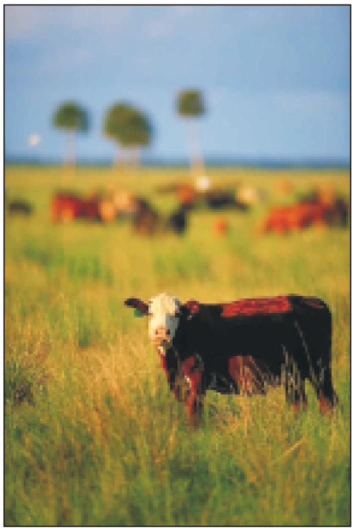
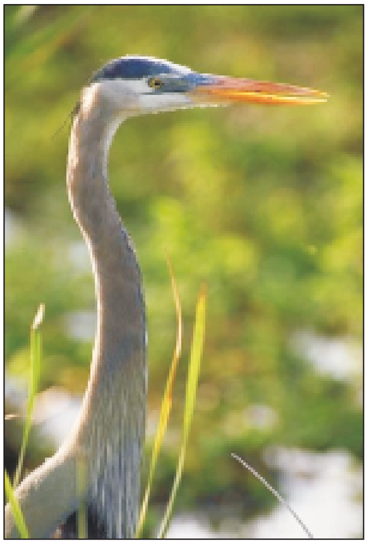
Work Plan
for the Evaluation of Alternatives

Lake Okeechobee
Sediment Management Feasibility Study

C-11650





May 13, 2002

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BLASLAND, BOUCK & LEE, INC.
engineers & scientists

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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C-11650

South Florida Water Management District
West Palm Beach, Florida

May 13, 2002

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Attachment

Section 3 from *Goals and Performance Measures for the Lake Okeechobee Sediment Management Feasibility Study* (finalized June 2001)

Acronym and Abbreviation List

NH_4^+	ammonium
ASR	aquifer storage and recovery
BBL	Blasland, Bouck & Lee, Inc.
CDF	confined disposal facility
CEAM	Center for Exposure Assessment Modeling
cm	centimeter
CERP	Comprehensive Everglades Restoration Plan
CSTR	continuous-stirred tank reactor
District	South Florida Water Management District
EA	Environmental Associates, Inc.
EFDC	Environmental Fluid Dynamics Code
ERP	environmental resources permit
ERS	Environmental Research Software
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FTP	file transfer protocol
FWC	Florida Fish and Wildlife Conservation Commission
LEC	Lower East Coast
LOHTM	Lake Okeechobee 3-D Hydrodynamic Transport Model
LOOP	Lake Okeechobee operating permit
LORSS	Lake Okeechobee Regulation Study Schedule
LOWQM	Lake Okeechobee Water Quality Model
m^3	cubic meter
MFLs	minimum flows and levels
ìg/L	microgram per liter
MS	Microsoft
NPDES	National Pollutant Discharge Elimination Discharge System
NPV	net present value
O&M	operation and maintenance
OMB	Office of Management and Budget
PDF	portable document format
POC	point of compliance
SAV	submerged aquatic vegetation
SIC	standard industrial classification
SPSS	statistical package for the social sciences
STAs	stormwater treatment area
SWIM	Surface Water Improvement and Management
TRT	technical review team
TMDL	total maximum daily load
TN:TP	ratio of total nitrogen to total phosphorus
C_T	total concentration
TSS	total suspended solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service

Executive Summary

Lake Okeechobee and Phosphorus

The Lake Okeechobee Sediment Management Feasibility Study was initiated by the South Florida Water Management District (District) in the fall of 2000 in order to analyze all of the possible options for reducing internal phosphorus loading in the lake. Internal phosphorus loading occurs when wind-driven waves move across the lake and stir up phosphorus-rich mud into the water. This loading is a problem because the high levels of phosphorus in the sediment can lead to decreased water quality, more frequent blooms of blue-green algae, and other problems that may affect drinking water supplies, interfere with recreation and commercial activities, and harm plants and wildlife.

Status of the Feasibility Study

The Sediment Management Feasibility Study consists of five main tasks:

Task 1. Development of Goals and Performance Measures
Task 2. Development of Alternatives
Task 3. Work Plan for Evaluation of Alternatives
Task 4. Evaluation of Alternatives
Task 5. Stakeholder Prioritization of Alternatives

The *Goals and Performance Measures* report, finalized in June 2001, identifies the five overall goals for the project:

Goal 1. Maximize Water Quality Improvements
Goal 2. Maximize Engineering Feasibility and Implementability
Goal 3. Maximize Cost Effectiveness
Goal 4. Maximize Environmental Benefits
Goal 5. Maximize Socioeconomic Benefits

The 26 performance measures associated with the goals for the study are listed in Table 3 on page 3-20, and described in detail in Attachment 1 to this report.

The seven sediment management alternatives, initially presented in the *Development of Alternatives* report, finalized in October 2001, are listed below. These alternatives (and the related sediment disposal/reuse sub-alternatives – see Table 1 on page 1-3 for a complete list) will be developed in greater detail in Task 4 of the feasibility study, and then evaluated against the goals and performance measures.

Alternative 1. No in-lake action
Alternative 2. In-lake chemical treatment (single application)
Alternative 3. Long-term periodic in-lake chemical treatment
Alternative 4. Dredging
Alternative 5. In-lake chemical treatment followed by dredging
Alternative 6. Dredging followed by in-lake chemical treatment
Alternative 7. Long-term periodic dredging from in-lake sumps followed by in-lake chemical treatment

Work Plan for the Evaluation of Alternatives

The current focus of the study is Task 3, the development of a Work Plan that describes how the alternatives will be evaluated against the goals and performance measures established for the project. This report lays out six work plan tasks that will be performed, including a detailed scoping and refinement of the alternatives, and the processes for conducting the detailed evaluation of alternatives against the goals and performance measures. Section 3 presents specific discussions of how the alternatives will be compared to each performance measure based on the following elements:

- **Targets**: Specific levels, quantities, or conditions necessary to meet or make progress toward a stated project goal.
- **Tools**: Quantitative and qualitative models, matrices, and other applications applied to estimate an alternative's feasibility and expected performance.
- **Critical Data/Input**: Data and sources of data essential to conduct an acceptable evaluation.
- **Methods**: How the tools and data will be used to judge the expected performance of an alternative relative to a particular goal.
- **Scoring**: Quantitative and qualitative results reported along with a relative score ranging from 1 to 5 (a score of 5 will represent the most desirable result).

- **Interrelationships with Other Performance Measures**: Identification of critical paths and need for coordination among various evaluations.
- **Uncertainty Considerations**: Description of potential limitations and sources or types of uncertainty associated with the tools, data, or methods. Despite certain data gaps and uncertainties identified in this work plan, there is sufficient technical information and field experience available to complete a thorough and comprehensive feasibility study to support District decisions regarding mitigation of internal phosphorus loading in Lake Okeechobee.

Discussions of the development of the *Evaluation of Alternatives* report; meetings, deliverables, and schedules for the rest of the feasibility study; and plans for public and interagency outreach and coordination are also provided. The results of the alternatives evaluation will be presented in a draft report available in November 2002 and the final evaluation will be complete in February 2003. The schedule for the feasibility study is driven by both a project management deadline of February 2003 and a statutory requirement that the entire project, including the District's prioritization of alternatives and selection of a recommended course of action, be complete by July 1, 2003.

For More Information

The feasibility study is an ongoing process that is an important part of charting a future course for Lake Okeechobee. With the evaluation of the alternatives (Task 4) and prioritization of those alternatives (Task 5) still ahead, the District welcomes public and interagency involvement in the process. For more information, access to other reports, and news regarding this feasibility study, please visit the project website at http://www.sfwmd.gov/org/wrp/wrp_okee/projects/sedimentmanagement.html or contact the District Project Manager as follows:

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1. Introduction

The Lake Okeechobee Sediment Management Feasibility Study is a three-year study that was commissioned in September 2000 by the South Florida Water Management District (District) and is being conducted by a team of technical experts led by Blasland, Bouck & Lee, Inc. (BBL). The primary purpose of the study is to analyze all of the possible options for reducing internal phosphorus loading in the lake. Internal phosphorus loading – which occurs when wind-driven waves move across the lake and stir up phosphorus-rich mud, releasing phosphorus into the water – is a problem because the high levels of phosphorus can lead to decreased water quality, more frequent blooms of blue-green algae, and other problems that may affect drinking water supplies, interfere with recreation and commercial activities, and harm plants and wildlife.

While separate efforts are underway to address external inputs of phosphorus to the lake from the watershed, it is important to understand that reductions in internal loading will not persist in the long term unless efforts to substantially reduce external loading are successful. In that sense, any plan to address internal loading is considered to be in addition to the various efforts to reduce contributions of phosphorus from the watershed. There are currently more than 51,600 metric tons (approximately 56,760 tons) of phosphorus in the mud sediments of the lake (see Figure 1 for spatial distribution of sediment types); unless addressed in some way, the relative contribution of this internal source will increase as the external sources are mitigated (Moss et al., 1999). However, it is the absolute magnitude of phosphorus loading that is most important, and if external loading is decreased to proposed levels, the loading magnitude should decrease over time and offset any increase in internal loading, as it has in other lakes (Welch and Cooke, 1995).

The three-year feasibility study is designed to progress in five major stages or tasks:

- Task 1 – Establishment of goals and performance measures, and identification of potential impacts;
- Task 2 – Development of a specific array of alternatives to be evaluated in detail in the feasibility study;

- Task 3 – Preparation of a work plan for conducting the detailed evaluation of alternatives (Task 3 is the focus of this document);
- Task 4 – Detailed evaluation of the alternatives; and
- Task 5 – Stakeholder prioritization of alternatives and selection of a recommended course of action.

The *Goals and Performance Measures* report (finalized June 2001; BBL, 2001a), and the *Development of Alternatives* report (finalized October 2001; BBL, 2001b), are both available for review on the project website (http://www.sfwmd.gov/org/wrp/wrp_okee/projects/sedimentmanagement.html). This document presents a summary of Task 3, the development of the *Work Plan for the Evaluation of Alternatives* (Work Plan). This Work Plan is designed to establish a work breakdown structure, schedule, and consistent methodological framework for the Task 4 formal evaluation of the various sediment management alternatives proposed for reducing internal phosphorus loading in Lake Okeechobee.

The 5 goals and 26 performance measures established in the *Goals and Performance Measures* report will be used to evaluate the 7 alternatives (20 overall when sediment disposal/reuse sub-alternatives are considered) presented in the *Development of Alternatives* report. For ease of comparison and reference, Section 3 from the Goals report – which describes all the performance measures – is included here as Attachment 1, and Table 1 on the next page lists the potentially feasible alternatives that will be evaluated against the goals and performance measures.

Table 1 **Potentially Feasible Alternatives** *(from Section 3.3 of the Development of Alternatives report)*
1) No in-lake action
2) In-lake chemical treatment (single application)
3) Long-term periodic in-lake chemical treatment
4) Dredging
4A) Dredging with disposal in in-lake island confined disposal facilities (CDFs)
4B) Dredging with disposal in near-shore CDFs
4C) Dredging with disposal in upland CDFs
4D) Dredging with beneficial reuse of dredged material
5) In-lake chemical treatment followed by dredging
5A) In-lake treatment followed by dredging with disposal in in-lake island CDFs
5B) In-lake treatment followed by dredging with disposal in near-shore CDFs
5C) In-lake treatment followed by dredging with disposal in upland CDFs
5D) In-lake treatment followed by dredging with beneficial reuse of dredged material
6) Dredging followed by in-lake chemical treatment
6A) Dredging followed by disposal in in-lake island CDFs and in-lake treatment
6B) Dredging followed by disposal in near-shore CDFs and in-lake treatment
6C) Dredging followed by disposal in upland CDFs and in-lake treatment
6D) Dredging followed by beneficial reuse of dredged material and in-lake treatment
7) Long-term periodic dredging from in-lake sumps followed by in-lake chemical treatment
7A) Long-term dredging from in-lake sumps followed by disposal in in-lake island CDFs and in-lake treatment
7B) Long-term dredging from in-lake sumps followed by disposal in near-shore CDFs and in-lake treatment
7C) Long-term dredging from in-lake sumps followed by disposal in upland CDFs and in-lake treatment
7D) Long-term dredging from in-lake sumps followed by beneficial reuse of dredged material and in-lake treatment
7E) Long-term dredging from in-lake sumps followed by disposal or beneficial reuse.[1]

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[1] Sub-alternative 7E was added after the *Development of Alternatives* (BBL, 2001b) report was finalized; therefore, it is not described in that document.

2. Scope of Work

As directed by the Statement of Work developed for this feasibility study (SFWMD, 2000c), Task 3 is dedicated to outlining the technical aspects of the processes that will be used to evaluate the sediment management alternatives (see Table 1 on page 1-3) against the 5 goals and 26 performance measures (see Attachment 1). The District's Technical Review Team (TRT) reviewed the initial draft of this Work Plan and made the decision whether or not to continue with the feasibility study process. This "Stop/Go" decision was based upon the considerations identified in the Statement of Work, which included review of the draft Work Plan, project priorities, and the feasibility of continuing with the work under this contract. Based on the District's "Go" decision on January 18, 2002, BBL organized a public/interagency meeting that was held on April 4, 2002, finalized this Work Plan, and has started the actual evaluation of alternatives.

The formal evaluation carried out in Task 4 will include both quantitative and qualitative assessments of the alternatives against the established goals and performance measures. BBL will prepare a detailed "Evaluation of Alternatives" report that will incorporate, to the extent possible, the information generated during Environmental Associates' (EA's) pilot dredging project and the findings of the lake sediment phosphorus dynamics study reported by the team from the University of Florida. In addition to the most current data and technical knowledge, BBL will gather input from appropriate local, state, and federal agencies and consider feedback received during all four public/interagency meetings. The Statement of Work indicates that the Task 4 "technical evaluation will represent the cornerstone of the feasibility study," and the evaluation report's level of detail will be sufficient to determine the feasibility of the alternatives. BBL will also present any potential outstanding information needs (e.g., data gaps, uncertainties) and/or recommendations for potential actions (e.g., large-scale pilot studies) for the District to consider. It is anticipated that the District will be able to use the results of the evaluation of alternatives developed in Task 4 of the study to prioritize the alternatives with stakeholder input and select a recommended course of action for Lake Okeechobee.

The remainder of this Work Plan sets forth the specific methods, tools, and data that will be used to evaluate alternatives during Task 4 of the feasibility study, scheduled to take place during the remainder of 2002 and early 2003.

3. Work Breakdown Structure

3.1 Introduction

This section presents the detailed work breakdown structure for coordinating and completing the feasibility study's Task 4 evaluation of alternatives based on:

1) The feasibility study's Statement of Work (SFWMD, 2000c), including the District's "Stop/Go" decision, which was made in January 2002;
2) The provisions of the *Public and Interagency Outreach Plan* (BBL, 2000);
3) The goals and performance measure metrics, targets, and methods established during Task 1 (BBL, 2001a);
4) The array of sediment management alternatives developed as a result of the technology screening and assessment process of Task 2 (BBL, 2001b); and
5) The program management requirement that the feasibility study be completed by February 28, 2003, and the statutory requirement that the overall feasibility study project be completed by July 1, 2003 (Florida Statute 373.4595(3)(f)).

This Work Plan is essentially an extension of the Statement of Work in that it provides a detailed "roadmap" of how the very diverse and complex evaluation of alternatives will be carried out over an approximately 14-month process. As discussed in the *Goals and Performance Measures* report (BBL, 2001a), the 5 goals and 26 performance measures are necessarily diverse so that the alternatives evaluation will comprehensively consider (and to the extent possible, quantify) all important benefits, costs, and impacts of various sediment management options on water quality (e.g., phosphorus loading, algae blooms), environmental quality (e.g., habitat quality/quantity, protection of key species), and socioeconomics (e.g., human use of the lake and its resources). For convenience, Section 3 of the Goals document, which provides the detailed discussion of the 5 overall goals and 26 specific performance measures, is included as Attachment 1 to this Work Plan, and Table 1 (page 1-3) lists the alternatives that will be evaluated against the goals and performance measures. Thus, with Section 3 of the Goals document as a starting point, the work breakdown structure presented here clarifies, and in some cases extends, the methodology discussed in the Goals document that will be used to evaluate the feasibility of the proposed sediment management alternatives.

Because the alternatives evaluation will rely upon extensive application of predictive modeling tools as well as less robust qualitative assessments of feasibility and environmental and other impacts, the objective of the work breakdown structure is to explain how each tool, method, data source, and quantitative/qualitative output will be developed and used during the evaluation process. Many of the data and tools originate from other projects or are otherwise outside the control of the project team and further, many of the performance measures unavoidably rely on qualitative judgements of the best available science and data; therefore, issues of data quality, methodological uncertainty, and subtask interdependence are addressed in this Work Plan. The project team will strive to minimize uncertainty and maximize information exchange across related projects (e.g., Lake Okeechobee feasibility study, pilot dredging project, and bench-scale sediment dynamics study), including the explicit consideration and reporting of associated constraints throughout the process and as these issues arise and impinge upon the evaluation.

The work breakdown structure specifies six tasks that will be performed during the study's Task 4 evaluation of alternatives. These six evaluation tasks are not to be confused with the five overall feasibility study tasks guiding the project (listed on page 1-1) – the reader is cautioned to keep in mind that the six tasks presented below are essentially subtasks to be performed under overall Task 4 of the feasibility study. Moreover, Task 3 of this Work Plan is further broken down into 26 subtasks that parallel the 26 performance measures from the Goals document. Given this preface, the six tasks of the work breakdown structure under Task 4 of the feasibility study are as follows:

Task 1: Preliminary Scoping of Alternatives and Data Acquisition; Tool Development
Task 2: Scoping/Detailed Development of Alternatives
Task 3: Evaluation of Alternatives (including 26 performance-measure-based subtasks)
Task 4: Development of Evaluation of Alternatives Document
Task 5: Meetings, Deliverables, and Schedule
Task 6: Public/Interagency Outreach and Coordination

The first two evaluation tasks involve preliminary work that is necessary to assemble the evaluation tools (e.g., models), input data (e.g., sediment data, economic data, unit costs, etc.), and key assumptions that will be used to further develop the specific scope of the alternatives and then evaluate those alternatives. Task 3 of the work breakdown structure then details how each of the alternatives will be evaluated against the project goals and performance measures. The remaining three tasks focus on developing the *Evaluation of Alternatives* report, and how the project schedule and public/interagency outreach activities will be managed.

3.2 Task 1: Preliminary Scoping of Alternatives and Data Acquisition; Tool Development

Before the detailed development of the sediment management and sediment disposal alternatives can move forward, a number of global engineering, scientific, and economic issues need to be addressed. The first task following the District's Stop/Go decision will therefore be dedicated to gathering critical preliminary information necessary to add greater detail to the basic framework of the alternatives that were first described in a general sense in the *Development of Alternatives* report (BBL, 2001b). Information gathered in this task will be used to more fully define and describe the scope and scale of the alternatives. This preliminary scoping and preparation process will be broken out into two subtasks. The first will address preliminary scoping and data acquisition; the second will address tool development needs.

3.2.1 Subtask 1a: Preliminary Scoping of Alternatives and Data Acquisition

The purpose of this subtask is to gather detailed, focused data in order to advance the alternatives beyond the preliminary, general descriptions provided in Section 3 of the *Development of Alternatives* report (BBL, 2001b). For example, in order to develop complete descriptions of the sediment management alternatives, the team will first have to refine (if possible) the spatial and areal extent of sediment targeted for treatment or removal. In the *Development of Alternatives* report (BBL, 2001b), a general assumption was made that the entire pelagic zone, covering approximately 83,000 hectares (Reddy, 1991) and containing approximately 193 million cubic meters (m^3) of fluid, phosphorus-rich sediments (Kirby et al., 1989), was the appropriate sediment area and volume to target for potential remedial action. A review of any new research or data will be necessary to determine if this preliminary assessment is appropriate or if the study should focus on either a larger or smaller area (opportunities to further define/refine the vertical sediment profile will be pursued). Once the area/volume targeted for action is better defined, the team will gather other information necessary to refine the alternatives. The list of issues and questions that follow is by no means all-inclusive, but rather includes the currently-identified issues the team will address in this subtask. Information gathered during this exercise may lead to other issues or questions that the team will follow up on as necessary.

Representative preliminary scoping issues, arranged by topic include:

Engineering:

- *Preliminary equipment availability survey*. In order to develop the dredging alternatives, the team will have to answer a number of questions, for example, how many dredges are available that could be deployed to Lake Okeechobee? Is equipment available locally, or will it have to be brought in from other areas?
- *Chemical availability survey and information on application/production rates*. For the chemical treatment alternatives, key data include how much of the chemical is readily available? Would any on-site storage or staging of the chemical be necessary? What are typical application rates (to estimate length of time needed for treatment)? Where are experienced contractors located? Are they available for work on this scale?
- *General sediment disposal requirements.* In order to scope out the sediment disposal options, the team will have to assess the volume of sediment to be removed. Once the area and vertical depth targeted for sediment removal is refined, disposal needs can be better estimated. This information is critical in siting considerations – finding open land or existing facilities to deal with several thousand cubic meters of material is quite different from the issues associated with managing several million cubic meters of sediment.
- *Data from the University of Florida sediment study and EA's pilot dredging project*. At this point in the feasibility study, consideration of the data generated by these two projects will be critical. The team will conduct a preliminary assessment of the availability, quality, and applicability of the data to develop a better understanding of how the results may apply to the detailed development of alternatives. It is important to note that if the results of these two site-

specific studies are not complete and available by the time alternative-specific modeling begins (i.e., April/May 2002), it may be too late to effectively integrate the findings of those studies into this feasibility study. However, the project team will endeavor to incorporate the findings to the extent practicable and applicable within the scope and framework of this study.

- *Lake Okeechobee waterway*. As the remedial area/volume is refined, potential impacts to the Lake Okeechobee waterway will also have to be considered. Would barges, pipelines, or dredges associated with removal operations interfere with water traffic? Does the United States Army Corps of Engineers (USACE) plan to maintain this waterway in the future? Proximity to the waterway will also be a factor when locating potential sites for in-lake confined disposal facilities (CDFs) or in-lake sumps.

Scientific:

- *Hydrological, hydrogeochemical, and physical data.* What overall data gaps still exist? Of these data needs, what can be met with available information or defensible assumptions? Data and information identified in this step could be used to model/predict future water quality; locate an in-lake sump or an in-lake or shoreline CDF; better define the characteristics of material dredged from the lake as they relate to beneficial reuse possibilities; estimate how quickly an in-lake sump would collect sediment; estimate the water and solids content of dredged material; etc.
- *Ecological data.* Ecological needs will, at this early stage, be focused on using readily available data to identify any sensitive or critical habitats where disruption should be avoided. To the extent possible, a desktop survey of in-lake, shoreline, on-shore, and upland areas will be carried out to locate, for example, particularly diverse or abundant benthic communities of known value, known submerged aquatic vegetation (SAV) beds, wetlands, protected areas, or sites with an otherwise identified ecological value or sensitivity. This basic information will then be specifically tailored to relevant performance measures during the evaluation of alternatives.

Economic:

- *Potential market for beneficial reuse of sediment*. One of the sediment disposal options to consider is beneficial reuse of dredged materials as topsoil, fill material, or other potential residential, commercial, or agricultural applications. Dredged slurry could also be transported via pipeline directly to nearby farm land for beneficial reuse. In order to evaluate the preliminary feasibility of these options, the potential viability of local and regional markets and location of suitable agricultural areas will be considered.

- *Land Use/Land Ownership/Land Values*. In order to develop a preliminary scope for where CDFs might be located or where staging of equipment might take place, a general (low resolution) desktop survey of existing land use, land ownership (general, large scale), and land values is necessary. Land use is important because residential or valuable commercial areas would not be appropriate for either disposal or staging needs, while open farm land, quarries, or low-value land might be parcels feasible enough to consider. Land ownership is critical information as the District may own suitable amounts and types of land around or near the lake, or there may be suitable private lands. District-owned land may be earmarked for other programs, so known conflicts should be identified as early as possible. Developing an understanding of general land values around the lake will also play into siting considerations and recognition of potential equity issues.

The information described above will be gathered and compiled in the first month of the alternative evaluation process. Results and findings will be carried forward into Task 2 of the evaluation – the detailed scoping and development of the sediment management and disposal alternatives.

3.2.2 Subtask 1b: Tool Development

The second component of Task 1 of the evaluation phase focuses on the steps necessary to ensure that the tools needed to carry out the detailed evaluation of alternatives (Task 3; see Section 3.4) are in place. For example, for the analysis of socioeconomic impacts, a correlation matrix will be developed using economic and demographic data from Claritas, Inc. (an economic forecasting firm) and sales tax data from the Bureau of Economic and Business Research at the University of Florida (the state's official outlet for sales tax data). The acquisition of these data will begin in the first quarter of 2002, and they will be used to build the correlation matrix. In addition, if any applicable and suitably detailed data become available from the District or other sources (e.g., Hazen & Sawyer study) throughout the remainder of the feasibility study, they will be incorporated into the matrix to strengthen the relationships calculated for the detailed analysis of alternatives.

