposed in this AMMP may need refinement. Therefore, items included in this plan are not

guaranteed to be funded as-is, but will be considered again when LOWRP 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. Costs for recommended AM and monitoring may be different during implementation. 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 subsection D.1.7**). 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.1.4 LOWRP Adaptive Management Uncertainties, Strategies, and Management Options

The LOWRP uncertainties in this section consist of prioritized needs and opportunities to learn in order to make scientifically sound recommendations to refine LOWRP design, construction, and operations; the strategies and management options provided to address each uncertainty are intended to guide LOWRP 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 LOWRP to maximize 'return on investment' for resources invested in pursuing the AM activities. As with the other monitoring plans in **Annex D**, the monitoring proposed in the AM strategies was guided in part by two objectives: to be complete from a LOWRP perspective by providing the monitoring required to address LOWRP-specific uncertainties; and to integrate with other Lake Okeechobee watershed and estuary monitoring to take advantage of existing monitoring efforts, knowledge, and information and thereby leverage dollars committed and spent elsewhere to avoid redundancies and ensure cost-effectiveness. Where possible, the LOWRP AM strategies 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 requirements described here are limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LOWRP-specific AM questions. This point is discussed in the LOWRP Adaptive Management Implementation section of this plan, and **Table D-11** 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 LOWRP. Please see **Section 1.6** (Implementation of LOWRP Adaptive Management) and the associated figures and tables for more detail on the estimated start- and stop-times for each AM strategy.

The uncertainties, their strategies, and management options are organized in this plan by the following categories: Lake Okeechobee, ASR, estuaries, invasive species, water supply, and wetlands.

The uncertainties, their identification numbers (ID#), and the LOWRP objective and/or constraint are listed here for reference. The project objectives and constraints are described in detail in LOWRP PIR **Section 1** (Introduction). A list of uncertainties that were screened out is provided in the final section of this AM plan (**Table D-16**) to show the array of ideas that were considered and brief notes from the screening process. As the LOWRP Project Team learns from LOWRP implementation, the list of LOWRP AM uncertainties will be updated to identify which have been addressed and where the risks to achieving LOWRP restoration success have been lowered. During implementation additional AM and monitoring may be required based on findings and new science available at that time.

The remainder of this section of the AMMP 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 because those that did not pass screening are no longer included. The ID numbers were maintained for organizational purposes; future refinements of the LOWRP AM Plan may include re-numbering of the uncertainties.

Lake Okeechobee

- Will adjustments in lake stages result in increases in ecological indicator abundances that will be above the projected range of their performance measure (PM) scores? (ID#25; LOWRP Objective 1)
- When storage is built and lake stages are better maintained, will ecological indicator species' abundance in the lake increase, or will consideration of supplemental habitat enhancements be warranted? (ID#26; LOWRP Objective 1)

Aquifer Storage and Recovery (ASR)

- Will ASRs exacerbate methyl mercury concentrations in surface waters that receive ASR releases, which would impact the habitats being restored in LOWRP? (ID#2; LOWRP Objective 2/3)
- Will project operations result in significant fish entrainment / impingement, reducing ecological function of the aquatic habitats that LOWRP will restore? (ID#3; LOWRP Objective 3)
- Will ASRs deliver the recovery efficiency we are expecting in order to achieve the hydrologic restoration objectives of the project? (ID#5; LOWRP Objective 1/2)

Estuaries

- When flows from Lake Okeechobee are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted? (ID#12; LOWRP Objective 2)
- Will augmentation of substrate be needed if desired salinities are achieved and recruitment is still not at expected levels? (ID#12; LOWRP Objective 2)
- Will there be displacement / limitation of spat / SAV in the St. Lucie Estuary as a result of the project? (ID#16; LOWRP Objective 2)
- Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project? (ID#16; LOWRP Objective 2)
- Will anticipated salinity improvements result in natural recruitment / reestablishment of SAV? (ID#40; LOWRP Objective 2)

Invasive Species

- How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands? (ID#17; LOWRP Objective 3)

Water Supply

- Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought? (ID#41; LOWRP Objective 4)

Wetlands

- When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted? (ID#46; LOWRP Objective 3)

Adaptive management strategies are provided in this section to describe and address each LOWRP AM uncertainty and inform LOWRP implementation based on the body of existing scientific knowledge of Lake Okeechobee watershed restoration. This section comprises the bulk of the LOWRP 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-1**. The strategy write-ups include information on drivers of the uncertainty, restoration targets and LOWRP 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 LOWRP 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, it provides an estimate of time needed to begin to be able to distinguish LOWRP effects. For practicality, the LOWRP 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 option matrices (MOM). These provide suggestions of paths forward and adjustments that can be made in order to keep LOWRP 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 1) background and detail of each strategy in the 1-2 page write-ups and 2) 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 MOMs (**Table D-1**). 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 LOWRP moves toward implementation and the AM 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 LOWRP, 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 AM 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 LOWRP is closer to being implemented and as appropriate, and funding decisions will be made commensurate with available funding at that time. The LOWRP AM uncertainties and the strategies to address them are provided in the format shown in **Table D-1**. The uncertainties and strategies are presented by project objective, and each objective’s set is followed by an 11x17 pull-out table of suggested management options that can support LOWRP and potentially CERP refinement (Management Option Matrices, or MOMs). The MOM shown in **Table D-2**, and those throughout the AM plan, help link

monitoring identified in specific AM strategies to decision criteria and suggested management options to consider for adjusting LOWRP if monitoring reveals performance issues related to LOWRP operations. The “timeframe to detect changes...” does not imply that changes will be complete in that timeframe; rather, it provides an estimate of time needed to begin to be able to distinguish effects of LOWRP. These timeframes are indications of response speeds, not limits on how long the monitoring will be conducted.

D.1.4.1 LOWRP Objective 1 - Lake Okeechobee Strategies and Management Options

Objective 1 of LOWRP is to improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often. The following AM strategies were developed to address the uncertainties about maintaining the ecologically desired lake stage ranges. From the AM uncertainties, a monitoring plan is presented in **subsection D.1.5.1** that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 1.

D.1.4.1.1 Lake Okeechobee Ecological Indicators: Fish and Wildlife Communities

LOWRP is expected to benefit floral and faunal communities of Lake Okeechobee by improving the quantity, timing, and distribution of flows into the lake, resulting in more ecologically desired lake stages. These expectations are based on known or assumed relationships of certain indicators and species to lake stage, based on varying periods of record. For many of the datasets, the period of record is marked by extreme weather events, including multiple hurricanes and record low lake levels, most of which occurred within 1-2 years of each other. Such events likely mitigated the effects of one another, and recent stable climatic periods (2012-2015) where extreme drought and floods were absent, resulted in an improvement in emergent and submerged aquatic vegetation, water quality, and fish communities (RECOVER 2014; SFWMD 2015). Therefore, while there is ample evidence regarding effects of extreme lake stages, there is more uncertainty regarding effects of stabilized water levels as predicted to occur with LOWRP. How the indicators and faunal communities respond will depend on the extent of stabilization that occurs from the additional water storage constructed in the Lake Okeechobee watershed.

The LOWRP AM strategy described here focuses on continuing long-term monitoring programs and updating analyses to improve LOWRP’s ability to achieve benefits in the lake ecosystem, concurrent with project objectives. This topic is included in the Adaptive Management Plan because of its level of uncertainty and risk to LOWRP outcomes, its ability to be addressed through management options, and to ensure that it remains part of LOWRP discussions as lessons are learned throughout the implementation of the project.

LOWRP AM Uncertainty #25 and 26: Will ecological indicator abundances stay within the range of their performance measure scores after lake stages change? Will fish and wildlife communities benefit from changes in lake stage or will additional habitat management be needed?

Objective or Constraint: These uncertainties are related to the objective of improving the quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges (Objective 1).

Region(s): Lake Okeechobee and the majority of watershed which is north of the lake.

Associated project features: WAF and ASR wells

Driver or uncertainty type: Ecological

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? Little new monitoring is proposed in this AM strategy, other than annual aerial (or satellite) imagery collection and classification for the littoral marsh. However, continuation of many ongoing monitoring efforts conducted by various entities and updating analyses will be key to addressing these uncertainties. Most of the specified ecological indicators are monitored by South Florida Water Management District (SFWMD) (including classifying littoral aerial imagery, when available), while various faunal groups are monitored by USACE and Florida Fish and Wildlife Conservation Commission (FWC). Thus far, these projects have provided fairly strong evidence for lake stage targets, but need to be collected across a wider variety of climate conditions to verify assumptions and refine predicted relationships. Specifically, the monitoring of the indicators and fauna need to assess what effects subtle increases in extreme high lake stages and decreases in lower lake stages, or stabilization of water levels overall may have on Lake Okeechobee's resources. Increasing the frequency and reliability of aerial imagery collection and classification will vastly improve our ability to detect change on a lake-wide scale, and be critical to discerning project-related effects from climate or other variability.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation to be tested is that maintaining lake stages within ecologically desired ranges (12.5– 15.5 feet NGVD) more frequently will offset impacts from very minor increases in the frequency of extreme high (>17.0 feet NGVD) lake stages. Additionally, the expectation that reducing the frequency of stages at the high end of the ecologically beneficial range (15.0 – 15.5 feet NGVD) will offset reductions in the frequency of stages at the low end of the beneficial range (12.0 – 13.0 feet NGVD) and lower (<12.0 feet NGVD) will be tested.

The attributes to be measured are representative of ecological conditions on the lake, and how they respond will be a direct measurement of LOWRP's impact to the system. Many of them will be monitored in the nearshore region, which is the area where changes in lake stages have the most immediate impact. These include submerged and emergent aquatic vegetation (SAV and EAV), cyanobacteria, periphyton, phytoplankton, and bluegill and redear sunfish creel data. Wading birds, snail kites, and vegetation composition/distribution will be monitored throughout the marsh, while fish communities will be assessed in the nearshore and pelagic zones.

All the attributes respond relatively quickly to hydrological changes or the indirect effects of stage variations on water quality parameters. While the initial responses could be detected within a year, correlating those responses to project implementation would likely take several years and cover a variety of climate conditions. Monitoring should be implemented concurrent with project implementation and continue through extreme dry and wet conditions (5-10 years) to fully evaluate responses.

Methodology for testing each expectation or hypothesis. Little new monitoring is proposed to address these uncertainties, other than classifying annual imagery (aerial or satellite) for the littoral marsh. All the monitoring proposed relies on existing long-term datasets and on maintaining or expanding monitoring programs that are currently running. LOWRP-specific analyses would be needed to determine how project operations affect various ecological indicators, these are currently being done by agencies, but if that monitoring is discontinued, LOWRP would need to cover the monitoring.

Most of the methodologies for the proposed monitoring can be found in existing sources. For the ecological indicators, see CERP's documentation sheet for Lake Okeechobee Ecological Indicator Score

(http://www.saj.usace.army.mil/Portals/44/docs/Environmental/RECOVER/Lake_Okeechobee_Ecological_Indicator_Score_Performance_Measure_Final_102016.pdf?ver=2016-10-26-131319-687). For SAV and EAV mapping procedures, wading bird foraging surveys, and fish monitoring see the Lake Okeechobee chapter of many South Florida Ecosystem Reports (SFER) (e.g., Zhang and Welch 2018). For information on wading bird nesting colonies, see the annual South Florida Wading Bird Report (SFWBR) (e.g., Cook and Baranski 2018), and for snail kites, see annual demographic reports from University of Florida's snail kite monitoring program (Fletcher et al. 2015).

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

The results for many of the monitoring activities, regardless of whether there was a significant relationship with LOWRP operations, are reported on annually in the South Florida Environmental Report (SFER) and once every five years in the RECOVER System Status Report (SSR). Exceptions are the epipelon, epiphyton, and panfish, which will only be reported with other indicators as specified below. Wading bird nesting is reported in the annual South Florida Wading Bird Report (SFWBR), and snail kite nesting in the annual demographic reports from the University of Florida (e.g., Fletcher et al. 2015).

For Uncertainty #25, related to the ecological indicators and their performance measure scores, those will be evaluated separately on an annual basis in the SFER. For example, the abundances and/or trends of the indicators will be compared to their corresponding scores and/or trends to determine whether lake stage and abundance relationships are accurate.

For individual triggers/thresholds that would indicate a need for action, see **Table D-2**.

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

For all of the monitored groups, one AM option would be to manipulate operations to affect lake stages so that they better align with needs of the specific flora or fauna. For example, if operations appear to be having detrimental impacts to a particular group due to high recession rates or high lake stages, reducing those stressors through operations might be feasible.

There are also various habitat management actions that could be implemented to reach target vegetation compositions or to improve habitat for specific wildlife, like fish, wading birds, snail kites, etc. For example, spraying cattail or torpedograss, implementing prescribed burns, or both. Further, for harvested species like sportfish, regulations for harvest could be revisited as well. Other options are provided in **Table D-2**.

Table D-2. Lake stage management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#25 Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	1 year	Ecological Indicators (EI) - <i>Chara</i> , cyanobacteria, epipelon, epiphyton, PanFish (bluegill and redear sunfish). Areal coverage of vascular SAV, total nearshore SAV, and 9 EAV spp. groups in littoral zone	Abundances of EI, as well as acreage of total SAV in nearshore and 9 EAV spp. in littoral zone Annual: <i>Chara</i> , vascular SAV, nearshore SAV, cyanos, littoral EAV Twice annually: epipelon and epiphyton, PanFish creel data	Adjust increased lake stage duration triggers to maximize storage in project features to increase storage during dry times or reduce any unforeseen impacts from slightly longer high stage durations. Reduction below the annual combined score (8 pts) for ecological indicators. Reduction of coverage (35k acres) for the nearshore SAV and below the combined score (4 pts) for select littoral zone species groups: bulrush, sawgrass, beakrush/spikerush, cattail, willow, floating leaf, torpedograss, other invasive exotics, and woody vegetation.	Adjust water level operations in Lake Okeechobee as appropriate for the ecological indicators, included but not limited to, recessions, low water, reduced highs, etc. Additional habitat management operations, e.g., exotic/nuisance vegetation removal, muck removal, prescribed burning, plantings, etc. Additional nutrient reductions in inflow and/or in-lake nutrient levels to reduce negative impacts to target attributes, Implement additional fish monitoring or analyses, adjust fishery regulations, stocking program, etc.
#26 Will fish and wildlife	1 year	Current annually monitored species:	Annual wading bird abundance and	Substantial reductions in abundance/composition/catch rates/age	Adjust water level operations as

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
communities benefit from project's effect on lake stages or will additional habitat management be needed?		Wading birds, snail kites, fish	nesting effort/success; snail kite nesting effort/success; fish composition/catch rate/age distribution	distributions, etc. of listed attributes: Annual wading bird abundance reduction 50% and reduction in nesting effort/success 50%. Annual snail kite reduction below 3-year moving avg in nesting effort/success. Annual fish composition/catch rate /age distribution reductions 50%.	appropriate for the listed attributes, included but not limited to, recessions, low water, reduced highs, etc. Additional habitat and/or species management operations, e.g., exotic/nuisance removal, muck removal, prescribed burning, plantings, harvest regulations, etc. Implement additional faunal monitoring or analyses. Implement additional fish monitoring or analyses, adjust fishery regulations, stocking program, etc.

*Timeframe could be shorter or longer, depending upon prevailing weather patterns.

D.1.4.1.2 ASR – Recovery Efficiency Strategy

The ASR system provides a significant portion of dynamic water storage in this project, and also contributes to maintenance of target flows during dry periods. As such, restoration success relies on the ability of the ASR clusters to deliver water volumes at appropriate times. Adaptive management measures are required if ASR clusters cannot deliver the expected water volumes. Hydrologic characteristics of the aquifer are the primary reason why ASR clusters may not meet performance objectives. The main performance metric is recovery efficiency — or percent recovered volume — that is anticipated to range between 30 percent and 70 percent at each system. Upper Floridan Aquifer (UFA) ASR wells are expected to have a recovery efficiency of 70% over the long-term. Avon Park Permeable Zone (APPZ) ASR wells are expected to have a recovery efficiency of 30% over the long-term. A persistent, significantly low recovery (<30%) would reduce the likelihood of meeting project storage benefits. This AM objective is to identify when, and if, recovery efficiency falls to unacceptable levels and how to remediate this potential.

LOWRP AM Uncertainty #5: Will ASRs be able to deliver the recovery efficiency we are expecting?

Objective or Constraint: Objectives 1 and 2 (meeting project storage target).

Region(s): Surface waters of LOWRP ASR operations

Associated project features: Wetland Attenuation Feature and ASR Wells

Driver or uncertainty type: Operational and Ecological

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty? This will improve the understanding and predictability of long-term ASR operations to provide necessary water storage for maximum project benefits.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation is that recovery efficiencies do not decrease significantly over time. Monitoring would begin with the onset of ASR operations and likely continue for the project lifespan.

Methodology for testing each expectation or hypothesis. Volume of water pumped into the aquifer versus the volumes recovered of acceptable quality; measured as required by National Pollutant Discharge Elimination System (NPDES) permit, compiled and reported annually.

The first task during the Preconstruction Engineering and Design (PED) phase is to construct a borehole into the UFA, and perform appropriate hydrologic tests to quantify aquifer permeability and characterize native groundwater quality. These test results will be the first indication of site suitability. If permeability measurements indicate that the aquifer can accept recharge water, this borehole will be completed as an ASR well.

Engineering-based adaptive management measures can be applied at the PED phase if the UFA permeability is low. The borehole can go into a deeper aquifer (the APPZ) for additional testing. Successful testing will confirm whether the deeper storage zone is appropriate for ASR operations. The estimated cost of this adaptive management measure reflects increased cost of drilling a deeper borehole and completing a deeper well. For example, this well deepening task was performed on UFA well MF-37

located at the Port Mayaca ASR Pilot site in 2007. The Port Mayaca ASR pilot site was never constructed, but may be developed as a watershed ASR cluster as part of this project. In 2007, well MF-37 was deepened from 1,039 feet to 1,690 feet below land surface, to be open to the APPZ. Total cost of this task (2007) was \$383,000. Applying a 20 percent contingency to estimate cost escalation to 2019 dollars results in a total cost of \$459,600 per well. If it is assumed that one ASR well in ten does not perform adequately, then 5 of the 50 ASR wells proposed in the UFA will require modification by deepening, leading to a total project cost of \$2,295,000.

Engineering-based adaptive management measures can be applied after ASR cluster construction is complete if, during operational testing, a significant decline in recovery efficiency occurs. Lower recovery efficiency can result from two factors: 1) mineral precipitates in the borehole, and 2) mixing of recharge water with high salinity native groundwater.

Carbonate precipitation is a common occurrence in production wells open to the UFA and APPZ. Routine maintenance to improve well capacity consists of acidization, or release of weak acid in the borehole to dissolve carbonate precipitates. This is a routine well maintenance task that is conducted once every five years if necessary by contractors that specialize in deep well construction and maintenance. ASR well acidization has been conducted at both CERP ASR pilot systems (Kissimmee River and Hillsboro) during operational testing. The most recent acidization task was completed in 2011 at the Hillsboro ASR system, at a cost of \$51,041. Applying a 20 percent contingency to estimate cost escalation to 2019 dollars results in a total cost of \$61,250 per well. We assume that 20 ASR wells will be acidized per year, so that all wells will be acidized at least once over a 5-year period. Acidization of 20 wells per year will have a total cost of \$1,225,000 per year.

The salinity of recovered water is limited to 250 mg/L chloride concentration, or a specific conductance value of 1,275 $\mu\text{S}/\text{cm}$. Values that exceed these standards cannot be released into fresh surface water bodies, and as such limit the recovery efficiency of an ASR cluster. Improved recovery efficiency usually is accomplished by changes in system operation. For example, longer recharge durations result in greater volumes of fresh water in the aquifer, and eventual freshening of the aquifer over time. These modifications to the operation plan would be accomplished as routine optimization of operations, without any additional infrastructure costs. Costs are detailed in **Table D-11**.

Triggers/thresholds that indicate good project performance or need for AM action: In accordance with Florida Department of Environmental Protection (FDEP) Permit (TBD, as appropriate) and a level of recovery that stays above 30% and does not drop significantly over the project's lifetime (**Table D-3**).

Management options that may be chosen to improve recovery efficiencies of ASR. 1) Back-plugging individual wells to draw from higher quality portions of the aquifers (well testing/assessment would be needed to do this); 2) concentrating well clusters in areas that have the highest quality or best aquifer attributes, and reducing the numbers of wells in poor producing areas (this option would best be served by constructing well clusters in a multi-phased approach, so that subsequent wells can be sited in the most optimal locations); 3) allow the well to recover "passively," using only the natural, artesian pressure of the Floridan aquifer (instead of actively pumping the ASR well). Substantially higher recovery efficiency has been observed elsewhere as a result of this method, which takes advantage of the buoyancy stratification within the aquifer as fresh water is stored within a saline zone. This is an example of how recovery efficiency can be modified through operational tweaks.

Table D-3. ASR recovery efficiency management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#5 Will ASRs be able to deliver the recovery efficiency we are expecting?	Months to years of operations	Volume pumped down vs volumes recovered. The specific conductance value in recovered water must not exceed 1,275 µS/cm	Volumes of water, measured daily, compiled monthly	A persistent, significantly low recovery (<30%)	<p>Would first need to understand why recovery efficiency reduced over time, and then evaluate the following:</p> <ol style="list-style-type: none"> 1) Back-plugging individual wells, to draw from fresher portions of the aquifers (well testing/assessment would be needed to do this); 2) Concentrating well clusters in areas that have the highest quality or best aquifer attributes, and reducing the numbers of wells in poor producing areas (this option would best be served by constructing well clusters in a multi-phased approach, so that subsequent wells can be sited in the most optimal locations); 3) Development of a bubble of fresh water around the well during cycle testing to develop a “target storage volume” of water within the aquifer to push more brackish water away from the well. 4) A cycle test at the Hillsboro ASR system was recently completed, where the well was allowed to recover “passively”, using only the natural, artesian pressure of the UFA (instead of actively pumping the ASR well during recovery). Substantially higher recovery efficiency was observed as a result of this method, which takes advantage of the buoyancy stratification that takes place within the aquifer as fresh water is stored within a saline zone. This is an example of how recovery efficiency can be modified through operational changes. <p>Note: a certain amount of “aquifer conditioning” needs to take place as an ASR system is operated. In order to achieve high recovery efficiencies, the saline water that is within the storage zone needs to be displaced away from the ASR well, and a freshwater “target storage volume” (the bubble) needs</p>

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
					<p>to be established within the aquifer. In order to accomplish this, the initial recharge volumes/durations should be large, and the recovery volumes should purposefully be limited, so that the freshwater bubble is created within the storage zone. It is instructive to note that “recovery efficiency” is a transient number that is only used to measure the early performance of an ASR cluster. This is why it takes months or years of operation to truly realize the full potential of an ASR facility.</p>

D.1.4.2 Objective 2 - Estuaries Strategies and Management Options

Objective 2 of the LOWRP is to improve estuary flows from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the Northern Estuaries. The following AM strategies were developed to address the uncertainties about improving estuary flows from Lake Okeechobee. From the AM uncertainties, a monitoring plan is presented in **subsection D.1.5.2.2** that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 2.

D.1.4.2.1 Estuaries – Submerged Aquatic Vegetation (SAV) Strategy

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 environmental conditions and restoration. Inherent uncertainties for SAV include species-specific salinity regimes, and some measurable parameters may be limited by species (e.g., productivity measurements for only *Vallisneria americana* and *Thalassia testudinum* due to blade size and width). 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, in which case mediation by changing other environmental conditions may be required (e.g., introduction of suitable substrate).

LOWRP AM Uncertainty #12 – Submerged Aquatic Vegetation – When flows from Lake Okeechobee are altered, and salinity regimes for SAV are improved, what changes to SAV abundance, extent, and species composition/diversity will occur in the estuaries? Further, will natural recruitment of SAV occur, or will other management actions/options be necessary? (Driver or uncertainty type: Ecological)

LOWRP Objective or Constraint: Objective 2 - Restore and/or maintain estuarine communities (oysters, fish, seagrass).

Region(s): St. Lucie Estuary (SLE) & Caloosahatchee River and Estuary (CRE)

Associated LOWRP features: Wetland Attenuation Feature and ASR wells

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

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 and distribution of SAV including estuarine seagrasses, and have marked positive effects on SAV with a lower salinity tolerance. However, if target freshwater flows are not achieved, there may be neutral or deleterious effects to SAV distribution, abundance, and productivity. Elucidating how restoration performance may influence SAV in the Northern Estuaries is imperative so that AM actions can be undertaken, ensuring restoration success.

Schedule and methodology for monitoring SAV:

REstoration COordination & VERification (RECOVER) SAV monitoring for the Northern Estuaries was updated in Spring 2018. The new protocol, the Northern Everglades Northern Estuaries SAV Ecosystem Assessment (NESEA), applies a nested, three-tiered hierarchical approach to address multiple scales of

SAV monitoring in the Northern Estuaries region, namely: 1) landscape, 2) patch, and 3) shoot-level scales. The tiers are summarized as:

- **Tier 1** - Landscape scale from which information on system-wide, long-term trends is attained. Currently, SFWMD has historical and current aerial mapping data for the east coast, which has previously occurred every two years, flown most recently in spring 2017 through current collaboration with St. John's River Water Management District (SJRWMD) and FDEP. Flights and photographs for the next set of maps were completed in May of 2017 and final maps completed in May 2018; this mapping has been ongoing since the late 1980s and is expected to continue. On the CRE, mapping is being performed approximately once every five years by the RECOVER program.
- **Tier 2** - Patch-scale measures which examine segments (or basins) of the system to determine segment-specific trends in ecological conditions at the species-specific level. This sampling may take place at the end of the dry and end of the wet season.
- **Tier 3** – Fixed-point sampling by which statistically significant differences in specific plant responses to environmental stressors at a shoot-scale range are measured. Metrics such as biomass and shoot density are attained at this level. This sampling may occur every other month from April through November.

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

To assess the LOWRP performance or whether there is a need for AM action as it pertains to SAV, decision criteria to trigger management action needs to be developed for each of the estuaries based on the best available science and known seagrass ecology and population dynamics. No framework exists for identifying ecological feedback mechanisms influencing seagrass ecosystems (Maxwell et al. 2016). Therefore, following the optimization of freshwater flows which would result in obtaining desired salinity ranges in locations in which SAV is or should be present, if seagrasses are unable to disperse, recruit, or grow in the expected or desired capacity, other management options may be necessary, including:

- Removal of fine-sediment (i.e., 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.1.4.2.2 Estuaries – Oyster Strategy

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 environmental conditions and restoration. Besides needing the correct salinity ranges, oysters also need proper sediment types for oyster spat settlement and reef growth. 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 (e.g., substrate limitation; spat limitation).

LOWRP AM Uncertainty #16 – Oysters – When flows from Lake Okeechobee are altered, and salinity regimes for oysters are improved, what changes to oyster abundance, density, and extent will occur in the estuaries? Further, will natural recruitment of oyster spat occur, or will supplemental habitat enhancements (i.e., substrate) be required, or other management actions/options be necessary?

Driver or uncertainty type: Ecological

LOWRP Objective or Constraint: **Objective 2** - Restore and/or maintain estuarine communities (oysters, fish, and seagrass).

Region(s): St. Lucie Estuary (SLE) & Caloosahatchee River and Estuary (CRE)

Associated LOWRP features: Wetland Attenuation Feature and ASR wells

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP 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 and abundance of oysters if restoration performance is not met. In addition, substrate and spat limitation may further impede restoration performance despite meeting suitable salinity envelopes. By addressing these uncertainties in the LOWRP monitoring plan, performance goals and subsequent AM actions are developed to ensure restoration success moving forward.

RECOVER Schedule and methodology for monitoring oysters:

- Growth – measured monthly
 - Disease prevalence – measured monthly
 - Predation – measured monthly
 - Recruitment – measured monthly during April - November
 - Reproductive Development – measured monthly
 - Density and live/dead counts (measured 4 times per year)
- Mapping (last conducted in 2010/2011; mapping contract for SLE and CRE completed in 2019) 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 environmental 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 AM.

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

To assess the LOWRP performance or whether there is a need for AM action as it pertains to oysters, decision criteria to trigger management action needs to be developed for each of the estuaries based on the best available science and known oyster ecology and population dynamics (**Table D-4**).

- Identifying triggers for AM is complicated in the Northern Estuaries, especially the SLE and CRE, by occasional (or seasonal), extended periods of freshwater inputs following high rainfall or

tropical storm events. For example, since 2005, five major, estuary-wide die-offs in the SLE have been observed including late 2017 following Hurricane Irma, following approximately 45-60 days of flows resulting in salinities of < 5 , and often paired with temperatures $> 25^{\circ}\text{C}$ (M. Parker, pers. comm.). Generally, within 4-8 months oysters return, which is attributed to persistent seed sources in the southern Indian River Lagoon (IRL; outside of the SLE proper); these larval oysters are transported through tidal forces from the mouth of the estuary/IRL, and repopulate dead shell material (M. Parker, pers. comm.). AM management triggers may be developed for the estuaries following this dynamic, whereby a given amount of time for oyster recruitment is used as a threshold. This will vary by estuary, and by location in the estuary. This also emphasizes the importance of remnant oysters in these highly urbanized systems.

- Within the Northern Estuaries, loss of oysters is typically a result of altered salinity regime, and other ecological effects associated with salinity and temperature interactions leading to increased predation and disease. In other estuaries (e.g., Gulf of Mexico), oyster harvest is an additional factor needing consideration for management due to the removal of shell material (Soniati et al. 2012). While loss in shell material may be a factor of sedimentation/burial rather than harvest in the Northern Estuaries, substrate enhancements may be required. An updated map of oysters and oyster shell in the SLE and CRE is contracted by RECOVER for fiscal year (FY) 2018, and will provide a baseline for LOWRP substrate availability, as well as estimates of live/dead oyster resources if present.
- For substrate-limitation, cultch or travertine tiles may be added. 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.

Table D-4. Estuaries oyster and SAV management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#12 and 16	<p><u>SAV</u>: 5 years</p> <p><u>Oysters</u>: 5 years (acres of live oysters)</p>	<p>SAV</p> <p>Oysters</p>	<p><u>SAV Monitoring</u>:</p> <p>Tier 1 - Landscape scale – aerial mapping every 2 years</p> <p>Tier 2 - Patch-scale – species-specific cover and abundance at the end of the dry and end of the wet season.</p> <p>Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November</p> <p><u>Oyster Monitoring</u>: Monthly at 18 existing RECOVER sites</p> <p>Growth</p> <p>Disease</p> <p>Predation</p> <p>Reproductive Development</p> <p>Recruitment</p> <p>Density; and Live and Dead counts (twice per year – spring and fall)</p>	<p><u>SAV</u>: TBD</p> <p><u>Oysters</u>: TBD</p>	<p><u>SAV</u>:</p> <p>Optimize flows to get the correct salinity in the correct locations</p> <p>Substrate issues – muck removal</p> <p>Assess water quality</p> <p>Seagrass plantings</p> <p><u>Oysters</u>:</p> <p>Change operations to increase or decrease flows if salinity envelope is not correct</p> <p>Add cultch</p> <p>If spat is a limiting factor, add mature oysters to existing beds or add spat or seeded cultch to water column, add travertine tiles</p>
#12 and 16		Substrate type	Benthic map at 2 years and then every 10 years after		

D.1.4.2.3 Estuaries – Substrate Strategy

Provided that restoration activities meet intended changes to timing in salinity, SAV and oysters may otherwise be limited by the available substrate. Specifically, areas susceptible to fine sediment entrainment (e.g., muck) can limit productivity or result in sedimentation. For oysters, in areas of good water quality and sediment, spat may be unable to locate suitable substrate on which to settle. 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.

LOWRP 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

LOWRP Objective or Constraint: **Objective 2** - Restore and/or maintain estuarine communities (oysters, fish, and seagrass).

Region(s): Caloosahatchee River Estuary and St. Lucie Estuary

Associated LOWRP features: Wetland Attenuation Feature and ASR Wells

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

Both oyster and seagrass communities in coastal estuaries have substrate requirements to persist and recruit in a system. By restoring the salinity regime in the system through restoration activities these communities will shift. 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 AM 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 and seagrasses in the estuaries. This is dependent on the availability of the appropriate substrate for each of these communities existing in these areas following two years of restoration activities. Restoration activities may suspend and redistribute fine-grained sediments and possibly muck in the water column, which may affect the distribution of oysters and SAV. This redistribution can result in covering of hard bottom surface needed for oyster reef growth. 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 may be conducted to determine if the appropriate substrate exists for these communities. Following this initial mapping there may be additional

mapping every 10 years. Depending on the timing of this need, a RECOVER map may be available or this may need to be a project funded effort.

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

If the substrate within the estuaries 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 (shell) 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 (**Table D-5**):

- 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.
- 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-5. Estuaries substrate management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#23	2 years	Substrate type	Benthic map at 2 years and then every 10 years after	<p>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)</p> <p>If muck is present in the area neither oysters nor will SAV be able to expand into the area.</p>	<p>Substrate remediation:</p> <ul style="list-style-type: none"> • Adding cultch • Removing or capping fine sediments • Sediment traps • Install breakwaters to protect areas from shear stress and/or sediment accumulation

D.1.4.2.4 ASR – Mercury Methylation Strategy

Mercury methylation is a microbe-mediated geochemical reaction that occurs in shallow submerged freshwater sediments. Sulfate-reducing microorganisms will, under certain conditions, create methyl mercury where mercury, sulfate, and total organic concentrations are favorable for their metabolism. Dissolved methyl mercury is more toxic than dissolved elemental mercury; it bioaccumulates in fatty tissues, and biomagnifies up the food chain.

The strategy to minimize mercury methylation in freshwater sediments is to minimize the release of sulfate-rich groundwater to surface waters of the WAF or adjacent to a watershed ASR cluster. Sulfate concentrations are measured as part of the operational monitoring program. Monthly measurement of methyl mercury and mercury during the recovery phase is warranted, to determine if mercury methylation is occurring.

The operation of ASR facilities in the LOWRP has the potential to recover groundwater having higher sulfate concentrations, and thus increase sulfate concentrations in receiving surface waters. This is particularly important for recovered water from the APPZ, which generally shows higher sulfate concentrations compared to that of the UFA in the project area. It is hypothesized that increased sulfate concentration in surface water can stimulate sulfate-reducing bacteria in sediments, and thus enhance mercury methylation in sediments downstream of the ASR release structures.

The preliminary operational strategy for ASR clusters co-located at the WAF will be to recharge from, and recover into the impoundment. This will reduce the risk of introducing water having elevated sulfate concentrations directly into the Kissimmee River and Lake Okeechobee. Recovered water from the ASR clusters will mix with surface water in the WAF, and then be conveyed into the Kissimmee River through gated culverts. This mode of operations will reduce the number of release points into the Kissimmee River.

The preliminary operational strategy for ASR clusters located in the watershed will rely on surface water dilution to manage release of recovered water into the receiving water body. Currently, there is no State or Federal surface water quality criterion for sulfate. However, ASR recovered water having elevated sulfate concentrations will also have elevated chloride and specific conductance concentrations. When recovered water quality equals the surface water criterion for chloride (250 mg/L) and/or specific conductance (1,275 $\mu\text{S}/\text{cm}$), recovery will cease. Therefore, sulfate loading of surface water bodies adjacent to watershed ASR clusters will be limited by chloride and specific conductance criteria. The LOWRP AM strategy described here focuses on monitoring and addressing the risks of sulfate loading from ASR operations; and, if the risk is significant, monitoring for increased methyl mercury concentration in vertebrates (most likely freshwater fish) collected near the site.

LOWRP AM Uncertainty #2: Will ASR operations exacerbate mercury methylation in downstream sediments?

Objective or Constraint: Constraint (of not worsening the existing mercury methylation issue).

Region(s): Surface waters downstream of LOWRP ASR releases where those releases comprise a significant proportion of surface water flow. This condition occurs primarily at watershed ASR clusters.

Associated project features: Watershed ASR clusters.

Driver or uncertainty type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and predictability of ASR operations' risk to exacerbating the mercury methylation issue.

Expectations and hypotheses to be tested to address uncertainty, and attributes that will be measured to test each: The expectation is that ASR operations will not cause a measurable increase in sulfate concentrations downstream. Typically, surface water concentrations of selected constituents are required by NPDES permit in downstream waters. Along with other constituents, sulfate will be measured as required to define how recovered water mixes with surface water in the receiving water body. Monitoring of sulfate (and other water quality parameters) in groundwater and surface water would start with the onset of ASR operations and will continue until, at least, the risk is quantified. Subsequent monitoring will continue for the life of ASR system operation as required by Underground Injection Control (UIC) and NPDES operational permits. A numerical relationship will be defined between sulfate and chloride or specific conductance concentrations in recovered waters at representative ASR clusters so that specific conductance (measured frequently) can serve as an indicator of potential releases having elevated sulfate. There may be other complementary monitoring for sulfate conducted by the State in Lake Okeechobee or other downstream surface water bodies, which may provide a long-term pre-release record, but these data may not be of sufficient frequency for future AM guidance. There is also a fish tissue mercury monitoring program in place, in which Lake Okeechobee is sampled once every seven years (see MOM below for more details).

Methodology for testing each expectation or hypothesis. Sulfate concentration shall be measured in accordance with requirements defined in all relevant FDEP Permits (e.g., UIC, Comprehensive Everglades Restoration Plan Regulation Act (CERPRA), NPDES) in recovered water at the ASR wellheads, in WAF surface water, and in adjacent water bodies at watershed ASR clusters.

If increased mercury methylation is quantified in sediments of the WAF or in sediments adjacent to watershed ASR clusters, methyl-mercury measurements in fish tissue is merited, annually or biannually. Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project shown below in **Table D-6** (see footnote*). Methyl mercury analyses in fish tissue, if required, will be consistent with CGM-42 protocol.

The strategy to minimize mercury methylation in freshwater sediments is to minimize the release of sulfate-rich groundwater to surface waters of the WAF or adjacent to a watershed ASR cluster. Sulfate concentrations are measured as part of the operational monitoring program, so no additional analytical or labor costs are added for the adaptive management monitoring plan. Monthly measurement of methyl mercury and mercury during the recovery phase is warranted to determine if mercury methylation is occurring.