Preparing the various mathematical models for use is a more complicated undertaking. Table 2 summarizes the models that will be used to conduct the feasibility assessments of different sediment management techniques, and Figures 2A and 2B provide graphical representations of the interrelationships among the models. The models can be separated into three fundamental groups based upon their intended use:

- ***Simulate spatial changes in sediment resuspension fluxes and associated fluxes of sedimentary phosphorus (spatially explicit models).***
  These analyses will allow an assessment of whether a particular management option will result in changes in the flux or movement of phosphorus from the pelagic to the near-shore and littoral zones of Lake Okeechobee. This analysis requires a spatially resolved model that is able to predict changes in sediment fluxes due to either changes in morphometry (e.g., lake stage manipulation) or sediment shearing characteristics (e.g., change in sediment bulk density and critical shear stress due to sediment mitigation), coupled with the ability to predict the lateral movement and deposition of resuspended particles. The modeling tool that the project team will use to conduct these simulations is the Lake Okeechobee 3-D Hydrodynamic Transport Model (LOHTM, see Table 2 and Figure 2A), which was developed explicitly for Lake Okeechobee by Jin and Hamrick (2000) from Hamrick and Wu's (1997) Environmental Fluid Dynamics Code (EFDC). LOHTM is a three-dimensional, dynamic model that was designed to examine circulation patterns and vertical mixing across the entire lake. The model has a grid structure of 58 x 66 horizontal cells (each cell is 925 meters to a side), with six vertically-stretched cells (i.e., each cell is 1/6 of the water depth), yielding a total number of 2,216 active water cells (Jin and Hamrick, 2000). Sediment resuspension due to wind-generated waves is predicted by LOHTM using predicted wave parameters derived from Delft University's SWAN model (Table 2) as input. This latter model has been used by the District to examine wind-wave current parameters for the year (360 days) beginning October 1, 1999 and concluding September 25, 2000. This year encompasses a broad range of meteorologic and hydrologic regimes, including the effects of a hurricane. Because of the

prohibitively time-intensive nature of conducting multiple long-term simulations with the model, the project team will use output files from SWAN developed by the District for this year only (see following section on scenario description and input files) rather than run the model itself.

- ***Simulate changes in overall lake phosphorus concentrations and lake trophic state, treating the lake as a single continuous-stirred tank reactor (CSTR models)***.

  The primary model the project team will use is the Lake Okeechobee Water Quality Model (LOWQM) developed by James and co-workers (James and Bierman, 1995; Bierman and James, 1995; James et al., 1997; Jin et al., 1998), which was recently revised to improve how sediment diagenesis of phosphorus is represented (James et al., in preparation). This latest version of LOWQM also has been recalibrated and validated for the period 1983-2000. Additional simulations will be conducted as appropriate using the Lake Okeechobee Internal Phosphorus Loading Model (Pollman, 2000) and the Walker (2000) box models of Lake Okeechobee. These models do not offer the complex treatment of the phosphorus and nitrogen cycles and their effect on the phytoplankton community dynamics and structure and associated effects on suspended particle concentrations inherent in LOWQM, but can serve as tools for hypothesis testing as the alternatives evaluation is conducted. These box models, however, are not appropriate for evaluating sediment management alternatives that influence sediment particle resuspension rates without modification to the models, and will not be used for all scenario analyses. See Table 2 and Figure 2B.

- ***Simulate changes in surficial sediment porewater chemistry, resulting either from the removal of overlying sediments enriched in phosphorus, or from chemical treatment (chemical equilibrium models).***

  The effects of chemical treatment will be analyzed using at least one of several thermodynamic equilibrium models derived from the original MINEQL model developed by Westall et al. (1976). These current generation models include: MINEQL+ developed by Shecher (Environmental Research Software [ERS], 2001), which is commercially available; MINTEQA2, which was developed by the United States Environmental Protection Agency (USEPA; Allison et al., 1991) and is available from USEPA Center for Exposure Assessment Modeling (CEAM;

www.epa.gov/ceampubl/minteq.htm); and KINETIQL, recently developed by Hudson (R. Hudson, personal communication). The effects of sediment removal on the development of porewater gradients of phosphorus concentrations and changes in passive diffusion rates across the sediment porewater interface will be evaluated using the Lake Okeechobee Phosphorus Diagenetic Model (Pollman, 1991). See Table 2 and Figure 2B.

With the exception of the thermodynamic equilibrium models, all the models the project team will use for the assessment of the effects of different sediment management alternatives on nutrient and trophic state dynamics have been developed specifically for and calibrated to Lake Okeechobee. No further model calibration will be undertaken as part of this work effort. The MINEQL model has been thoroughly reviewed and tested (cf., Nordstrom et al., 1979) and both MINEQL+ and MINTEQA2 reflect updates to the thermodynamic database completed in 1999 by USEPA.

Model Acquisition

The feasibility study modeling team, led by Dr. Curtis Pollman of Tetra Tech, Inc., currently has the following models in house:

- LOWQM (James et al. [in preparation] revision and recalibration)
- Lake Okeechobee Internal Phosphorus Loading Model (Pollman, 2000)
- Walker (2000) Lake Okeechobee Model
- Lake Okeechobee Phosphorus Diagenetic Model (Pollman, 1991)
- KINETQL
- MINTEQA2
- MINEQL+ (DOS version 3.01b)

LOHTM and the latest version of LOWQM will be obtained directly from the District in the first quarter of 2002. At that point, key project team staff will coordinate a trip to District offices in West Palm Beach to review critical aspects of how each model works and how the input and output data files are structured. The models will then be installed and run using input files provided by the District to verify that Tetra Tech is running the models properly. The Windows version of MINEQL+ will be obtained from ERS in the first quarter of 2002.

Model Linkage

The LOWQM (Table 2) is a 1-box model that can use output from the LOHTM to predict sediment resuspension rates (an important component of internal phosphorus loading). The LOHTM model will be used to analyze issues of spatial significance (e.g., impacts on submerged aquatic vegetation in the near-shore zone) over a comparatively short time frame (one year or less), while the LOWQM will be used to simulate long-term phosphorus and nitrogen dynamics in the pelagic zone. Thus, LOHTM and LOWQM will not be linked for long-term simulations. Figures 2A and 2B provide graphical representations of the linkages between the three different groups of models.

The effects on porewater chemistry of chemical treatment will be evaluated using the thermodynamic equilibrium models. Integrating those results into LOWQM will likely require minor code modifications designed to maintain porewater soluble reactive phosphorus concentrations at a level specified by the thermodynamic model. This will then affect the amount of phosphorus sorbed onto surficial sediment particles and available to repartition into the water column following resuspension.

Model Input Files and Model Scenarios

Analyses examining the spatial effects of a mitigation scenario with LOHTM will focus on the period October 1, 1999 to September 25, 2000, which was a year that encompassed both high and low lake stages and included the effects of high winds on sediment resuspension (including a hurricane). Output files for wave parameters predicted by SWAN for this year have already been developed by the District, and these files will be made available to the project team to use as input to LOHTM (Figure 2A). Differences between the proposed mitigation measures will therefore be examined for this year on a relative basis. The District will also provide the project team with data on critical light extinction coefficients for existing near-shore SAV and an empirical relationship between total suspended solids (TSS) and the light extinction coefficient so that the analyses of sediment resuspension and transport can be extended to assess SAV impacts.

Long-term analyses using the LOWQM will be conducted using the following flow-weighted average input total phosphorus concentrations:

- Current Loading Conditions – 157 micrograms per liter (ìg/L) phosphorus (based on flow-weighted average concentrations over the past 10 years);
- Surface Water Improvement and Management (SWIM) – 180 ìg/L phosphorus;
- Total Maximum Daily Load (TMDL) – 40 ìg/L phosphorus; and
- 0 ìg/L total phosphorus.

The hydrodynamics will remain the same for all loading scenario analyses described above, and will cover the period of existing record, 1973-2000. During each scenario run, the defined input phosphorus concentration will remain constant throughout the simulation.

Total nitrogen dynamics also influence the overall trophic status of Lake Okeechobee, and it is reasonable to assume that external load reductions of phosphorus should result in reductions in total nitrogen loading as well. We will assume for each of the scenarios above that nitrogen is removed in a fashion similar to total phosphorus. More explicitly, we will use existing 5-year average weighted N:P ratios, and phosphorus and nitrogen speciation relative to total concentrations to develop nitrogen loading rates based on the assumed total phosphorus loading rate. The District will provide flow-weighted ratios for nitrogen and phosphorus species for inflows. The same approach can be used to estimate external inputs of TSS.

The District will also provide the project team with recent pore water chemistry data, including data derived from *in situ* samplers or peepers. These data are expected to include pH, calcium and other major ion concentrations, as well as nitrogen and phosphorus species, and manganese and iron (II/III) data if available.

3.3 Task 2: Scoping/Detailed Development of Alternatives

Prior to evaluating the alternatives against the performance measures, the level of descriptive detail for each alternative will be expanded beyond the initial concept-level presentation used in the *Development of Alternatives* report (BBL, 2001b). This increased level of detail is necessary to support the quantitative and qualitative aspects of the alternative evaluation process as described in Task 3 of this Work Plan. As noted in Subtask 1a, there are several key technical questions and assumptions that should be finalized prior to developing the detailed alternative descriptions. It is these assumptions that will form the core of the detailed descriptions of the alternatives. For example, it will not be possible to evaluate an alternative that includes dredging and disposal in a shoreline CDF without making the following detailed assumptions:

- Location and area of sediments targeted for dredging (the overall area and location);
- Amount to be dredged (the sediment depth and estimated volume);
- Dredging approach (hydraulic versus mechanical);
- In-situ solids content of the sediments targeted for dredging;
- Environmental controls during dredging;
- Potential seasonal or navigational limitations on dredging;
- Dredge production rates;
- Dredged material transport method;
- Dewatering characteristics of the sediment;
- Dewatering method to be used;
- Water treatment requirements (flow rate, influent characteristics, and effluent requirements);
- Required sediment disposal volume;
- Location of the sediment disposal facility (in-lake, near-shore, or upland); and
- Post-dredging internal phosphorus loading rates.

The assumptions identified above will be used to develop the alternatives that include a dredging component, while alternatives based on in-lake chemical treatment would rely on a different set of assumptions. For example, in-lake chemical treatment would likely be implemented in the same locations as dredging, yet would not require making assumptions about sediment transport, sediment disposal, or residual water treatment. The detailed descriptions of the treatment alternatives would however need to include assumptions for the dose of chemical required per unit area, the rate of application that is achievable, and the length of time before re-application of the chemical will be required to continue to mitigate internal loading. Once more detailed descriptions of each of the seven primary alternatives identified in the *Development of Alternatives* report (BBL, 2001b) are developed, the descriptions of the various disposal sub-alternatives can be based on similar assumptions, and will likely require only minor changes in assumed scope to reflect the range of proposed sediment disposal options.

It is also important to note that seemingly similar alternatives may have detailed descriptions that are different in a subtle, but important manner. For example, a removal alternative that includes dredging and beneficial re-use of sediment may have a significantly different removal production rate (m^3 of sediment removed per year) than an alternative that includes dredging and disposal. For example, production rates could be limited by the local annual market for a blended soil product manufactured with sediment dredged from the lake, which could be considerably less than the annual quantity of dredged sediment that could be managed in a shoreline CDF, where rates may be limited only by equipment availability in the southeastern United States. A substantial difference in the dredging production rate could substantially affect critical performance measures such as the time to achieve water quality goals, cost, or community acceptance.

The detailed descriptions of the alternatives will be presented as a textual summary including the key assumptions as well as the projected overall sequence, timing, and duration of the construction activities. When appropriate, conceptual-level sketches will be included to facilitate communication of technical elements of the alternatives.

As noted in Subtask 1a, to the extent possible technical information from the EA pilot dredging study and the University of Florida sediment study will be incorporated into the development of the detailed descriptions of the alternatives. If this information is not available in a time frame to meet critical feasibility study milestones (e.g., data will be useful if available early in 2002, but of little use if not available until mid or late 2002), engineering judgment based on literature and case study data, as well as professional experience at other sites, will be used to develop the descriptions of alternatives.

3.4 Task 3: Evaluation of Alternatives

After completing the detailed scoping of the alternatives and acquiring and organizing the necessary data and tools, the detailed evaluation of alternatives can begin. The overall goal of the evaluation is to perform an objective, science- and engineering-based analysis of the feasibility and, to the extent possible, evaluate the expected performance of each alternative if it were to be implemented within Lake Okeechobee. To meet this goal, a consistent approach is required that will not introduce unnecessary and undesirable bias or error in the method, results, or reporting. Thus, the evaluation subtasks are organized by performance measure, meaning each of the seven sediment management alternatives will be evaluated in a consistent manner against each of the 26 performance measures. The same methods, tools, and data prescribed under each performance measure will be used to evaluate the merits of each alternative. In this way, the relative feasibility and performance of each alternative can be estimated and compared against that performance measure's target value or condition.

It is anticipated that the evaluation process will require approximately 14 months to complete, including development of draft and final reports (see Section 3.6 regarding deliverables). The evaluation will be conducted and documented during 2002, with the draft and final reports generated between November 2002 and February 2003. The evaluation process is expected to be moderately complex, with a high degree of coordination needed among the water quality modeling, engineering/cost analyses, environmental impact evaluations, and socioeconomic analyses activities. To assist in managing an efficient and productive process, the performance-measure-specific discussions within this subsection address the critical aspects of data and tool interdependencies among evaluation subtasks, and also anticipate potential sources of uncertainty.

To help understand the overall approach to be employed in the evaluation, Figure 3 presents a schematic of the major components and how they are organized within a framework to facilitate work flow and task coordination and interdependencies. As shown in Figure 3, once modeling tools and data are in place, the primary critical path becomes the interaction between water quality modeling and engineering analyses. Clearly, all goals and performance measures are important, but those dependent upon modeling and engineering analyses are likely to be the most challenging to manage and coordinate effectively. Within this overall framework, each of the alternatives will be evaluated against the performance measures to generate the specific output that the project team will use to develop the draft *Evaluation of Alternatives* report, and the associated raw data and quantitative scores can be used by the District to prioritize alternatives (with stakeholder input) and ultimately determine a recommended course of action.

The six Work Plan tasks and associated subtasks designed to conduct the detailed evaluation of alternatives and prepare the final report are presented in graph format in Figure 3. The figure highlights the relationships between the initial scoping activities under Tasks 1 and 2, the performance measure evaluations subtasks under Task 3, and preparation of the *Evaluation of Alternatives* report under Task 4. Other elements of the overall project schedule (Tasks 5 and 6) are discussed later in Section 3.6. It is important to note that the evaluation of the performance measure subtasks, and hence preparation of the *Evaluation of Alternatives* report, are tied to the completion of the modeling activities (including both the no-action case and the sediment management alternatives). As such, there are several critical input parameters assumed to be available from the District that are on the project's critical path. These include:

- External loading data for nitrogen and phosphorus;
- Lake hydrology input files;
- Sediment resuspension input files;
- Meteorology input files; and,
- Updated models.

Based on the schedule, in order to conduct the evaluation of the alternatives versus the performance measures under Task 3 and complete the Task 4 evaluation report, the District will need to provide the project team with the items listed above in early 2002.

Following are summaries of the 26 subtasks, including synopsis tables and descriptions of the specific target, tools, data, method, scoring, timing, and potential uncertainties associated with each performance measure. These descriptions are intended to provide clarification and, where necessary or possible, an extension of the methodologies provided in the *Goals and Performance Measures* document (for convenience, Section 3 of the Goals document is provided as Attachment 1 to this Work Plan). These discussions are organized to be as concise as possible while maintaining an acceptable level of thoroughness in describing the methods to be used during the evaluation. As with most activities that take place in the future, all possible methods and activities that may be used during the evaluation cannot be completely and accurately predicted. However, every effort is made in the remainder of this subsection to anticipate how and why each performance-measure-specific method will be used in evaluating the alternatives. Moreover, the draft *Evaluation of Alternatives* report will describe any deviations in methodology, tools, or data sources/quality that become necessary as the evaluation progresses over the next several months.

As a guide to the summary tables and discussions for each of the 26 performance measures, definitions of key terms are provided here.

- ***Performance measure*** – Each performance measure represents a particular aspect of the project's five overall goals. When assessment of each performance measure is carried out as described below, enough specific, relevant information will be generated to develop a clear picture of not only whether or not an alternative could be expected to achieve the stated goals, but also to what extent and under what conditions, assumptions, and time frames.

- ***Target*** – Each performance measure has a target, which is the specific level, quantity, or condition desired or deemed necessary to assume achievement of a goal or significant progress toward achieving a goal. For example, the target water column concentration of total phosphorus to be achieved by an alternative is 40 µg/L. Performance measure targets can be mandated by state or other laws or regulations, or be based on site-specific testing, experience, or other sound scientific or engineering judgement.

- ***Tool(s)*** **–** In order to carry out the evaluations, a number of different tools, both quantitative and qualitative, will be used to estimate each alternative's feasibility and performance. Tools applied range from mathematical models, to literature surveys, to correlation matrices. Brief descriptions of the tools, their source, and what if anything needs to be completed to ready them for use are provided. Application of the tools is described in the methods sections.

- ***Critical Data/Input*** **–** Evaluation of alternatives against each performance measure will obviously require certain data or input; therefore, each performance measure discussion that follows includes a brief description of data and data sources that are critical to perform an acceptable evaluation. In many cases, output data generated during evaluation of one performance measure (e.g., water quality) is needed as critical input to evaluation of some other measure (e.g., habitat quality, downstream impacts, etc.).

- ***Method*** **–** The method discussion provides important details as to how the performance measure and tools will be used to evaluate alternatives. For example, computer-based modeling will be performed or appropriate assessment criteria (e.g., site-specific or case-study data and experience, data collected during pilot-scale test projects) will be applied to determine the expected outcome of an alternative relative to a particular goal. To conduct a thorough and objective evaluation, it is essential that the methodology of *how* the evaluation will be conducted is specified before work begins. For example, for modeling activities, the method description will include what data will be used, what output will be generated, and how the data will be used and reported. For cost estimating activities, the method description will include how the estimates will be developed and reported.

- ***Scoring*** – The outcome of the evaluation of alternatives relative to performance measures will be reported either quantitatively or qualitatively, depending on specific target parameter and availability of hard data. Quantitative metrics will produce raw results in units (metrics) appropriate to each performance measure (e.g., dollars, ìg/L). For those performance measures with metrics that are qualitative, scoring will be reported on a simple scale ranging from 1 to 5. For example, typically a relative value of 1 will be assigned for the lowest or least favorable performance, and 5 will be assigned for the highest or most favorable performance of an alternative. The result of the scoring process will be a raw number for each performance measure that the District will be able to weight appropriately during the alternative prioritization/selection process to aid in the final recommendation of the best overall course of action. Where appropriate, the evaluation of some performance measures may generate two scores – one related to short-term impacts or benefits, the second to the long-term impacts or benefits.

  Scores (i.e., outcomes) of the evaluations will be reported in two ways in the Evaluation of Alternatives report. First, the scores for all alternatives will be reported for each performance measure so that relative result of each alternative evaluation can be easily compared against *each single* performance measure. Secondly, at the end of the evaluation process, all scores will be compiled into a single matrix to allow for a convenient comparison of how each alternative performs relative to *all* performance measures. In this way, the overall performance of the alternatives can be assessed and compared and the District and other users of the feasibility study data will have a convenient cross-indexing of scores. See Section 3.5 for a brief description of the expected outline and format for how information will be reported in the Evaluation of Alternatives document.

  To facilitate Task 5 of the overall project (Stakeholder Prioritization of Alternatives), all scores will be clearly reported within the Evaluation of Alternatives report, and supporting quantitative and qualitative results (i.e., raw data/output) also will be summarized and reported for further use by the District.

- ***Interrelationships with Other Subtasks/Timing*** – As mentioned previously, in some cases the evaluation will involve activities and data input/output that need to be highly coordinated. Therefore, this discussion for each performance measure describes which data and tools are fundamentally important inputs for an evaluation and which outputs become fundamentally important in enabling other analyses to proceed. In other cases, such as impacts on certain target species (e.g., alligator, manatee, etc.), evaluations are qualitative and do not depend to a large degree on data generated from results of other performance measure evaluations.

- ***Uncertainty Considerations*** **–** It is important to recognize that some level of uncertainty will exist in evaluating each alternative against the performance measures. To assist decision makers as they review the results of the evaluation of the alternatives, the level of uncertainty for each performance measure will be discussed within the Evaluation of Alternatives document. The discussion will highlight areas of uncertainty and give the reader a sense of how definitive the qualitative or quantitative results are. The uncertainty may be associated with the tools used to evaluate the impacts of a given alternative, such as the simulation and prediction of water column phosphorus concentrations using a computer model. Where possible, the estimate of uncertainty will be quantitative to the extent that data are available to support this process. For some performance measures, the estimates of uncertainty will be more qualitative. For example, the level of uncertainty for "Maximizing Technical Scalability" will be estimated using engineering judgement and case study information considered during the evaluation process to assign the qualitative score. The end result of this discussion may take the form of "the score of this alternative relative to the performance measure is a 3, based on a scale of 1 to 5. However, given the limited nature of pilot testing and case study data available during this evaluation, there is a level of uncertainty such that the rating could range between 2 and 4."

  Each of the 26 performance-measure-specific subtask discussions that follow in this subsection include a brief description of anticipated sources and types of uncertainty that may be encountered during the evaluation. Some tools, data, and methods will inherently produce a greater degree of uncertainty than others. In all cases, the evaluation team will strive to limit uncertainty and, at a minimum, report sources and types of error as well as estimate (to the extent possible quantitatively

> and/or qualitatively) the potential implications of the uncertainty. It is anticipated that the Evaluation of Alternatives report will therefore include a global discussion of uncertainty issues as well as performance-measure-specific discussions of uncertainty.
>
> It is very important to note that despite the anticipated uncertainties, unprecedented scale/complexity of the problem, and in some cases lack of data (site specific or case study), published literature (applicable to this system and project goals), or extensive operational histories (relevant and scalable to this system and alternatives array), there is sufficient technical information and field experience available to complete a thorough and comprehensive feasibility study to support District decisions regarding mitigation of internal phosphorus loading in Lake Okeechobee. Certainly, additional site-specific pre-design studies will be necessary to fill current data gaps and decrease uncertainty before any particular course of action could be fully designed, permitted, and constructed.

For added convenience, Table 3 (on the next page) provides a simple index of where each performance measure's methodology is located within the remainder of this subsection. Note that for purposes of this Work Plan, each performance measure is listed as a "Subtask" with a nomenclature that corresponds to the designations assigned to each performance measure in the Goals document. For example, Performance Measure 1A (Minimize Time to Achieve Phosphorus Target) is discussed as "Subtask 3.1A" here. Note that the "1A-type" designation is used consistently for all 26 performance measures and associated subtasks.

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Table 3
Summary of Performance Measures/Subtasks

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Subtask 3.1A – Minimize Time to Achieve Phosphorus Target **Subtask 3.1B – Maximize Reductions in Water Column Phosphorus Concentrations**	
Targets	1A: The time for lakewater total phosphorus concentrations to reach 40 µg/L, or a fraction of this goal. 1B: Average total phosphorus concentration of 40 µg/L in the pelagic zone.
Tool(s)	LOWQM is the primary tool. Supplemental modeling with Lake Okeechobee Internal Phosphorus Loading Model (Pollman, 2000), Walker (2000) Lake Okeechobee Model, Lake Okeechobee Phosphorus Diagenetic Model, MINEQL+.
Critical Data/Input	Current sediment chemistry, vertical fine structure data on sediment chemistry and physical properties, including critical shear stress, water column major ion chemistry. External loading scenarios need to be carefully articulated by the District.
Method	Modeling using principally LOWQM to simulate dynamic response of lake to alternatives; supplemental modeling to predict porewater chemistry changes using thermodynamic models. Supplemental dynamic modeling using Lake Okeechobee Internal Phosphorus Loading Model (Pollman, 2000), and Walker (2000) model, as appropriate. Analyses of different alternatives, including the No Action alternative, should be based on external loading scenario sufficient to produce a predicted long-term (steady state) in-lake total phosphorus concentration of 40 µg/L.
Scoring	1A: Higher score means a more rapid rate of recovery. 1B: Higher score means average total phosphorus concentration at or near 40 ìg/L.
Interrelationships with Other Subtasks/Timing	This evaluation comprises the fundamental framework for the evaluations for subtasks 3.1A, 3.1B, 3.1C, and 3.1D. Nitrogen loads defined as critical for 3.1D also will be used in this analysis. These will be among the first subtasks conducted.
Uncertainty Considerations	Effects of changing nutrient dynamics on sediment bulk phase properties (bulk density) and thus critical shear stress and resuspension rates. Residence time (depends on active exchange depth assumed) of available phosphorus in surficial sediments.

Targets: **1A** – Reduce response time of Lake Okeechobee water column total phosphorus concentrations to changes in long-term external phosphorus loading rates in order to achieve the ultimate goal of 40 ìg/L.

1B – Achieve an average total phosphorus concentration of 40 ìg/L in the pelagic zone of Lake Okeechobee.

Tools: LOWQM is the principal analysis tool the project team will use for both subtasks 3.1A and 3.1B. Supplemental modeling, depending on the type of mitigation considered, may be conducted using the Lake Okeechobee Internal Phosphorus Loading Model (Pollman, 2000), Walker (2000) Lake Okeechobee Model, Lake Okeechobee Phosphorus Diagenetic Model, and MINEQL+ or the other MINEQL-based models (MINTEQA2 and KINETIQL).

Critical Data/Input: Data required for these subtasks include data on current sediment chemistry in Lake Okeechobee (Fisher et al., 2001), fine vertical structure on sediment concentration profiles for phosphorus species (Brezonik and Engstrom, 1998), and the current study being conducted at the University of Florida by Reddy and colleagues on the effect of sediment dredging on rates of phosphorus release (Reddy et al., 2001). Also important will be the work by Kirby et al. (1989) defining the relationship between sediment bulk density and vane shear strength, and input files for sediment resuspension rates used to drive LOWQM that reflect long-term (typical) meteorology. External loading regimes (lake hydrology and stage) and phosphorus input loading rates (as a function of time) will be defined or supplied by the District consistent with their long-term management goals for the lake. Data will be needed on changes in sediment parameters (spatial extent of material removed; physico-chemical properties of exposed material; changes in porewater concentrations of dissolved inorganic phosphorus following chemical treatment).