The following assumptions are made for estimating cost:

- Six-month recovery duration for WAF-assisted and watershed ASR clusters
- No methyl mercury or mercury samples collected during storage
- Recovered water samples collected monthly for methyl mercury and mercury analysis

- Analytical costs are based on “low level” mercury and methyl mercury analyses
- Samples will be collected during an operational sampling event so additional labor costs are negligible

Total costs for low-level mercury and methyl mercury analyses, collected once a month from each ASR well during a six-month recovery phase, are found in **Table D-11**.

Triggers/thresholds that indicate good project performance or need for AM action: No significant increase in sulfate concentrations in surface water within the WAF or at watershed ASR clusters, or in methyl mercury concentrations in sediments or fish tissue, attributable to LOWRP operations.

Management options that may be chosen to reduce the impacts of sulfate in ASR releases. Blend recovered water at ASR clusters with surface water within the WAF, or reduce release volumes (**Table D-6**).

Table D-6. ASR – methyl mercury (MeHg) management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
<p>#2 Will ASR recovered water increase methyl mercury methylation in downstream sediments?</p>	<p>1 to 3 years of operation</p>	<p>Increased sulfate concentrations in WAF surface water or at downstream receiving water bodies; and increase in methyl mercury concentration in downstream sediments</p>	<p>Sulfate in ASR recovered water released into the WAF, or in adjacent flowing surface water body.</p> <p>Sulfate plumes in receiving water, if they exist, should be delineated if required by NPDES permitting.</p> <p>For frequency of MeHg fish tissue monitoring: One approach is to monitor MeHg in fish tissue in the WAF, which would be more closely related ASR release effects on impounded fish. Additional fish tissue analyses from downstream areas annually or biannually (depending on amount of ASR release and any sulfate monitoring or modeling).</p>	<p>Elevated concentrations of sulfate in the release with sufficient volume to potentially affect mercury methylation in downstream sediments.</p> <p>If mercury methylation increases, a more stringent fish consumption health advisory compared with current advisories (see table below for 8 fish species).</p>	<p>Blend ASR recovered water with surface water in the WAF or flowing receiving water to dilute sulfate concentrations to surface water quality at the respective site.</p> <p>Quantify the relationship between sulfate concentration and chloride and/or specific conductance in recovered water at representative ASR clusters so sulfate loading in the receiving water can be predicted.</p> <p>Develop a bubble of fresh water around the well during cycle testing to create a “target storage volume” of water within the aquifer to push more brackish water away from the well.</p> <p>Generally, FWC collects the fish, FDEP analyzes fish, and Department of Health (DOH) issues advisories. FWC samples Lake Okeechobee once every seven years. Therefore, if sulfate levels indicate an increased risk of me-Hg bioaccumulation, additional samples would be needed (likely annually until the risk is characterized).</p> <p>Annual collection of largemouth bass (N=5) per site (4 quadrants). Cost is ~\$20,000/year</p>

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
			Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project shown below.*		

* CERPRA permit for the Kissimmee River ASR Pilot Project required the following during the recovery phase:

- Six-month recovery duration for WAF-assisted and watershed ASR clusters
- No methyl mercury or mercury samples collected during storage
- Recovered water samples collected monthly for methyl mercury and mercury analysis
- Analytical costs are based on “low level” mercury and methyl mercury analyses
- Samples will be collected during an operational sampling event so additional labor costs are negligible
- Initially, sulfate monitoring frequency was weekly at the release point and monthly at the monitoring wells.
- After several cycle tests, the CERPRA permit was modified to allow sulfate monitoring to be conducted biweekly for 2 months and then monthly at both the release point and at the monitoring wells.
- Initially, total mercury (THg) and methyl mercury (MeHg) monitoring frequency of surface water samples was weekly at the release point and monthly at upstream and downstream locations.
- After several cycle tests, the CERPRA permit was modified to allow THg and MeHg monitoring of surface water samples to be conducted monthly at the release point.
- THg monitoring in mosquitofish would be triggered if either of the following occurred:
 - MeHg concentrations at the downstream site were significantly greater than MeHg concentrations at the upstream site.
 - THg or MeHg concentrations at the ASR well during recovery were significantly greater than THg or MeHg concentrations at the upstream site.

D.1.4.2.5 ASR – Recovery Efficiency Strategy

Recovery efficiency is defined as the volume of water recovered that does not exceed the primary drinking water standard for chloride (250 mg/L), as a percentage of volume recharged. UFA ASR wells are expected to have a recovery efficiency of 70% over the long-term. APPZ ASR wells are expected to have a recovery efficiency of 30% over the long-term. A persistent, significantly low recovery (<30%) will reduce the likelihood of meeting project storage benefits. This AM objective is to identify when, and if, recovery efficiency falls to unacceptable levels and how to remediate this potential. The LOWRP AM Uncertainty #5 also relates to Objective #1; therefore was detailed previously in **subsection D.1.4.1.2** and **Table D-3**.

D.1.4.3 Objective 3 – Wetland/Wildlife/Habitat Strategies and Management Options

Objective 3 of the LOWRP is to increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed. The following AM strategies were developed to address the uncertainties about conserving and restoring biota and habitat in and around Lake Okeechobee. From the AM uncertainties, a monitoring plan is presented in **subsection D.1.5.2.3** that documents the ecological monitoring and AM monitoring required to measure success of the project in reaching the goals of Objective 3.

D.1.4.3.1 ASR - Fish Entrainment Strategy

The lower Kissimmee River is a nursery area for black crappie and threadfin shad, both important to commercial and recreational fisheries. Larval fish can be drawn into the ASR cluster during recharge, and this is problematic when recharge coincides with fish spawning periods. Typical ASR cluster intake design includes a 1-mm mesh screen through which surface water is drawn. This screen design minimizes the possibility of larval fish entrainment, but anecdotal evidence at the Kissimmee River ASR cluster suggested that some larval fish can be entrained in the system.

To minimize the potential for larval fish entrainment at WAF co-located ASR wells, it was decided during the feasibility phase that WAF ASR recharge water would be drawn from the seepage canal at the WAF, and recovered water would be released directly into the WAF. Due to concerns about fish entrainment along the C-38 canal, options will be evaluated during PED that may include screening and/or wildlife exclusion barriers to minimize those concerns.

The strategy to minimize larval fish entrainment at WAF-assisted ASR clusters will be to recharge from and recover to the impoundment. This AM objective is to minimize the magnitude of larval fish entrainment at ASR intake structures. Additional design refinements will be incorporated at WAF intake pumps. Currently, the abundance of fish or aquatic invertebrates at risk in the surface water is not known. Therefore, a risk characterization study based on sampling could be useful prior to implementing alternative strategies to reduce entrainment.

LOWRP AM Uncertainty #3: Will project operations (i.e., WAF pumps or ASR pumps) result in significant occurrences of fish entrainment / impingement?

Objective or Constraint: Constraint (of not adversely affecting the local fisheries).

Region(s): Surface waters with LOWRP ASR and/or WAF pumps, especially the Kissimmee River, Indian Prairie Canal, and Lake Okeechobee.

Associated project features: WAF, ASR intake structures and/or wetland restoration site pumps

Driver or uncertainty type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and predictability of the effects of pumping operations on fishery spawning areas.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. Operations of the LOWRP pumps for the WAF and wetlands or at ASR cluster intakes located in the watershed should not appreciably reduce the number of larval fishes in the Kissimmee River or other similar nursery areas. These fisheries are important to the local economy and as such, should not be diminished. The impacts to the fisheries could be identified immediately by sampling the pump intake water for evidence of entrained organisms; therefore, sampling should begin as soon as operations start and end when the risk is characterized and remediated, if necessary.

Methodology for testing each expectation or hypothesis. The potential for larval fish entrainment exists at watershed ASR clusters. A survey of larval fish entrained at the Kissimmee River ASR cluster intake is proposed when the system becomes operable. However, because fisheries resources in the Kissimmee River are probably more diverse than what would appear at the other watershed ASR clusters, an alternative operating ASR cluster (perhaps that at Hillsboro Canal) should also be considered for this survey. A test would include diurnal samples of recharged surface water within the wet well, after surface water has passed through the intake screen. Testing should occur at the times most favorable for spawning of representative fish species. Samples would be identified and quantified by an experienced freshwater biologist, with a report to document the results. A sampling protocol will be defined during the intake design phase.

Triggers/thresholds that indicate good project performance or need for AM action: Significant numbers of larval fish entrainment during the monitoring period may trigger AM (**Table D-7**).

Management options that may be chosen based on test results. Implement new intake screening techniques (smaller pore size or larger screen area) or wildlife exclusion barrier systems. Operate ASR clusters at the WAF conjunctively (recharging from and recovering to the WAF) to minimize impacts to Kissimmee River fisheries. Evaluate strategies to minimize fish entrainment during PED. Coordinate with FWC on design strategies.

Table D-7. ASR fish entrainment management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
#3 Will project operations (i.e., WAF and wetland pumps or ASR intake pumps) result in significant occurrences of fish entrainment?	Days to weeks of operations	Number of fish and aquatic invertebrates entrained	Number of entrained aquatic organisms associated with ASR intakes or WAF pump operations until the risk is quantified, then frequency may be reduced. Sampling is not needed if pumps are not operating (i.e., during storage and recovery) and assuming no other significant fishery risk is evident (i.e., fish are trapped in the intake even though pumps are not operational).	Unacceptable amount of organisms entrained (TBD)	<p>Implement new intake screening techniques (smaller pore size or larger screen area) or other wildlife barrier exclusion systems.</p> <p>Operate ASR clusters at the WAF conjunctively (recharging and recovering to the WAF) to minimize impacts to Kissimmee River fisheries.</p> <p>Evaluate strategies to minimize fish entrainment during PED. Coordinate with the FWC on design strategies.</p>

D.1.4.3.2 ASR - Methyl Mercury Strategy

Recovered groundwater can show sulfate concentrations greater than that in surface water and sediments. Increased surface water sulfate concentrations is one of several mechanisms that has been hypothesized to increase the rate of mercury methylation in sediments, possibly leading to methyl mercury bioaccumulation up the food chain. The LOWRP AM strategy described here focuses on monitoring and addressing the threat of additional sulfate from ASR operations; and, if the threat is present, monitoring for increased methyl-mercury bioaccumulation in vertebrates (most likely freshwater fish). LOWRP AM Uncertainty #2 is detailed in **subsection D.1.4.2.4** and **Table D-6**.

D.1.4.3.3 Invasive Plant and Animal Species Strategy for Proposed Wetland Restoration Areas

Invasive plant and animal species are important to control if full restoration of wetlands and the WAF are to be achieved. Such species can alter plant community structure, species composition, fire frequency and intensity, habitat quality, compete with and displace native species, threaten endangered species, and alter trophic dynamics and food webs. High profile floral and faunal species (e.g., *Melaleuca*, Brazilian Pepper, Burmese python) and their impacts to the landscape are well documented. However, these species are only a fraction of the invasive and nuisance species found in the Lake Okeechobee region. Many of the other species' life histories and responses to disturbance and treatments are important to understand in order to prevent their proliferation in LOWRP implementation. The targeted wetlands areas currently have Bahia grass, Brazilian pepper, and other invasive plant species that need to be eradicated or controlled. Soil and hydrologic disturbances associated with construction of the wetland restoration features, as well as future operation and maintenance of the wetlands, has the potential to allow colonization by invasive species if the species are not controlled. After restoration, invasive or exotic animal species (e.g., hogs, fish [armored catfish, tilapia, or other cichlids], pythons or other herps) may move into these wetlands and disrupt native ecosystems. Uncontrolled proliferation of these species undermines restoration efforts and prevents the LOWRP from achieving restoration objectives.

Under fully restored conditions there would be minimal unwanted invasive species. The strategy described here focuses on monitoring and addressing the extent of unwanted species, primarily plants. The team recognizes that there will be an Invasive and Nuisance Species Management Plan for LOWRP and control of certain animal species will be governed by that plan.

LOWRP Uncertainty #17. How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?

Objective or Constraint: LOWRP Objectives #1 and #3

Region(s): Paradise Run and Kissimmee River-Center wetland restoration sites.

Associated Project Feature: None specifically; however consideration of hydrologic conditions, as affected by other LOWRP management measures (ASR or WAF), may be needed assuming a connection to the wetland sites. For example, if a wetland site needs to be dried down for invasive species control, it may not be able to receive co-located ASR or WAF flows; therefore, ASR or WAF operations may need tweaking.

Driver or Uncertainty Type: Ecological and Operational

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? This will improve the understanding and control of invasive species dynamics within these sites and the efficacy of implementing these types of sites elsewhere in the region to achieve habitat restoration.

Expectations or hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation is that the invasive plants currently on the sites will be controlled and that as additional invasive species invade the sites, the monitoring plan will detect this and control or eradication of invasive species will be implemented. It is also expected that this type of work will be more intensive for the first 5 years of the project until the sites become more ecologically “stabilized”. The attributes to be monitored are the location, percentage, and types of invasive species on the site. To this extent, the other anticipated monitoring of wetland vegetation (conducted under Uncertainty #46) should provide the data needed to implement any AM for this uncertainty. In the case of invasive animal species, the vegetative surveys could be designed to detect their presence. We expect that invasive plants will be more problematic and expensive to manage than invasive animal species. Monitoring for invasive species will be covered in the Invasive and Nuisance Species Management Plan for LOWRP (**Annex G**).

What is the time frame in which changes to this attribute are expected to be measurable? Although changes could occur any time, we expect the greatest change and potential need for action to occur within 1 year of acquisition, then within 1–5 years after construction.

When during LOWRP’s life cycle should this monitoring begin? After acquisition and within the appropriate season (within 12 months of acquisition).

Methodology for testing each expectation or hypothesis. Assessment of sites via aerial or photographic interpretation in conjunction with ground surveys. Invasive vegetative communities may be mapped to show location and species composition. Post-treatment surveys may report percentage of invasive species controlled or eliminated. For invasive animal species determined to be of significant risk to restoration, standard sampling (and eradication) techniques may be employed (see **Annex G**).

Triggers/thresholds that indicate good project performance or need for AM action: Minimal unwanted invasive species. In the case of invasive plants, the target is less than 5% coverage (**Table D-8**).

Management options that may be chosen to reduce the impacts of invasive species. Please refer to **Annex G**, the LOWRP INSMP. The efforts of the INSMP and the AM strategy will be coordinated to minimize redundancy. Remediation techniques (flooding, burning, or herbicide) may be appropriate for cost and efficacy. Control techniques for invasive animal species could include trapping or hunting (hogs, pythons), spraying (mosquitos/insects), or electro-fishing/dry-down (fish).

Table D-8. Invasive species management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
<p>#17 How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?</p>	<p>Seasonally to years</p>	<p>Percent of invasive plant coverage, or appearance of new plant or animal invasive species, changes in density of existing invasive species in project footprint</p>	<p>Percent invasives, species composition; measured annually during appropriate season for spp.</p>	<p>Infestations above 5% for plants; or if there is the presence of damaging (hogs) or dangerous (pythons) animals.</p>	<p>Use standard practices (burning, flooding, and herbicides) or novel techniques to control or eradicate invasive plants; also refer to Invasive and Nuisance Species Management Plan. This MOM will be coordinated as much as possible with the INSMP to minimize redundancy.</p> <ul style="list-style-type: none"> • Adjust LOWRP-related management decisions such as timing of delivering water, or routing water through an area slightly differently than originally specified, in addition to informing the invasive and nuisance species management team actions. • Contribute monitoring data to the refinement of Invasive Risk Assessment Tools used by invasive species management practitioners. <p>During PED, redesign of existing or planned features, as appropriate and feasible, based on lessons learned by ongoing invasive species management efforts in south FL, to make the features less supportive of invasive exotic species proliferation/movement.</p> <p>Note: There is potential overlap with wetland restoration uncertainties, as invasive spp. control is used as a tool to improve success of native plant communities. During implementation these management actions will be coordinated to complement each other and minimize redundancy.</p>

D.1.4.3.4 Wetlands Strategies and Management Options

Wetland restoration is a LOWRP management measure and objective designed to improve habitat for fish and wildlife and provide water storage in the Lake Okeechobee watershed. The LOWRP AM strategy described here focuses on monitoring hydrology and vegetation in the restored wetlands and WAF to maximize project benefits and determine when (or if) the restoration trajectory is not being achieved.

LOWRP AM Uncertainty #46: When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?

Objective or Constraint: This uncertainty is related to LOWRP objective 3 to increase spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.

Region(s): Kissimmee River-Center and Paradise Run

Associated project features: Kissimmee River-Center and Paradise Run

Driver or uncertainty type: Ecological

What is expected to be learned by addressing this uncertainty, i.e., how will LOWRP benefit from addressing this uncertainty? Addressing this uncertainty will identify the level of effort that may be needed to ensure restoration of native habitat in this area (i.e., documentation of anticipated project benefits). Greater coverage with desirable wetland species will provide more appropriate and productive habitat (greater foraging space, better nesting habitat, etc.) which ties into and enhances the LOWRP goal for increasing the spatial extent and functionality of aquatic and wildlife habitat.

Expectations or hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. Restoring topography and hydrology to former wetland sites is expected to result in the recruitment of wetland vegetative species to complete the restoration of wetland habitat (a project objective). The plan should establish a target to encourage 90% or greater coverage by desirable plant species in both wetland and upland areas. Assuming the appropriate hydrology and topography have been restored, this is further dependent upon the presence of a seed bank within the restored soils as well as limiting (or controlling) coverage of invasive species. Herbaceous wetland systems will respond within one year although may take up to 3-5 years for full development. Forested wetlands would take additional time (as much as 30 years) to determine whether there is appropriate tree growth. Monitoring should be conducted annually for the first 5 years, then at a reduced frequency if restoration trajectory is being met for the life of the project.

Methodology for testing each expectation or hypothesis. One year following wetland creation and construction of the WAF, annual surveys of species composition, diversity, and abundance through either: 1) photo stations and mapping of vegetative communities; or 2) stem counts along transects (monitoring method TBD based on cost). Frequent water level monitoring, most likely using SCADA and telemetry, will also occur to determine short vs long hydrology and maximum depths.

How results will be reported, and the triggers/thresholds that indicate good LOWRP performance or need for AM action: Plant species and community specific success criteria should be established based on the anticipated hydrology (i.e., short vs long-hydroperiod). The results will be reported as percent coverage of desirable vegetation and invasive or non-desirable vegetation. If greater than 10% of the area

where hydrology and topography have been restored are colonized with invasive or undesirable species, or if vegetative diversity is lower than expected, management action options will be implemented. Triggers include unexpected low species diversity, vegetation appears to be stressed, or plant diversity differing from the hydrology of the wetland.

Management options that may be chosen to supplement the return of wetland vegetation.

If the vegetation in wetland areas is not appropriate and/or supplemental habitat enhancement is needed the following actions may be applied to provide the appropriate habitat (**Table D-9**):

- 1) Seeding or planting of desirable plant species may be necessary if the existing seed source is not adequate for anticipated wetland plant generation.
- 2) Alterations to wetland hydrology to meet a certain wetland community type may be needed. If unable to meet a desired wetland type, a different plant community may need to be chosen.
- 3) Implement fire management (or other acceptable vegetative control mechanism) to match natural frequency as needed.
- 4) As identified for the Invasive Species Management (**subsection D.1.4.3.3**), remove undesirable/exotic vegetation (or animal) species to allow natural vegetation to establish and prevent natural vegetation from being outcompeted. To the extent practicable, exotic vegetation may be treated with an appropriate systemic herbicide such as an approved brand that may be used near water, or removed using hand-held equipment in a manner that will minimize impacts to the existing native wetland plants and will not cause ruts in the wetland soils which will impede or divert the flow of surface waters.

Cost saving for wetland monitoring may arise by combining water quality sampling occurrences with any overlap with annual plant monitoring events.

Table D-9. Wetland vegetation management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
<p>#46 As wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?</p>	<p>1+ years for herbaceous system; and 5+ longer for forested wetlands (to determine if trees are growing appropriately)</p>	<p>Plant species composition, diversity, and relative abundance.</p> <p>Species- and community-specific success criteria may be established; county / Natural Resources Conservation Service (NRCS) criteria may inform this indicator</p>	<p>Water level (weekly; stage recorder installation needed);</p> <p>Plant health, diversity, and abundance (annually or seasonally as appropriate) photo points, and mapping of diversity.</p>	<p>Is the species diversity as expected (adequate seed bank or do seeds/plants need to be brought in)?</p> <p>Do plants appeared stressed from improper hydrology (can we change hydrology, or should we try for a different plant community)?</p> <p>Is the plant diversity what we'd expect based on the hydrology (or are there improvements needed to the hydrology)?</p>	<p>Plant desirable species; Change hydrology if needed; Implement fire management as necessary; and as linked to Invasive Species Management Option: Remove undesirable/exotic plant (or animal) species to allow natural vegetation to establish.</p> <p>Because these will be new sites, a monitoring plan is proposed below. Cost may drive the scope of monitoring performed. There may also be opportunities for cost-savings by combining any water quality sampling (yet to be determined) with plant monitoring.</p>

D.1.4.4 Objective 4 – Water Supply Strategies and Management Options

Objective 4 of the LOWRP is to increase availability of the water supply to the existing legal water users of Lake Okeechobee. The following AM strategies were developed to address the uncertainties about project performance during droughts. From the AM uncertainties, a monitoring plan is presented in **subsection D.1.5.2.4** that documents the AM monitoring required to measure success of the project in reaching the goals of Objective 4.

D.1.4.4.1 Water Supply in the LOWRP Footprint

The LOWRP AM for water supply focuses on the uncertainty associated with project performance during droughts. The specific concern is whether the actual project performance during challenging drought conditions matches expectations from the project's formulation and modeling phases. If LOWRP's expected ecological benefits are not realized during drought events, AM options exist that can be implemented to improve performance.

LOWRP AM Uncertainty #41: Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought?

Driver or type: Ecological and operational; balancing multiple objectives (ecological health of Lake Okeechobee and water supply).

This uncertainty is related to two of LOWRP's ecological objectives:

- Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often (Objective 1).
- Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed (Objective 3).

What is expected to be learned by addressing this uncertainty (i.e., how will LOWRP benefit from addressing this uncertainty)? It is anticipated that addressing this uncertainty will clarify whether LOWRP's storage features are capable of supplying water adequate for maintaining Lake Okeechobee's ecology during droughts. The uncertainty is focused on whether the project features deliver water supply (specifically quantity and timing of deliveries) that match the expectations from plan formulation and modeling simulations. If the project features are found to have lower than expected performance during actual, rather than modeled, drought events, then LOWRP operations can be adaptively managed to improve performance.

Expectations and hypotheses to be tested to address uncertainty, and attribute(s) that will be measured to test each. The expectation to be tested is that actual project performance during drought events will match performance modeled during plan formulation. No new monitoring is proposed in this AM strategy to improve predictions and risk assessment. Data from existing ecological monitoring (e.g., monitoring associated with the Lake Okeechobee Ecological Indicator Score) and Lake Okeechobee stage data will be used for analysis.

Methodology for testing each expectation or hypothesis. This uncertainty is focused on performance during droughts. Given that the timing and severity of droughts in the project areas is unpredictable, the uncertainty cannot be tested until one or more droughts of significant severity is experienced. An

additional constraint is that the project's storage (i.e., WAF storage and ASR storage) will require a start-up period of approximately three years to reach full capacity and allow full assessment of the project's performance. During and after a drought event, the project's performance will be assessed by comparing the calculated Lake Okeechobee Ecological Indicator Score with the indicator score calculated during plan formulation and modeling. If the comparison shows that the indicator score is lower than expected for a drought of similar characteristics, then AM management actions should be considered.

How results will be reported, and the triggers/thresholds that indicate good LOWRP performance or need for AM action: During and after a significant drought event, expected versus actual performance will be compared. A post-drought summary report will be created, and based on performance results, either verify good performance or recommend AM management options to address any shortcomings. Lessons learned will be provided as feedback to the next stages of CERP design, construction, and implementation.

Management action options that may be chosen include (**Table D-10**):

- Adjust operations of WAF and ASR cluster (changing timing and rate of releases/recovery).
- Consider operations to recover more water from ASR wells that are in "fresh" aquifers (e.g., aquifers with specific conductance < 1275 $\mu\text{mhos/cm}$) to maximize recovery efficiency/rate.

Table D-10. Water supply management option matrix.

Uncertainty tracking ID#	Timeframe to detect change of attributes*	Attribute or indicator	Proposed Property to be Measured and Frequency	Decision Criteria: Trigger(s) for Management Action	Management Action Options Suggestions
<p>#41</p> <p>Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought?</p>	<p>Minimum of 3 years.</p> <p>Three years from project start-up to reach full storage, plus an additional period of time to experience one or more drought events.</p>	<p>Lake Okeechobee Ecological Indicator Score</p>	<p>Monthly average Lake Okeechobee stage</p>	<p>Conduct performance review post drought event. Did LOWRP storage features significantly deviate from expected performance based on LOWRP modeling?</p> <p>Was the actual annual Lake Okeechobee Ecological Indicator Score computed after a drought event significantly lower than the annual score computed after a similar modeled drought?</p> <p>Use “drought performance curve” to verify drought is within envelope of period of record (POR) used for modeling.</p>	<p>1.) Adjust operations of WAF and ASR cluster (changing timing and rate of releases/recovery).</p> <p>2.) Consider operations to recover more water from ASR wells that are in “fresh” aquifers (i.e., aquifers with specific conductance < 1275 micromhos/cm) to maximize recovery efficiency/rate.</p>

D.1.5 LOWRP Monitoring Plan

The primary objective of the LOWRP AMMP is to identify the monitoring necessary to inform decision-makers, LOWRP partner agencies, and the public on achieving restoration success, as well as to address uncertainties with efficiently structured approaches. The monitoring plan specifies what monitoring is necessary to measure and detect the benefits of capturing, storing, and redistributing water entering the north part of Lake Okeechobee to improve lake stage levels for both environmental restoration and water supply purposes; improving flows to the Caloosahatchee and St. Lucie estuaries; restoring wetland habitats; and reestablishing connections among natural areas that have become spatially and/or hydrologically fragmented. This monitoring plan also includes monitoring required to reduce uncertainties and address the prioritized AM uncertainties described in **subsection D.4**.

This second objective of the LOWRP AMMP is to contain the monitoring and associated costs required under the U.S. Fish and Wildlife Service's Biological Opinion (BO) and other agency permits that are needed to protect and conserve natural resources. The BO and associated monitoring information for LOWRP can be found in **Annex A**, Fish and Wildlife Coordination Act Report and Endangered Species Act Compliance. Cost estimates for monitoring associated with the BO, including a project-wide contingency cost, is in **Section 6**, **Table 6-9**, and **subsection D.1.7**.

The LOWRP AMMP will be closely coordinated with the CERP RECOVER Monitoring and Assessment Plan (MAP) to ensure that measures and targets selected by the project teams are consistent with system-wide measures and to avoid duplication of efforts. Furthermore, the LOWRP AMMP will ensure temporal and spatial coverage of monitoring parameters that are appropriate to detect changes at the project level. The AMMP will fill gaps in the MAP monitoring parameters to address LOWRP-specific needs by adding additional project-level parameters not included in the MAP. Thus, the LOWRP AMMP will cover LOWRP regions within the watershed that are not covered in the MAP in order to evaluate project success.

Table D-11 summarizes the AM monitoring and includes (1) uncertainty, (2) monitoring attributes, (3) RECOVER costs, (4) other agency costs, (5) LOWRP costs, and (6) sampling frequency that summarizes the monitoring required to address the uncertainties described in **subsection D.1.4**. In **Table D-11**, LOWRP monitoring costs are shown as if all monitoring will take place in one 10-year window. Therefore, LOWRP costs here are a 'worst case', whereas the actual monitoring schedule is expected to be staggered over the LOWRP implementation schedule as shown in **Figure D-1** and would therefore cost the project less per year.

For each LOWRP project objective, monitoring has been identified to measure progress toward success of meeting the objective. **Table D-13** summarizes the project-specific monitoring and includes (1) monitoring attributes, (2) monitoring methodology and frequency, (3) monitoring cost estimates, (4) LOWRP monitoring locations, (5) Current MAP monitoring component (6) Current monitoring by other agencies/universities and (7) Performance Measures and ecological indicators. In **Table D-13**, LOWRP monitoring costs are shown as if all monitoring will take place in one 10-year window. Therefore LOWRP costs are a 'worst case', whereas the actually monitoring schedule is expected to be staggered over the LOWRP implementation schedule as shown in **Figure D-1** and would therefore cost the project less per year.

D.1.5.1 Adaptive Management Monitoring

Table D-11 summarizes the AM monitoring to address the prioritized uncertainties. The AM monitoring also covers some of the project-level monitoring described in **Table D-13** and is noted in where AM monitoring will also be used as project-level monitoring.

Table D-11. LOWRP AM monitoring cross-walked with other monitoring programs.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Proposed Sampling Frequency	Notes
1	Lake Okeechobee	Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	25	Abundances of ecological Indicators: <i>Chara</i> – nearshore 1km grid cell centers Cyanobacteria – three pelagic and one nearshore site Epipelton – three nearshore sites Epiphyton – around 20 nearshore sites, depends on amount of SAV Panfish – data collected from fishermen (creel surveys) SAV – nearshore 1km grid cell centers and 4 nearshore transects with 9 or 11 sites	\$0	All but panfish: \$201,610 (SFWMMD) Panfish: \$5,280 (FWC) Lake Imagery: \$75,000 (every 3 years, SFWMMD)	\$0	Annual summer: <i>Chara</i> , vascular SAV, nearshore SAV, cyanobacteria, littoral EAV Twice annually (spring and fall): epipelton and epiphytes Annual winter two-month panfish creel data	
1	Lake Okeechobee	Will fish and wildlife communities benefit from project's effect on lake stages or will additional habitat management be needed?	26	Wading birds, snail kites, fish	Wading bird nesting: \$100,000	Snail Kites: \$150,000 (USACE regulatory) Wading Bird Foraging: \$25,000 (SFWMMD) Fish: \$25,500 (FWC electrofishing)	\$0	Annual: wading bird and snail kite abundance and nesting effort/success, fish composition/catch rate/age distribution	
1/2	ASR	Will ASRs be able to deliver the recovery efficiency we are expecting?	5	Volumes of water recharged and recovered, measured daily, compiled monthly		Likely to be additional FDEP permitting costs not captured in this spreadsheet	This is a spreadsheet exercise assuming a regulatory requirement of accurate, continuous recordkeeping (of volume in vs. volume out) to be maintained by the project. Total \$100,000.00 per year	Daily, compiled monthly	The end point of this monitoring is to determine recovery efficiency and track any changes.
2	Estuaries	<u>Oysters</u> When flows from Lake Okeechobee (LO) are reduced and salinity regimes	12	Monthly at 18 existing RECOVER sites Growth Disease Predation	\$55,000	NA	\$0	Monthly at existing RECOVER sites	RECOVER oyster mapping was completed in 2019 and will be repeated approximately every five years.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Proposed Sampling Frequency	Notes
		improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted? Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project?		Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)					
2	Estuaries	<u>Submerged Aquatic Vegetation</u> When flows from Lake Okeechobee are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted? Will there be displacement / limitation of spat / SAV in the Caloosahatchee Estuary as a result of the project? Will anticipated salinity improvements result in natural recruitment / reestablishment of SAV?	16	Tier 1 - Landscape scale – aerial mapping every 2 years on the east coast Tier 2 - Patch-scale - species specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	\$200,000 every 2 years for Tier 1 mapping \$105,000 for Tiers 2 and 3	NA	\$0	Tier 1 - aerial mapping every 2 years Tier 2 - at the end of the dry and end of the wet season. Tier 3 –every other month from April through November	RECOVER maps SAV approximately once every five years, and through a partnership with SJRWMD the IRL gets mapped approximately every two years.
2	Estuaries	Will augmentation of substrate be needed if desired salinities are achieved and	23	<u>Substrate Type</u> Benthic map at 2 years and then every 10 years after Benthic maps available from 2011	NA	NA	\$75,000	Benthic map at 2 years and then every 10 years after	Depending on the timing, a RECOVER map may be available for use.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Proposed Sampling Frequency	Notes
		recruitment is still not at expected levels?							
2/3	ASR	Will ASRs increase mercury methylation in downstream sediments?	2	<p>Sulfate measured in recovered water at ASR wellheads and at representative surface water locations in the WAF and adjacent surface water bodies at watershed ASR clusters if required by permit</p> <p>Sulfate plumes, if they exist in receiving waters, should be defined if required by NPDES permit</p> <p><u>Additional Discussion needed</u> for frequency of MeHg fish tissue monitoring. One approach is to monitor MeHg in fish tissue in within the WAF or adjacent to watershed ASR clusters</p> <p>Alternatively, the frequency could be based on the triggers used in the CERPRA permit for the Kissimmee River ASR Pilot Project</p>	NA	<p>See Subsection C in "LOWRP 1-yr cost" Column (for MeHg sampling).</p> <p>The FWC, DOH, and FDEP conduct fish tissue monitoring every 7 years on Lake Okeechobee, so we can assume FWC will absorb sampling costs once every 7 years but the project will have to cover the other years. (i.e., \$10,000/year)</p>	<p>Total Max if all 3 below are done = \$238,000 (would be reduced in out years)</p> <p>A. For detailed ASR mercury information, see Table D-12.</p> <p>B. To delineate sulfate plumes would require a mixing model or more intensive release sampling downstream at various flow rates. A one-time cost of \$10,000 should be sufficient to determine this.</p> <p>C. Total analytical costs associated with methyl mercury fish tissue monitoring = \$10,000 maximum for each sampling event per year (5 bass per year per quadrant)</p>	<p>Year 1 Weekly during recovery</p> <p>Year 2+ Biweekly for two months and then monthly</p>	
3	ASR	Will project operations result in significant occurrences of fish entrainment?	3	<p>Number of entrained organisms.</p> <p>Sampling of entrained fish larvae will occur only at representative watershed ASR clusters where fisheries resources are well-defined. Fish entrainment studies are not necessary at WAF because all recharge and recovery will occur within the WAF.</p>	NA	NA	<p>Total cost for larval fish sampling (per year) is \$7,400 (\$6,400 for staff time and sampling and \$1,000 equipment and reporting).</p> <p>8 sampling events per year spread out amongst the spawning season to characterize the threat. Each event consists of one day sampling (up to 4 temporal samples, sampled</p>	<p>8 sampling days per year (based on an anticipated six-month recharge operations coinciding with the 4-5 month fish spawning season).</p> <p>When the risk is quantified, then frequency may be reduced in out years unless threat is mitigated (and sampling can stop).</p>	<p>Cost based on weekly sampling (while pumping during breeding season) but separated into 4 individual grab samples on that day for delineation of daylight vs nighttime entrainment. Maximum of 8 sampling days per year.</p> <p>Staff time cost based on previous uncertainty (i.e., #2) (\$400/day),</p>

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Proposed Sampling Frequency	Notes
							<p>immediately pre- and post-sunset and sunrise) (\$400); and one day (8 hours) identification time (\$400) to guild (invertebrate order or fish family) (assumes 2hrs processing per each of 4 samples).</p> <p>If any larval fish are entrained, then that indicates a potential problem to be adaptively managed.</p> <p>A test would include diurnal samples of recharged surface water within the wet well, after surface water has passed through the intake screen. Testing should occur at the times most favorable for spawning of representative fish species. Samples would be identified and quantified by an experienced freshwater biologist, with a report to document the results. Total cost of this study would be approximately \$100,000</p>		but Day 1 for collection and Day 2 for identification.
3	Invasive Species	How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?	17	% invasives, species composition	NA	NA, unless FWC wishes to take responsibility for management of exotic invasive species on the site (but this would only be for out-years, after construction is completed)	<p>Total costs for identification of an invasive plant problem would be minimal as activities under Uncertainty #46 will identify if a problem exists.</p> <p>If exotic plants need to be treated on the entire 4800 acres of wetland sites, then one-time spray costs = \$156,000. This cost is based on one \$80 jug of Round-up Pro Max will treat 2.46 acres.</p>	Annually.	<p>This is linked to Uncertainty #46 in that plant identification and mapping will guide the need for Adaptive Management here.</p> <p>We received another flat cost estimate of \$100 per acre for spraying and \$10 per acre for burning (which would be triple the cost in the column to the left)</p>

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-yr Cost	LOWRP 1-yr Cost*	Proposed Sampling Frequency	Notes
3	Wetlands	When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?	46	Water level (weekly) Plant diversity and abundance (annually)	NA	NA	Water level monitoring could be automated and relatively inexpensive in out-years (i.e., once installed). Installation = \$120,000 for 6 recorders. Annual O&M for all = \$3,000. Year one cost for hydrologic monitoring = \$123,000. Vegetation Monitoring costs will be dependent on the level of effort needed to determine success. The Uniform Mitigation Assessment Method (UMAM) will be needed to determine pre-restoration conditions, along with annual aerial photo-interpretation with GIS mapping, total Year-1 costs = \$14,800; (broken down in Notes column). Out-year costs reduced for aerial photo interpretation.	Water Level Weekly Plant Diversity and Abundance Annually	Assumes 4800 acres total. Six digital stage recorders (4 in Paradise Run and 2 in Kissimmee River-Center site). Each cost \$20,000 for installation and annually \$500 for data collection and Operations and Maintenance (O&M). GIS Mapping of Vegetative Groups at 6 locations (4 in Paradise Run, 2 in Kissimmee River-Center) = \$3,000. Aerial Photo Interpretation for Vegetation across entire sites once every 5 years = \$10,000. UMAMs pre-restoration (annual cost = 10 days for 3 staff; = 30 x \$60 = \$1800 for all acreage. Staff time = \$60/hr.
4	Water Supply	Will there be sufficient water availability to maintain Lake Okeechobee ecology during a drought?	41	Monthly average Lake Okeechobee stage	No field costs. Staff time for data evaluation.	No field costs. Staff time for data evaluation.	No field costs. Staff time to calculate and report the Lake Okeechobee Ecological Indicator Score during and after a drought event is ~2 hours. Total cost in a drought year = \$120.	Stage data is already routinely collected. No additional sampling is required.	

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Table D-12. ASR annual mercury costs.