Method: The primary method for assessment will be to conduct modeling using the most recent version of the LOWQM (James et al., in preparation). Long-term input files of external loading rates and lake hydrology (inflows, outflows, lake stage) will be obtained from or developed in concert with the District (see Section 3.2.2). Input files on sediment resuspension rates used to calibrate LOWQM (18-year period of record) will be obtained from the District as well. As described in Section 3.2.2., four long-term scenarios will be conducted using LOWQM for each mitigation option. Long-term analyses using the LOWQM will be conducted using the following flow-weighted average input total phosphorus concentrations:

- Current Loading Conditions – 157 ìg/L phosphorus;
- SWIM – 180 ìg/L phosphorus;
- TMDL – 40 ìg/L phosphorus; and
- 0 ìg/L total phosphorus.

The hydrology used to drive the model will be the period of record 1973 to 2000. For each of the loading scenarios conducted above, the hydrology will remain the same. During each scenario run, the defined input phosphorus concentration will remain constant throughout the simulation.

Total nitrogen dynamics also influence the overall trophic status of Lake Okeechobee, and it is reasonable to assume that external load reductions of phosphorus should result in reductions in total nitrogen loading as well. We will assume for each of the scenarios above that nitrogen is removed in a fashion similar to total phosphorus. More explicitly, we will use existing 5-year average weighted N:P ratios, and phosphorus and nitrogen speciation relative to total concentrations to develop nitrogen loading rates based on the assumed total phosphorus loading rate. The District will provide flow-weighted ratios for nitrogen and phosphorus species for inflows. The same approach can be used to estimate external inputs of TSS.

Nutrient dynamics in the water column and response times can be calculated for some management scenarios using the Lake Okeechobee Internal Phosphorus Loading Model developed by Pollman (2000) and the input-output model developed by Walker (2000). Both of these models, which are conceptually much simpler than the LOWQM, may be used, as appropriate, to verify whether similar results in terms of response time are predicted. These latter models, however, are not appropriate for evaluating management approaches that influence sediment particle resuspension rates without modification to the models, and will not be used for all scenario analyses.

Thermodynamic (equilibrium) modeling using MINEQL+ or the other MINEQL-based models (MINTEQA2 and KINETIQL) likely will be required to answer specific geochemical questions imposed by chemical treatment alternatives. Effects of alum or calcium additions on water column and surficial porewater chemistry will be calculated based on simple mass balance calculations of existing total concentrations (C_T) for major ions and aluminum, and how C_T for each constituent will change with treatment. These models are capable of predicting porewater inorganic phosphorus concentrations that may be regulated by a controlling mineral phase such as hydroxyapatite, or different iron mineral phases under oxic regimes. The output equilibrium concentrations for porewater phosphorus concentrations will then be input to the LOWQM and Lake Okeechobee Internal Phosphorus Loading Model to then examine how this type of mitigative measure influences response time.

Since the goals of these subtasks are to determine which alternative produces the fastest recovery time for the lake and has the best potential to reduce total phosphorus to the target concentration of 40 ìg/L, all alternative evaluations should be placed on an equivalent and valid basis for comparison, including the no-action alternative. More specifically, in the absence of any mitigative measures other than external load reductions, the external loading scenario must be sufficient to produce a predicted long-term (steady state) in-lake total phosphorus concentration of 40 µg/L. The model output will be graphically presented to show the predicted decreases (or increases) in total water column phosphorus concentrations as a function of time.

Scoring: 1A – A higher score will be assigned to alternatives that equate to a more rapid rate of recovery to the 40 ìg/L target (or a specified fraction of the goal) or a faster response time for a given external load scenario. Raw results (e.g., response time) will be reported, as will relative scores assigned from 1 to 5.

1B – Alternatives will be scored on a relative scale of 1 to 5. A higher score means long-term water column total phosphorus concentrations are closer to the 40 ìg/L target. Raw output will also be reported (e.g., concentration change).

Interrelationships with Other Subtasks/Timing: This evaluation comprises the fundamental framework for the evaluations for subtasks 3.1A, 3.1B, 3.1C, and 3.1D, and thus subtasks 3.1A and 3.1B will be among the first conducted. The analysis of response dynamics is critical for both subtasks 3.1A and 3.1B. Predicted TSS concentrations from the LOWQM modeling also form the basis for conducting the evaluative analysis of subtask 3.1C, while the predicted total nitrogen and total phosphorus concentrations that are produced from the LOWQM simulations form the basis for Subtask 3.1D. Since phosphorus cycling and primary production/particle dynamics are influenced by nitrogen loadings as well in LOWQM, the nitrogen loads defined as part of the evaluation for Subtask 3.1D need to be incorporated in this analysis. Results from the evaluation of subtasks 3.1A and 3.1B will also be considered in subtasks 3.1E, 3.2F, 3.4A, 3.4B, 3.4C, 3.4D, and 3.5C.

Uncertainty Considerations: Although LOWQM maintains a sediment mass balance, it is unclear if LOWQM has the inherent ability to predict changes in bulk density in the surficial sediments. Following sediment removal, the exposed sediments likely will have higher critical shear stresses than the original surficial material. Nonetheless, newly accreting material will be comparatively enriched in organic matter relative to the more mineralized, newly exposed sediments. This will result in a gradual increase in water content and a reduction in bulk density in the uppermost, surficial layer of the remediated sediments towards the original values of the undisturbed sediments. The critical shear stress thus should begin to drop shortly after mitigation, and resuspension rates should begin to increase. Although LOWQM currently does not have the ability to predict these changes, the possibility exists that LOWQM could be modified to compute changes in bulk density and resultant changes in shearing strength using the Kirby et al. (1989) algorithm.

Changes in porewater chemistry (and thus passive diffusive fluxes and release of sorbed and entrained porewater phosphorus during resuspension events) can be predicted using the MINEQL-based thermodynamic models. The changes in porewater chemistry can be set as “boundary” conditions in the LOWQM and the Lake Okeechobee Internal Phosphorus loading models, but this is a condition that is likely to change with time unless the additions of alum or calcium are continued periodically. LOWQM does not simulate alum or calcium concentrations in the water column or porewater; thus assumptions will have to be made regarding the long-term concentrations of these components (and thus porewater phosphorus concentrations) following treatment.

A primary source of uncertainty governing the expected rate of recovery of Lake Okeechobee in response to changes in external loading rates is the residence time of phosphorus in the surficial sediments available for exchange with the water column. The earliest version of LOWQM assumed an exchange depth of 10 centimeters (cm), which resulted in very long (hundreds of years) predicted recovery times. The current version of LOWQM has modified its treatment of sediments substantially, and this should influence the predicted dynamic response of the lake: LOWQM now treats the surficial sediments as 2 layers – a surface layer 1 cm thick, and an underlying layer 5 cm thick (James et al., in preparation). The Walker (2000) and the Lake Okeechobee Internal Phosphorus loading models both assume an active exchange depth of 5 cm. Because this assumption exerts such a strong effect on predicted recovery rates, the depth of active exchange assumed for the surficial sediments will be examined through sensitivity analysis for selected scenarios (e.g., the “no-action” alternative).

Subtask 3.1C – Maximize TSS Reductions in the Short Term and Long Term	
Target	The critical light extinction coefficient required to support the submerged aquatic vegetation community.
Tool(s)	SWAN-LOHTM, LOWQM; supplemental modeling using thermodynamic models (see subtasks 3.1A/3.1B)
Critical Data/Input	Relationship between the light extinction coefficient and TSS. Definition of $k_{e,critical}$ for submerged aquatic vegetation in Lake Okeechobee.
Method	Simulate changes in TSS and light extinction coefficient, k_e
Scoring	Two scores will be given – one for the short term and one for the long term; higher scores mean greater TSS reductions, and an increase in the maximum water depth able to support submerged aquatic vegetation in the near-shore zone (i.e., improved light transparency).
Interrelationships with Other Subtasks/Timing	Subtask 3.1A analysis (long term) will precede this subtask; results from this analysis support evaluation of subtasks 3.4A, 3.4B, and 3.4D.
Uncertainty Considerations	Likelihood of defining a quantitative relationship between light transparency and macrophyte community structure and standing crop is not very good; more qualitative ranking schemes likely will have to be developed.

Target: The overall goal is to reduce turbidity or suspended solids in the near-shore zone of the lake such that sufficient light transparency exists to support an active, viable population of submerged aquatic macrophytes. Restated, light transparency (or the depth of the euphotic zone) in the water column must be sufficient to support viable SAV communities throughout the entire depth regime of the near-shore zone. Light transmission through the water column often is expressed in terms of an extinction coefficient, k_e; thus, the target will be defined by establishing the critical light extinction coefficient, $k_{e,critical}$, that if not exceeded, yields sufficient light transparency in the near-shore zone such that submerged aquatic macrophyte colonization and growth is not precluded as a result of too much light being absorbed and scattered in the water column by turbidity and suspended particles.

Tools: LOHTM to predict short-term changes in sediment resuspension rates and TSS; LOWQM to predict resultant long-term changes in pelagic concentrations of TSS and total phosphorus. Supplemental modeling (e.g., MINEQL+) as required based on the sediment management alternative evaluated (see discussion in subtasks 3.1A/3.1B for more detail).

Critical Data/Input: See discussion in subtasks 3.1A/3.1B. It will be extremely important to define both the relationship between the light extinction coefficient, k_e as a function of TSS and $k_{e,critical}$ for SAV in Lake Okeechobee. The District currently is undertaking efforts to define both data needs and has indicated that this information will be made available to the project team in the near future. Alternatives (especially dredging options) need to be carefully defined in scope, duration, and timing.

Method: This analysis has two components. First, comparatively short-term (e.g., occurring over the course of a year) changes in TSS resuspension fluxes owing to, for example, changes in the physical properties of the sediments (e.g., critical shear stress), will be predicted using the linked SWAN-LOHTM models (see Section 3.2.2)[2]. This phase of the analysis will result in direct predictions of TSS in the critical near-shore zone. Simulation methods and data sets will follow those defined in subtasks 3.1A/3.1B. In addition, long-term changes in total phosphorus and TSS dynamics in the pelagic zone will be simulated using LOWQM. Changes in TSS will be evaluated in the context of a specified load reduction, thus producing a time trajectory of predicted TSS concentrations for each load reduction scenario.

The second component of the analysis is to predict changes in the light extinction coefficient, k_e, and compare the resultant value with $k_{e,critical}$. The District is currently developing empirical relationships between light extinction and suspended solids in Lake Okeechobee. The District also is conducting studies to elucidate $k_{e,critical}$. This work involves examining data on macrophyte coverage available from April 1999 through October 2000, coupled with experimental studies, and both $k_{e,critical}$ and an empirical relationship relating k_e to TSS are expected to be available to the project team before modeling begins in earnest.

Scoring: The same metric and method will be used to generate results and scores on a scale of 1 to 5 for both the short (during construction or implementation of an alternative) and long term (after an alternative is complete). The alternatives will be evaluated on a relative scale, with higher scores assigned to those measures that yield greater TSS reductions and, accordingly, increasing light

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[2] Note that the effect of changes in lake stage on sediment resuspension will be implicitly evaluated when the year 2000 simulations are conducted.

transparency and thus an increase in the maximum water depth able to support SAV in the near-shore zone. For example, the alternative(s) that compares most favorably to $k_{e,critical}$ will receive a 5 and the result farthest from $k_{e,critical}$ will score a 1. The other alternatives will be scored accordingly. Both the short- and long-term results and scores will be reported.

Interrelationships with Other Subtasks/Timing: This evaluation extends the analysis conducted for subtasks 3.1A and 3.1B. The effects on light extinction and SAV, and performance of total phosphorus concentrations and resultant TSS levels resulting from a particular sediment management strategy will be calculated. Results from this analysis will be used to the extent possible in the evaluation of subtasks 3.4A (wetland vegetation), 3.4B (SAV), and 3.4D (manatee).

The dredging alternatives will be carefully defined early in the evaluation process so that different configurations or spatial removal schemes can be considered.

Uncertainty Considerations: Assessment of direct effects within the near-shore zone ideally would involve application of the 5-box version of the LOWQM. Currently, only the single-box version of the LOWQM is available, and direct simulations of sediment transport impacts in the near-shore zone owing to resuspension alone will only be possible using the linked SWAN-LOHTM models for the October 1, 1999 to September 25, 2000 period for which SWAM output data are available (Section 3.2.2).

Subtask 3.1D – Minimize Algal Blooms	
Target	Total phosphorus concentration < 40 μg/L; TN:TP > 30
Tool(s)	SWAN-LOHTM, LOWQM; supplemental modeling using thermodynamic models (see Subtask 3.1A)
Critical Data/Input	Nitrogen loading scenarios must be defined.
Method	Methods similar to those described for subtasks 3.1A/3.1B. LOWQM used to simulate total phosphorus and total nitrogen and the dynamics of three algal groups. Impact to near-shore region evaluated using regression relationship.
Scoring	Higher score means lower incidence of blooms, and reduced likelihood of cyanobacterial dominance of phytoplankton community.
Interrelationships with Other Subtasks/Timing	Analyses conducted for subtasks 3.1A/3.1B form the basis for this analysis. Nitrogen loadings developed for this analysis also must be incorporated into analyses of subtasks 3.1A and 3.1B.
Uncertainty Considerations	Magnitude of changes in nitrogen budgets that would occur concomitantly with reductions in phosphorus external loading rates. Change in internal recycling rates and NH_4^+ release with sediment management, particularly sediment removal.

Target: The goal for this subtask is based on two objectives: First, minimize the likelihood of algal blooms in general occurring in Lake Okeechobee by reducing in-lake total phosphorus concentrations below 40 μg/L. Second, minimize the likelihood of nuisance cyanobacterial blooms. This second goal is based on the understanding that non-cyanobacterial species tend to be dominant at total nitrogen to total phosphorus (TN:TP) ratios greater than 29, while nitrogen-fixing cyanobacterial species tend to be dominant at TN:TP < 14. Thus, this goal seeks to maintain the TN:TP ratio greater than 30.

Tools: SWAN-LOHTM will be used to predict short-term (one year or less) changes in TSS and, by regression relationship between total phosphorus and TSS, and changes in total phosphorus in the near-shore region. LOWQM will be used to predict resultant changes in total phosphorus and total nitrogen in the pelagic zone. Supplemental modeling (e.g., MINEQL+) will be needed as required based on the sediment management alternative evaluated (see subtasks 3.1A/3.1B for more detailed explanation).

Critical Data/Input: See discussion in subtasks 3.1A/3.1B. Nitrogen loading scenarios will be defined as discussed in Section 3.2.2. Information on changes in internal release rates of nitrogen due to sediment management is lacking. Since measurements of ammonium (NH_4^+) concentrations as a decomposition product were planned during the sediment core studies of Reddy et al. (2000 and 2001), these data may help provide some insight on reductions in nitrogen release rates due to sediment dredging. Porewater concentrations from the recent study on characterizing the spatial distribution of sediments in Lake Okeechobee (Fisher et al., 2001) also will be used.

Method: Modeling conducted as described for subtasks 3.1A/3.1B will form the basis of this analysis. Modeling to evaluate TN:TP ratio changes will be restricted to using the LOWQM since this is the only calibrated and validated model available for predicting both phosphorus and nitrogen cycling in Lake Okeechobee. Support modeling will be conducted using SWAN-LOHTM and thermodynamic models. Total phosphorus and nitrogen concentrations will be simulated using LOWQM and predicted total phosphorus concentrations compared to the 40 µg/L target level. LOWQM has the ability to simulate the dynamics of three algal groups: cyanobacteria, diatoms, and green algae.

Protecting the near-shore region against the occurrence of algal blooms is particularly important because it is this region that is most heavily used by fish, wildlife, and for drinking water intakes. Because the LOWQM, Walker (2000), and the Lake Okeechobee Internal Phosphorus loading models are all 1-box models that essentially predict total phosphorus in the pelagic zone of the lake, these predictions need to be related to both concentrations in the near-shore zone and the likelihood of algal bloom occurrence. Havens and Walker (2001) have developed a regression relationship between pelagic and near-shore concentrations of total phosphorus as a function of lake stage; this regression will allow for the calculation of the likelihood of occurrence of blooms in the near-shore region. In addition, because most of the phosphorus present in the water column is particulate and because total phosphorus correlates closely with TSS (Maceina and Soballe, 1990), the spatially-explicit LOHTM model can be used to predict both sediment resuspension rates (when coupled with SWAN to provide the wind-wave parameters) and associated total phosphorus fluxes to and concentrations within the near-shore region of the lake.

Scoring: Scoring will be based on two measures: Predicted TN:TP ratios and total phosphorus concentrations. A higher score will be assigned to sediment management alternatives that promote both lower total phosphorus concentrations (and thus a lower expected incidence of algal blooms), and higher TN:TP ratios (which equate to a lower likelihood of cyanobacterial dominance and blooms). Both relative scores and raw results will be reported.

Interrelationships with Other Subtasks/Timing: This analysis essentially extends the evaluation of subtasks 3.1A and 3.1B by examining predicted TN:TP ratios. The modeling conducted for 3.1A with the LOWQM for different sediment management strategies thus will be used for this evaluation. The empirical relationships between pelagic and near-shore total phosphorus concentrations also will be used in the evaluation of subtasks 3.1C and 3.4A.

Uncertainty Considerations: Nitrogen concentrations will be predicted based on the phosphorus loading scenarios defined in Section 3.2.2, coupled with the assumption that N:P ratios in the surface water inputs to Lake Okeechobee are the same as the flow-weighted average observed over the last five years. There are no empirical studies of internal nitrogen loading rates in Lake Okeechobee or how those rates may change with sediment removal. LOWQM does predict changes in sediment deposition with changing nutrient inputs, and this will provide some predictive capability to simulate reductions in porewater NH_4^+ concentrations (and thus fluxes across the sediment-water interface) as primary production rates decline in response to changing rates of external nutrient supply. Nonetheless, we will have limited ability to predict changes in rates of internal resupply of nitrogen due to sediment removal, and no ability to predict changes that may be coupled with chemical treatment other than described above.

Subtask 3.1E – Minimize Exceedances of Water Quality Standards in the Short Term and Long Term	
Target	No exceedances of FAC 62-302 or the Lake Okeechobee Operating Permit (LOOP) in the short or long term.
Tool(s)	SWAN-LOHTM; information from case studies, vendors, and existing databases.
Critical Data/Input	Concentrations of relevant constituents in Lake Okeechobee sediments and surface water; results of pilot dredging and University of Florida studies; FAC 62-302 and LOOP.
Method	Short-term release rates estimated using relevant case study data and vendor information. Suspended sediment transport in lake (and associated contaminant concentrations) predicted by LOHTM.
Scoring	Two scores will be given – one each for short- and long-term effects; higher scores mean fewer predicted exceedances.
Interrelationships with Other Subtasks/Timing	Subtasks 3.1A, 3.1B, 3.1C, and 3.1D will precede this evaluation. Results will be used in 3.1F, 3.2F, 3.5C, and 3.5D assessments. University of Florida study and pilot dredging project information must be available.
Uncertainty Considerations	Considerations discussed in the modeling write-ups apply here as well. Scaleability and applicability of case study information.

Target: No exceedances of Florida Administrative Code (FAC) 62-302 or the Lake Okeechobee Operating Permit (LOOP) in the short or long term, either through direct in-lake construction activities or through the potential discharge of treated water returned to the lake or other waters. Alternatively, there may be allowable exceedances within a certain distance from the potential work sites as long as there are no exceedances at a sentinel point of compliance (POC); this would be agreed to by the Florida Department of Environmental Protection (FDEP) in a variance on an Environmental Resources Permit (ERP).

Tools: Existing data gathered by the District and derived from EA's pilot dredging project will be used to provide information on actual concentrations (e.g., µg/L) of chemicals in surface water and sediment. LOHTM has the ability (when coupled with SWAN) to predict sediment resuspension rates and suspended sediment transport in Lake Okeechobee. There are also models available to evaluate both near-field and far-field impacts of dredging on TSS that may be used in this analysis.

Critical Data/Input: Develop information on short-term or pulsed release rates of suspended sediment based on case studies and vendor information. Available sediment and water quality data from the District or other sources along with associated information on toxicant concentrations related to resuspended sediment. Latest list of criteria in FAC 62-302 and LOOP. Results from the University of Florida's sediment phosphorus dynamics study, EA's pilot dredging project, and other relevant case studies.

Method: Short-term modeling has two components: (1) predict near-field, short-term, or pulsed release rates of sediment into the water column related to the sediment management activity; and (2) predict suspended sediment transport using LOHTM. The near-field effects of short-term or pulsed release rates related to implementation of alternatives will be estimated based on results from the pilot dredging project and the University of Florida study, other case study data, and vendor information. In addition, if enough sediment and water quality data are available, relationships between constituents and both mud type and spatial location could be established to enhance the evaluation of predicted effects of alternatives that involve moving sediment. Far-field effect simulations (if necessary) will then be calculated using LOHTM. Evaluations of short- and long-term water quality impacts will be compared to case study information.

Scoring: The same metric and method will be used to generate results and scores for both the short and long term. Scores will be assigned based on the number of exceedances of FAC 62-302; higher scores will be assigned to those sediment management alternatives that produce fewer predicted exceedances. Both the short- and long-term results and scores will be reported.

Interrelationships with Other Subtasks/Timing: All modeling runs described for subtasks 3.1A, 3.1B, 3.1C, and 3.1D should be complete before moving on to the evaluation of 3.1E. In addition, data from the University of Florida study and the pilot dredging project must be available. Results will be used in the assessments of subtasks 3.1F (downstream impacts), 3.2F (permitting), 3.4D (manatee), 3.4E (alligator), 3.5C (community acceptance), and 3.5D (water supply).

Uncertainty Considerations: Uncertainty considerations associated with the modeling efforts described in subtasks 3.1A, 3.1B, 3.1C, and 3.1D apply here as well since those results will impact this evaluation. Results from the pilot dredging project and the University of Florida study related to sediment release rates may not be reliable or applicable to all areas of the lake or all sediment management actions; further, the scale of those projects is likely not sufficient to generate reliable estimates for the scope of the sediment management alternatives contemplated here. Furthermore, the existing sediment and water quality databases may not be sufficient to adequately characterize the entire lake.

Subtask 3.1F – Minimize Downstream Impacts	
Target	Targets for other subtasks 3.1A through 3.1E.
Tool(s)	Models and information as described in subtasks 3.1A through 3.1E.
Critical Data/Input	Current water quality measurements at outlet points; descriptions and requirements of relevant activities.
Method	Water quality modeling; results will be compared to ultimate goal of 40 ìg/L total phosphorus.
Scoring	Higher score means net positive impacts.
Interrelationships with Other Subtasks/Timing	This evaluation will take place after assessments of subtasks 3.1A through 3.1E are complete. Results will be considered in subtasks 3.5C, 3.5D, and perhaps 3.2F.
Uncertainty Considerations	Current conditions may not be adequately documented at outlet points and ability to predict post-remedial conditions at specific outlet points will be limited.

Target: Targets for subtasks 3.1A through 3.1E, as applicable, at lake outlet points. In addition, preferred alternatives will not degrade downstream water quality in any way or significantly increase additional costs/problems (e.g., increased treatment of potable water supply). Improving water quality in Lake Okeechobee (with regard to the other parameters listed in subtasks 3.1A through 3.1E) will clearly benefit downstream areas. In addition, alternatives should not create new problems and associated cost increases (such as greater need for treatment of potable water supply) for local water treatment plants.

Tools: Models and information as described in subtasks 3.1A through 3.1E.

Critical Data/Input: Current water quality measurements at lake outlet points; other input parameters as described for subtasks 3.1A through 3.1E. Descriptions/requirements of relevant District and Comprehensive Everglades Restoration Program (CERP) activities.

Method: Changes in the quality of water leaving the lake could have a direct impact on the water quality, habitat quality, and recreational and commercial opportunities in downstream areas. Special attention will also be paid to potential impacts on specific CERP activities, including the quality of water delivered to downstream stormwater treatment areas (STAs), the Indian River Lagoon, and the St. Lucie estuary; as well as potential impacts on future aquifer storage and recovery (ASR) well implementation.

For each alternative evaluated, an estimate of lake-wide water quality will be made using model predictions for targets under subtasks 3.1A through 3.1E. To the extent possible and reliable, expected water quality conditions at some major outlet point(s) will also be estimated. Results will be compared to the no-action alternative, current conditions, the total phosphorus target of 40 ìg/L, and other qualitative targets.

Scoring: A comparative analysis of predicted impacts resulting from each alternative to both current conditions and the no-action scenario will be carried out. Alternatives that result in an overall net positive impact will be scored higher than alternatives that have either no net impact or a net negative impact. Scores will be assigned and reported on a relative scale of 1 to 5, and to the extent possible, other results relevant to this subtask will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: This evaluation will take place after the alternatives are clearly defined and the assessments of subtasks 3.1A through 3.1E are complete. Output from this evaluation will be considered in subtasks 3.5C (community acceptance), 3.5D (water supply), and perhaps 3.2F (permitting).

Uncertainty Considerations: Current conditions may not be adequately documented at outlet points, and the ability to predict post-remedial conditions at specific outlet points will be limited. Further, uncertainty considerations associated with the modeling efforts described in subtasks 3.1A through 3.1E apply here as well.