LOCATION	Number of ASR Wells	Number of samples (recovery only)	Unit cost Mercury Analysis	Unit cost Methyl Mercury Analysis	Total Cost Mercury Analysis	Total Cost Methyl Mercury Analysis
WAF-Assisted ASR clusters	25	150	\$ 162.00	\$ 273.00	\$ 24,300.00	\$ 40,950.00
Watershed ASR clusters	55	330	\$ 162.00	\$ 273.00	\$ 53,460.00	\$ 90,090.00
Sub-total by species					\$ 77,760.00	\$ 131,040.00
Sum all Mercury Analyses						\$ 208,800.00

D.1.5.2 LOWRP Project-specific Monitoring

For each LOWRP objective, monitoring has been identified to measure progress toward success of meeting the objective. **Table D-13** summarizes the proposed (1) monitoring attributes, (2) monitoring methodology and frequency, (3) monitoring cost estimates, (4) monitoring locations, (5) current MAP monitoring component, (6) current monitoring by other agencies/universities, and (7) PMs and ecological indicators. The goal of project-specific monitoring is to detect the expected improvements from LOWRP features and operations.

D.1.5.2.1 Objective 1

Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often.

This objective has three main components: one is the amount of time Lake Okeechobee remains in the ecologically preferred envelope; another is the amount of time the lake is above the extreme high lake stage and the amount of time the lake is below the extreme low lake stage, and the third is the ecological response to lake hydrology. The nearshore and pelagic regions of Lake Okeechobee are occupied by a number of key ecological communities which can be used to evaluate the environmental health of the lake as a function of their responses to changing hydrologic conditions. For this objective, two attributes will be monitored: a) lake stage and b) ecological indicators (vascular SAV, *Chara*, panfish, cyanobacteria, epiphyton and epipelon). Lake stage data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**). Ecological indicator data will be leveraged from existing monitoring done by the SFWMD, but additional monitoring of panfish will be required for this project. The detailed field methodology to accomplish this objective will be described in more detail once LOWRP is authorized. Additional AM monitoring may be required and is discussed in **subsection D.1.6.2 and Table D-11**.

D.1.5.2.2 Objective 2

Improve estuary flows from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the Northern Estuaries.

Using LOWRP planning model output, areas have been identified within the Northern Estuaries where the most change is expected due to LOWRP. In these areas salinity conditions will improve the habitat for oysters and SAV, which will be the attributes to measure for project success in meeting Objective 2. For this objective, three attributes will be monitored: 1) Lake Okeechobee flows to the Caloosahatchee and St. Lucie Estuaries, 2) oyster abundance, health, and distribution; and 3) SAV shoot count, density, and canopy cover. Lake flow data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**). The monitoring methodology includes gage data at S-79 and S-80. Oyster and SAV data will be leveraged from the RECOVER MAP. Oyster data will include density, live and dead counts, growth, disease, predation, reproductive development, and recruitment. SAV data will include a nested, multi-tiered monitoring approach that looks at regional, patch, and shoot-level responses to environmental change, and may include aerial mapping, haphazard sampling within tessellated hexagons, and Braun-Blanquet densities, shoot counts, and biomass metrics as to better understand within-bed productivity, respectively. The detailed field methodology to accomplish this objective is described in the RECOVER MAP and will be described in more detail once LOWRP is authorized and the SAV protocol is approved by the RECOVER Executive Committee. Additional AM monitoring may be required and is discussed in **subsection D.1.6**.

D.1.5.2.3 Objective 3

Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.

Increased spatial extent of desirable wetland species will provide more appropriate and productive habitat (greater foraging space, better nesting habitat, etc.) which ties into and enhances the LOWRP goal of increasing the spatial extent and functionality of aquatic and wildlife habitat. This objective has three main components: water level, vegetation change, and biological indicators such as wading birds, aquatic fauna, and fish. The wetland restoration components are expected to restore wetland hydrology and increase the spatial extent of aquatic vegetation and wildlife. For this objective six attributes may be monitored: 1) water levels in the wetlands; 2) vegetation; 3) wading birds; 4) anurans; 5) small mammals; and 6) fish. Water level data will be leveraged from existing monitoring networks and the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**). Vegetation data may include percent coverage of native desirable species and percent coverage of invasive exotic or undesirable species through visual observation of species diversity and coverage in the two wetland restoration sites (Kissimmee River-Center and Paradise Run). Wading bird data may include total wading bird counts, species richness, species diversity, and nesting success. Anuran data may include species richness, species diversity, species occupancy, and water bodies for breeding. Small mammal data may include species richness, species diversity, and species occupancy. Fish data may include species richness, species diversity, migration/movement and age/size class. Detailed field methodology to accomplish this objective will be described in more detail once LOWRP is authorized. Additional AM monitoring may be required and is discussed in **subsection D.1.6** and **Table D-14**.

D.1.5.2.4 Objective 4

Increase availability of the water supply to the existing legal water users of Lake Okeechobee.

Monitoring for this objective is covered in the LOWRP Hydrometeorological Monitoring Plan (**Annex D, Part 3**).

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Table D-13. LOWRP project-specific monitoring cross-walked with other monitoring programs.

LOWRP Objective	Proposed LOWRP Monitoring Attributes	Proposed Monitoring Methodology	Proposed Number of Transects / Sampling Points	Proposed Monitoring Frequency	Proposed LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
<p>1 - Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often.</p>	<p>Abundance of ecological Indicators (<i>Chara</i>, cyanobacteria, epipelton, epiphyton, PanFish (bluegills and redear sunfish) and vascular SAV), as well as acreage of total SAV in nearshore and coverage of 9 EAV spp groups in littoral zone</p>	<p>–See Table D-11</p>	<p>See Table D-11</p>	<p>See Table D-11</p>	<p>See Table D-11</p>	<p>\$0</p>	<p>See Table D-11</p>	<p>NA</p>	<p>RECOVER Lake Okeechobee Ecological Indicator PMs Lake Stage Envelope PM Extreme High and Extreme Low Lake Stage PMs</p>	<p>The Ecological Indicator PMs target is a cumulative point score of 427 points over the 41 period of record (POR) lake stages The annual summer nearshore SAV target is 50,000 acres. The littoral EAV cumulative target is 28,825 hectares with four of the individual targets including a range that could be smaller and three including a range that could be larger. The annual sentinel sites cumulative target is 850 hectares with the same indicators having either smaller or larger ranges.</p>
<p>2 - Improve estuary flows from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the Northern Estuaries.</p>	<p>Oysters Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)</p>	<p>See Table D-11</p>	<p>See Table D-11</p>	<p>See Table D-11</p>	<p>See Table D-11</p>	<p>\$0</p>	<p>See Table D-11</p>	<p>Monthly oyster monitoring at 18 sites Growth Disease Predation Reproductive Development Recruitment Density; and Live and Dead counts (twice per year – spring and fall)</p>	<p>RECOVER Northern Estuaries Salinity Envelope PM RECOVER Oyster PM</p>	<p>Maintain a salinity range favorable to fish, oysters and submerged aquatic vegetation (SAV) 834 acres of live oyster habitat in the St. Lucie Estuary 500 acres of live oyster habitat in the Caloosahatchee Estuary.</p>

LOWRP Objective	Proposed LOWRP Monitoring Attributes	Proposed Monitoring Methodology	Proposed Number of Transects / Sampling Points	Proposed Monitoring Frequency	Proposed LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
2 -Improve estuary flows from Lake Okeechobee to improve the salinity regime and the quality of oyster, SAV, and other estuarine community habitats in the Northern Estuaries.	Submerged Aquatic Vegetation Tier 1 - Landscape scale – aerial mapping every 2 years Tier 2 - Patch-scale - species specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	See Table D-11	See Table D-11	See Table D-11	See Table D-11	\$0	See Table D-11	Fixed transects 3x/yr during growing season for monitoring Mapping 1x/3-5 years	RECOVER Northern Estuaries Salinity Envelope PM RECOVER SAV PM	Maintain a salinity range favorable to fish, oysters and submerged aquatic vegetation (SAV) SAV coverage
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Wetland Vegetation Percent cover of native desirable species Percent cover of invasive exotic or undesirable species	Visual surveys, UMAMs, and Aerial Photo Interpretation for Vegetation across entire sites once every 5 years.	A total of 12 transects in Kissimmee River Center (2 transects), Paradise Run (4 transects) and the WAF (6 transects).	Annually for transects, once every 5 years for photo interpretation and mapping	Kissimmee River Center (covered in AM Monitoring, Table D-11) Paradise Run (covered in AM Monitoring, Table D-11) 1BW WAF	For WAF an additional \$14,800 is needed for Year one. Years 2-5 = \$6,800 (annualized for 5 year deliverable)	None	None	UMAM Wetland vegetation	100% coverage with desirable wetland species
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Wading Birds and waterfowl Total wading bird count Species richness Species diversity Nesting success	Visual surveys Aerial surveys, count number of nests per species	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually / Monthly	Kissimmee River Center Paradise Run 1BW WAF	For Kissimmee Center, use existing SFWMD monitoring program for Kissimmee River (minimal cost to add on). For Paradise Run and WAF, expand RECOVER contract.	None	WAF and Paradise Run could be covered by current RECOVER contract (may require contract mod and small cost increase)	Wading bird usage of the restored site	Increase in the number of nesting birds. Wading bird recruitment and survival of offspring.

LOWRP Objective	Proposed LOWRP Monitoring Attributes	Proposed Monitoring Methodology	Proposed Number of Transects / Sampling Points	Proposed Monitoring Frequency	Proposed LOWRP Monitoring Locations	Estimated Annual Cost	Current Monitoring (Other)	Current Monitoring (RECOVER)	Performance Measures/Ecological Indicators	Monitoring Targets
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Anurans Species richness Species diversity Species occupancy Water bodies for breeding	Acoustic surveys Transect and pipe surveys Wet season dipnet sampling	Sites in Kissimmee River Center, Paradise Run and the WAF	Bi-annually Wet season breeding surveys	Kissimmee River Center Paradise Run 1BW WAF	\$25,000	None	None	Diversity and abundance of anurans	Anuran diversity and recruitment in the project area including reproduction and survivability of offspring
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Small mammals Species richness Species diversity Species occupancy	Camera tapping	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually	Kissimmee River Center Paradise Run 1BW WAF	\$20,000	None	None	Diversity and abundance of small mammals	A diverse mix of small mammal species
3 - Increase the spatial extent and functionality of aquatic and wildlife habitat within Lake Okeechobee and the surrounding watershed.	Fish Species richness Species diversity Migration/movement Age/size class	Seines, dip nets, electroshockers (non-lethal), cast nets	Transects in Kissimmee River Center, Paradise Run and the WAF	Bi-annually (mid and late wet season)	Kissimmee River Center Paradise Run 1BW WAF	\$20,000	None	None	Fish species diversity, abundance and seasonal variation.	Fish species diversity, recruitment and movement

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D.1.5.3 Biological Opinion Monitoring and Regulatory Monitoring

The LOWRP AMMP is to contain the monitoring and associated costs required under the BO and other agency permits that are needed to protect and conserve natural resources. The LOWRP AMMP will be updated accordingly when the BO is received and the FDEP and other agency permits are obtained. Additional regulatory monitoring will be added as required.

D.1.6 Implementation of LOWRP Adaptive Management

Adaptive management provides an interdisciplinary, integrated, structured process for lowering risk, increasing certainty and informing decisions. For AM to be successful in ensuring the delivery of intended benefits and avoiding unintended negative impacts of LOWRP, AM activities should continue beyond project planning for the entire project-life cycle from completion of the PIR through all aspects of monitoring, engineering, design, construction, operations, and maintenance components. In addition, mechanisms must be in place to collect, manage, analyze, synthesize, coordinate, and integrate new information into management decisions. Adaptive management implementation can only succeed when decision makers have sufficient funding and staffing resources to implement the AM and monitoring plans. In addition, success requires political and stakeholder support to implement the AM decision methodology and to adjust management decisions based on what is learned.

Per the Programmatic Regulations for the Comprehensive Everglades Restoration Plan (2003), an AM process has been developed for CERP that guides system-wide CERP AM and project-level AM (CGM 56 2010; RECOVER 2011b). This detailed CERP guidance adheres to WRDA 2007 and the WRDA 2007 implementation guidance provided by USACE in 2009 in that it focuses on using monitoring information to inform projects and project components by resolving uncertainties and providing mechanisms to efficiently incorporate new knowledge in project planning, design, and implementation. LOWRP has and will use this framework to implement AM. Doing so will allow LOWRP to both take advantage of and contribute to work being done system-wide and by other projects. Because new information is continually becoming available, the LOWRP AMMP must be recognized as a living document that is improved upon through incorporation of new information. In particular, as each project component is designed and implemented, specific AM strategies and monitoring should be reviewed and adjusted as necessary.

To facilitate implementation of the LOWRP Adaptive Management Plan, RECOVER scientists will coordinate the AM monitoring, analysis, and reporting throughout the life of the project. RECOVER will include expertise from multiple agencies and disciplines, such as, hydrologists, engineers, and water managers; in other words, while RECOVER will be the central organizing entity of the AM monitoring, analysis, reporting, and elevating of options to adjust LOWRP, RECOVER will continually coordinate with others to ensure that a full suite of experts is included. RECOVER scientists will coordinate with project managers to inform possible AM actions as outlined in subsequent sections. LOWRP project funds during PED, construction, and operations and maintenance will support RECOVER's coordination efforts and the AM strategies described in this LOWRP Adaptive Management Plan. LOWRP funds will be used to fund monitoring directly related to LOWRP AM monitoring needs and the funds are not designed to replace RECOVER's system-wide monitoring and science efforts. However, the RECOVER system-wide monitoring information will be used in combination with LOWRP's monitoring to best address key questions about achieving restoration success. The intent is to have complementary efforts that maximize efficiency of monitoring. RECOVER will be responsible for ensuring that the AMMPs are implemented and that the

information is appropriately managed and integrated into the CERP decision process as outlined in the Adaptive Management Integration Guide (RECOVER 2011b).

This section identifies which AM activities will occur during the phases of LOWRP project implementation and how they relate back to the project's AM plan. Unless otherwise noted RECOVER will be engaged in all activities. Adaptive management will be reiterated in the coming phases of LOWRP, and the Adaptive Management Plan will be reviewed and updated. At such time, more baseline data and lessons learned will be available from other monitoring programs and restoration projects. Given the new knowledge, key questions, monitoring thresholds/triggers, and AM options proposed in this plan may need refinement. Therefore, items included in this plan are not guaranteed to be included or funded as-is, but will be refined and considered again prior to LOWRP implementation.

Adaptive management was incorporated during LOWRP's planning with AM experts integrally involved throughout the planning process. All of the items in the CERP "Project Level Adaptive Management Checklist" were considered and/or incorporated during the planning of LOWRP. CEMs were used for the other project areas including Lake Okechobee, Northern Estuaries, and the total system (<http://141.232.10.32/pm/recover/cems.aspx>). A cost effectiveness/incremental cost analysis of the future AM options was not conducted due to time constraints during planning. Adaptive management activities on the checklist that will take place during and after the project's implementation are described here in the Adaptive Management Plan (CERP AM checklist: http://141.232.10.32/pm/program_docs/adaptive_mgmt.aspx#p7HGMpc_1_2). The following subsections identify how AM has been and will be incorporated into each LOWRP project phase: planning, design, construction, and operations and maintenance.

D.1.6.1 How Adaptive Management Activities Were Applied During LOWRP Planning

Concerns and uncertainties were identified in an initial step for LOWRP, discussed throughout the USACE "In Progress Review" meetings, and discussed throughout the interagency and public participation process. During screening of management measures to develop alternative plans, screening criteria included flexibility (the speed, ease, efficiency that a management measure could move water to adjust to changing real-time conditions such as storms or extreme events), robustness (the ability to function effectively in the face of broad-scale, uncertain future conditions such as climate change [NRC 2007]), and future compatibility (the efficiency with which this management measure or configuration would complement future restoration work). Finally, a broadly invited interagency team developed the AM plan to prioritize the remaining uncertainties and describe in the plan how they may be addressed through the life of LOWRP and inform CERP implementation.

Overall, the inclusion of AM principles during this study provided several avenues to address and reduce risks and uncertainties and, during its continued implementation in the following phases of LOWRP, will provide a mechanism to continue LOWRP's achievement of its vision, goals, and objectives and effectively remain within its constraints.

D.1.6.2 How Adaptive Management Activities Will Be Applied during LOWRP Implementation

RECOVER will work with the LOWRP 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 AM strategies identified in the Annex D. At a minimum, one RECOVER scientist should be dedicated to oversee all coordination of the LOWRP monitoring and AM efforts. Additional technical expertise should be engaged as needed. AM activities will be implemented in sequence with the

project components being implemented (see **Table D-1**). 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 LOWRP dependency constraints (state and federal projects required prior to implementation of a specific LOWRP project component). Time needed to conduct certain AM activities and tasks to inform subsequent project component is incorporated in the LOWRP implementation schedule and the Strategies section of the LOWRP Adaptive Management Plan. Each AM 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 LOWRP implementation. **Figure D-1** shows that AM 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 AM purposes, as described in the AM 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 AM strategies or made to the next set of LOWRP project components. The information can also be used to inform future CERP projects.

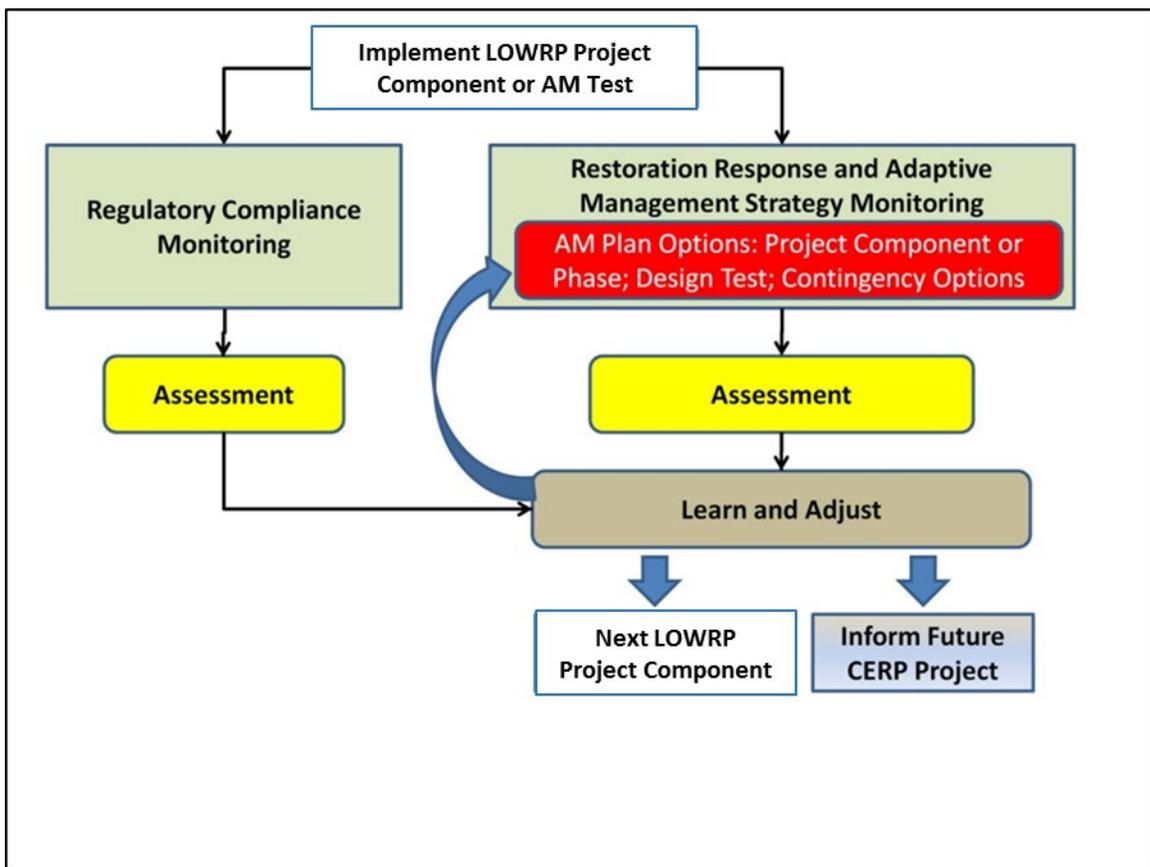


Figure D-1. Adaptive management strategies and project implementation diagram.

Adaptive management during LOWRP'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, AM strategies will need to be implemented in sequence with the project schedule.

D.1.6.3 Design

AM activities will also be executed during the preconstruction engineering and design (PED) phase of the project. Adaptive management strategies that may involve pilot projects (ASR), operational tests, and phased implementation and 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 LOWRP AM will coordinate with the LOWRP engineers and water managers to ensure project designs, tests, and project operations manual allow flexibility for AM 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 AM 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 LOWRP project components is completed.

D.1.6.3.1 Monitoring and Experimental Design

RECOVER, other agency monitoring, and other contracts that are being relied upon to inform the LOWRP implementation as identified in the AMMP will be reviewed to determine if changes in scope and frequency are needed to better capture LOWRP effects. The activities described here fall within the approved LOWRP AM budget. LOWRP specific monitoring identified in the monitoring and AM 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 LOWRP project hypotheses (AM triggers needed for NE SAV and oysters, **D.4.2.1** and **D.4.2.2**). 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. LOWRP 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.

D.1.6.3.2 Baseline Monitoring

In cases where there is not sufficient pre-project data monitoring, contracts will need to be initiated prior to construction of specific LOWRP components. 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 AM plan.

D.1.6.3.3 Pre-construction Engineering and Design

Project component designs will be developed and coordinated with RECOVER to ensure project component designs are consistent with the testing objectives identified in the AM plan strategy. Further data analysis or review of other project design and monitoring information may be required to inform the design of LOWRP project components (e.g., WAF, ASR, and wetland restoration 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 AM plan. RECOVER LOWRP 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.

D.1.6.3.4 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 AM 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 LOWRP points of contacts, as well as regulatory agencies, to coordinate with the AM strategies outlined in the PIR monitoring and AM plan and with regulatory permit requirements.

D.1.6.4 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 AM plan. Schedules and implementation should include monitoring and operational tests consistent with the AM strategies described in the AM plan in order to learn from project component implementation. In some cases, when agreed to by the implementing agencies, AM 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.

D.1.6.5 Post-construction Monitoring and Operations, Maintenance, Repair, Replacement, and Rehabilitation

This subsection discusses how AM will handle post-construction monitoring and OMRR&R.

D.1.6.5.1 Post-construction Monitoring

The LOWRP 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 AM 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 LOWRP 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 LOWRP operations or construction of subsequent project components.

D.1.6.5.2 Post-construction Assessment, Reporting, and Linking to Decision-making

The LOWRP assessment results will be reported to the implementing agencies and LOWRP partner agencies as part of the RECOVER system-status report, South Florida Environmental report, or more frequently as 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).

Monitoring results will be reported in the context of the triggers/thresholds identified in the AM 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 LOWRP implementing agencies and associated regulatory agencies with suggestions of management options to implement, as stated in the AM plan management options matrices (MOM), 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 LOWRP 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 annually.
2. NEPA Covered Options, No Modeling Needed: LOWRP AM 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: LOWRP AM plan options that are covered by NEPA but may require model runs to determine best option;
4. Not NEPA Covered: LOWRP AM 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 LOWRP AM plan: In some cases, the monitoring results may indicate the need for an option not identified in the AM plan or PIR/EIS. This may result in agency-approved temporary adjustment to LOWRP 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 AM plan MOMs need to be implemented.

D.1.7 LOWRP Adaptive Management Plan Cost Estimate

Identification of the LOWRP monitoring contained in Annex D was guided partly by two objectives. First, it must be complete from a LOWRP perspective in that it must provide the monitoring required to address LOWRP-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 ensure cost-effectiveness. These two objectives guided development of the AMMP, hydrometeorological monitoring plan, and the water quality monitoring plan. Where possible, LOWRP 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 LOWRP Adaptive Management and Monitoring plan is limited to the additional, marginal increase in monitoring resources and analysis efforts needed to address LOWRP-specific questions. It is assumed that the monitoring programs will continue for at least the time needed by LOWRP. The cost estimate for the AM monitoring and project-specific monitoring can be found in **Table D-14**. **Table D-15** presents the cost estimate for all parts of the LOWRP AMMP, including AM monitoring, project-level monitoring, water quality monitoring, hydrometeorological monitoring, required USFWS Biological Opinion monitoring, and other required regulatory monitoring.

Table D-14. Adaptive management and monitoring cost estimate.

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
1	Lake Okeechobee	Will ecological indicators respond to lake stage changes as their PM scores suggest? (i.e., are the PM scores indicative of ecological responses?)	AM 25	Abundances of ecological Indicators (<i>Chara</i> , cyanobacteria, epipelon, epiphyton, PanFish (bluegills and redear sunfish) and vascular SAV), as well as acreage of total SAV in nearshore and coverage of 9 EAV spp groups in littoral zone	\$0	\$206,890	\$0
1	Lake Okeechobee	Will fish and wildlife communities benefit from project's effect on lake stages or will additional habitat management be needed?	AM 26	Wading birds, snail kites, fish	\$100,000	\$200,000	\$0
1/2	ASR	Will ASRs be able to deliver the recovery efficiency we are expecting?	AM 5	Volumes of water, measured daily, compiled monthly	\$0	\$0	\$100,000
2	Estuaries	Oysters - When flows from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted	AM 12	Monthly at 18 existing RECOVER sites <ul style="list-style-type: none"> • Growth • Disease • Predation • Reproductive Development • Recruitment • Density; and Live and Dead counts (twice per year – spring and fall) 	\$236,000	\$0	\$0

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
2	Estuaries	Submerged Aquatic Vegetation - When flows from LO are reduced and salinity regimes improved, will species' abundance and diversity in the estuaries increase, or will consideration of supplemental habitat enhancements be warranted?	AM 16	Tier 1 - Landscape scale – aerial mapping every 2 years Tier 2 - Patch-scale - species-specific cover and abundance at the end of the dry and end of the wet season. Tier 3 – Fixed-point sampling – cover, abundance, shoot density, canopy height, above and below ground biomass - sampling occurs every other month from April through November	\$102,000	\$0	\$0
2	Estuaries	Will augmentation of substrate be needed if desired salinities are achieved and recruitment is still not at expected levels?	AM 23	Substrate Type	\$0	\$0	\$75,000
2/3	ASR	Will ASRs exacerbate mercury methylation in adjacent sediments?	AM 2	Sulfate measured in recovered water at ASR wellheads and at representative surface water locations in the WAF and adjacent surface water bodies at watershed ASR clusters	\$0	\$0	\$238,000

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
3	ASR	Will project operations result in significant occurrences of fish entrainment?	AM 3	Number of entrained organisms. Not needed if intake pumps are not operating (i.e., during storage and recovery) and assuming no other significant fishery risk is evident (i.e., fish are trapped in the intake even though pumps are not operational).	\$0	\$0	\$100,000
3	Invasive Species	How will new hydrologic regimes affect the occurrence of invasive species in restored wetlands?	AM 17	% invasives, species composition	\$0	\$0	\$60,000
3	Wetlands	When wetlands are restored, will wetland vegetation return or will consideration of supplemental habitat enhancements be warranted?	AM 46	Water level and plant diversity and abundance (annually)	\$0	\$0	\$120,000
4	Water Supply	Will there be sufficient water availability to maintain LO ecology during a drought?	AM 41	Monthly average Lake Okeechobee stage	\$0	\$0	\$5,000

LOWRP Objective	Category or Specific LOWRP Area	Uncertainty or Project PM	AM ID# or PM	Proposed Attributes to be Monitored	Ongoing RECOVER 1-Yr Cost	Ongoing Other Agency 1-Yr Cost	LOWRP 1-yr Cost*
3	Wetlands	Project Performance	PM 1	Wading Birds and waterfowl <ul style="list-style-type: none"> • Total wading bird count • Species richness • Species diversity • Nesting success 	\$0	\$0	\$50,000
3	Wetlands	Project Performance	PM 1	Anurans <ul style="list-style-type: none"> • Species richness • Species diversity • Species occupancy • Water bodies for breeding 	\$0	\$0	\$25,000
3	Wetlands	Project Performance	PM 1	Small mammals <ul style="list-style-type: none"> • Species richness • Species diversity • Species occupancy 	\$0	\$0	\$20,000
3	Wetlands	Project Performance	PM 1	Fish <ul style="list-style-type: none"> • Species richness • Species diversity • Migration/movement • Age/size class 	\$0	\$0	\$20,000
Total Annual Adaptive Management and Ecological Monitoring Costs					\$438,000	\$406,890	\$813,000

Table D-15. Total cost estimate for AM, project-level, water quality, hydrometeorological, and Biological Opinion.

Part	Annual (1-Year)	2-5-Year	10 –year	6 to 50-Year
AMMP	\$853,000	\$4,265,000	\$8,530,000	N/A
WQ	\$492,978	\$1,204,988		\$12,474,296
Hydro	\$ 1,323,900	\$6,619,500		\$66,195,000
BO	\$250,000	\$1,250,000		N/A
Total	\$2,919,878	\$13,339,488	\$8,530,000	\$76, 846,504

D.1.8 LOWRP Screened Uncertainties

Table D-16 lists the uncertainties screened out of the AM plan. Reasons for screening out suggested uncertainties included lack of direct relevance to project objective or constraint, low ratings in the screening criteria (Tier 3) described earlier in this plan, inappropriate scale for LOWRP (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 LOWRP performance by understanding more about the uncertainty, or simply that the uncertainty was already covered by another that had been suggested (duplicates).

Table D-16. Uncertainties screened from the AM Plan.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
#23, 24	Lake Okeechobee	Are we meeting lake stage envelope with projected frequency?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#1	ASR	Will temperature of ASR release alter fish spawning patterns?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#4	ASR	Are ASRs having expected effects on groundwater levels?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#16	Fauna	Will displacement of upland species (T&E and others) from reservoir footprint result in impacts to adjacent landowners?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#30	Reservoirs	If ideal design is implemented and negative impacts to fish / other spp. occur, are there other options that could be implemented to offset those negative effects?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
#35	Water Quality	Will the project result in mobilization of pollutants (i.e., N, P) from reservoir / wetland sites?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
42	Water Supply	Will there be unanticipated changes in water levels that impact existing level of service to nearby residential areas?	Not screened out initially, went through the prioritization process.	Tier 3 of prioritization so not carried forward.
6	Climate Change	Will a major storm event overwhelm the flows to reservoirs and flows to estuaries?	If a severe weather event overwhelms reservoirs, AM strategies may not be feasible / effective, and may be secondary to health and safety concerns.	AM not feasible.
7	Climate Change	Climate change effects on water supply and reservoir operations	Depending on context this may be a program- or system-scale uncertainty; what AM strategies could be implemented to offset climate change at a project level?	System-wide, not project-level AM.
8	Climate Change	Will project changes offset SLR effects? How will it affect what we are trying to do?	Depending on context this may be a program- or system-scale uncertainty; what AM strategies could be implemented to offset climate change at a project level?	System-wide, not project-level AM.
9	Engineering	How will the southern reservoir affect this project?	Effects from outside projects would be addressed under their respective scopes.	Not project-level.
10	Engineering	Reservoir - will there be seepage through the berm of the reservoir?	Strategies to address seepage may not fall under AM Plan; concern to be reported to Engineering team.	Engineering design concern - covered in PED, not AM.
11	Engineering	Reservoir - will there be seepage into the groundwater table?	Strategies to address seepage may not fall under AM Plan; concern to be reported to Engineering team.	Engineering design concern - covered in PED, not AM.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
15	Estuaries	How will Lake O water quality affect our ability to restore the estuaries?	Water quality is not an objective of the project.	Not project-level.
27	Land Use	Land use in the watershed outside of the project features.	This may exceed project scale, and would be addressed under NEPA.	Not project-level and project-level uncertainties covered in the PIR/EIS under NEPA.
28	Operations	How will a change in lake regulation schedule affect this project?	This would be addressed during Plan Formulation.	Addressed during plan formulation.
29	Reservoirs	Maintain reservoir levels - drought, dry season, wet season.	Need additional info / specific question; none proposed by team in subsequent discussions.	No specific uncertainty identified.
24	Lake Okeechobee	Extreme high and low - duration and frequency.	Discussed during teleconferences; concept merged with uncertainties 23 and 25.	Merged with Uncertainties #23 and 25.
31	Reservoirs	Will there be recreational access to the reservoirs?	This would be addressed under NEPA.	Not an AM uncertainty - addressed in the PIR/EIS.
32	Reservoirs	Buffer lands around the reservoirs to protect uplands in the area.	This would be addressed during project design.	Not an AM uncertainty - addressed during PED.
33	Reservoirs	Effect of reservoirs on groundwater levels.	There is existing knowledge / modeling for anticipated effects to groundwater levels. Also, how would this be related back to at least one of the stated objectives or constraints?	Not tied directly to a project objective or constraint.
34	Reservoirs/Wetlands/Fauna	Impacts to uplands/wetlands in reservoir footprints.	This would be addressed under NEPA.	Not an AM uncertainty - addressed in the PIR/EIS.

Uncertainty ID #	Category	Risk or question or uncertainty	Meeting notes and discussions	Rationale of uncertainty removal
39	Water Quality	Nutrient inflows into Lake Okeechobee.	Need additional info / specific question; none proposed by team in subsequent discussions.	No specific uncertainty identified and not at a project-level.
43	Wetlands	Ability of engineering the wetlands to provide the hydrology for our endpoint.	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed during PED.
44	Wetlands	Impacts of reservoirs on adjacent and nearby wetlands	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed in the PIR/EIS.
45	Wetlands	Will there be short-circuiting due to the wetlands?	Need additional info / specific question; none proposed by team in subsequent discussions.	Not an AM uncertainty - addressed in the PIR/EIS.
47	Wetlands/Estuaries/Lake	How do habitat changes unrelated to the project affect restoration?	Outside project scope.	Not in project scope.
48	Wildlife	Will species (T&E) impact our ability to manage the features for the benefit of the project?	This will be addressed under NEPA / ESA section 7 consultation.	Not an AM uncertainty - addressed in the PIR/EIS and under Section 7 ESA consultation.

D.1.9 Adaptive Management Plan References

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ATTACHMENT 1: SUMMARY OF COMMENTS/RECOMMENDATIONS FROM THE NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES TO THE CERP ASR REGIONAL STUDY

Summary comments and recommendations are presented by category as listed below.

Operations to Maximize Recovery

- o Improve/understand cycle tests to increase recovery efficiency
- o Establish and maintain freshwater buffer zone during cycle testing
- o Operate multi-well pairs and clusters to improve performance
- o Locate ASR systems adjacent to large water bodies to allow for adequate mixing zones

Ecotoxicology and Ecological Risk Assessment

- o Continue chronic toxicity testing at points of release using larger, longer storage and recovery volumes
- o Additional bench-scale chronic toxicity testing, using recovered water from multiple ASR sites should be undertaken, including changes in hardness and how that affects toxicity to sensitive aquatic species
- o Examine the in-situ and community-level impacts of recovered water calcium and hardness on soft-water areas of the Everglades. These studies should also consider both bioaccumulation as well as potential shifts in community composition
- o Prolonged bioconcentration studies using mussels, periphyton and/or aufwuchs should be conducted
- o A more refined ecological risk assessment should be conducted using more robust data from multiple sites, probabilistic in nature, using modernized quantitative methods

Water Quality

- o More research is needed to understand the impacts of different source water qualities on the long-term redox evolution of the aquifer and its effect on arsenic mobilization
- o Need to determine how far arsenic can be transported within the aquifer using extended (> 1 year) cycles and development of a buffer zone
- o Need to determine how development of a buffer zone can be utilized to reduce sulfate concentrations in recovered water or determine limits on recovery based upon sulfate concentrations
- o Further modeling on the fate of sulfate in recovered water should be conducted, along with additional study on the temporal and spatial variability of sulfate and mercury methylation in Lake Okeechobee is warranted
- o More understanding on the spatial variability of gross alpha and radium at future ASR locations should be addressed during longer term testing

Understanding Phosphorous Reduction Potential

- o More research into long-term nutrient removal mechanisms and rates under varying aquifer conditions should be undertaken

Disinfection/Treatment Technology

- o Examine treatment technologies to consistently meet regulatory requirements
- o Develop appropriate pretreatment strategies to attenuate arsenic mobilization
- o Continue research on subsurface pathogen inactivation using wider array of pathogens
- o Couple pathogen inactivation studies to groundwater travel times and distances using local scale groundwater modeling

Cost and Performance of ASR Compared to Alternatives

- o A comparative cost-benefit assessment of integrated operation of ASR wells with surface storage reservoirs should be undertaken

Future Construction and Testing

- o More local scale information is needed on the attributes of the APPZ, including a groundwater model to assess storage effects on the APPZ
- o Local-scale groundwater modeling should be undertaken to refine uncertainties about aquifer heterogeneity and anisotropy, travel times, and analysis of potential fracturing
- o The effects of aquifer anisotropy should be assessed, including the consideration of orienting recovery wells along the direction of preferential groundwater flow
- o Consider the use of tracer studies to determine hydraulic flow directions to properly orient/locate monitoring wells
- o Consider the use of cross-well seismic tomography and regional seismic evaluation to assess the effects of tectonic faults on well location and performance
- o Analysis of optimal wellfield cluster configurations and well spacing should be undertaken to promote maximum recovery efficiency
- o Additional analysis of injection pressures on the propagation of fractures should be undertaken, perhaps using step-rate tests that assess injectivity as a function of injection pressure

PART 2: WATER QUALITY MONITORING PLAN

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D.2 Introduction to the LOWRP Water Quality Monitoring Plan

This document serves as a preliminary reference for monitoring surface and ground water quality for the LOWRP. Monitoring will be conducted to evaluate the LOWRP's performance with regard to restoration goals and regulatory compliance. Specifically, the project is intended to improve the quantity, timing and distribution of water entering Lake Okeechobee; provide for better management of lake water levels; reduce high volume flows to the Caloosahatchee and St. Lucie estuaries (collectively referred to as the Northern Estuaries) from Lake Okeechobee; improve system-wide operational flexibility; increase the spatial extent and functionality of wetland habitat; and improve water supply to existing legal water users of Lake Okeechobee. The area of the Recommended Plan extends east from the C-40 canal to the Kissimmee River and includes the Paradise Run wetland, Kissimmee River Center wetland and watershed ASR wells. The LOWRP above ground storage feature and proposed wetlands are located in the northwestern side of the Lake. The Recommended Plan also includes 80 ASR wells See **Figure D-2** for a map of the project. The plan is organized into three geographic areas: Lake Okeechobee Watershed, Lake Okeechobee, and the Northern Estuaries.