Subtask 3.2A – Maximize Technical Reliability	
Target	Sediment management alternatives that are considered highly reliable.
Tool(s)	Qualitative engineering judgement using information developed for the specific sediment management alternatives and case study/literature data.
Critical Data/Input	A detailed description of the sediment management alternatives, data for other in-lake sediment-phosphorus management projects, and estimated operation and maintenance (O&M) scope and costs for the sediment management alternatives.
Method	Estimates of technical reliability will be qualitatively developed using a combination of long-term performance data gathered from similar sites and a relative comparison of O&M scope and costs among alternatives.
Scoring	Technologies with higher scores are indicative of greater reliability.
Interrelationships with Other Subtasks/Timing	This evaluation can be completed once the detailed descriptions of the sediment management alternatives are developed, the literature review and case study data are compiled, and the O&M scope and cost estimates are prepared.
Uncertainty Considerations	Ability to find data for projects that are similar in scope and size to Lake Okeechobee, the transferability of results from other projects, and the predictive limitations of long-term O&M cost estimates.

Target: Although no specific target exists, sediment management alternatives that use technologies with demonstrated long-term reliability (i.e., lower degree of technical problems associated with the construction and operation of the technology) are preferable.

Tool(s): The sediment management alternative will be evaluated qualitatively using information from other sediment management sites in conjunction with quantitative operation and maintenance (O&M) costs based on assumed long-term O&M scope of each alternative.

Critical Data/Input: In order to generate meaningful estimates of reliability, it will be necessary to have a detailed understanding of each sediment management alternative considered for Lake Okeechobee. In addition, long-term performance data for similar sediment management approaches implemented elsewhere (to the extent available and applicable) along with long-term O&M cost estimates will be required.

Method: To develop qualitative estimates of reliability, the major components of each sediment management alternative (e.g., dredging, dredged material transport, sediment disposal, water treatment, etc.) will be identified and placed in a matrix along with applicable long-term performance data gathered through the review of relevant literature/case studies. The O&M cost estimate for each alternative will also be segregated by components (scope) and placed within the matrix table. This will facilitate a complete evaluation of the alternative at the component (or technology) level, which is important because different components for a given alternative may have differing levels of reliability. For example, available literature may indicate that the reliability of dredging to manage internal phosphorus loading over the long-term is lower than other components such as water treatment, that have a long history of reliable performance.

Scoring: Sediment management alternatives will be scored on a scale of 1 to 5 based on a relative comparison. Alternatives judged to have higher long-term reliability will receive a higher score. Other relevant information or results will also be summarized and reported.

Interrelationships with other Subtasks/Timing: In order to evaluate alternatives against this performance measure, detailed descriptions of the sediment management alternatives must be developed. Moreover, the literature and case study information (to the extent available and applicable) for other similar projects should be collected and assembled, and the cost estimates for long-term O&M prepared (Subtask 3.3B).

Uncertainty Considerations: The primary sources of uncertainty for this performance measure include the transferability of data from other sites, given the unique characteristics of Lake Okeechobee and the goal of large-scale, long-term reductions in phosphorus loading; finding projects that are similar in scope and size within the literature to use for comparative purposes; and the predictive limitations of long-term O&M costs that are based on conceptual-level assumptions.

	Subtask 3.2B – Maximize Technical Scalability
Target	Technologies that have either been proven at a scale similar to Lake Okeechobee or are readily scaleable are preferable.
Tool(s)	Qualitative evaluation using available case study and literature data, product literature, professional experience, and the results of available and applicable site-specific studies.
Critical Data/Input	Detailed descriptions of the Lake Okeechobee sediment management alternatives, literature case study information for similar projects, and data for other Lake Okeechobee studies, if available.
Method	Qualitative evaluation using the individual components of the sediment management alternatives. Case studies will be reviewed along with Lake Okeechobee-specific study results.
Scoring	Higher scores indicate that the approach is more likely to be scalable to meet the needs of this project.
Interrelationships with Other Subtasks/Timing	This evaluation can be completed once the detailed descriptions of the sediment management alternatives have been developed and the available and applicable literature case study data have been compiled and reviewed.
Uncertainty Considerations	The ability to find data for similar projects in the literature, the transferability of information from these other projects or vendor information to Lake Okeechobee, and the ability to estimate the ease of scaling up a specific technology.

Target: Although no specific target exists, sediment management alternatives that use technologies either proven at a scale similar to Lake Okeechobee, or that can easily be increased in scale to meet the requirements of the lake are preferable.

Tool(s): Qualitative assessment using engineering judgment and data inputs noted below.

Critical Data/Input: The detailed descriptions of the sediment management alternatives will be required along with relevant case study and literature data, product literature from equipment vendors, professional experience, and the results of site-specific studies such as the University of Florida study and the pilot dredging project, if applicable and available to fit the evaluation schedule. Data for sediment dredging will likely be developed from a range of sources and include navigational, remediation, and restoration projects for relevant lake, river, and coastal sites.

Method: To develop the qualitative estimates of scalability, the major components of the sediment management alternatives (e.g., chemical treatment, dredging, dredged material transport, sediment disposal, water treatment, etc.) will be identified and placed in a matrix table including scalar quantities where available. This scalar information could include items such as quantities, areas, or throughput rates (e.g., quantity of sediment to be removed in m^3, the area to be dredged or treated in hectares, or water treatment rates in millions of liters per hour). Information available from the literature, case studies, product vendors, or prior experience would be listed in a corresponding column of the matrix to assess the scale at which components of a given alternative have historically been implemented. Conducting the assessment in this manner will facilitate an evaluation of the alternatives at the component (or technology) level. This is an important consideration as some components of a given alternative may have been conducted at a similar scale, while others may not. For example, water treatment facilities may have been built and operated at the required capacity, yet dredging to address internal loading of phosphorus in a shallow lake may have been conducted only for projects a fraction of the size contemplated for Lake Okeechobee. These differences may or may not be important depending on the relative ease of scalability. Because of these limitations, the evaluation matrix will also include a column with a qualitative assessment of how easily a given technology could be scaled up to the size that may be required for Lake Okeechobee. An example where numerical scale may be less important is the case of a shoreline sediment disposal facility. The historical application of this technology is for projects addressing much smaller quantities of sediment than the total amount that may have to be dredged from the lake; yet, the essential manner in which shoreline disposal facilities are designed, constructed, and operated will likely not be a significant limitation from a scalar perspective. Information regarding the ease of scalability will be developed from the evaluation of case study and literature data, product literature, professional experience, and possibly the results of applicable site-specific studies.

Scoring: Sediment management alternatives will be scored from 1 to 5. Higher scores will be indicative of approaches proven to reduce internal phosphorus loading in shallow lakes of similar scale to Lake Okeechobee, and/or those that could easily be increased in scale to meet the needs of the lake. Supporting information also will be summarized and reported.

Interrelationships with Other Subtasks/Timing: The detailed descriptions of the sediment management alternatives and the compilation and review of relevant literature/case studies should be completed before this evaluation can take place. Subtasks 3.1A (time to achieve phosphorus target) and 3.5C (community acceptance) are reliant on the results of this evaluation, as scalability will impact the length of time necessary to implement a given alternative.

Uncertainty Considerations: The uncertainly associated with this performance measure will be a function of the ability to find data for similar projects in the literature, the transferability of information from these projects or vendor information to Lake Okeechobee, and the ability to estimate the ease of scaling a particular technology. It is also important to note that some degree of uncertainty will exist for any project that is the first of its kind. While sediment management approaches such as dredging and in-situ treatment to reduce internal phosphorus loading have been implemented elsewhere, the scale of their historic implementation is far below that which may be contemplated for Lake Okeechobee. As such, the uncertainty surrounding this performance measure will be an important factor to consider in the overall evaluation of the alternatives. To put this into perspective, the volume of sediment that may have to be dredged from the lake to remove the phosphorus-containing sediment is roughly equivalent to the combined total dredging that occurs within a calendar year across the entire United States (i.e., approximately 200 million m^3).

In addition, the timing, quality, and applicability of site-specific studies (e.g., University of Florida, EA) are important considerations that may limit their use in this evaluation and overall feasibility study. For example, if the results of these two site-specific studies are not complete and available by the time alternative-specific modeling begins (i.e., early 2002), it may be too late to effectively integrate the findings of those studies into this feasibility study. However, the project team will endeavor to incorporate the findings to the extent practicable and applicable within the scope and framework of this study.

Subtask 3.2C – Maximize Equipment and Material Availability	
Target	Maximize equipment and material availability.
Tool(s)	Quantitative and qualitative tools will be used including information from suppliers, contractors, vendors, previous engineering experience, and information available from the literature.
Critical Data/Input	Alternatives will need to be clearly defined in terms of remedial objective, scope (remedial volume and extent), and schedule (production rates and construction management).
Method	Equipment and material availability will be qualitatively assessed using the tools indicated above.
Scoring	Scores will be assigned from 1 to 5, based on relative and predicted ability to implement (i.e., supply) construction of an alternative. A higher score (i.e., 5) would imply that sufficient equipment and materials are locally and readily available.
Interrelationships with Other Subtasks/Timing	Scope of alternatives must be as narrowly defined as possible prior to starting this evaluation, which will be performed in conjunction with subtasks 3.3A and 3.3B.
Uncertainty Considerations	Uncertainty in market forces is the primary concern (i.e., the demand for similar equipment and materials during the assumed construction time at this site). Equipment/method production rates and number of construction units in concurrent operation will be assumed for alternatives, which may not accurately reflect how the alternative would ultimately be implemented by a construction contractor.

Target: Maximize equipment and material availability to fulfill the greatest number of sediment management goals.

Tool(s): Quantitative and qualitative information on equipment and material availability will be obtained from suppliers, contractors, vendors, previous engineering experience, and information available from the literature. Information will also be gathered from dredging and construction trade publications such as *International Dredging Review, Dredging and Port Construction,* and *World Dredging, Mining and Construction.*

Critical Data/Input: In order to be able to assess equipment and material needs in a meaningful way, the sediment management and disposal/reuse alternatives will need to be clearly defined in terms of their scope (e.g., type, volume, and location/depth of sediment removal, tolerance required, etc.) and schedule (production/construction rates). Clear definition of the land use requirements (in-lake, adjacent to the lake, or upland) will also be critical to determine the equipment and material needs of sediment processing, transport, and disposal components.

Method: A qualitative evaluation will be performed to assess the availability of equipment and material within the local, regional, national, and international marketplaces, as required for the alternatives. As part of the evaluation, suppliers, contractors, manufacturers, and vendors will be contacted regarding the availability of suitable equipment, skilled labor force, and materials. Where available and applicable, literature will be reviewed to help ascertain recent developments and marketplace demands.

In the international marketplace, the evaluation will consider the implications of the Jones Act, which restricts the operation of foreign-hulled vessels in United States waters. The evaluation will also consider the necessary lead-times for manufacture of innovative equipment, should their use be deemed necessary and appropriate for any of the alternatives. Finally, the evaluation will consider land and access needs for construction- and disposal-related activities, both in the short term and in the long term.

Scoring: Using the criteria and methodology described above, scores will be assigned from 1 to 5, based on relative and predicted ability to adequately supply the equipment, labor, and materials needed to implement an alternative. A higher score (for example, 5) would imply that equipment and materials of sufficient quantity and quality are locally and readily available. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: This evaluation will be conducted once the alternatives are as narrowly defined as possible. This evaluation will be performed in coordination with subtasks 3.3A (construction costs) and 3.3B (O&M costs).

Uncertainty Considerations: Uncertainty in market forces is the primary concern here (i.e., the demand, availability, and need for equipment and materials during the assumed very lengthy construction period at Lake Okeechobee). Given the unprecedented scale and complexity of the remedial actions contemplated, fundamental questions of constructability must be considered. In addition, equipment/method production rates and number of construction units in concurrent operation will be assumed for the alternatives, but may not accurately reflect how a given design engineer or construction contractor would ultimately implement an alternative. In addition, there is little experience elsewhere in managing phosphorus loading in a system of this scale and complexity.

Subtask 3.2D – Maximize Permanence	
Target	An alternative that can provide optimal effectiveness over time and withstand normal wind-wave activity and infrequent events such as hurricanes is preferred.
Tool(s)	Quantitative and qualitative tools will be used including numerical models, case studies, and related literature. Results from the pilot dredging project will also be used to the extent available and applicable.
Critical Data/Input	Data of specific interest include wave and storm data for Lake Okeechobee and results of computer modeling of related hydrodynamic and erosive forces. Predicted (modeled) post-remedial phosphorus flux rates and assumed O&M requirement will also be considered.
Method	A qualitative evaluation of the effectiveness of the processes and technologies will be initially conducted using case study data from similar projects and related sources. Recovery projections generated using numerical models described in subtasks 3.1A though 3.1D will also be considered.
Scoring	Permanence will be rated using a relative scale of 1 to 5 (i.e., 5 for highest degree of permanence) based on qualitative and quantitative estimates of performance.
Interrelationships with Other Subtasks/Timing	Alternatives need to be as clearly defined as possible prior to starting this evaluation. This evaluation will be performed in conjunction with subtasks 3.1A, 3.1B, and 3.2A.
Uncertainty Considerations	Uncertainty in the effectiveness of the technology and the projected duration of the remedy will significantly affect these evaluations.

Target: No approach can offer a truly permanent solution. Alternative(s) that can provide optimal effectiveness over time and withstand normal wind-wave activity and infrequent events such as hurricanes are preferred, as are alternatives that require minimal recurrence or maintenance.

Tool(s): Quantitative and qualitative tools will be used including numerical models, and related literature case studies. Results from the pilot dredging project will also be used to the extent available and applicable. It is expected that output from subtasks 3.1A through 3.1D will also be valuable.

Critical Data/Input: Overall, for an effective evaluation of permanence, the alternatives will need to be clearly defined in terms of their scope (e.g., treatment vs. removal vs. a combination approach), duration (e.g., production/construction rates), and scale/location (e.g., target depth and extent of lake affected). Data of specific interest include wave and storm data for the lake (i.e., the 1999/2000 data used for the modeling subtasks), and results of computer models of predicted hydrodynamic and erosive forces. Predicted (modeled) post-remedial phosphorus flux rates and assumed O&M requirements (e.g., repeated treatment or dredging, permanence of disposal and reuse options) will also be considered.

Method: A qualitative evaluation of the effectiveness of the processes and technologies will be initially conducted using case study data from similar projects and related sources (to the extent available and applicable). The case study information could include monitoring results (i.e., physical, chemical and/or biological data), and general observations regarding long-term performance. Projections of permanence will also be generated using numerical models (recognizing that the use of LOHTM is restricted to a maximum simulation length of one year – see subtasks 3.1A through 3.1D) that would account for the effects of wind-wave action and extreme events, associated potential for losses from erosion and/or transport, and changes in phosphorus flux. These approaches will be combined to generate estimates of permanence of the various alternatives.

Scoring: Permanence will be rated using a relative scale of 1 to 5, based on qualitative and quantitative estimates of performance. A score of 5 will imply a higher probability for permanence, and indicate that the alternative is assumed to be effective over the long term (and maintain that effectiveness) and not highly susceptible to disturbance. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Alternatives need to be as clearly defined as possible prior to starting this evaluation and all the modeling runs should be complete. This evaluation will be performed in coordination with subtasks 3.1A, 3.1B, 3.1C, 3.1D, and 3.2A.

Uncertainty Considerations: Uncertainty in the transferability of case study data, the assumed/projected effectiveness of technologies, and the projected duration of the remedy will significantly affect these evaluations.

Subtask 3.2E – Minimize On-Shore Land Use Needs and Conflicts	
Target	Minimize short- and long-term use of on-shore acreage and conflicts with public land uses in the vicinity of Lake Okeechobee.
Tool(s)	Quantitative and qualitative tools will be used in this evaluation including estimating the acreage of on-shore land required by a given alternative, duration of long-term and short-term uses, and information pertaining to ongoing or planned public projects in the region.
Critical Data/Input	Alternatives must be well defined in scope, duration, and timing to assess the on-shore land use requirements and the duration of such land uses.
Method	A quantitative engineering estimate of the acreage of on-shore land required to support the implementation of the alternative and the duration of land use will be made. The evaluation will qualitatively assess the potential conflict that a sediment management alternative might have with local or regional public projects.
Scoring	Relative scores will be assigned from 1 to 5, based on estimated amount of on-shore land required, duration, and potential conflicts with public projects (lower scores for alternatives with greater land use and potential conflict; higher scores for alternatives with minimal land use and lesser potential conflict).
Interrelationships with Other Subtasks/Timing	This evaluation will be conducted in coordination with subtasks 3.3A and 3.3B.
Uncertainty Considerations	At the feasibility study level of precision, estimates of land use, duration, and probability of conflicts will be limited. However, assumptions and sources of information will be clearly summarized and reported.

Target: Minimize short- and long-term use of on-shore acreage. This includes minimizing the duration of short-term land use, minimizing conflicts with other (presumably more valuable) public land uses in the vicinity of Lake Okeechobee.

Tools: Quantitative and qualitative tools will be used in this evaluation. The primary metrics will be the acreage of on-shore property required to implement a given alternative, as well as the duration of long-term and short-term uses. Information pertaining to current or planned public projects will be obtained from federal, state, and local governmental sources, as available or applicable, and reviewed to assess potential conflicts regarding land use.

Critical Data/Input: Alternatives must be well defined in scope, duration, and timing to assess the on-shore land use requirements and the duration of such land uses. Information from governmental sources, such as timing of other projects that might require land in the Lake Okeechobee area, should be as complete as possible to assess potential land use conflicts. In addition, the preliminary scoping information on land ownership, land use, and general land values gathered during Work Plan Tasks 1 and 2 will be expanded as necessary.

Method: Some alternatives are likely to require on-shore facilities to support in-lake operations. The potential need for on-shore land to support an alternative is an important consideration as it could potentially displace or conflict with current or planned land use activities. This may increase project costs if the purchase or lease of land is necessary, or if land requirements compete significantly with other uses or projects.

For this evaluation, a quantitative engineering estimate of the acreage of on-shore land required by a given alternative will be based on the scope of each alternative. This would include the amount of land required both permanently and in the short term to support construction, treat and temporarily store dredged materials, and provide permanent disposal of materials. Based on estimates of the volume of materials to be managed on shore and the phasing and duration of alternative implementation, an assessment of the required construction support areas and acreage of disposal area required (if necessary) will be developed.

In addition, a broad qualitative assessment will be made of planned and ongoing large-scale local/regional public projects (CERP, in particular) that may have local land use needs of their own (for stormwater treatment areas, wetland reclamation, ASR projects, tributary dredging, etc.). The evaluation will assess the potential conflict that a sediment management alternative might have with the needs of the local or regional public projects.

Scoring : Alternatives will be scored on a relative basis on a 1 to 5 scale. A higher score means less on-shore land needed, reduced duration of land use, and minimal predicted potential conflict with large-scale local/regional public projects. A lower score indicates higher on-shore land use requirements, greater duration of such land uses, and/or greater potential conflicts with local/regional public projects. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: This evaluation will be conducted once the alternatives are as narrowly defined as possible. This evaluation will be conducted in coordination with subtasks 3.3A (construction costs) and 3.3B (operation and maintenance costs). Results from this evaluation will be necessary to fully assess subtask 3.5C (community acceptance).

Uncertainty Considerations: At the feasibility study level of precision (i.e., this is not a construction or pre-design effort), estimates of land use, duration, and probability of conflicts will be limited. However, assumptions and sources of information will be clearly summarized and reported.

Subtask 3.2F – Satisfy Permitting Requirements	
Target	Satisfy compliance criteria for the joint ERP and other permits as assumed necessary.
Tool(s)	Qualitative tools will be used including information from contractors, vendors, trade publications, the EA pilot dredging project, case studies, and regulatory review to assess the permitting probability of the various alternatives.
Critical Data/Input	Alternatives will need to be well defined in scope, schedule, location, and land use in order to successfully estimate the permitting probability. Critical input data will be derived from the EA permit, sediment and water quality data, assumed ecological impacts, and applicable pilot study results.
Method	Available sediment and water quality data will be reviewed to determine the compliance potential of the various alternatives. Following this, a review of ecological criteria (wetlands, benthic impacts, etc) and archeological criteria (areas of cultural significance) will be undertaken. Engineering judgement, data from literature, and discussions with regulatory agencies will be used/performed.
Scoring	All alternatives will be scored based on a qualitative evaluation of permitting probability as described above. Alternative evaluation scores will range from 5 (high permitting probability) to 1 (low permitting probability).
Interrelationships with Other Subtasks/Timing	This evaluation will be conducted once the alternatives are as narrowly defined as possible. The evaluation will be performed after all the modeling, engineering, and environmental analyses are complete.
Uncertainty Considerations	Uncertainty in construction equipment performance and duration will significantly affect the estimates, as will the unprecedented scale of this phosphorus mitigation project.

Target: Satisfy compliance criteria for the joint ERP, and other permits, as assumed necessary. At this point, it is estimated that the ERP would be the one over-arching permit that would be required to implement any of the alternatives. At the time of this writing, the FDEP did not expect that a separate National Pollutant Discharge Elimination System (NPDES) permit would be necessary (the pilot dredging project conducted by EA required only an ERP).

Tool(s): Qualitative tools will be used that consider information from contractors, vendors, trade publications, case studies, desktop assessments, and regulatory review to assess the permitting probability of the various alternatives. In addition, quantitative comparisons of sediment and water quality data to Sediment Quality Assessment Guidelines (McDonald, 1994) and surface water criteria in FAC 62-302 will be conducted.

Critical Data/Input: Alternatives will need to be well defined in scope, schedule, location, and land use in order to successfully estimate the permitting probability. Critical input data will be derived from the ERP issued for the pilot dredging project, a desktop assessment of wetland nature and extent, critical habitat assessment (also a desktop review), results from the pilot dredging study (as applicable), and previously collected (and readily available) water quality and sediment data for a variety of relevant constituents. For alternatives with a beneficial reuse component, pertinent criteria in FAC 62-777 will be gathered, and the Florida Division of State Lands will be consulted on ownership issues surrounding materials that could be potentially sold to generate revenue. Information will also be gathered from discussions with regulatory agencies such as the USACE, the United States Fish and Wildlife Service (USFWS), the Florida Fish and Wildlife Conservation Commission (FWC), FDEP, and others.

Method: Existing sediment and water quality data will be initially reviewed to determine the compliance potential of the various alternatives. Following this, a review of ecological criteria (wetlands, benthic impacts, etc) and archeological criteria will be undertaken using engineering judgement, data from literature, and discussions with regulatory agencies (USACE, USFWS, FWC, FDEP, etc).

Potential for permit compliance will be assessed by generating a qualitative estimate of the potential for variances/mitigative measures, predicted (to the extent possible) water column and sediment concentrations of constituents of concern, estimated number of acres and types of habitats and species that may be affected, and any loss of flood storage. In addition, FDEP may require an assessment of impacts to areas of potential archeological value. Each alternative will then be scored based on its probability of obtaining an ERP.

Scoring: Alternatives will be scored based on a qualitative evaluation of permitting probability as described above. Relative scores will range from 5 (indicating a high probability of receiving an ERP) to 1 (indicating a low probability of receiving an ERP). Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: The evaluation of permit probability will be one of the last steps in the alternatives evaluation process. First the alternatives need to be as narrowly defined as possible, then the modeling, engineering, and environmental analyses must be carried out. This information will then be reviewed and, as needed, discussed with the various agencies involved with the development and issuance of an ERP.

Uncertainty Considerations: Uncertainty in construction equipment performance and duration will significantly affect the estimates of permit compliance. Equipment performance factors and production rates for each alternative will be assumed based on literature review and engineering judgement. In addition, while the FDEP currently believes that an ERP will be sufficient for any sediment management alternative and does not anticipate that an NPDES permit would be necessary, the possibility that other permits could be required is a source of uncertainty. The fact that there is no precedent for phosphorus mitigation of the scale and complexity being considered for Lake Okeechobee also significantly limits the ability to accurately predict the likelihood of obtaining and complying with an ERP and other potential regulatory requirements.

Subtask 3.3A – Minimize Construction Costs	
Target	Lowest construction cost possible to achieve goals.
Tool(s)	Quantitative tools will be used that consider information from contractors, vendors, Means cost data, and other construction/equipment/labor cost indices. The pilot dredging project will also be considered as a cost estimating source.
Critical Data/Input	Alternatives will need to be well defined in scope, duration, location, and land use in order to develop meaningful cost estimates. Uncertainty in construction parameters will significantly affect cost estimates.
Method	Costs for alternatives will be quantitatively developed and then converted into a net present value parameter.
Scoring	Using the range of costs developed for the alternatives, scores will be assigned from 1 to 5, based on a relative order of magnitude (1 for the highest cost alternatives and 5 for the lowest cost alternatives). Cost values will also be directly reported.
Interrelationships with Other Subtasks/Timing	This evaluation will precede subtasks 3.3B and 3.3C. Results will be considered in 3.2E and 3.5C.
Uncertainty Considerations	Uncertainty in construction duration will significantly affect cost estimations. Equipment/method production rates and number of construction units in concurrent operation are assumed values based on best engineering judgment for the alternatives. A +50%/-30% level of accuracy will be targeted and an uncertainty analysis conducted for the most sensitive cost-related assumptions.

Target: Lowest construction cost possible to fulfill the greatest number of the sediment management goals.

Tool(s): Quantitative information on construction, equipment, and labor rates and costs will be obtained from contractors, vendors, the Means catalog, and other construction cost indices. To the extent available and applicable, the pilot dredging project will also be considered as a cost estimating source for alternatives containing dredging and/or dewatering components.

Critical Data/Input: To obtain meaningful cost estimates from this evaluation, the alternatives will need to be well defined in terms of their scope (e.g., volume of sediment removal), duration/timing (based on production/construction rates), and scale/location (e.g., sediment depth and extent of lake affected). Definition of the land use requirements (in-lake, adjacent to the lake, or upland) also will be critical for cost development for alternatives with disposal components.

At the outset of cost development, production rates for equipment/methods to be used in the various alternatives (e.g., cubic meters of removal per hour for a specified diameter hydraulic dredge) will be assumed based on best engineering judgment and relevant case study data. In addition, the number of construction crews/equipment in concurrent operation will be assumed for specific alternatives, and the anticipated availability of equipment, labor, and materials (subtask 3.2C) will be considered.

Method: Costs for alternatives will be quantitatively developed using the cost information tools/sources indicated above. Construction, equipment, and labor costs will be estimated separately or as a combined unit, as appropriate. The estimates will be based on standardized unit cost data, experience at similar sites or with similar technologies, and best engineering judgment. The estimate will also include indirect cost items such as engineering design, permitting, and engineering support during construction.

The net present value (NPV) approach will be used as a cost comparison tool, as alternatives will likely have wide-ranging implementation periods. The NPV costs will incorporate the Federal Office of Management and Budget (OMB) discount rate of seven percent. The cost estimates will also recognize an annual inflation rate for construction activities that span more than one year in length. The inflation rate will be estimated using an assumed rate of increase in the federal Gross Domestic Product deflator for the period of construction, up to six years. For projects that span more than six years, the rate of inflation for the sixth year will be carried through the remaining years of the project. Costs will be adjusted and reported in 2002 dollars.

Scoring: Costs developed for the various alternatives will likely differ by orders of magnitude. Using the order of magnitude range of costs, relative scores will be assigned from 1 to 5. Since lower costs are preferred, a score of 5 (highest score) will be assigned to the alternative(s) with the lowest order of magnitude costs, and 1 (lowest score) will be assigned to the highest order of magnitude cost alternatives. Supporting information will also be summarized and reported, as will the estimated dollar values for each alternative (in non-adjusted and NPV-adjusted form).

Interrelationships with Other Subtasks/Timing: This evaluation will be conducted once the alternatives are as narrowly defined as possible. The evaluation will be performed prior to subtasks 3.3B (operation and maintenance costs) and 3.3C (benefits), and the results will be considered in subtasks 3.2E (on-shore land use needs and conflicts) and 3.5C (community acceptance).

Uncertainty Considerations: Consistent with feasibility study practice, cost estimates will be targeted for +50%/-30% level of accuracy. This range is intended to reflect the uncertainty regarding many of the details of such a large and complex project that can not be completely quantified at this stage of development. An example of this is the time required to implement an alternative, which is a function of several key assumptions, such as the production rates for equipment/methods to be used in the various alternatives (e.g., cubic meters of removal per day for a specified diameter hydraulic dredge) and the number of construction crews/equipment in concurrent operation. To further assist in understanding the potential cost impacts of the uncertainty surrounding the assumptions used to develop the alternatives, an evaluation of uncertainty will be conducted for the more sensitive assumptions (from a cost perspective).

Subtask 3.3B – Minimize O&M Costs	
Target	Lowest O&M costs to achieve goals.
Tool(s)	Quantitative tools that consider contractor information, experience at other sites, and best engineering judgment, as well as the NPV metric, will be used to develop O&M cost estimates.
Critical Data/Input	Alternatives will need to be well defined in scope, duration, and location in order to develop meaningful O&M cost estimates.
Method	The O&M cost estimate will incorporate likely post-construction monitoring, reporting, and assumed operating and maintenance activities and include anticipated equipment, manpower, and materials. O&M cost estimates will be converted to NPV (for a 50-year O&M period).
Scoring	Using the range of costs developed for the alternatives, relative scores will be assigned from 1 to 5, based on order of magnitude estimates (1 for the highest cost alternatives and 5 for the lowest cost alternatives).
Interrelationships with Other Subtasks/Timing	This evaluation will follow subtask 3.3A (construction costs), and will be conducted in coordination with subtask 3.3C (maximize benefits). Results will be considered in 3.5C.
Uncertainty Considerations	Similar to construction related costs, the O&M costs will be subject to potentially significant uncertainty as many assumptions will be used to develop the O&M cost estimates. A +50%/-30% level of accuracy will be targeted and supported by an uncertainty analysis of the most sensitive cost parameter.

Target: Lowest O&M cost possible to fulfill the greatest number of the sediment management goals.

Tool(s): The O&M cost estimates will be developed using contractor cost information, O&M experience and case studies at other sites, and best engineering judgment. Based on the likelihood that the alternatives will have wide-ranging implementation and O&M periods, the O&M costs for each alternative will be converted to an NPV basis.

Critical Data/Input: To obtain meaningful estimates of O&M costs, the alternatives will need to be well defined in terms of the duration and extent of the construction activities, the acreage and location of land necessary (if any), and the assumed operation, maintenance, and monitoring activities.

Method: Similar to the construction cost estimates (Subtask 3.3A), the estimated long-term O&M costs are a quantitative measure of the financial resources required to maintain the effectiveness of each alternative over time, and are useful in conducting a comparative analysis of initial capital construction costs versus ongoing O&M costs. O&M costs include components such as long-term monitoring of alternative effectiveness, maintenance of equipment or infrastructure, maintenance or repair of remedial components such as an in-lake sump or CDF (if either were to be implemented), and the labor, engineering, data collection and analysis, and other required resources or activities.

The O&M cost estimate will be based upon contractor cost information, O&M experience and case studies at other sites, and best engineering judgment. To allow consistent reporting of results from alternatives that have wide-ranging O&M periods, O&M costs for individual alternatives will be presented on an NPV basis for a 50-year period. The NPV estimate will use the OMB discount rate of seven percent and an annual inflation rate. The inflation rate will be estimated as described in the Methods section for subtask 3.3A. O&M NPVs for the alternatives will be reported in 2002 dollars.

Scoring: The NPV estimates will likely differ by orders of magnitude for the individual alternatives. Using the order of magnitude range of costs, relative scores will be assigned from 1 to 5. Since low O&M costs are preferable, a score of 1 (lowest score) will be assigned to the alternative(s) with the highest order of magnitude costs, and 5 (highest score) will be assigned to alternatives with the lowest order of magnitude O&M costs. Supporting information will also be summarized and reported, as will the estimated O&M dollar values for each alternative (in non-adjusted and NPV-adjusted form).

Interrelationships with Other Subtasks/Timing: This evaluation will be conducted once the alternatives are as narrowly defined as possible. This evaluation will follow subtask 3.3A (construction costs), and will be conducted in coordination with subtask 3.3C (benefits). Results will be considered in subtask 3.5C (community acceptance).

Uncertainty Considerations: Similar to construction related costs, the O&M costs will be subject to potentially significant uncertainty as many assumptions will be used to develop the O&M cost estimates. A +50%/-30% level of accuracy will be targeted and supported by an uncertainty analysis of the most sensitive cost parameter. The primary source of uncertainty for the O&M costs are the assumptions made to complete an activity (e.g., the level of effort to repair the rip-rap around an on-site or in-lake CDF) and the frequency of an O&M activity (e.g., how often is follow up chemical treatment of the in-situ sediment required for the phosphorus to remain sequestered).

Subtask 3.3C – Maximize Benefits (Material Reuse)	
Target	Maximize net revenue generated from the beneficial reuse of materials produced during alternative implementation.
Tool(s)	Quantitative and qualitative tools will be used, considering estimated volumes (and production costs) of alternative-derived materials and potential market demand/prices for such materials.
Critical Data/Input	The alternatives will need to be well defined in terms of the potential volumes of materials produced and the production cost/rate/timing/delivery of such materials.
Method	Net revenue will be estimated by comparing how much of the cost of an alternative can be offset by revenue generated (if any) through beneficial reuse of materials. Estimates of the potential revenue stream will be based on the magnitude and timing of the alternatives, assumed product type, and the production rate and potential marketability of the material.
Scoring	Using the range of costs developed for the alternatives and the potential revenue generated by the material reuse sub-alternative, relative scores will be assigned from 1 to 5, based on order of magnitude estimates (5 for the highest benefits and 1 for the lowest benefits).
Interrelationships with Other Subtasks/Timing	This evaluation will follow subtask 3.3A (construction costs), and will be conducted in coordination with subtask 3.3B (O&M costs). Results will be considered in subtask 3.5C (community acceptance).
Uncertainty Considerations	Uncertainty in product type, market values, and construction scope and duration will significantly affect revenue estimates.

Target: Maximize net revenue from the beneficial reuse of materials produced during alternative implementation. Revenue streams that can be developed early in the project and last for a significant period of time are preferable. It is assumed that costs of processing dredged material for reuse will likely exceed revenue generated from sale of the material. However, to the extent practicable, estimates of net revenue (or cost savings) will be developed to predict estimated net benefit from the reuse sub-alternative.

Tool(s): Quantitative and qualitative tools will be used to estimate production costs and revenue in terms of dollars over the implementation period of the alternative. Information from beneficial reuse case studies and estimates of material volumes, assumed market demand/prices, cost of processing and transporting the materials generated during alternative implementation, and any fees associated with generation of revenues from Lake Okeechobee-derived materials will be used to estimate net revenue.

Critical Data/Input: To obtain net revenue estimates from this evaluation, the alternatives will need to be well defined in terms of the potential volumes of materials produced from the implementation of a specific alternative and the production rate and costs of generating materials suitable for reuse. In addition, information on potential products and markets as well as general estimates of market value will be required.

Method: During implementation, alternatives may generate materials (i.e., dredged material) that could be reused or sold to generate revenue (e.g., building materials, fill/soil, soil amendments, etc.). The revenue from the sale of these products could be used to offset capital and/or O&M costs associated with implementing an alternative. As discussed in subtask 3.2F, compliance with FAC 62-777 and agreement with the Division of State Lands regarding ownership of any potentially marketable materials would be required prior to the generation of any revenue stream.

Net revenue for the beneficial reuse of materials will be evaluated by developing an estimate of the cost of processing the materials generated through implementation of an alternative (i.e., preparing the product for market), then determining how much of that cost (as well as the overall cost of alternative implementation) could be offset by the potential revenue generated through beneficial reuse, after any applicable fees are paid. An estimate of the magnitude and timing of the potential revenue stream would be developed based on the production and potential marketability (assumed demand and pricing) of the material. Material volume estimates would be based on the scope of the alternative and the equipment/method production rates (as specified during the definition of alternatives). Market demand and pricing would be based on available case study information where sediment materials have been beneficially reused (and revenue obtained for such materials), as well as a limited desktop assessment of current market conditions for such materials within Florida and the southeastern United States. Market assessments will include assumed transportation costs of materials, as appropriate. Only those options estimated to be feasible and capable of generating a reasonably reliable revenue stream will be considered in this evaluation.

Scoring: Net revenue estimates for the various alternatives will likely differ by orders of magnitude. Using the order of magnitude range of potential revenue, relative scores will be assigned from 1 to 5.

A score of 1 (lowest score) will be assigned to the alternative(s) with the lowest (or no) potential benefit (net revenue), and 5 (highest score) will be assigned to those alternatives estimated to generate the greatest benefit (net revenue). Supporting information including estimates of costs and revenue will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: This evaluation will be conducted once the alternatives are as narrowly defined as possible. This evaluation will follow subtask 3.3A (construction costs), and will be conducted in coordination with subtask 3.3B (O&M costs). Results will be considered in the evaluation of subtask 3.5C (community acceptance).

Uncertainty Considerations: Uncertainty in construction scope and duration will significantly affect cost and revenue estimates, as will uncertainty in product type, value, and assumptions about market demand. Assumed level of compliance with FAC 62-777 and agreement with the Division of State Lands regarding ownership of any potentially marketable material are other important uncertainty considerations.

Preface to Subtasks 3.4A through 3.4G – Goal 4: Maximize Environmental Benefits

The next seven subtasks (3.4A thorough 3.4G) are all related to the potential environmental and ecological impacts resulting from implementation of the proposed sediment management alternatives. The performance measures evaluated in these subtasks were developed cooperatively with the District and the FWC in Juno Beach and Tallahassee, Florida. Although particular aspects of quantitative modeling results will be applied where appropriate, the evaluations of these subtasks will be primarily qualitative in nature. The primary reason for this qualitative approach is because while links between sediment substrate, water clarity, and the health and abundance of both emergent plant species in the littoral zone and SAV beds in the near-shore zone have been discussed in the literature, there is a lack of specific, identified relationships linking phosphorus flux, TSS, and other parameters directly to the health (e.g., abundance, diversity, complexity) of plants, fish, benthic macroinvertebrates, manatees, alligators, wading birds, the Okeechobee gourd, and other wildlife.

It is widely accepted that the presence of healthy, established beds of SAV increase the structural complexity of lake habitats and support a greater richness of macroinvertebrates, fish, and wildlife (Ayvazian et al., 1992; Bain and Boltz, 1992; Furse and Fox, 1994; Randall et al., 1996; Rozas and Odum, 1987; Warren and Vogel, 1991). Beds of SAV also attenuate wave energy and water velocities, which stabilizes the sediment bed by increasing solids deposition and reducing sediment shear stresses (Vermaat et al., 2000). Further, SAV can be a critical factor in nutrient cycling through its role in assimilating phosphorus from both sediments and the water column. While the health and extent of SAV in Lake Okeechobee appears to be primarily influenced by lake stage (SFWMD, 2001), anecdotal evidence and field studies indicate that "widespread increases in submerged aquatic vegetation … will give rise to clearer water, help lower phosphorus concentrations, and provide conditions conducive to a healthy community of fish, wading birds, and other wildlife. The extent to which fish and birds will recover following a sustained recovery of these plants remains to be seen, and is a major focal area of ongoing research" (SFWMD, 2001).

When developing the ecological and environmental performance measures for this feasibility study, the District and FWC staff acknowledged the lack of research demonstrating direct, quantifiable links between SAV and wildlife health as well as the lack of established relationships between phosphorus levels and the health of flora and fauna in the lake. It is reasonable to assume, however, that if sediment management alternatives are shown to successfully improve water quality, decrease levels of phosphorus and turbidity, and improve sediment substrate, there should be beneficial effects for the entire system, including SAV, other plants, and wildlife. Further, as observed during the District's efforts to monitor ecological conditions in the lake, areas showing a strong recovery in SAV appear to be supporting recovering communities of forage fish and wading birds (SFWMD, 2002). In short, the establishment of one healthy community seems to lead to development of other healthy communities. The overall goal then for the alternatives evaluated under subtasks 3.4A through 3.4G is to show an improvement in water quality, phosphorus concentrations, or sediment substrate to provide conditions suitable for the support and expansion of SAV beds. These improvements should in turn foster the chain of recovery in the lake, extending to the habitat and forage needs of other important organisms and communities.

Subtask 3.4A – Maximize Benefits to Wetland Vegetation in the Littoral Zone	
Target	Decrease phosphorus flux into the littoral zone.
Tool(s)	SWAN-LOHTM (see subtasks 3.1A through 3.1D). Available information on responses of vegetation to changes in phosphorus and TSS flux.
Critical Data/Input	Available data on current phosphorus concentrations in the littoral zone, current extent of vegetation, abundance and diversity of waterfowl and fish. Estimates/descriptions from literature of responses of plant community to changes in phosphorus flux.
Method	Quantitative estimate based on modeled phosphorus flux to area; qualitatively estimate changes in plant community.
Scoring	Higher score means greater decrease in phosphorus and likely improvement in plant community structure.
Interrelationships with Other Subtasks/Timing	This evaluation will take place after assessments of subtasks 3.1A through 3.1D are complete. Results may be considered in 3.2F, 3.4E, and 3.5C.
Uncertainty Considerations	See subtasks 3.1A through 3.1D. Phosphorus and TSS flux to littoral zone may be estimated. Clear links between phosphorus and TSS flux and effects on vegetation are not currently available and may be difficult to identify and predict.

Target: Decrease phosphorus in the pelagic zone sediments, and therefore, decrease phosphorus fluxes from resuspended sediment to the littoral zone. As phosphorus transport decreases, emergent plant communities are expected to respond favorably, which will benefit waterfowl and other wildlife. In addition, reductions in cattail (*Typha spp.*) would be expected, although other factors, such as lake stage, play a key role in determining community structure.

Tools: SWAN-LOHTM (see subtasks 3.1A through 3.1D for discussion, in particular, subtask 3.1C). To the extent quantitative tools are unable to estimate phosphorus flux into the littoral zone and its potential effects on wetland vegetation, qualitative estimates will be necessary.

Critical Data/Input: Information on current concentrations of phosphorus in the littoral zone and the current extent of both native and exotic vegetation will be necessary (to the extent readily available), along with estimates of responses of vegetation to changes in phosphorus and TSS flux (this latter need, which would have to be provided by the District or others, is central to this evaluation). The

District will be consulted for the most reliable sources of existing data. In addition, scientists from FWC and FDEP may be consulted to identify currently available information.

Method: If possible, a quantitative estimate based on modeled phosphorus flux to the littoral zone will form the basis of this analysis, coupled with a qualitative estimate of resulting changes in the emergent wetland plant community. Because total phosphorus correlates closely with TSS (Maceina and Soballe, 1990), the spatially explicit SWAN-LOHTM will be used (see Subtask 3.1C) to examine sediment management scenarios that involve spatial changes in surficial sediment due to dredging. This analysis will predict for each appropriate scenario sediment resuspension rates and transport to the littoral zone. The resultant effects on emergent wetland vegetation induced by changes in TSS and phosphorus flux to the littoral zone will be made based on the results of Subtask 3.1C.

Scoring: A higher score means greater decrease in phosphorus flux to the littoral zone and resulting benefits to desirable emergent vegetation. Scores between 1 and 5 will be assigned on a relative basis after assessing the percentage increase or decrease in the base amount of phosphorus and associated projections of effects on vegetation.

Interrelationships with Other Subtasks/Timing: This analysis is linked to the modeling conducted for subtasks 3.1A through 3.1D. Results from this analysis may impact permittability (3.2F) and will be considered in the evaluations of impacts to the alligator (3.4E) and community acceptance (3.5C).

Uncertainty Considerations: All the uncertainty considerations discussed for subtasks 3.1A through 3.1D apply since the results of those analyses will be considered here. It will be difficult to identify in the literature unequivocal links between changes in phosphorus and TSS flux and effects on the emergent macrophyte community. Establishing this link is beyond the scope of this feasibility study, so if the data are not available, the project team will conduct a qualitative assessment or rely on the District to provide the necessary relationship and attendant assumptions. In addition, vegetation locations can change from season to season based on water levels and lake conditions; therefore, there is uncertainty associated with any survey results since what is observed at the time of the survey may be different in the future.

Subtask 3.4B – Maximize Benefits to SAV	
Target	500-meter buffer zone; restoration plan if SAV destruction cannot be avoided; achievement of critical light extinction coefficient target set forth in subtask 3.1C.
Tool(s)	SWAN-LOHTM (see subtasks 3.1A through 3.1D), and qualitative assessment as needed.
Critical Data/Input	Maps of spatial distribution of SAV. Assumptions regarding spatial scale of alternatives and water column impacts (e.g., resuspension).
Method	Desktop comparison of spatial extent of existing SAV to areas likely to be impacted by an alternative to determine if 500-meter buffer zone would be violated during implementation. Evaluation of SAV restoration plan, where necessary. Comparison to subtask 3.1C target will be used to assess long-term impacts.
Scoring	Higher score means a low probability of short-term impacts and high potential for improved conditions in the long term.
Interrelationships with Other Subtasks/Timing	Analysis performed in coordination with subtask 3.1C. Results considered in 3.2F, 3.4D, and 3.5C analyses.
Uncertainty Considerations	Degree of protection offered by 500-meter buffer zone to existing SAV beds. Ability to accurately simulate/predict changes to SAV extent. Uncertainties associated with subtasks 3.1A/B and 3.1C.

Target: Subtask 3.1C (maximize TSS reductions) will use modeling results to set a maximum target TSS concentration and light extinction coefficient that are assumed favorable for increased establishment of SAV over the long term. In the short term, the target for this subtask is to prevent the physical disturbance of existing SAV beds due to implementation of an alternative. Thus, in addition to long-term improvements that may result from achieving performance measure 1C, the short-term target for this subtask is no potentially disruptive alternative is to be implemented within 500 meters of known SAV beds. Based on research conducted since the finalization of the *Goals and Performance Measures* report (BBL, 2001a) in June 2001, the buffer zone has been modified from 400 meters to 500 meters.

The distance of 500 meters is believed to be a buffer zone sufficiently large enough to mitigate the effects of resuspended sediment plumes or other stressors that may migrate from a construction zone into areas containing SAV. This buffer zone was chosen based on the most recent surveys of SAV extent in Lake Okeechobee (September 2001; SFWMD 2002) and the example provided by the state of

Maryland’s tidal regulations. SAV extent in Lake Okeechobee is surveyed on a yearly basis by dividing the near-shore region of the lake (see Figure 1) into a grid of cells 1 kilometer by 1 kilometer in size. If District staff identify stands of SAV in the center of a cell, it is assumed that the plants occur throughout the entire 1 square kilometer cell. When this approach is considered along with the fact that the area of implementation for a sediment management alternative will likely focus on the pelagic zone and not the near-shore area, it is unlikely that either encroachment of the 500-meter buffer zone or impacts to the SAV beds will be an issue. Further, the state of Maryland’s tidal regulations, designed to protect the vital resources of Chesapeake Bay, prohibit dredging within 500 yards of SAV beds during the growing season of April through October (Code of Maryland Regulations 26.24.02.06). Maryland’s requirement provides support for the selection of a 500-meter buffer zone in Lake Okeechobee.

In the event an alternative must encroach upon the buffer zone and directly impact existing SAV beds to achieve some greater overall benefit (e.g., removal or treatment of underlying sediment), then such alternatives should include a specific plan that will result in either the restoration of existing beds or establishment of SAV beds with a greater spatial extent and functional benefit to the ecosystem. After the completion of Task 2 (Scoping/Detailed Development of Alternatives), it may be necessary to revisit the buffer zone distance if there is evidence it will not be sufficiently protective during implementation of a particular alternative.

Tools: SWAN-LOHTM to predict changes in sediment resuspension rates and spatial extent of transport of suspended sediment. See subtasks 3.1A/3.1B for detailed description. Qualitative assessments will be made of encroachment on the 500-meter buffer zone and the adequacy of restoration plans, as needed.

Critical Data/Input: Current maps of spatial distribution of SAV will be necessary. Also see data needs for subtask 3.1C.

Method: Using District maps of known SAV distribution, alternatives will be evaluated as to where they are likely to be implemented (assumed to be primarily in the pelagic zone) and whether construction (e.g., chemical treatment, sediment removal, etc.) would directly impact SAV or encroach within 500 meters of known SAV. Alternatives that can improve near-shore conditions (e.g., improve water quality and/or substrate in the short term) and be implemented without disrupting or encroaching upon SAV will be favored over alternatives that adversely impact SAV. Alternatives that unavoidably impact SAV will be further evaluated to determine the sufficiency of mitigative measures and the probability for success of SAV restoration plans. For example, plans would be evaluated on their ability to successfully and quickly restore spatial extent of SAV or, based on habitat equivalency analysis or some comparable method and associated data (if readily available), restoration of the functional equivalent of degraded SAV within the disrupted area or elsewhere within Lake Okeechobee. An alternative's likelihood of improving conditions for expansion of SAV over the long term (projected achievement of critical light extinction coefficient) will be considered under subtask 3.1C.

Scoring: A score of 5 indicates a low probability that an alternative would adversely impact SAV in the short term, and high probability that conditions needed to support expansion of existing SAV (e.g., transparency) would improve over the long term. A score of 3 indicates an alternative or its effects (e.g., treatment or resuspension of sediment) are not likely to destroy or encroach on SAV and are likely to improve conditions for SAV in the long term. A score of 1 indicates a high probability of short-term disruption or destruction of SAV and/or minimal long-term expansion of SAV.

Interrelationships with Other Subtasks/Timing: Evaluation is linked to the analyses conducted for subtasks 3.1A/B and 3.1C. Results will be considered in subtasks 3.2F (permitting), 3.4D (manatee), and 3.5C (community acceptance).

Uncertainty Considerations: It is assumed that a 500-meter buffer zone is sufficiently large enough to mitigate the effects of resuspended sediment plumes or other stressors that may migrate from a construction zone. In addition, the effects of storms or droughts and the effects of changes in water level on SAV extent are sources of uncertainty. Uncertainty associated with subtasks 3.1A/B and 3.1C also apply.

Subtask 3.4C – Maximize Benefits to Fish and Aquatic Invertebrate Communities	
Target	Benefit or improve fish and aquatic invertebrate communities and their habitats in the long term. Avoid short-term disruption or degradation of existing healthy communities and suitable habitats.
Tool(s)	Qualitative assessment based on readily available data and case studies.
Critical Data/Input	Results of the latest surveys/studies on existing fish and invertebrate community abundance, diversity, and location; state and location of critical habitat; relevant information from the literature and case studies.
Method	Review of quantitative modeling results; qualitative assessment of impacts on habitat and substrate.
Scoring	Higher score means high probability for enhancement of habitat quality and community composition and structure.
Interrelationships with Other Subtasks/Timing	Evaluate after subtasks 3.1B, 3.1C, and 3.1D. Results carried into 3.2F, 3.4E, 3.5A, 3.5B and 3.5C.
Uncertainty Considerations	See 3.1B and 3.1C; also lack of relevant, interpreted, site-specific data.

Target: Sediment management alternatives employed in Lake Okeechobee should, in the long term, benefit or improve fish and aquatic invertebrate communities and their habitats. In the short term, alternatives should minimize disruption or degradation of existing healthy or other known communities and associated habitats.

Tool(s): Qualitative assessment based on output from subtasks 3.1B, 3.1C, and 3.1D; relevant case studies; readily available and applicable site-specific data.