D.2.1 Project Description

The LOWRP project features include the following elements:

1. Wetland Attenuation Feature
 - a. The WAF is primarily used for surface water storage to attenuate peak flows into Lake Okeechobee from the Kissimmee River basin.
2. Aquifer Storage and Recovery Wells
 - a. A total of 80 ASR wells are proposed. The wells will utilize the UFA and the APPZ for storage and recovery.
 - b. Wetland attenuation ASR wells are used to increase the total storage capacity of the WAF. There are 25 wells co-located with the WAF. The wells will utilize the UFA and the APPZ for storage and recovery. It is anticipated that the ASR wells will support maintenance of wetland habitat during dry periods to minimize the risk of dryout in the WAF is minimized.
 - c. Watershed ASR wells: The remaining 55 ASR wells are located at sites adjacent to flowing surface water throughout the watershed.
3. Wetland Restoration Sites
 - a. A pump station on the C-41A canal downstream of S-84 serves as the water source for Paradise Run wetland rehydration.
 - b. A pump station on the Kissimmee River north of S-65E serves as the water source for the Kissimmee River Center wetland rehydration.

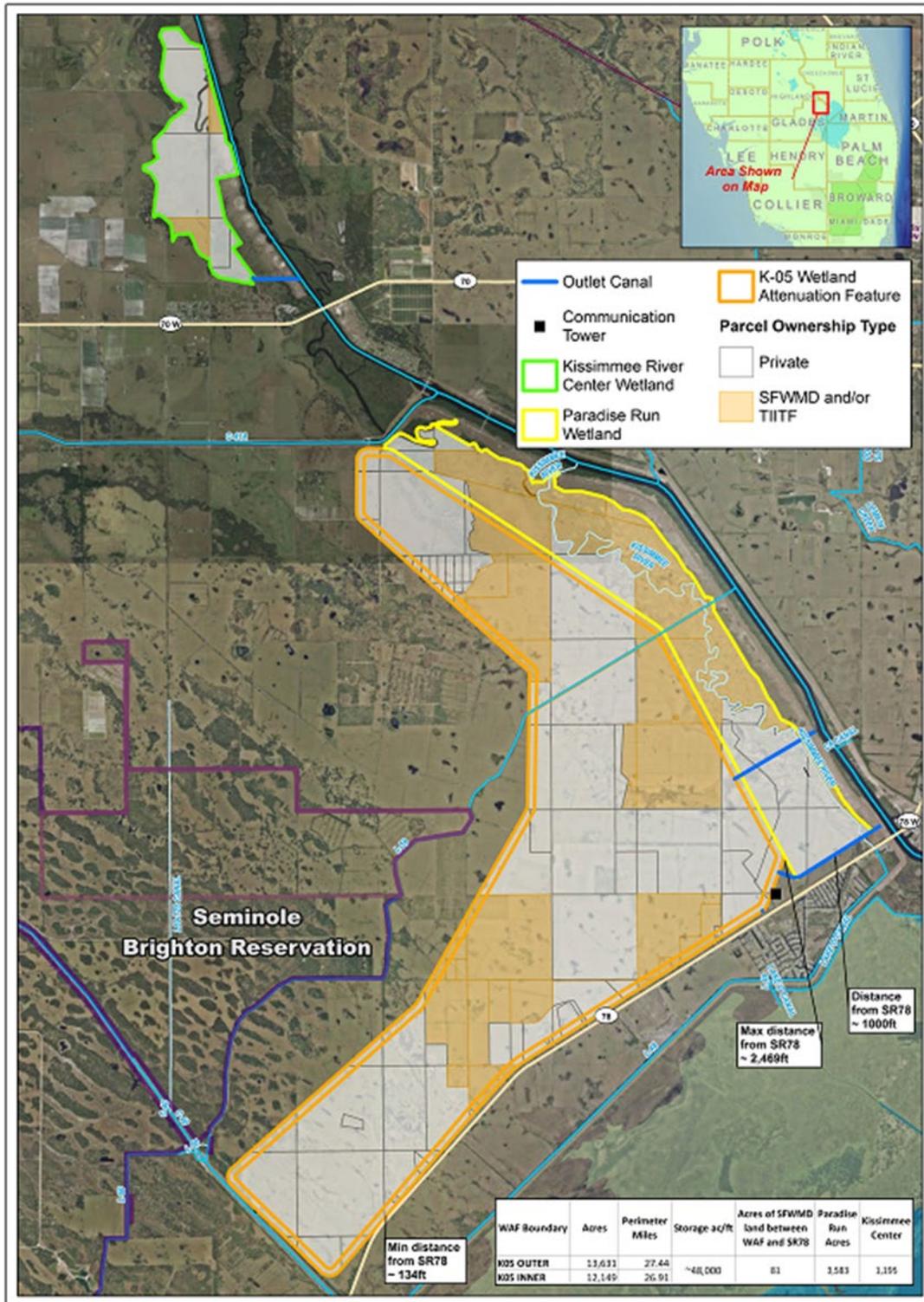


Figure D-2. LOWRP footprint map.

D.2.2 Water Quality Monitoring Objectives

The monitoring stations described in this document are referenced to satisfy requirements of the LOWRP and 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, Under Ground Injection Well permit (UIC) and an Industrial wastewater discharge permit (point source NPDES permit). This plan provides a preliminary outline for quantifying the quality of surface water entering and downstream of the project area for a period of ten years. This plan may be updated to meet permit requirements as necessary. The final monitoring plan for the ASR and surface water facilities will be developed during the permitting process.

Surface water samples have been collected and analyzed for multiple constituents and at various frequencies within south Florida from stations adjacent to or nearby the targeted project features. These baseline data are compiled in the SFWMD's DBHYDRO database (<https://www.sfwmd.gov/science-data/dbhydro>) and in the annual South Florida Environmental Report (SFWMD 2018). The U.S. Geological Survey also collects surface water quality data in this region that may be relevant to the project as baseline data. To access relevant data, contact the program manager at the SFWMD.

Historical groundwater quality data also have been collected from wells open to the surficial aquifer system (SAS), the UFA, and the APPZ. These data also appear in DBHYDRO, in the U.S. Geological Survey National Water Information System database, in the CERP technical data reports for the ASR pilot systems, and in technical reports documenting exploratory borehole construction and testing in the FAS.

The water quality data obtained under this program will be used for these purposes:

1. Evaluate water quality status and trends.
2. Assess compliance with federal and state water quality statutes, comply with permit monitoring requirements, the Everglades Forever Act, and the applicable Everglades Consent Orders.
3. Guide mid- and long-term resource management decisions as part of the adaptive management plan for the project.

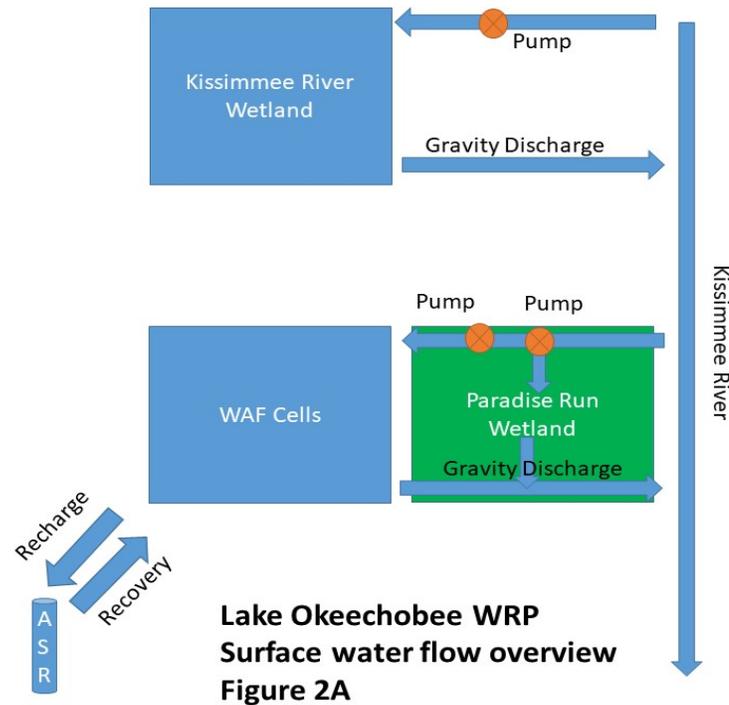
D.2.3 Surface Water and Groundwater Quality Monitoring

The goal of surface water quality monitoring is to ensure that surface water quality released into the Kissimmee River will not be negatively impacted by the project and is in compliance with applicable state and federal water quality standards. 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 WAF or ASR clusters is in regulatory compliance. The water quality monitoring plan presents a conceptual outline for surface water and groundwater monitoring in relation to the operation of the WAF and ASR and their subsequent releases into adjacent waterways.

D.2.3.1 Surface Water Quality Monitoring

Surface water on the site will be pumped into the WAF from the Kissimmee River. Flow out of the WAF will pass via a culvert back into the Kissimmee River or into the seepage management canal that surrounds the WAF. Surface water from the WAF will be conveyed to the northern portions of Paradise Run for wetland rehydration via gated spillways. Surface water will be monitored at the intake and outflow structures of the WAF and at culvert release structures to Paradise Run. Surface water quality criteria are

defined in the Clean Water Act and also Florida Administrative Code (FAC), Chapter 62-302, Surface Water Quality Criteria. The final surface water quality monitoring plan (location of monitoring points, frequency of sampling, and required analytes) will be developed during the permitting process. See Figure D-2A for the current general surface water routing concept for this project.



D.2.3.2 Groundwater Quality Monitoring

Groundwater quality at ASR clusters is typically monitored during recharge, storage, and recovery phases. The most intensive monitoring periods are during recharge and recovery. Groundwater quality monitoring criteria for ASR clusters are defined in the Safe Drinking Water Act and in FAC Chapter 62-528, Underground Injection Control, during recharge and Chapter 62-302, Surface Water Quality Criteria, during recovery. In the project area, 25 ASR wells are located within the footprint of the WAF and 55 ASR wells are located in clusters throughout the watershed.

Figure D-3 presents the conceptual locations of ASR well clusters. This monitoring plan is preliminary because the actual ASR well locations and numbers of ASR and monitoring wells will be configured based upon the results of exploratory wells. The ASR wells will be arranged in well pairs, to have vertically “stacked” underground storage zones in the UFA and the deeper APPZ. In this configuration, efficiencies in ASR facility design and costs will be achieved by co-locating wells.



Note: Red circles denote watershed ASR clusters; yellow circles denote WAF ASR clusters. ASR cluster locations are considered preliminary.

Figure D-3. Recommended Plan Features.

When ASR clusters 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 clusters will commence, with recharge, storage, and recovery durations linked to watershed flows and water levels within the project area and operation of the WAF.

During recharge into the ASR wells (both WAF and watershed systems), 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 clusters. 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. Actual sampling locations and frequencies are typically determined during the permitting process.

During recovery, water quality monitoring takes place to assure that surface water quality is not negatively impacted by water released 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 are typically determined during the permitting process. For the WAF wells, water recovered from the ASR wells may be routed back into the WAF storage volume to optimize operation of the combined system. Water quality monitoring of the release from the WAF will take place as described in **subsection D.2.3.1**.

D.2.3.3 Surface and Groundwater Quality Monitoring during ASR Cycle Testing

A final surface water and groundwater monitoring plan for ASR cycle testing will be developed during the permitting process. A preliminary surface and groundwater monitoring plan was developed for cost estimation purposes. This monitoring plan was developed in conjunction with the draft Project Operating Manual. **Table D-17** shows the surface water quality monitoring costs. Reference **subsection D.3.9** for Groundwater Quality Monitoring strategy and estimates.

D.2.4 Surface Water Quality Monitoring Cost Estimate

The following information describes the minimal surface water monitoring needs for the three surface water impoundment cells, within the WAF, included in the LOWRP Recommended Plan. The purpose of the surface water quality monitoring is to address the expected surface water regulatory monitoring requirements and the startup monitoring required for mercury/toxicants required by CGM 42. The two natural wetland areas without significant previous agricultural activity (Kissimmee River Wetland and Paradise Island Wetland) that will be rehydrated by the project from Kissimmee River water are assumed to not fall under the requirements of CGM 42 and therefore will not require water quality startup or routine water quality monitoring. The SFWMD is in the process of finalizing evaluation of the project lands for HTRW and legally applied residual agricultural amendments. Some remediation may be conducted by the SFWMD (removal of above ground fuel tanks, etc., if necessary). Pending any new information acquired from that investigation (to be completed before start of any construction activity), the surface water quality monitoring plan may have to be revisited and potentially amended. Based on the final results of the SFWMD investigations additional surface water quality monitoring may be required to include the wetland area. The final surface water quality monitoring plan will be developed during the permitting process.

D.2.4.1 Wetland Attenuation Feature and Wetland Restoration Areas

Development of the surface water monitoring features for this project is based on measurement of inflow and release points for each feature, making six total monitoring points for the three internal WAF cells. The primarily natural wetland areas (Kissimmee River Wetland and the Paradise Run Wetland that will be rehydrated by the project) are not expected to be monitored for water quality but are currently planned to be monitored for vegetation response (not included in the surface WQ monitoring plan). It is also assumed there is startup monitoring for mercury/toxicants and that monitoring will be suspended after 5 years for the wetland attenuation features. Each of the three cells within the WAF will be monitored for inflow and outflow. The SFWMD is still in the process of fully characterizing the project footprint for HTRW and legally applied residual agricultural amendments. Once that investigation is completed (expected before any construction start) the surface water quality plan may need to be amended to reflect new information. Surface water parameters will address nutrients, ions, and physical parameters. Flow measurement is assumed to occur on a weekly basis for each feature. Weekly sampling is assumed for this cost estimate. The assumption is that the weekly sampling/preparation/sample disposition of the 6 inflow/outflow sampling points for each feature, internal monitoring for the WAF cells, plus quarterly fish tissue sampling will require ½ full time employee. Biweekly sampling is a possibility to be finalized during the permitting process. Costs are estimated for year 1, years 2-5, and years 6-50. Quarterly sampling for fish tissue is assumed for years 1-5, and it is assumed there will be no negative indications requiring further investigation of toxicants/mercury. Please see **Table D-17** for cost breakdown. The 50-year surface water monitoring cost is estimated at \$12,474,296.

Table D-17. Summary of surface water quality monitoring costs.

Budget Area	Year 1	Years 2-5 Annual Cost	Years 6-50 / Annual Cost
Capital (sampling platforms, equipment, vehicle cost, etc.)	\$135,000	0	\$2,000
Fuel and maintenance	\$10,000	\$10,000	\$10,000
Consumables	0	0	0
SW Nutrients and Ions	\$650	\$650	\$650
SW Hg and Toxins	\$125	0	0
Small Fish Hg	\$100	\$100	0
Small Fish Toxicants	\$25	0	0
Large Fish Hg	\$25	\$25	0
Sediment Hg and Toxins	\$25	0	0
Annual Sums	\$145,950	\$10,775	\$12,650
Analytical	-	-	-
SW Nutrients and Ions	\$106,080	\$106,080	\$106,080
SW Hg and Toxins	\$16,500	0	0
Small Fish Hg	\$7,680	7,680	0
Small Fish Toxicants	\$14,208	0	0
Large Fish Hg	\$19,200	\$19,200	0
Sediment Hg and Toxins	\$14,400	0	0
Annual Sums	\$178,068	\$132,960	\$106,080
Staff	-	-	-
SW Nutrients and Ions	\$120,744.00	\$120,744	\$120,744
SW Hg and Toxins	\$5,256.00	0	0
Small Fish Hg	\$24,768.00	\$24,768	0
Large Fish Hg	\$12,000.00	\$12,000	0
Sediment Hg and Toxins	\$6,912.00	0	0
Annual Sums	\$168,960	\$157,512	\$120,744
Annual Totals	\$ 492, 978	\$ 301,247	\$239,474
Number of years	1	4	45
Item Subtotals	\$492,978	\$1,204,988	\$ 10,776,330
Grand Total	-	-	\$ 12,474,296

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PART 3: HYDROMETEOROLOGICAL MONITORING PLAN

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D.3 Hydrometeorological Monitoring

The following information describes the minimal gauging needs for the LOWRP Recommended Plan.

D.3.1 Data Quality Objectives

Developing Data Quality Objectives (DQO) is an integral and important part of a systematic planning process that is designed to ensure that the final results can be used for the purpose for which the data were generated. This systematic planning process for purposes of these discussions on environmental data quality is the quality system that each organization must develop, implement, and evaluate on a continuing basis.

The data will be used to measure project performance. It will also be used to comply with monitoring requirements of an operational permit. The DQOs to be considered include accuracy, precision, sampling frequency, availability, completeness, reporting frequency, and timeliness. These are addressed in CERP's *Quality Assurance Systems Requirements*, Chapter 6, Table 6.1, dated 7 December 2010. The DQOs are further outlined in **subsection 3.1.1** of this document.

D.3.1.1 Monitoring Data Elements/Indicators/Cost Estimate

Hydrometeorological and hydraulic monitoring data will be collected, at a minimum, at each of the new structures; gate openings at gated structures; ASR wells; and pump stations. **Table D-18** provides a list of existing gauges at main structures within the LOWRP project area. Structures proposed in the Recommended Plan are subject to change during PED.

Table D-19 describes a preliminary list of minimal gaging needs for the Wetland Attenuation Feature (WAF) and wetland areas. This table lists the necessary gaging parameters to be collected as part of LOWRP, which are in addition to current monitoring stations that will be leveraged for the LOWRP. The headwater and tailwater stage gages located directly upstream and downstream of the structures, respectively, along with the gate openings, are used in computing flows through structures, as well as assisting in determining the operations. The 15-minute frequency is the USACE required standard for these parameters. Breakpoint data for a pump is collected when changes to the revolutions per minute (RPM) are made, up to a frequency of 1 minute. The hydrologic and meteorological data collection equipment used for this project would be installed either as part of the construction contract or via a separate contract with construction funding. Hydrometeorological parameters such as surface and ground water stages require accurate estimates of the water elevation height compared to a known reference. All new surface-water 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 datum. Several of the structures are located within a close proximity to each other and/or existing gages, and therefore fewer new gages will be needed. See **Figure D-4** for a map of the conceptual structures proposed in the K05 WAF. Refer to **subsection D.3.9** for the hydrometeorological needs of the ASR wells.

The USACE-Jacksonville District receives data from various sensors and data collection platforms to monitor surface water flows and levels. 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, United States Geologic Survey (USGS), and Everglades National Park (ENP).

As the Recommended Plan is optimized and further developed during PED, estimates and contingencies for hydrometeorological monitoring during Operational Testing and Monitoring Period, and Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) are expected to change. For the purpose of this planning phase, the cost to monitor minimal gauging needs for the WAF and wetlands is \$170,000 per year. The cost for groundwater monitoring is detailed in **Section D.3.9**. The total cost of the hydrometeorological monitoring plan is summarized in **Section D.4**. This cost is also captured in **Section 6**.