Critical Data/Input: Definition of the relationship between the light extinction coefficient k_e as a function of TSS and definition of $k_{e,critical}$ as well as maximum depth of colonization for SAV in Lake Okeechobee. The District currently is working on defining both of these data needs. All alternatives must be clearly defined, particularly in terms of location and duration. Results of the latest surveys/studies (from FWC and others) on existing fish and invertebrate community abundance, diversity, and location; and condition and location of critical habitat will be necessary to establish a basis for predicting potential impacts. Regarding the treatment alternatives, the project team will review available information on potential toxic effects of treatment chemicals on fish and benthic communities. Monitoring information from relevant case studies will also be considered. Input from District and FWC scientists with field experience and consultation with study/survey authors will be sought as needed.

Method: Once the location, duration, and scope of the sediment management alternatives are well defined, existing and readily-available data on fish and invertebrate community location and structure will be reviewed to make a qualitative assessment of potential impacts. For example, predicted changes in the frequency of algal blooms, phytoplankton community structure (this directly impacts fish community structure), and SAV community structure all will be reviewed (the results of subtasks 3.1C and 3.1D) to determine which communities, habitats, or critical substrates could be impacted by implementation of the various sediment management alternatives. Relevant case studies where adequate pre- and post-implementation monitoring data were gathered will also be considered. The scope and location of the sediment management alternatives will help to understand the nature and extent of any potential physical impacts (e.g., if dredging is implemented, what areas will be targeted for sediment removal; how would chemical treatment alter substrate; would island building impact nesting or foraging areas, etc.).

Scoring: A score of 5 means a high probability for enhancement of habitat quality and community composition and structure; a score of 3 means no net impact is expected; and a score of 1 means a high probability of unacceptable adverse impacts. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Analyses of effects of altering algal bloom frequency, impacts on SAV, and impacts on phytoplankton community structure assessed in subtasks 3.1C and 3.1D should be complete prior to carrying out this evaluation. Results of this subtask will be considered in the assessments of permittability (3.2F), impacts to the alligator (3.4E), socioeconomics (3.5A), and community acceptance (3.5C).

Uncertainty Considerations: Uncertainty associated with the subtask 3.1C and 3.1D analyses apply here as well. In addition, it is likely that detailed, site-specific data on current populations and habitat locations and conditions are not readily available and interpreted by FWC and others. It is also possible that data clearly linking changes in phosphorus and TSS flux to changes in habitat, food sources, or species abundance and diversity may not be available (District to provide if or when available).

Subtask 3.4D – Minimize Negative Impacts to the Manatee	
Target	Increase in desirable native plant forage species (i.e., SAV).
Tool(s)	Qualitative assessment based on available data and case studies.
Critical Data/Input	Locations of forage base; literature review; results of 3.1B, 3.1C, and 3.4B evaluations.
Method	Review of quantitative modeling results; qualitative assessment of potential effects on vegetation and manatees.
Scoring	Higher scores mean high probability for positive impacts on the habitat and forage requirements
Interrelationships with Other Subtasks/Timing	Evaluation will follow subtasks 3.1B, 3.1C, and 3.4B; findings considered in subtasks 3.2F and 3.5C.
Uncertainty Considerations	Same considerations associated with 3.1B, 3.1C, and 3.4B; also lack of relevant, interpreted, site-specific data.

Target: Since manatees are on the federal endangered species list, special steps must be taken to protect them in both the short and long term. Sediment management alternatives will be evaluated based on their ability to avoid impacts to manatees themselves or their food sources in the short term, as well as the probability of improving (or maintaining) extent of desirable forage species. Thus, the target is to maintain or increase desirable forage species such as *Potamogeton spp.* (pond weeds), *Najas guadalupensis* (southern naiad), *Pontederia cordata* (pickerelweed), *Ceratophyllum demersum* (coontail), *Sagittaria spp.*, and *Cabomba spp* (fanwort) (Walsh et al., 2001). In addition, the target defined in subtask 3.4B, that no alternative will be implemented within 500 meters of known SAV beds will be useful in preventing physical disturbance or destruction of existing SAV beds that manatees may rely upon.

Tool(s): Qualitative assessment based on output from subtasks 3.1B, 3.1C, and 3.4B; relevant case studies; readily available and applicable site-specific data.

Critical Data/Input: Results of evaluations of subtasks 3.1B, 3.1C, and 3.4B. Existing surveyed locations (data, if available, provided by FWC or others) of critical vegetation manatees rely on for food, including *Potamogeton spp.* (pond weeds), *Najas guadalupensis* (southern naiad), *Pontederia cordata* (pickerelweed), *Ceratophyllum demersum* (coontail), *Sagittaria spp.*, and *Cabomba spp* (fanwort). Location and duration of alternatives.

Method: The methods described in subtask 3.4B will be applied to assume protection of existing SAV beds. A qualitative assessment will be carried out to estimate the potential impacts of alternatives on the manatee's desirable forage species. The assessment will include a review of relevant, site-specific data interpretations, case-studies, and literature.

Scoring: A score of 5 means a high probability for enhancement of habitat and forage required by the manatee, a score of 3 means an estimated no net impact is expected, and a score of 1 means a high probability of habitat/forage loss. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Results of the analyses of subtasks 3.1B, 3.1C, and 3.4B should be available to evaluate potential impacts to SAV forage base for the manatee. Since the manatee is on the federal endangered species list, the findings of this evaluation will be important in the assessments of permittability (3.2F) and community acceptance (3.5C).

Uncertainty Considerations: Uncertainty associated with the 3.1B, 3.1C, and 3.4B analyses apply here. In addition, important site-specific and case study data on how alternatives may impact SAV or the manatee are lacking. FWC and other sources have been and will be contacted, but accurate, supportable, and reliable predictions of impacts will be limited.

Subtask 3.4E – Minimize Negative Impacts to the Alligator	
Target	Maintain or increase available nesting, juvenile, and adult habitat in the littoral zone.
Tool(s)	Qualitative assessment based on readily available data and case studies.
Critical Data/Input	Results of site surveys, to the extent available and interpreted.
Method	Qualitative assessment of an alternative's potential to impact or enhance habitat.
Scoring	Higher scores mean high probability for enhancement of suitable habitat.
Interrelationships with Other Subtasks/Timing	Evaluation will follow subtasks 3.4C and 3.5D; findings considered in subtasks 3.2F and 3.5C.
Uncertainty Considerations	Available data likely not sufficient to estimate impacts.

Target: Maintain or increase available nesting, juvenile, and adult habitat for the American alligator (*Alligator mississippiensis*) in the littoral zone of Lake Okeechobee.

Tool(s): Qualitative assessment based on relevant and readily available case studies and site-specific, interpreted data.

Critical Data/Input: A variety of data may be useful if available and interpreted, including: acreage and density of *Eleocharis* marshes, *Phragmites spp*., and *Typha spp*.; biomass of fish, turtles, and invertebrates used by alligators for food; total number of nests; spring night-light surveys; and critical lake stage/hydroperiod requirements. This information will be considered, but will also introduce unique assumptions and uncertainties into this subtask.

Method: After the scope, location, and duration of the alternatives are clearly defined and the impacts to water level and quality have been evaluated, this information will be used in conjunction with the results of relevant site-specific survey interpretations from FWC and others (described in the critical data section) to estimate each alternative's potential to impact either critical habitat or food sources. In addition, the results of the evaluations of subtasks 3.4A (benefits to wetland vegetation in the littoral zone) and 3.4C (benefits to fish and aquatic invertebrates) will be considered since each one may provide important information related to foraging and nesting requirements of alligators.

Scoring: A score of 5 means a high probability for enhancement of suitable habitat for the alligator; a score of 3 means an estimated no net impact is expected; and a score of 1 means a high probability of unacceptable adverse impacts. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Evaluations of subtasks 3.4C and 3.5D will be considered in this evaluation. Results of this subtask may be useful in the evaluations of permittability (subtask 3.2F) and community acceptance (subtask 3.5C).

Uncertainty Considerations: Current survey data and interpretations on alligator populations or health may not be sufficient to carry out a quantitative assessment of whether the alternatives really have an impact on the target (to maintain or increase available nesting, juvenile, and adult habitat). It appears that the alligators' success is primarily dependent upon water levels; therefore, any effects due to implementation of a sediment management alternative may not be discernable beyond its influences on lake stage, which are to be avoided (see subtask 3.5D). In addition, important site-specific and case study data on how alternatives may impact alligators is lacking. FWC and other sources have been and will be contacted, but accurate, supportable, and reliable predictions of impacts will be limited.

Subtask 3.4F – Minimize Negative Impacts to the Okeechobee Gourd	
Target	Increase suitable habitat for the Okeechobee gourd and, at a minimum, do not disturb or negatively impact areas known to support the Okeechobee gourd.
Tool(s)	Qualitative assessment based on readily available data and case studies.
Critical Data/Input	Available survey results and interpretations by FWC and others.
Method	Alternatives evaluated qualitatively for their potential to create or impact known existing critical habitats.
Scoring	Higher score (up to 5) means an increase in suitable habitat is likely; alternatives that require actions in near-shore areas, Kreamer, Torry, or Ritta islands, or near the rim canal would be given a low score (1).
Interrelationships with Other Subtasks/Timing	Will follow subtask 3.5D; findings considered in subtasks 3.2F and 3.5C.
Uncertainty Considerations	Sufficient data may not be available or interpreted; location of gourd not permanent.

Target: Take no action that will disturb or otherwise negatively impact current habitat of the Okeechobee gourd (a federally-listed endangered species) and, if possible, create or enhance habitat that could support the gourd. Kreamer, Torry, and Ritta islands and the southern rim canal are the areas supporting current populations (FDEP, 2001; USFWS, 2000). In addition, alternatives should not disturb or negatively impact the Okeechobee gourd at other transient sites that are currently not well understood or mapped, but generally are located within the near-shore zones of the lake (FDEP, 2001).

Tool(s): Qualitative assessment based on readily available data and case studies.

Critical Data/Input: Readily available survey data identifying the location and extent of mature and healthy populations will be considered as will the lake levels that would inundate key islands (Kreamer, Torry, and Ritta) and location of island CDFs that may be built as part of some alternatives.

Method: After the alternatives are clearly defined, each one will be qualitatively evaluated based on its potential to impact critical Okeechobee gourd habitat. Alternatives that involve building island CDFs may be assessed to consider if their construction could result in new suitable habitat. Areas of the lake potentially impacted by the various alternatives will be compared to known locations of current populations. For assistance, FWC and FDEP may be contacted for information.

Scoring: For the purposes of this study, alternatives that would require actions in near-shore areas, near Kreamer, Torry, or Ritta islands, or near the rim canal would be given a low score (1) relative to this subtask. Higher scores (up to 5) indicate an alternative is expected to create or enhance suitable habitat and have no negative impacts. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Subtask 3.5D results may be considered here regarding the potential role of lake stage on critical habitat. Results of this subtask will be considered in the evaluations of permittability (3.2F) and community acceptance (3.5C).

Uncertainty Considerations: Data or current data interpretations on critical gourd habitat in Lake Okeechobee may be limited; however, the FWC and FDEP (or others) may be contacted. Existing survey data may not be reliable because locations of gourd populations are not static – the gourd may appear in different areas in different years depending on water quality and lake stage.

Subtask 3.4G – Minimize Negative Impacts to the Snail Kite and Wading Birds	
Target	Improve or have no net impact on the habitat or forage base of the snail kite or wading birds.
Tool(s)	Qualitative assessment based on quantitative modeling results and available data and case studies.
Critical Data/Input	Results of subtasks 3.1B, 3.1C, and 3.4A; existing survey results and interpretations.
Method	Qualitative; available data will be used to estimate the likelihood of benefits (or impacts) from a given alternative.
Scoring	Higher scores mean a high probability of positive effects on critical habitat/forage.
Interrelationships with Other Subtasks/Timing	Evaluation will follow subtasks 3.1B, 3.1C, 3.4A, and 3.5D; findings considered in subtasks 3.2F and 3.5C.
Uncertainty Considerations	Data are limited, links between TSS and phosphorus and impacts to birds are not established, knowledge base is incomplete – assessment will be limited and highly qualitative in nature as a result.

Target: The Snail Kite is an endangered species, and therefore must be afforded special protection. Sediment management alternatives will be evaluated based on their ability to avoid adverse impacts in the short term (high turbidity will negatively impact sight-foraging birds) and the long term (reduced phosphorus concentrations may contribute to declines in dense stands of invasive species accompanied by increases in desirable native vegetation and food sources). Thus, the target for this performance measure is that an alternative is to improve or, at a minimum, have no net impact on the habitat or forage base of the Snail Kite or wading birds.

Tool(s): Qualitative assessment of potential effects on critical vegetation based on quantitative modeling results, available data, and case studies.

Critical Data/Input: Results of evaluations of subtasks 3.1B, 3.1C, and 3.4A. Readily-available surveyed locations of apple snail (and FWC or other interpretation of results); critical lake stage and hydroperiod requirements of the wading birds and the apple snail.

Method: A desktop review of readily-available data and interpretations from FWC, FDEP, or others will be considered along with modeling results (3.1B and 3.1C) to qualitatively estimate potential benefits or impacts.

Scoring: A rating of 5 means a high probability of positive impacts (benefits/enhancements) on the habitat and forage base of the Snail Kite and wading birds, a rating of 3 means an estimated no net impact is expected, and a rating of 1 means a high probability of unacceptable adverse impacts. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: Results of subtasks 3.1B, 3.1C, 3.4A, and 3.5D should be available to evaluate potential impacts to the Snail Kite and other wading birds. Since the Snail Kite is an endangered species, the findings of this evaluation will be important in the assessments of permittability (subtask 3.2F) and community acceptance (subtask 3.5C).

Uncertainty Considerations: Data currently available on populations or health of the Snail Kite (and food supply) or other wading birds in Lake Okeechobee appear to be outdated and/or limited. Ability to accurately predict potential future conditions resulting from the implementation of a particular sediment management alternative will be limited since direct links between TSS or phosphorus and impacts to the Snail Kite or other wading birds has not been established (and will not be established by the project team), survey data are limited, and the available base of knowledge is incomplete. As a result, this evaluation will likely be limited and highly qualitative in nature.

Subtask 3.5A – Maximize Regional Socioeconomic Benefits	
Target	No effect, or a beneficial effect, on the region's socioeconomic status.
Tool(s)	Regional economic activity correlation matrices for 2000-2002 will be calculated using Statistical Package for the Social Sciences (SPSS) software. The matrices will provide detail to the zip code level and be the basis for estimating the effects of sediment management alternatives.
Critical Data/Input	1) Estimates of economic activity using 2-digit Standard Industrial Classification (SIC) codes; 2) Monthly retail and commercial sales tax revenues; 3) General spatial description of the economic centers in the region; and 4) Employment, equipment, and land use requirements and physical location of each alternative.
Method	Correlation matrices will be calculated from the SIC and sales tax data to identify the predominate economic sectors and sector interrelationships by sub-region. The physical requirements of the alternatives will be applied to the affected sub-region(s) to estimate (to the extent possible) the resulting effects on the dominant economic activities in the affected zip code areas.
Scoring	Relative scores will be assigned from 1 to 5 (5 assigned to alternatives with the greatest beneficial impact, 1 assigned to alternatives with the greatest negative impact).
Interrelationships with Other Subtasks/Timing	No direct inputs necessary from any other subtask; however, the output from this subtask is necessary to score subtask 3.5B and to estimate the probabilities estimated in subtask 3.5C.
Uncertainty Considerations	Some of the input data are estimates and the projections of future effects are based on the assumption that the interrelationships are represented accurately. To the extent that the estimates and assumptions are incorrect, the estimated future impact may be incorrect. This error will be minimal to a 3-year time frame, but will grow for the projections based on long-duration alternatives.

Target: Alternatives that either do not affect or have a beneficial effect on the region's socioeconomic status are preferred.

Tool(s): To estimate the potential impacts of the various sediment management alternatives, two regional economic activity correlation matrices providing detail to the zip code level will be calculated and maintained using Statistical Package for the Social Sciences (SPSS) software. The matrices will incorporate data on estimated economic activity and sales taxes in the Lake Okeechobee rim communities during 2000, 2001, and 2002. A map or other spatial tool identifying the locations of the general categories of economic activity (i.e., residential, commercial, agriculture, manufacturing, transportation, etc.) and the relevant demographic information for each economic sub-region will be used to augment the matrices.

Critical Data/Input: 1) Estimates of economic activity at the 2-digit standard industrial classification (SIC) code level of aggregation, including dollar volumes, employment totals, and number of establishments (see Table 5 in the *Goals and Performance Measures* report [BBL, 2001a] for a list of potentially relevant SIC codes and descriptions). Data will be obtained from Claritas, Inc. 2) Monthly retail and commercial sales tax revenues. Data will be obtained from the University of Florida's Bureau of Economic and Business Research, the official outlet for the Department of Revenue's tax data. 3) A general spatial description of the economic centers in the region. 4) An accurate estimate of the employment, equipment, and land use requirements and physical location of each alternative. All data, except item #4, are currently available at the zip code or locality level. Data describing item #4 will be gathered and evaluated after the alternatives have been fully specified.

Method: The 2-digit SIC economic activity and sales tax data will be combined to create 3-year time series tables that will be used to establish baseline estimates of activity in the predominate economic sectors if no sediment management alternatives were undertaken. Similarly, sales tax data will define correlation matrices of economic sector interrelationships. Both of these tools will be specified for zip code areas as well as economic sub-regions (population concentrations comprised by multiple zip codes). Using these tools, the sub-region's baseline economic activity will be projected three years into the future. This baseline will establish the basis for comparison of the effects of various alternatives.

The spatial description of the economic centers (item #3 in Critical Data/Input) will identify the geographical loci of the identified economic activities and relevant demographic data. Once the requirements of the various alternatives are identified, each alternative's impact on an affected sub-region's dominant economic activities will be estimated for the same three-year period. The difference between a sub-region's baseline economic activity and its activity as affected by each alternative will be calculated. These calculations will provide an estimated dollar-valued economic impact for each alternative.

Scoring: The scores for each alternative will be reported on a relative scale of 1 to 5. The alternative(s) that best satisfies the target will be assigned a value of 5, while a value of 1 will go to the alternative(s) with the greatest negative effect on the region's socioeconomic status. The other alternatives will be scored based on their relative position between the high and low. For example, if the economic impacts for alternatives A, B, and C were no impact (a $0 effect), a negative $2.5 million impact, and a negative $4 million impact respectively, then A would receive a score of 5, C would receive a score of 1, and B would receive a score of 3. Supporting information and relevant dollar estimates will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: There are no direct inputs necessary from any other subtask. However, information developed during Task 2 (the detailed development/scoping of alternatives) will be used as initial input for item #4 described in the Critical Data section above (accurate estimate of employment, equipment, and land use requirements and physical location of each alternative). The Task 2 information will also be used to test and calibrate the model and to provide an early warning of major economic impacts, if necessary. The results of the evaluations of subtask 3.4C (benefits to fish and aquatic invertebrate communities) may be considered here since tourism-based fishing businesses and related activities are a source of income to communities around the lake. The output from this subtask is necessary to score subtask 3.5B and to estimate the probabilities to be developed in subtask 3.5C.

Work on the correlation matrices and the spatial description will start in the first month following the District's Stop/Go decision and continue as the alternatives are developed in detail and other subtasks are evaluated. In this way the tools will be calibrated and ready for use when they are needed.

Uncertainty Considerations: All SIC code-based data, employment information, dollar volumes, and number of establishments are estimates. To the extent that the data misstate the actual values, the relative estimates of the dominant economic activities may be incorrect. The sales tax data are counts; therefore, the correlation coefficients calculated from those data will be accurate for the period defined. However, the purpose of this subtask is to estimate <u>future</u> economic activity. For the short term – 3 to 5 years – both tools are likely to be sufficiently accurate. After that time period, the effects of changes in population, the economic relationships between the sectors, state and national economic cycles, technological advances, and many other factors will widen the margin of error of the evaluations.

As a practical matter, it is normally the case that a plethora of small errors in a variety of data points cancel each other out when they are factored together. The result is a generally accurate estimate of future conditions. We will aid this tendency by using only conservative values for data used to project future conditions.

Subtask 3.5B – Minimize Environmental/Social Inequities	
Target	Uniform distribution of economic/environmental impacts.
Tool(s)	Regional economic activity correlation matrices and general spatial descriptions of economic activity developed in subtask 3.5A.
Critical Data/Input	The employment, equipment, and land use requirements and physical location of each alternative; the correlation matrices and spatial descriptions from subtask 3.5A.
Method	The resource requirements for each alternative will be defined. These data will be used to identify the geographical locations and degree of potential impact. These measures will be applied on a zip code basis to determine the burdens borne, both financially and in quality of life, in each area.
Scoring	A 5 (high score) will be assigned to the alternatives with the most even allocation of impact, and a 1 will be assigned to the alternatives that result in the most lopsided allocation of impact.
Interrelationships with Other Subtasks/Timing	This subtask requires the output of subtask 3.5A and the detailed descriptions of the alternatives. The output from this subtask is necessary to determine the probabilities estimated in subtask 3.5C.
Uncertainty Considerations	Estimates and assumptions carried through from subtask 3.5A may introduce uncertainty. Further, use of zip codes to define evaluation areas may mask the presence of unique demographic groups.

Target: Alternatives that have uniform distribution of economic/environmental impacts across the region are preferred.

Tool(s): Regional economic activity correlation matrices and general spatial descriptions of economic activity created in subtask 3.5A.

Critical Data/Input: The employment, equipment, and land use requirements and physical location of each alternative will be used in conjunction with the correlation matrices and spatial descriptions developed in subtask 3.5A.

Method: The resource requirements, potentially affected in-lake or on-shore locations, and other tangible events for each alternative will be defined to the extent possible. These data will estimate the degree of impact created by each alternative and the geographical locations of that impact. By combining that information with the economic activity data and demographic data established for each zip code area tangent to the lake shore, the degree of financial burden placed on varying demographic groups will be estimated. The magnitude of the burden (or benefit) created by each alternative will be estimated in both financial terms (effect on the economic activity) and in more qualitative terms (e.g., encroachment on residential and recreational areas).

Scoring: The dollar estimates of impacts on local economic activity will be calculated and reported. In addition, quantitative scores based on, for example, the amount of residential area and/or the number of recreation areas impacted will be assigned to each alternative. These scores will then be allocated to the different demographic groups living in the zip code-defined areas and the average impact on a per-person, per-demographic group basis will be calculated. Scores will range from 1 to 5, with 5 being the highest. Alternatives that result in the most even allocation of impact across demographic groups will receive a 5, and the alternatives that result in the most lopsided allocation of impact will receive a 1.

Interrelationships with other Subtasks/Timing: This subtask requires the output from the evaluation of subtask 3.5A and the information regarding the alternatives described in the Critical Input/Data discussion above. The output from this subtask along with the output from subtask 3.5A will be necessary to determine the probabilities used in the evaluation of subtask 3.5C. Work on the correlation matrices and the spatial description will start in the first month following the District's Stop/Go decision, and information developed during Task 2 (the detailed scoping of alternatives) will be used when it is available. In this way the tools will be calibrated and ready for use when they are needed toward the end of Task 3. The results of the evaluations of subtask 3.4C (benefits to fish and aquatic invertebrate communities) may be considered here since tourism-based fishing businesses are a source of income to communities around the lake.

Uncertainty Considerations: Some of the input data used to develop the correlation matrices in subtask 3.5A are estimates, and the projections of future effects are based on the assumption that the interrelationships are described accurately and will not change significantly. To the extent that the estimates and assumptions are incorrect, the estimated future impact may be incorrect. Further, the geographical unit of measure is a zip code. There can be many different demographic communities within a single zip code that may be masked by the necessary use of this geographic definition. To the extent possible, this source of error will be mitigated by generally identifying demographic communities on the spatial descriptions of economic activity. These errors will be minimal in a 3-year time frame, but may grow as the projections are pushed further into the future for long-duration alternatives.

Subtask 3.5C – Maximize Community Acceptance	
Target	An alternative with a high probability of community and interagency acceptance along with a low probability of legal challenge is the most desirable outcome.
Tool(s)	Qualitative. Final implementation of the *Public and Interagency Outreach Plan* (BBL, 2000) and finalization of the stakeholder database will be necessary.
Critical Data/Input	Feedback received throughout the feasibility study; case studies, legal literature, newspaper clippings.
Method	Qualitative assessment/comparison.
Scoring	Higher score means greater degree of apparent community acceptance and lower probability of legal challenge.
Interrelationships with Other Subtasks/Timing	Will likely be the last subtask evaluated as details from all other analyses will be necessary to develop the final assessment of probability of community acceptance and legal challenge.
Uncertainty Considerations	Important community issues or concerns may not have all been identified. Case studies and legal literature may be subjective, and their applicability may be limited by the potentially precedent-setting scale of many of the proposed alternatives.

Target: An alternative with a high degree of community and interagency acceptance or buy-in along with a low probability of legal challenge is the most desirable outcome.

Tool(s): This is a qualitative performance measure, and as such, no specific tools (such as a model) are necessary; however, completion of the tasks outlined in the *Public and Interagency Outreach Plan* (BBL, 2000) is necessary and the input of information gathered as a result of the public outreach process (specifically at the public/interagency meetings) into the stakeholder database must be complete before analysis of those data can begin.

Critical Data/Input: Data gathered throughout the feasibility study (as described in the *Public and Interagency Outreach Plan*) will be reviewed, along with case studies of other similar or relevant restoration projects, legal literature, and newspaper clippings. District, FDEP, FWS, and USACE case study experience in south Florida will be sought and considered as a particularly relevant source of information.

Method: A qualitative assessment of the probability of community/interagency acceptance and probability for legal challenge will be made based on:

- Feedback (support and opposition) received throughout the feasibility study (the database will be queried to gauge reaction from involved individuals and organizations);
- Discussions with agency and organization contacts (District, FDEP, FWS, USACE, Friends of Lake Okeechobee, etc.);
- Review of newspaper clippings (to assess type/tone of information individuals who have not attended the public meetings held during the study may have received); and
- Case studies and legal literature (to compare reaction/legal actions in response to other restoration projects).

This type of qualitative evaluation/comparison will be conducted for each alternative, and each alternative will be assigned a score of 1-5 as an estimate of its relative acceptability and potential to trigger legal challenge.

Scoring: Scoring of each alternative will be reported on a relative 1 to 5 scale. A score of 5 will be given to those alternatives with a high probability of community acceptance/low probability for legal challenge; 3 for a medium probability of community acceptance and legal challenge; and 1 for low probability of community acceptance/high probability for legal challenge. Supporting information will also be summarized and reported.

Interrelationships with Other Subtasks/Timing: The evaluation of the proposed alternatives with respect to the probability for community acceptance and legal challenge will be among the very last steps in the evaluation process. The degree of community acceptance and the potential for legal challenge will hinge on details such as length of time to implement the alternative (3.1B), permittability (3.2F), impact on the local economy (3.3A, 3.3B, 3.5A, and 3.5B), and nature of the effects on land use (3.2E), recreation (3.5A and 3.5B), and wildlife (3.4D-3.4G); this type of information will not be available until the evaluation against all other performance measures is complete.

Uncertainty Considerations: Every attempt has been made to involve, inform, and gather input from all potentially affected members of the community and staff from multiple federal, state, and local agencies. There is, however, the possibility that an important community issue or concern may not be identified. This potential gap in the stakeholder database will be considered in the final evaluation. Case studies and legal literature may be subjective, and their applicability may be limited by the potentially precedent-setting scale of many of the alternatives.

Subtask 3.5D – No Impacts on Water Supply or Lake Operations	
Target	No adverse effect on water supply or lake operations.
Tool(s)	Quantitative output from models; most recent versions of relevant plans and reports.
Critical Data/Input	Output from models; regulations and requirements in most recent plans and reports.
Method	Quantitative comparison of potential impacts an alternative would have on water supply or lake stage against requirements outlined in current plans and regulations.
Scoring	Scores assigned on a relative basis, with 5 assigned to alternatives that do not have any impact, and 1 assigned to those with significant adverse impacts.
Interrelationships with Other Subtasks/Timing	This evaluation will follow completion of all the modeling runs, and will likely be conducted in coordination with subtasks 3.2A and 3.2D. Subtasks 3.2F, 3.4E, 3.4F, 3.4G, and 3.5C will be reliant on the results of this evaluation.
Uncertainty Considerations	Uncertainty is primarily related to modeling uncertainty.

Target: A preferred alternative would have no adverse impact on water supply, lake operation, or lake stage and would not interfere with implementation of any current regulations or strategies.

Tool(s): Quantitative data generated by various models (i.e., LOHTM, Lake Okeechobee Internal Phosphorus Loading model, and MINEQL+) will be used to evaluate the effects of the alternatives in relation to lake stage. Preparation of the necessary models is described in more detail in subtasks 3.1A through 3.1D. Lake operation, water supply, and lake stage information/requirements will be gathered from the most recent versions of relevant plans and reports.

Critical Data/Input: Output from the modeling runs, particularly as related to physical and hydrological parameters (e.g., changes in lake stage, effects of building islands or near-shore CDFs, changes related to digging a sump, etc.) will be critical to this evaluation. The most recent version of various plans in place to manage lake stage, water budget, and environmental needs of water conservation areas, the Everglades, and downstream estuaries will be considered. Specific plans to be reviewed include the SWIM Plan (SFWMD, 1997), the Lake Okeechobee Regulation Schedule Study (LORSS; USACE, 1999), the District's Lower East Coast (LEC) Plan (SFWMD, 2000b), and the minimum flows and levels (MFLs) as discussed in *Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer* (SFWMD, 2000a). District staff will be consulted to determine which plans and reports are most relevant for this evaluation.

Method: Output from the relevant models will be compared to the up-to-date requirements for lake stage management, water budget, and environmental needs to determine if any of the proposed alternatives would be likely to have an effect on water supply or lake stage. In addition, the detailed descriptions of the alternatives will be evaluated against current regulations and strategies to identify potential conflicts. While the potential impacts of all alternatives will be considered carefully, alternatives that involve filling in areas of the lake (i.e., building islands or near-shore CDFs) will be the focus of this evaluation. Input from water utility directors around the lake may also be solicited.

Scoring: Relative scores will be assigned on a scale of 1 to 5 based on the probability that an alternative would have an impact on water supply or lake operation or create conflicts with existing plans or regulations. A score of 5 will be assigned to those alternatives that appear likely to not cause adverse impacts or conflicts, while alternatives that will likely lead to adverse impacts and conflicts will score a 1.

Interrelationships with Other Subtasks/Timing: Evaluation of this performance measure can only take place after the alternatives are as narrowly defined as possible (Task 2) and all the modeling runs are complete. Consideration of the results of subtask 3.1E (exceedances of water quality standards) will be necessary; this evaluation will be performed in coordination with subtasks 3.2A (reliability) and 3.2D (permanence). Subtasks 3.2F (permit probability), 3.4E (impacts to the alligator), 3.4G (impacts to the Snail Kite), and 3.5C (community acceptance) will be reliant on the results of this evaluation.

Uncertainty Considerations: Uncertainty associated with the results of this evaluation will be almost entirely related to the modeling issues identified in the discussions of subtasks 3.1A through 3.1D.

3.5 Task 4: Development of Evaluation of Alternatives Document

The *Evaluation of Alternatives* report will present the actual detailed evaluation of the sediment management (and sediment disposal/reuse) alternatives relative to the 26 performance measures finalized in the *Goals and Performance Measures* report (BBL, 2001a). Unlike a traditional feasibility study where the analysis is driven by the alternatives, the structure of the *Evaluation of Alternatives* report will be driven by the performance-measure-based evaluations. This structure makes the most sense for this project, as the approach is driven by the scope of work, presents the required information in as streamlined a fashion as possible, and acknowledges the District's need both for raw data/scores and the flexibility to prioritize the alternatives and select an appropriate course of action. The generation of a preliminary outline designed to clearly present the results of the alternatives evaluation is complete; the tasks of the overall feasibility study are inextricably linked, and it was necessary to establish the framework for the *Evaluation of Alternatives* report in conjunction with the framework for this Work Plan. The main section and sub-section titles for the report are expected to be as follows:

1. Executive Summary
2. Introduction (purpose, scope, background)
3. Evaluation Approach (characterization of alternatives, application of tools, how data gaps and uncertainty were addressed, scoring)
4. Evaluation of Alternatives with Respect to Performance Measures
    (repeat the five subsections below for all 26 performance measures/subtasks)
    - 4.1 Performance Measure Description/Rationale
    - 4.2 Performance Measure Metric/Target/Method/Scoring
    - 4.3 Specific Uncertainty Considerations
    - 4.4 Evaluation and Scoring of Each Sediment Management Alternative (detailed analysis of the alternatives relative to the performance measure)
    - 4.5 Summary Evaluation Relative to the Performance Measure (raw quantitative and qualitative results and 1-5 scores will be summarized)

5. Summary of Analyses with Respect to Alternatives (raw data and scores developed above for each performance measure subtask will be grouped by alternative instead so the reader can develop a sense of each alternative's overall performance)
6. Recommendations (no specific alternative will be recommended, but as appropriate, recommendations regarding potential data needs and/or suggested follow-up actions will be presented in this section)

3.6 Task 5: Meetings, Deliverables, and Schedule

Throughout the development and finalization of the work plan and the detailed evaluation of alternatives, a number of meetings may be necessary in order to gather critical input and feedback, and a variety of deliverables will be generated. A schedule for the meetings and submission of the deliverables is outlined below. It is important to note that some of the dates presented here are subject to change if all parties agree to the modification.

Target Date	Activity/Date Completed
09/28/01	Meeting with the District's TRT to discuss the framework for the development of the Work Plan and Evaluation of Alternatives documents. Complete 09/28/01.
12/21/01	Submission of the draft Work Plan for review. Ten (10) hard copies sent to the District Project Manager, Microsoft (MS) Word and portable document format (PDF) files posted to a file transfer protocol (FTP) site. Complete 12/21/01.
01/24/02	District makes Stop/Go decision. Complete 01/18/02 (decision is to go forward with the study).

After reviewing the draft Work Plan, the District made the decision to continue with the project (i.e., a "Go" decision); as a result, the District posted the draft Work Plan to the project web site and work on the feasibility study will continue as described on the next page.

Target Date	**Activity/Date Completed**
01/24/02	District provides written comments on the draft Work Plan. Complete 02/05/02.
01/31/02	TRT meeting to discuss Work Plan. Complete 02/12/02.
01/31/02	Modeling meeting – District and BBL/Tetra-Tech staff. District submits to BBL requisite input data sets (e.g., long-term external nutrient loading scenarios) as specified in the Statement of Work. Complete 03/11/02.
02/22/02	Submission of the draft final Work Plan for review. Complete 03/08/02.
03/13/02	Public/Interagency Meeting #3. Complete 04/04/02.
03/15/02	District provides consolidated written comments on the draft final Work Plan. Complete 04/24/02.
03/30/02	District posts minutes and handouts from Public/Interagency Meeting #3 to the project web site.
04/12/02	Submission of the final Work Plan. Ten (10) hard copies sent to the District Project Manager, MS Word and PDF files posted to an FTP site or provided on CD. The District will post the final Work Plan to the project web site. Complete 05/13/02.
11/22/02	Submission of the draft Evaluation of Alternatives document for review. Ten (10) hard copies sent to the District Project Manager, MS Word and PDF files posted to an FTP site or provided on CD.
12/20/02	District provides consolidated written comments on the draft Evaluation of Alternatives document and posts the draft document to the project web site.
12/20/02	Meeting with the TRT to discuss District comments and finalization of the Evaluation of Alternatives document.
01/31/03	Public/Interagency Meeting #4.
02/28/03	Submission of final *Evaluation of Alternatives* document. Ten (10) hard copies sent to the District Project Manager, MS Word and PDF files posted to an FTP site or provided on CD. The District will post the final report to the project web site.
March 2003	Presentation of the final evaluation of alternatives to the Governing Board (if appropriate).
Ongoing	Progress reports submitted to the District on a monthly basis in electronic format.

In addition to the activities described above, it may be necessary to schedule meetings with the District's modeling staff and others in order to gather critical information, discuss various approaches, and resolve any issues that develop during the evaluation process. Supplemental TRT meetings may also be scheduled to discuss District comments on deliverables or address questions that arise.

3.7 Task 6: Public/Interagency Outreach and Coordination

The importance of broad-based public and interagency participation has been recognized since the beginning of this feasibility study. BBL developed a *Public and Interagency Outreach Plan* (BBL, 2000; available on the project website) to encourage participation in the study, facilitate interagency communication and cooperation, and educate stakeholders and other interested parties about the project and its potential implications. Three informational fact sheets have been developed and distributed to over 700 individuals and organizations; one more is planned to provide a status report during the alternatives evaluation. The fourth fact sheet will also announce the fourth and final public/interagency meeting, currently planned for February 2003. The first three meetings (held in January and July 2001 and April 2002) were well attended (approximately 30 to 45 participants at each), and provided valuable opportunities for the District and the project team to exchange information and ideas with interagency staff and members of the community. Group consensus is not an objective of the outreach process. However, since implementation of some of the proposed sediment management alternatives could require a great deal of time (up to 25 years or more) and money (potentially tens or hundreds of millions of dollars), if affected members of the community and representatives from various local, state, and federal agencies are involved in and understand the process, widespread acceptance of any final decision is more likely.

With this overall goal in mind, the project team has established contacts with key members of various agencies in order to draw on the expertise of specific individuals and involve others in the process from the start. Several of the alternatives to manage internal phosphorus loading in Lake Okeechobee would require permits from state and federal agencies, so these contacts will be maintained throughout the rest of the project in order to lay the groundwork for a smooth transition from the feasibility study to implementation of the alternative selected by the District, as necessary and appropriate. To date, representatives of the following key agencies have actively provided input to the project:

- USACE: Restoration & Planner and Outreach Specialist, Civil Engineer, and the Chief of the Environmental & HTRW Section of the Jacksonville District
- USEPA: Ecosystem Restoration Section

- FDEP: Environmental Manager for the Southeast District
- St. Lucie River Initiative representatives
- FWC: Bio-Administrator II and Biological Scientist IV
- Friends of Lake Okeechobee
- Environmental and Land Use Law Center
- Florida Sportsmen Conservation Association

As discussed above, cooperation and coordination with individuals from these organizations, members of the community, and others identified during the remainder of the study will be the focus of the outreach effort. This task is already underway, and will continue until the project is complete.

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Tables

TABLE 2

LAKE OKEECHOBEE SEDIMENT MANAGEMENT FEASIBILITY STUDY
WORK PLAN FOR EVALUATION OF ALTERNATIVES

OVERVIEW OF MATHEMATICAL MODELS

Overview of mathematical models to be used in predicting effects of sediment mitigative measures on internal loading fluxes and lake response in Lake Okeechobee.

Model	**Type/Spatial Scale**	**Time Step**	**Inputs**	**Outputs**
SWAN	3-D[1], 925 m x 925 m	10 minutes	Lake morphometry, hydrology, fetch, wind parameters	Significant wave height and period. Outputs drive LOHTM.
LO Hydrodynamic Transport Model	3-D, 925 m x 925 m, multiple layers in sediment.	Time step varied according to wind speed from 180 sec (high wind) to 200 sec (low wind)	Significant wave height and period, wind parameters, inflows and outflows, water depth, lake morphometry, sediment parameters.	Current velocities, surface elevation, temperature, suspended sediment concentrations, hydrodynamic parameters.
LOWQM	CSTR[2] (single box for water column)	Daily	Lake hydrology, input loads for phosphorus and nitrogen (speciated), suspended sediment concentrations, surface elevation, water temperature.	Water column TP and SRP, nitrogen species, chlorophyll *a*, total suspended solids, and algal speciation into three major groups: greens, diatoms, and cyanophytes.
Walker (2000)	CSTR (single box for water column, single sediment box)	Annual	Lake hydrology and morphometry, total phosphorus load, total calcium load	Annual water column Ca, P and sediment P concentrations. Model predicts internal load as a function of "labile" sediment P but does not explicitly simulate $P_{porewater}$. Model thus may not prove useful for evaluating certain mitigative measures imposed on sediments.

TABLE 2

LAKE OKEECHOBEE SEDIMENT MANAGEMENT FEASIBILITY STUDY
WORK PLAN FOR EVALUATION OF ALTERNATIVES

OVERVIEW OF MATHEMATICAL MODELS

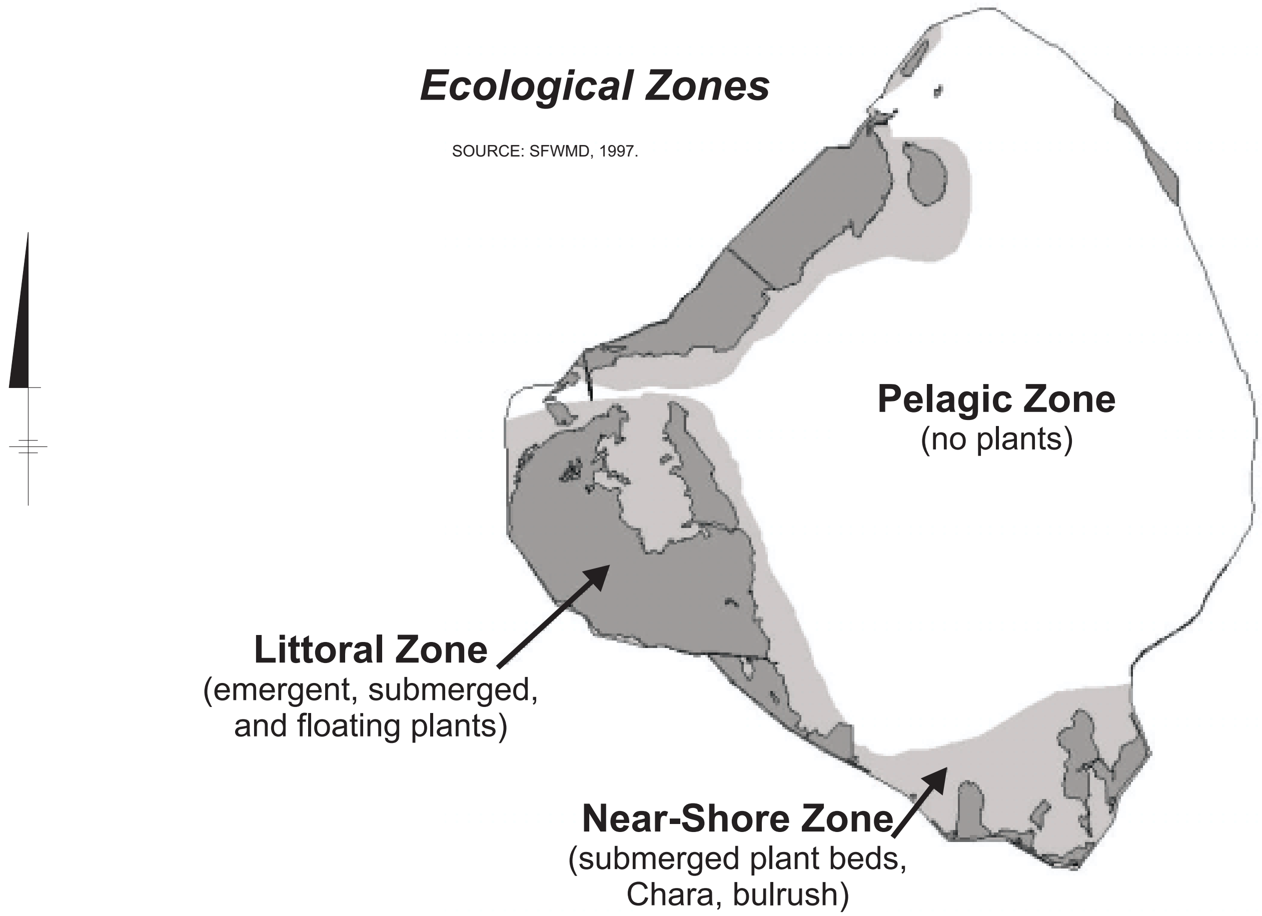
Model	**Type/Spatial Scale**	**Time Step**	**Inputs**	**Outputs**
LO Internal P Loading Model (Pollman, 2000)	CSTR (single box for water column, single sediment box)	0.001 yr	Lake hydrology and morphometry, total phosphorus load	Annual water column, sediment and porewater P concentrations. Short time step required because of magnitude of sediment internal fluxes due to adsorption-desorption relative to the size of the interstitial pool. Model predicts resultant changes in $J_{internal}$ that can arise due to changes in sediment sorption characteristics, porewater dynamics, $\upsilon_{diffusion}$, and sedimentary P concentrations.
MINTEQA21/MINEQL+	Batch (static system, no hydrology)	Not applicable (assume rapid kinetics leading to "instantaneous" equilibrium)	Major cations and anions, pH, alkalinity, iron, redox conditions, total dissolved inorganic P.	Equilibrium concentrations of phosphorus species and predictions of formation of mineral phases removing dissolved inorganic P. Model can consider sorption as well. Output can be used to change calibration parameters in LOWQM (e.g., fix maximum $P_{porewater}$ that can develop due to change in controlling mineral phase chemistry)
LO Phosphorus Diagenetic Model	1-D (1 cm resolution of vertical sediment profile)	Daily	Organic matter sedimentation rate, sorption characteristics, sediment mixed depth and physical characteristics, sediment organic P mineralization rate.	Values for $J_{internal}$, vertical profile of $P_{porewater}$.

Notes:
[1] 3-D = three dimensional
[2] CSTR = continuous stirred tank reactor (i.e., well-mixed, homogeneous box)

Figures

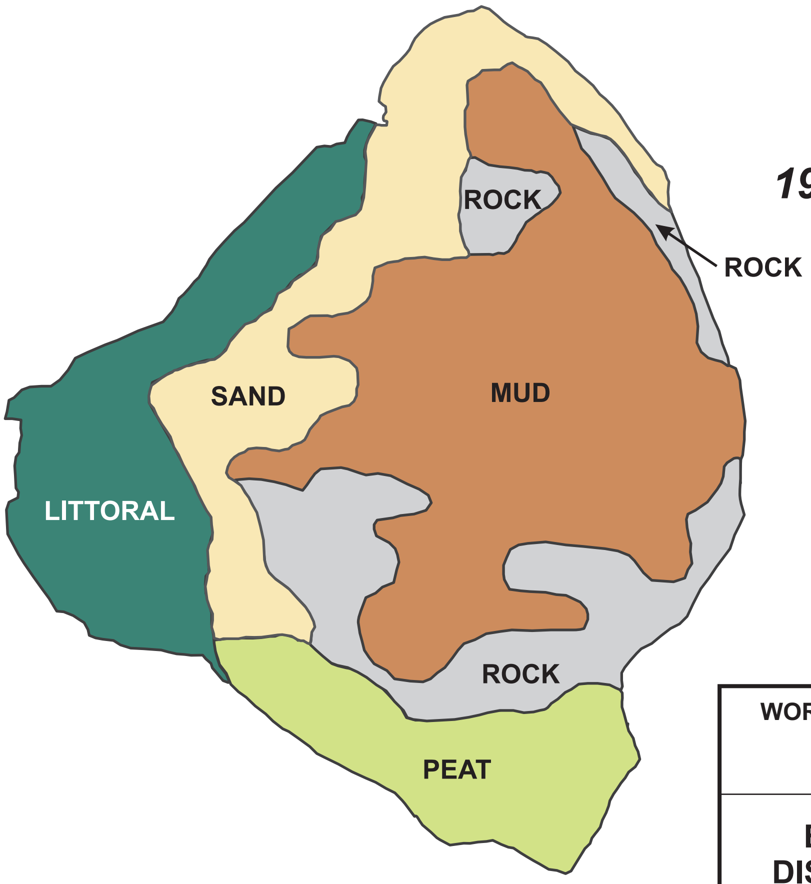
Ecological Zones

SOURCE: SFWMD, 1997.



1998 Spatial Distribution of Sediment Types

ADAPTED FROM: FISHER ET AL., 2001



DRAWINGS ARE NOT TO SCALE

WORK PLAN FOR EVALUATION OF ALTERNATIVES

LAKE OKEECHOBEE
SEDIMENT MANAGEMENT FEASIBILITY STUDY

ECOLOGICAL ZONES & SPATIAL DISTRIBUTION OF SEDIMENT TYPES

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FIGURE
1

05/02 SYR-37 MFE
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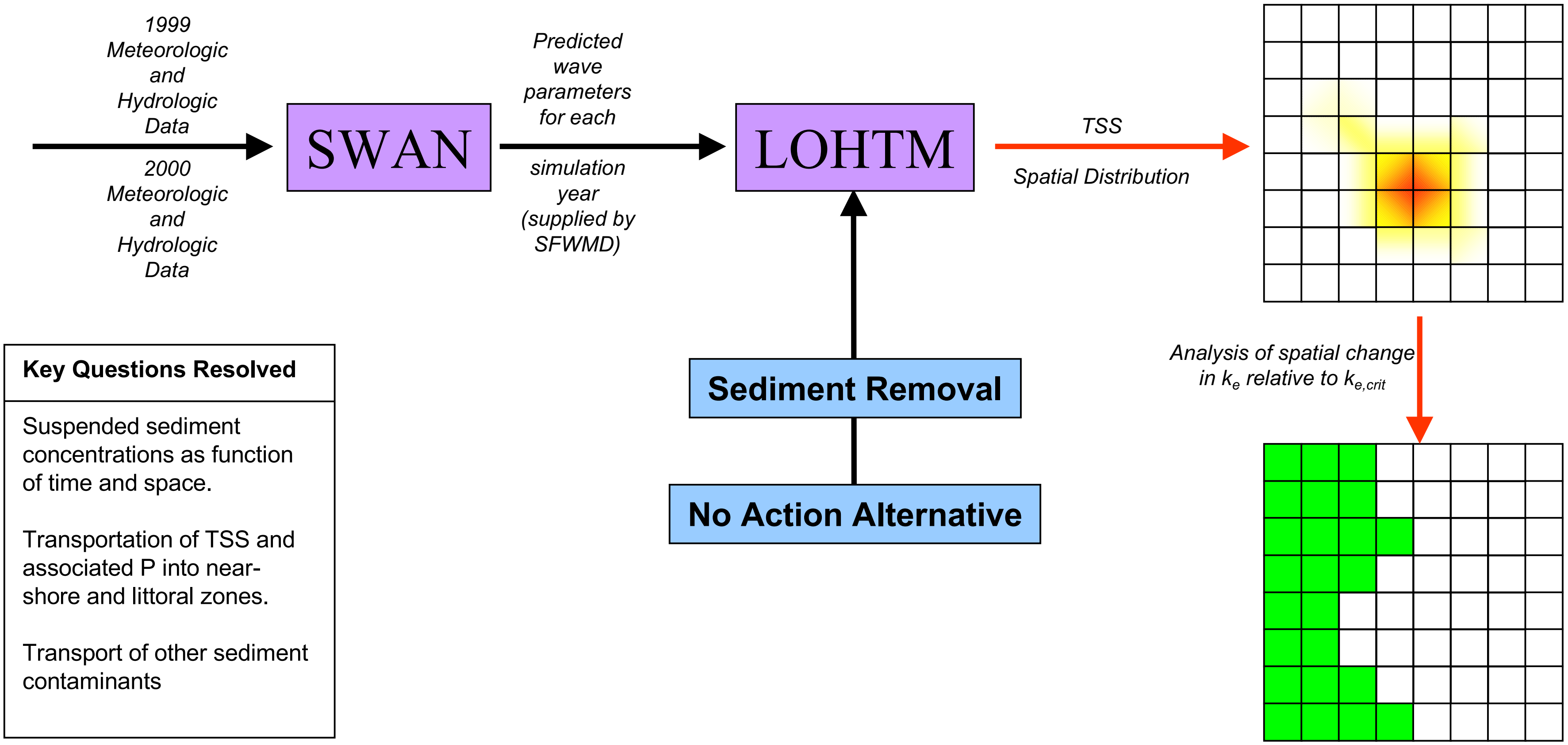
Spatially Explicit Models



1999 Meteorologic and Hydrologic Data

2000 Meteorologic and Hydrologic Data

SWAN

Predicted wave parameters for each

simulation year (supplied by SFWMD)

LOHTM

TSS

Spatial Distribution

Analysis of spatial change in k_e relative to $k_{e,crit}$

Sediment Removal

No Action Alternative

Key Questions Resolved

Suspended sediment concentrations as function of time and space.