Table D-18. Monitoring gauges at existing structures in the LOWRP.

Structure	Gauge Parameter	Frequency of Reading
S-84	Headwater and tailwater stage	15-minutes
S-65E	Headwater and tailwater stage	15-minutes
S-77	Headwater and tailwater stage	15-minutes
S-78	Headwater and tailwater stage	15-minutes
S-79	Headwater and tailwater stage	15-minutes
S-308	Headwater and tailwater stage	15-minutes
S-80	Headwater and tailwater stage	15-minutes

Table D-19. LOWRP minimal gauging needs for the WAF and proposed wetlands.

Structure/Feature Number	Structure/Feature Type	Gauge Parameter	Frequency	Location
S-720	Inflow Pump (WAF)	Pump RPMs	Breakpoint	North Cell
S-721	Inflow Pump (PR)	Pump RPMs	Breakpoint	North Paradise Run
S-722	Weir	Headwater and tailwater stage	15-minutes	West Perimeter Central Cell
S-723	L-59 Inflow Culvert	Gate opening, headwater and tailwater stage	15-minutes	L-59 at Perimeter Canal
S-724	Cell Division Spillway	Gate opening, headwater and tailwater stage	15-minutes	North to Central Cell
S-725	Seepage Pump	Pump RPMs	Breakpoint	North Perimeter of South Cell
S-726	Weir	Headwater and tailwater stage	15-minutes	North Perimeter of South Cell
S-727	Cell Division Spillway	Gate opening, headwater and tailwater stage	15-minutes	Central to South Cell
S-728	Primary WAF Outlet	Gate opening, headwater and tailwater stage	15-minutes	East Perimeter of South Cell
S-729	Gated Culvert to Outlet Canal	Gate opening, headwater and tailwater stage	15-minutes	Outlet Canal
S-730	South Paradise Run Inlet Riser Culvert	Headwater and tailwater stage	15-minutes	South Paradise Run
S-731	Spillway to C-38	Gate opening, headwater and tailwater stage	15-minutes	Outlet Canal

Structure/Feature Number	Structure/Feature Type	Gauge Parameter	Frequency	Location			
S-732	South Paradise Run Outlet Riser Culvert	Headwater and tailwater stage	15-minutes	South Perimeter Paradise Run			
S-733	Seepage Pump	Pump RPMs	Breakpoint	South Perimeter of South Cell			
S-734	Seepage Canal Emergency Outlet Riser Culvert	Headwater and tailwater stage	15-minutes	South Perimeter of South Cell			
S-735	Inflow Pump (KRC)	Pump RPMs	Breakpoint	North End of KRC			
S-736	Outlet Riser Culvert	Headwater and tailwater stage </tr <tr> <td></td> <td></td> <td></td> <td>15-minutes</td> <td>South End of KRC</td> </tr>				15-minutes	South End of KRC
			15-minutes	South End of KRC			

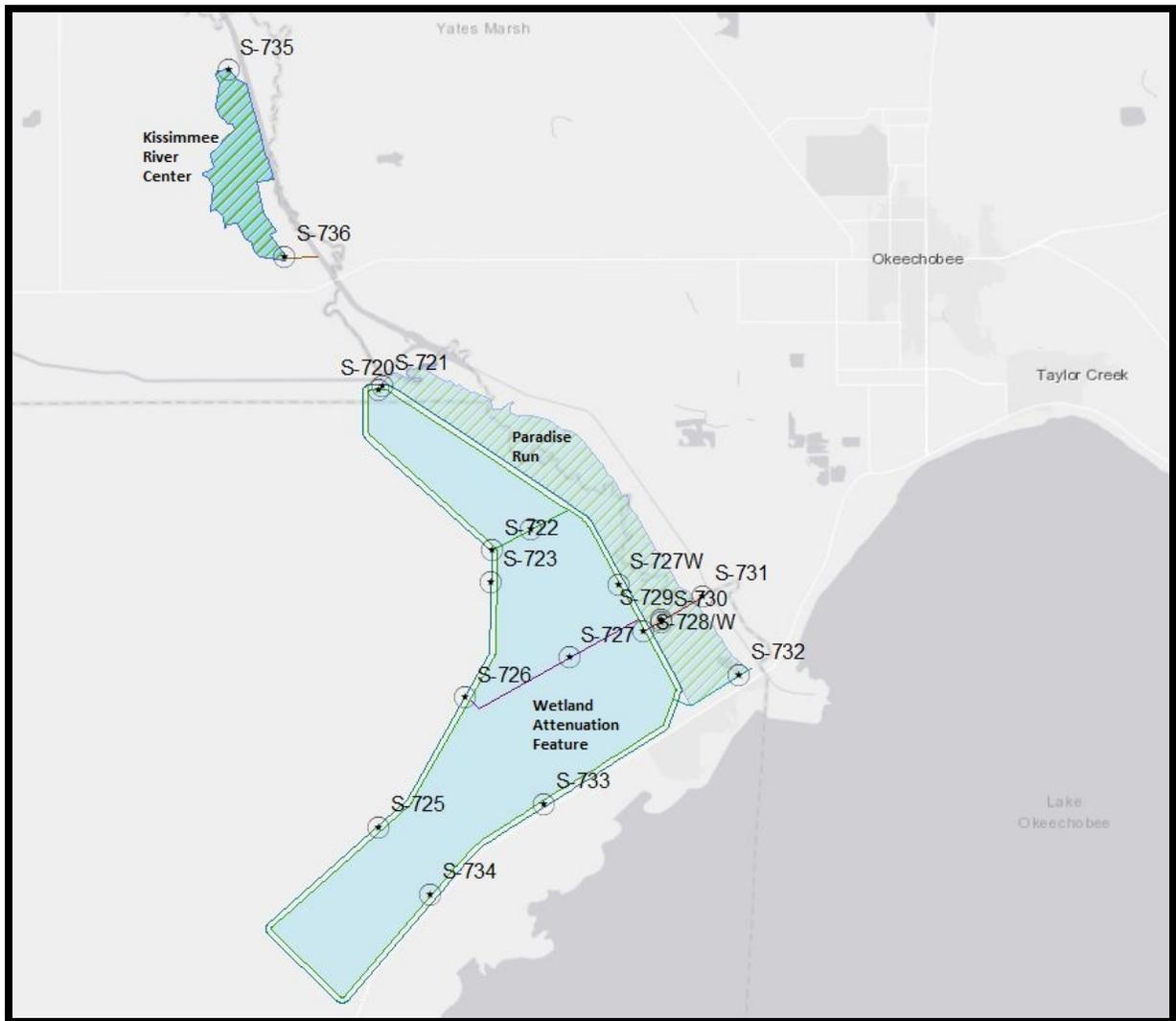


Figure D-4. WAF with proposed structures.

D.3.1.2 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 a Serial Digital Interface (SDI) encoder at each monitoring location. The accuracy required is ± 0.02 ft. for critical sites and ± 0.03 ft. for non-critical sites. The reported resolution will be 0.01 feet and the instrument range will be 0 to 20 ft. The precision will be ± 0.01 ft. The sampling frequency will likely be 15 minutes, at 0, 15, 30, and 45 minutes past each hour (e.g. at 1500 hrs., 1515 hrs., 1530 hrs., and 1545 hrs.) though breakpoint sampling may be done.

Groundwater stages will be measured using an SDI encoder at each monitoring location. The accuracy required is ± 0.03 ft. The reported resolution will be 0.01 feet and the instrument range will be 0 to 30 feet. The precision will be ± 0.01 ft. The sampling frequency will likely 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 likely be 15 minutes. At this time the location of rainfall gauges has not yet been determined.

Gate positions will be measured using gate position indicators with an accuracy of ± 0.05 ft., 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 $\pm 0.02\%$ full stroke. The reporting frequency will likely 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 $\pm 10\%$ for inland spillways, $\pm 15\%$ for culverts, and $\pm 15\%$ for pumps. The velocity instrumentation will have a precision of ± 0.01 ft./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.3.2 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.3.3 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 at least 15 minutes, at 0, 15, 30, and 45 minutes past each hour (e.g. at 1500 hrs., 1515 hrs., 1530 hrs., and 1545 hrs.)

Groundwater stages recording frequency will be at least 15 minutes.

Rainfall recording frequency will be at least 15 minutes.

Gate positions recording frequency will be at least 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.3.4 Assessment Process and Decision Criteria (Triggers and Thresholds)

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

D.3.4.1 Data Collection

This section outlines the data collected.

D.3.4.2 Sample/Data Collection Standards and Ethics

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

D.3.4.3 Sample Submission

No samples will be collected for hydrometeorological monitoring.

D.3.4.4 Chain of Custody

No samples will be collected for hydrometeorological monitoring.

D.3.4.5 Quality Control Samples

No samples will be collected for hydrometeorological monitoring.

D.3.4.6 Data Validation

Data validation processes will follow the current Standard Operating Procedures at the time of data collection. The current USACE 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 USACE data validation may be accomplished by automated or manual means. This process may include estimating values for missing or erroneous 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 USACE is maintained in databases and further computations are applied to generate additional databases of computed data.

D.3.4.7 Data Validation Processing

Data validation processing will follow the current Standard Operating Procedures at the time of data collection. The current USACE 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.

Data processing shall 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) knowledge management.

D.3.4.8 Data Storage and Archiving

Data collected or obtained by the USACE will be stored and archived in accordance with ER 1110-2-8155, *Hydrometeorological Data Management and Archiving*, dated 31 July 1996. The USACE maintains 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.3.5 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.3.5.1 Field Notes

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.3.5.2 Field Instrument Calibration Documentation

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

D.3.5.3 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, and initialing and dating the change. On occasion, a detailed explanation of the error may be required.

D.3.6 Quality Assurance and Quality Control

The following sections the quality assurance and quality control procedures.

D.3.6.1 System for Assessing Data Quality Attributes

The standards as set forth under the USACE and the SFWMD's respective requirements will be adhered to and followed.

D.3.6.2 Data Quality Qualifiers

The data quality standards for hydrometeorological data are determined by the USACE and SFWMD's respective guidance and will be followed.

D.3.6.3 Field Audits

The data quality standards for hydrometeorological data are determined by the USACE and SFWMD's respective guidance and will be followed.

D.3.7 Data Analyses and Records Management

The USACE 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.

D.3.7.1 Data Quality Evaluation and Assessment

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

D.3.8 Adaptive Management Considerations

Where possible, LOWRP hydrometeorological data will support adaptive management by contributing data needed to address LOWRP uncertainties and future project adjustments. The adaptive management strategies that will leverage hydrometeorological data include but are not limited to optimizing water deliveries from the K05 WAF and ASR wells to Lake Okeechobee.

D.3.9 Groundwater Monitoring Plan and Cost: Operational and Regulatory

The following information describes the minimal groundwater monitoring needs for the ASR wells proposed on the LOWRP Recommended Plan.

D.3.9.1 Wetland Attenuation Feature Assisted Aquifer Storage and Recovery Wells

Development of the groundwater sampling plan at the WAF is based on the groundwater monitoring plan currently (2019) in force at the multi-ASR well Peace River Regional Water Supply Facility. This monitoring plan is part of the approved UIC operation permit for the ASR facility (Permit file number 0136595-014-UO/5Q). The plan requires continuous monitoring of physical parameters such as wellhead pressure and groundwater levels at instrumented wells during recharge, storage, and recovery. Groundwater quality field parameters (pH, specific conductivity, temperature, dissolved oxygen, oxidation-reduction potential and turbidity) and inorganic constituent concentrations are measured at different frequencies at ASR wells and monitoring wells during recharge and recovery phases. Only physical parameters are measured during storage at the ASR wells. The groundwater monitoring plan is shown in **Table D-20**.

To estimate the cost of a complete cycle test (recharge-storage-recovery) requires definition of a representative schedule for ASR operation. For purposes of cost estimation, a representative cycle consists of 6 months recharge (wet season, June through December), 1 year storage (January-December), and 6 months recovery (dry season, January-June), with all wells functioning in unison. Because the durations of recharge and recovery phases are identical, the number of samples obtained from all wells during recharge and recovery are identical. This is an over-simplification of ASR cluster operation at the WAF. The number of sampling events for those parameters that are not monitored continuously is based on semi-monthly sampling frequency for ASR wells, and every other month for monitoring wells. The cost estimate assumes 25 ASR wells (n=24 samples per year per well) and 17 monitoring wells (n=6 samples per year per well) at the WAF. Additional information and modeling will be required during PED to define the operation plan. Regulatory and Operational Groundwater Monitoring Costs during a Single Cycle.

The UIC permit for each ASR cluster defines the groundwater quality constituents and physical parameters to be monitored, and their sampling frequency, to be reported monthly to the permitting agency (FDEP). The cost estimate reported in **Table D-21** is based on annual costs and is the sum of two cost categories: analytical and field and regulatory reporting labor costs.

The following assumptions are made in this cost estimate:

- Power costs are not included

- SCADA and telemetry equipment costs are not included
- Only limited field sampling occurs during storage, only continuous recording of water levels and wellhead pressures for monthly operating reports (MORs).
- Groundwater quality sampling will be required by permit at each ASR wellhead and monitoring well at the frequency defined in **Table D-20**.
- Travel and per diem are not included in field sampling costs

The total cost for groundwater quality analyses and labor for field sampling, data compilation, and regulatory reporting for one complete ASR cycle conducted at the WAF is \$418,200.

Table D-20. Example groundwater monitoring plan for ASR cluster associated with the WAF.

PARAMETER	UNIT	RECORDING FREQUENCY	FREQUENCY OF SAMPLING ASR WELLS (n=25)	FREQUENCY OF ANALYSIS Upper Floridan Aquifer Monitor Wells (n=10)	FREQUENCY OF ANALYSIS Avon Park Permeable Zone Monitor Wells (n=7)
Flow Rate, max.	gallons per minute	continuous	a	N/A	N/A
Flow Rate, min.	gallons per minute	continuous	a	N/A	N/A
Flow Rate, avg.	gallons per minute	continuous	a	N/A	N/A
Total Volume Recharged	million gallons	Daily/Monthly	a	N/A	N/A
Total Volume Recovered	million gallons	Daily/Monthly	a	N/A	N/A
Net Storage	million gallons	Monthly	a	N/A	N/A
ASR Well Pressure, max.	pounds per square inch	Continuous	a	N/A	N/A
ASR Well Pressure, min.	pounds per square inch	Continuous	a	N/A	N/A
ASR Well Pressure, avg.	pounds per square inch	Continuous	a	N/A	N/A
Water Level, max.	feet (NGVD) / PSI	Continuous	N/A	a	a
Water Level, min.	feet (NGVD) / PSI	Continuous	N/A	a	a
Water Level, avg.	feet (NGVD) / PSI	Continuous	N/A	a	a
pH ^b	std. units	Grab	W ^c	M	M
Specific Conductivity ^b	µmhos/cm	Grab	W ^c	M	M
Temperature ^b	°C	Grab	W ^c	M	M
Dissolved Oxygen ^b	mg/L	Grab	W ^c	M	M

PARAMETER	UNIT	RECORDING FREQUENCY	FREQUENCY OF SAMPLING ASR WELLS (n=25)	FREQUENCY OF ANALYSIS Upper Floridan Aquifer Monitor Wells (n=10)	FREQUENCY OF ANALYSIS Avon Park Permeable Zone Monitor Wells (n=7)
Turbidity ^b	NTU	Grab	W ^c	M	M
Oxidation – Reduction Potential ^b	mV	Grab	W ^c	M	M
Total Dissolved Solids	mg/L	Grab	W ^c	M	M
Chloride	mg/L	Grab	W ^c	M	M
Sulfate	mg/L	Grab	W ^c	M	M
Arsenic	µg/L	Grab	W ^c	M	M
Gross Alpha	pCi/L	Grab	Q	Q	Q
Total Uranium	µg/L	Grab	Q ^e	Q ^e	Q ^e
Tot Trihalomethanes	mg/L	Grab	A ^d	A ^d	A ^d
Primary and Secondary constituents	N/A	Grab	A ^f	N/A	N/A

Note: W – Weekly; M - Monthly; Q - Quarterly; A – Annually. No Sampling of ASR wells during storage.

a - Operational data reporting for flows, pressures and water levels: daily max, min and average from continuous reporting; monthly max, min and average (calculated from daily averages).

b – Field samples

c – Weekly during recovery from currently operating wells, monthly from common distribution during recharge

d – During recovery only

e – Analyzed only if Gross Alpha exceeds 15 pCi/L

f – July (finished water) – annual analysis for all primary and secondary water quality constituents.

Table D-21. Annual cost of groundwater monitoring required by permit for the WAF-assisted ASR clusters.

COST CATEGORY	ANNUAL COST
Analytical	\$ 275,700.00
Labor	\$ 142,500.00
Total Annual Monitoring Cost	\$ 418,200.00

D.3.9.2 Watershed Assisted Aquifer Storage and Recovery Wells

Ten watershed ASR clusters are proposed for this project. Fifty-five ASR wells will be constructed throughout these 10 systems. The groundwater monitoring plan for each watershed ASR cluster is

identical to that at WAF-assisted ASR clusters, and differs only in the number of ASR wells and monitoring wells. This plan assumes that there will be two UFA monitor wells and two APPZ monitor wells at each ASR cluster, for a total of 40 monitor wells. Watershed ASR clusters are likely to recharge during the wet season and recover during the dry season, with storage durations less than one year. Because groundwater monitoring during the storage phase is limited to continuous measurements in instrumented wells, differences in storage duration do not have an impact on cost.

Identical to the WAF-assisted groundwater monitoring plan presented in **Table D-20**, this plan requires continuous monitoring of physical parameters such as wellhead pressure and groundwater levels at instrumented wells. Groundwater quality field parameters (pH, specific conductivity, temperature, dissolved oxygen, oxidation-reduction potential and turbidity) and inorganic constituent concentrations are measured at different frequencies at ASR wells and monitoring wells during recharge and recovery phases. Only physical parameters are measured during storage.

The total cost for groundwater quality analyses and labor for field sampling, data compilation, and regulatory reporting for one year conducted at all watershed ASR clusters is \$837,700.

Table D-22. Annual cost of groundwater quality analyses required by permit for watershed ASR clusters.

COST CATEGORY	ANNUAL COST
Analytical	\$ 636,700.00
Labor	\$ 201,000.00
Total Annual Monitoring Cost	\$ 837,700.00

D.4 Total Adaptive Management and Monitoring Costs

Table D-23 below shows the total cost estimate for adaptive management monitoring, ecological monitoring, water quality monitoring and hydrometeorological monitoring over the life cycle of the project.

Table D-23. LOWRP total cost estimate for AM, project-level, water quality, hydrometeorological, and Biological Opinion.

Part		Annual (1-Year)	2-5-Year	10 –year¹	6 to 50-Year
AMMP		\$853,000	\$4,265,000	\$8,530,000	N/A
WQ		\$617,804	\$1,204,988		\$10,776,330
Hydro		\$ 1,323,900	\$6,619,500		\$66,195,000
BO		\$250,000	\$1,250,000		N/A
Total		\$3,044,704	\$1,333,9488	\$8,530,000	\$76,971,330

¹ Adaptive Management and Monitoring (Ecosystem Restoration Success) plan costs are construction funded up to 10 years post construction, per HQ implementation guidance on Section 1161 of 2016 Water Resources Development Act.