Transportation of TSS and associated P into near-shore and littoral zones.

Transport of other sediment contaminants

Source: Pollman, 2002

WORK PLAN FOR EVALUATION OF ALTERNATIVES

LAKE OKEECHOBEE
SEDIMENT MANAGEMENT FEASIBILITY STUDY

INTERRELATIONSHIPS BETWEEN MATHEMATICAL MODELS

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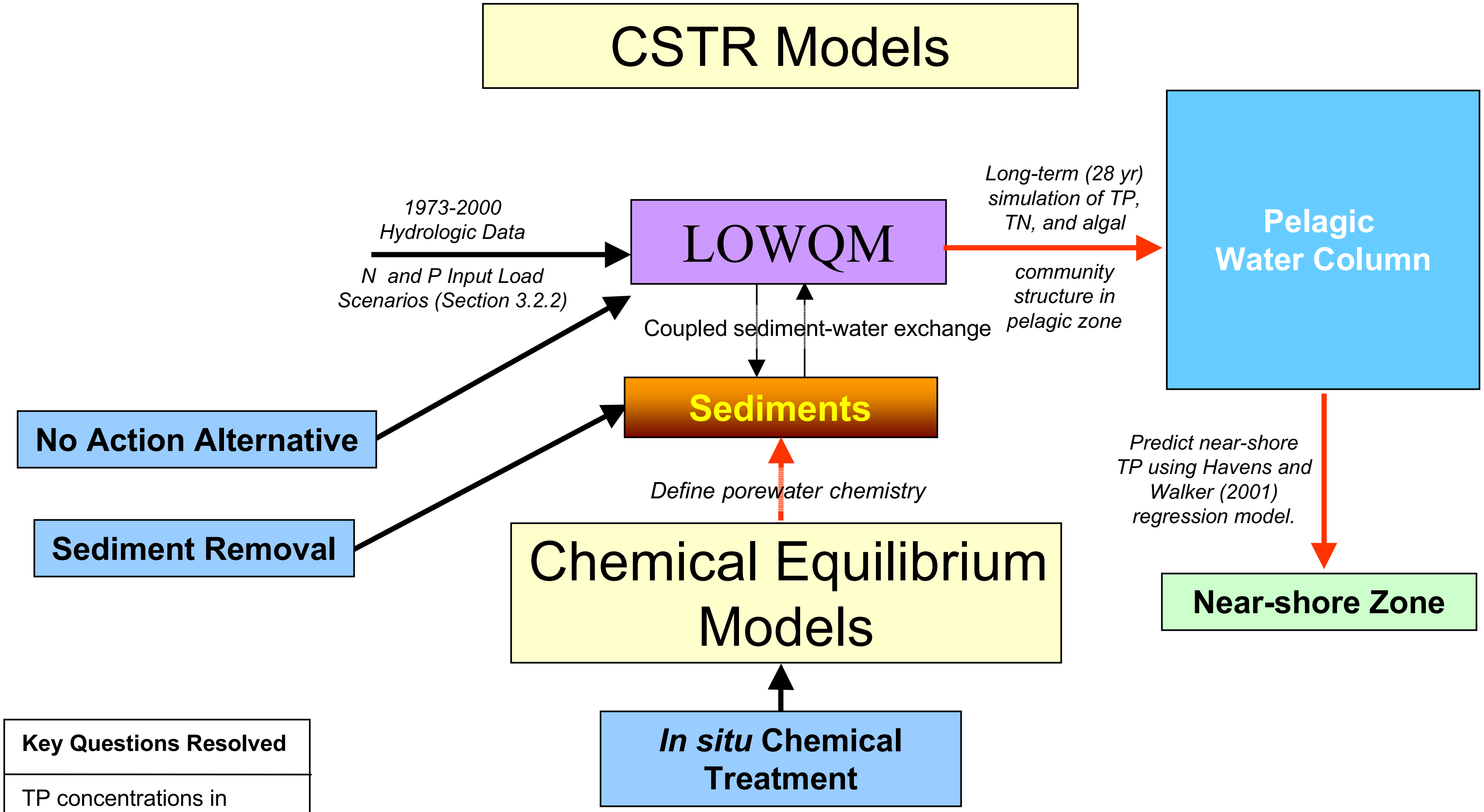
FIGURE 2A



CSTR Models

LOWQM

1973-2000 Hydrologic Data

N and P Input Load Scenarios (Section 3.2.2)

Long-term (28 yr) simulation of TP, TN, and algal community structure in pelagic zone

Pelagic Water Column

Coupled sediment-water exchange

Sediments

No Action Alternative

Sediment Removal

Define porewater chemistry

Chemical Equilibrium Models

In situ Chemical Treatment

Predict near-shore TP using Havens and Walker (2001) regression model.

Near-shore Zone

Key Questions Resolved

TP concentrations in pelagic zone as function of time.

TN concentrations and N:P ratios

Algal speciation

Source: Pollman, 2002

WORK PLAN FOR EVALUATION OF ALTERNATIVES

LAKE OKEECHOBEE
SEDIMENT MANAGEMENT FEASIBILITY STUDY

INTERRELATIONSHIPS BETWEEN MATHEMATICAL MODELS

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FIGURE 2B

ID	Task Name	Start	Finish
1	Notice to Proceed	Thu 1/24/02	Thu 1/24/02
2	**Task 1 - Preliminary Scoping of Alternatives, Data Acquisition, Tool Development**	**Fri 1/25/02**	**Thu 2/28/02**
3	Subtask 1a: Data Acquisition	Fri 1/25/02	Thu 2/28/02
4	Subtask 1b: Initial Tool Development	Fri 1/25/02	Thu 2/28/02
5	**Task 2 - Detailed Development of Alternatives**	**Fri 3/1/02**	**Thu 3/28/02**
6	Dredging Alternatives	Fri 3/1/02	Thu 3/28/02
7	Chemical Treatment Alternatives	Fri 3/1/02	Thu 3/28/02
8	**Task 3 - Evaluation of Alternatives**	**Fri 3/1/02**	**Fri 9/27/02**
9	**Modeling**	**Fri 3/1/02**	**Thu 5/9/02**
10	No-action Modeling	Fri 3/1/02	Thu 3/28/02
11	Remedial Action Modeling	Fri 3/29/02	Thu 5/9/02
12	**Subtask 3.1**	**Fri 5/10/02**	**Fri 7/26/02**
13	Subtask 3.1A: PM 1A - Minimize time to achieve phosphorus target	Fri 5/10/02	Thu 6/20/02
14	Subtask 3.1B: PM1B - Maximize reductions in water column phosphorus concentrations	Fri 5/10/02	Thu 6/20/02
15	Subtask 3.1C: PM1C - Maximize TSS reductions in the short and long term	Fri 6/21/02	Fri 7/5/02
16	Subtask 3.1D: PM1D - Minimize algal blooms	Fri 6/21/02	Fri 7/5/02
17	Subtask 3.1E: PM1E - Minimize exceedences of water quality standards in the short and long term	Mon 7/8/02	Fri 7/26/02
18	Subtask 3.1F: PM1F - Minimize downstream impacts	Mon 7/15/02	Fri 7/26/02
19	**Subtask 3.2**	**Fri 3/29/02**	**Fri 8/30/02**
20	Subtask 3.2A: PM2A - Maximize technical reliability	Fri 6/21/02	Fri 7/12/02
21	Subtask 3.2B: PM2B - Maximize technical scalability	Fri 4/19/02	Thu 5/9/02
22	Subtask 3.2C: PM2C - Maximize equipment and material availability	Fri 3/29/02	Thu 4/18/02
23	Subtask 3.2D: PM2D - Maximize permanence	Mon 7/29/02	Fri 8/16/02
24	Subtask 3.2E: PM2E - Minimize on-shore land use needs and conflicts	Fri 6/21/02	Fri 7/19/02
25	Subtask 3.2F: PM2F - Satisfy permitting requirements	Mon 8/5/02	Fri 8/30/02
26	**Subtask 3.3**	**Fri 4/19/02**	**Thu 6/20/02**
27	Subtask 3.3A: PM3A - Minimize construction costs	Fri 4/19/02	Thu 5/30/02
28	Subtask 3.3B: PM3B - Minimize operation & maintenance costs	Fri 5/31/02	Thu 6/20/02
29	Subtask 3.3C: PM3C - Maximize benefits (material reuse)	Fri 5/31/02	Thu 6/20/02
30	**Subtask 3.4**	**Mon 7/8/02**	**Fri 8/23/02**
31	Subtask 3.4A: PM4A - Maximize benefits to wetland vegetation in the littoral zone	Mon 7/8/02	Fri 8/2/02
32	Subtask 3.4B: PM4B - Maximize benefits to SAV	Mon 7/8/02	Fri 7/19/02
33	Subtask 3.4C: PM4C - Maximize benefits to fish and aquatic invertebrate communities	Mon 7/8/02	Fri 7/19/02
34	Subtask 3.4D: PM4D - Minimize negative impacts to the manatee	Mon 7/29/02	Fri 8/9/02
35	Subtask 3.4E: PM4E - Minimize negative impacts to the alligator	Mon 8/12/02	Fri 8/23/02
36	Subtask 3.4F: PM4F - Minimize negative impacts to the Okeechobee gourd	Mon 8/12/02	Fri 8/23/02
37	Subtask 3.4G: PM4G - Minimize negative impacts to the snail kite and wading birds	Mon 8/5/02	Fri 8/16/02
38	**Subtask 3.5**	**Mon 7/22/02**	**Fri 9/27/02**
39	Subtask 3.5A: PM5A - Maximize regional socioeconomic benefits	Mon 7/22/02	Fri 8/16/02
40	Subtask 3.5B: PM5B - Minimize environmental/social inequities	Mon 8/19/02	Fri 9/13/02
41	Subtask 3.5C: PM5C - Maximize community acceptance	Mon 9/16/02	Fri 9/27/02
42	Subtask 3.5D: PM5D - No impacts on water supply or lake operations	Mon 7/29/02	Fri 8/9/02
43	**Task 4 - Evaluation of Alternatives Report**	**Mon 9/30/02**	**Fri 2/28/03**
44	Prepare Draft Evaluation Report	Mon 9/30/02	Fri 11/22/02
45	Submit Draft Evaluation Report	Fri 11/22/02	Fri 11/22/02
46	District Review	Mon 11/25/02	Fri 12/20/02
47	Receipt of District Comments	Fri 12/20/02	Fri 12/20/02
48	Prepare Final Evaluation Report	Mon 12/23/02	Fri 2/28/03
49	Submit Final Evaluation Report	Fri 2/28/03	Fri 2/28/03
50	**Tasks 5 and 6 - Meetings and Outreach**	Fri 1/25/02	Wed 4/16/03

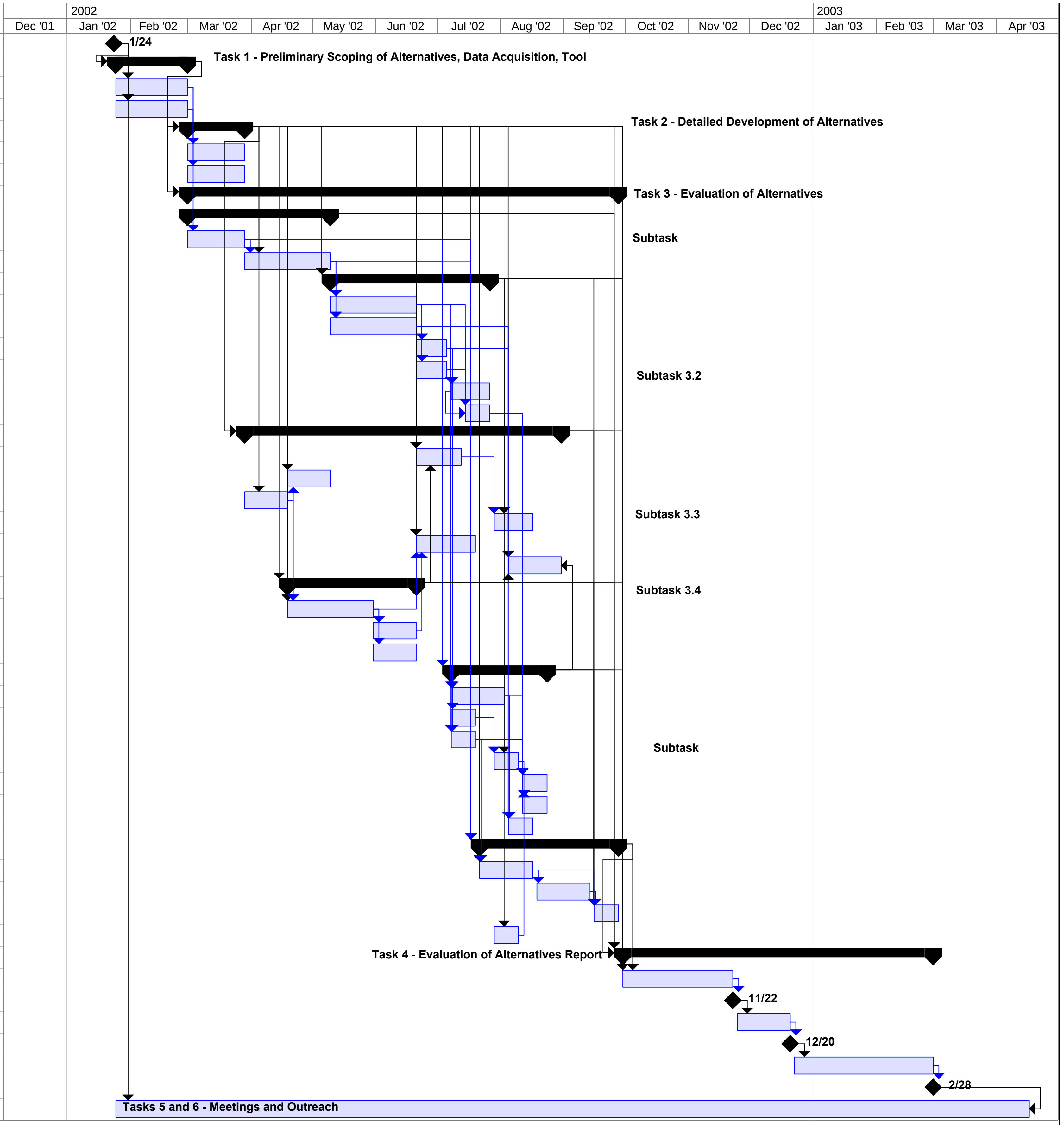

Figure 3
Lake Okeechobee Sediment Management Feasibility Study
Work Plan for the Evaluation of Alternatives - Gantt Chart

Task	▭	Progress	▬	Summary	▼▬▼	External Tasks	▭	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▼▬▼	External Milestone	◆		

Attachment 1

Section 3 from *Goals and Performance Measures for the Lake Okeechobee Sediment Management Feasibility Study* (finalized June 2001)

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

3. Sediment Management Goals, Performance Measures, and Potential Impacts

3.1 Overview

The overall objective of the Lake Okeechobee Sediment Management Feasibility Study is to evaluate a variety of sediment management options to address the internal phosphorus loading in the lake in order to improve water quality to the extent possible in terms of decreases in total phosphorus, turbidity, and blue-green algae. Sediment management alternatives will be evaluated with regard to what extent they can achieve the following five overall goals:

- Maximize water quality improvements;
- Maximize engineering feasibility and implementability;
- Maximize cost effectiveness;
- Maximize environmental benefits; and
- Maximize socioeconomic benefits.

These primary goals were established to specifically articulate the desired outcomes for any sediment management strategy ultimately adopted by the District to address internal phosphorus loading and associated issues. During Task 4 of the feasibility study, each alternative or potential course of action will be evaluated based on its ability to achieve these stated goals and ultimately contribute in a meaningful way to the restoration of Lake Okeechobee.

In this section, these overall goals are broken down into several specific measurable objectives (i.e., performance measures). The associated rationale, metric, target, method, and score for evaluation of each performance measure are presented based upon the following definitions/approach:

- ***Performance measure*** – In order to evaluate the likelihood that an alternative will achieve the project goals and compare each alternative to the others, a set of performance measures/objectives specific to each goal was developed. Each performance measure represents a particular aspect of a goal; when assessment of each performance measure is carried out as described below, enough specific, relevant information will be generated to develop a clear picture of not only whether or not an alternative could be expected to achieve the stated goals, but also to what extent. Descriptions of metric, target, method, and scale/score – the elements and tools of the evaluation process – follow.

- ***Rationale* –** The rationale describes the engineering, scientific, or economic importance of the performance measure, and indicates what assumptions or hypotheses form the basis for the performance measure.

- ***Metric* –** Performance measure metrics are the quantitative or qualitative units of measure (e.g., concentration of total phosphorus in the water column) that will be used to quantify specified parameters. In addition to the selected units of measure, metrics are specifically defined based on where data will be collected, how often, under what conditions, and using what standardized or other methodology. Qualitative metrics are developed by scoring appropriate factors or indicators on a relative scale.

- ***Target* –** Each performance measure has a target, which is the specific level or quantity desired or deemed necessary to assume achievement of a goal or significant progress toward achieving a goal. For example, the target water column concentration of total phosphorus to be achieved by an alternative is 40 µg/L. Performance measure targets can be mandated by state or other laws or regulations, or be based on site-specific testing, experience, or other sound scientific or engineering judgement.

- ***Method* –** The method provides important details as to how the performance measure will be evaluated in the feasibility study. For example, computer-based modeling could be performed or appropriate assessment criteria (e.g., site-specific or case-study data and experience, data collected during pilot-scale test projects) could be applied to judge the expected outcome of an alternative relative to a particular goal. To conduct a thorough and objective evaluation, it is essential that the methodology of *how* the evaluation will be conducted is specified before work begins and what tools will be used to make judgements among competing alternative courses of action. For example, if a model is used, what data will be used, what output will be used, and how will the data be formatted? If cost estimates are required, how will estimates be developed?

- ***Score*** **–** The outcome of the evaluation of alternatives relative to performance measures will be reported on a common scale of 1 to 5 in order to assess expected performance measure response on a consistent basis. Quantitative metrics will produce raw results in units appropriate to each performance measure (e.g., dollars, mg/L), which will be reported along with the 1 to 5 score. For those performance measures with metrics that are qualitative, scoring will be reported on a simple scale ranging from 1 to 5. The work plan will establish appropriate intervals and/or categories to express these qualitative results on the common 1 to 5 scale for each performance measure; 1 will be assigned for the lowest or least favorable performance, and 5 will be assigned for the highest or most favorable performance of an alternative. The qualitative result will be reported along with the score of 1 to 5. The result of the scoring process will be a raw number for each performance measure that the District will be able to weight appropriately during the alternative selection process to aid in the final choice of a sediment management alternative. Where appropriate, the evaluation of some performance measures may generate two scores – one related to short-term impacts or benefits, the second to the long-term impacts or benefits.

The specific details of the alternative evaluations will be determined and developed during Task 3 of the feasibility study project – development of the Evaluation of Alternatives Work Plan. The work plan will also include a detailed discussion of the rationale and technical basis for the evaluation methodology and development of the scores, based on consultation with the Technical Review Team, regulatory and scientific communities, and other interested parties or stakeholder groups. The results of Tasks 3 (work plan) and 4 (evaluation of alternatives) will then be summarized in a multi-level decision matrix that the District and others can use to balance the relative positives and negatives of each alternative. Based on that process, the District will then be able to select the best overall course of action for addressing internal loading of phosphorus in Lake Okeechobee.

Uncertainty **–** It is important to recognize that some level of uncertainty will exist in evaluating each alternative against the performance measures. To assist decision makers as they review the results of the evaluation of the alternatives, the level of uncertainty for each performance measure will be discussed within the score section of the document produced in Task 4 – Evaluation of Alternatives. The discussion will highlight areas of uncertainty and give the reader a sense of how definitive the rating is. The uncertainty may be associated with the tools used to evaluate the impacts of a given alternative, such as the projection of water column phosphorus concentrations using a computer model. Where possible, the estimate of uncertainty will be quantitative to the extent that data are available to support this process. For example, the uncertainty of the modeling results may be presented as a numerical estimate of uncertainty such as "the model results have a 50% level of uncertainty on the numerical predictions." These uncertainty evaluations will be focused on the most sensitive model parameters that could have the largest impact on the overall results and decisions made based on the results. A second example of a quantitative estimate of uncertainty is the evaluation of costs. The uncertainty of the dollar estimates will be presented as a percentage. For example, "the level of accuracy of these dollar estimates is typically on the order of +50%/-30%."

There may be performance measures where the estimates of uncertainty are more qualitative. This will typically occur when the rating of a performance measure is based on a qualitative method of evaluation. For example, the level of uncertainty for "Maximizing Technical Scalability" will be estimated using engineering judgement and case study information considered during the evaluation process to assign the rating. The end result of this discussion may take the form of "the score of this alternative under the given performance measure is a 3, based on a scale of 1 to 5. Based on the information considered during this evaluation, there is a level of uncertainty such that the rating could range between 2 and 4."

Table 4 (on the next page) and Figure 13 summarize the five overall goals and associated performance measures. Each performance measure and its rationale, metric, target, method of evaluation, and the basis for the score is discussed individually in the remainder of this section. Table 3 provides a convenient summary of this section.

Table 4
Summary of Goals and Performance Measures

GOAL 1: Maximize water quality improvements
1A – Minimize time to achieve phosphorus target
1B – Maximize reductions in water column phosphorus concentrations
1C – Maximize TSS reductions in the short term and the long term
1D – Minimize algal blooms
1E – Minimize exceedances of water quality standards in the short term and the long term
1F – Minimize downstream impacts
GOAL 2: Maximize engineering feasibility and implementability
2A – Maximize technical reliability
2B – Maximize technical scaleability
2C – Maximize equipment and material availability
2D – Maximize permanence
2E – Minimize on-shore land use needs and conflicts
2F – Satisfy permitting requirements
GOAL 3: Maximize cost effectiveness
3A – Minimize construction costs
3B – Minimize O&M costs
3C – Maximize benefits (material reuse)
GOAL 4: Maximize environmental benefits
4A – Maximize benefits to wetland vegetation in littoral zone
4B – Maximize benefits to SAV
4C – Maximize benefits to fish and aquatic invertebrate communities
4D – Minimize negative impacts to the manatee
4E – Minimize negative impacts to the alligator
4F – Minimize negative impacts to the Okeechobee gourd
4G – Minimize negative impacts to the snail kite and wading birds
GOAL 5: Maximize socioeconomic benefits
5A – Maximize regional socioeconomic benefits
5B – Minimize environmental/social inequities
5C – Maximize community acceptance
5D – No impacts on water supply or lake operations

3.2 Goal 1: Maximize Water Quality Improvements

3.2.1 Performance Measure 1A: Minimize Time to Achieve Phosphorus Target

1A: Minimize Time to Achieve Phosphorus Target	
Rationale 1A:	The time to achieve the phosphorus target is an important measure of the effectiveness of a given alternative. The target (40 µg/L) identified here is the in-lake goal of the SWIM Program and the proposed in-lake goal for total phosphorus under the Florida Department of Environmental Protection's proposed TMDL.
Metric 1A:	Predicted phosphorous concentration as a function of time for a given external load and internal load reduction scenario.
Target 1A:	The time for lakewater total phosphorus concentrations in the water column to reach 40 µg/L, or a fraction of this goal.
Method 1A:	LOWQM, SWAN, MINEQL+ or MINTEQ2A1, Pollman and Walker models
Score 1A:	Higher score means a more rapid rate of recovery.

Rationale 1A: Two basic philosophical strategies towards sediment mitigation and restoration can be articulated for Lake Okeechobee: The first assumes that mitigative measures are implemented essentially at only one point in time; the second considers that an active and ongoing plan of mitigation and maintenance is pursued beyond the initial phase of mitigation. By limiting mitigation to only a single phase during lake recovery, the first approach is guided by the principal that lakewater TP concentrations ultimately are a direct function of external inputs, and that changing internal loads alone during a single point in time will not produce stable changes in total phosphorus concentrations in the lake consistent with the target goal. Mitigating the internal load, however, will reduce the amount of time the lake will require to effectively reach the target goal. The second approach recognizes that the relationship between lakewater TP concentrations and external inputs is also governed by the ability of the lake to trap and retain phosphorus in its sediments (i.e., v_{net} in the conceptual model presented in Appendix III). To the extent an active program of sediment mitigation maintained indefinitely can effectively modify and increase v_{net}, the requisite reductions in the external load to produce the target in-lake TP concentration are diminished. This performance measures embraces the first approach – *viz.*, mitigation will be implemented during lake recovery only and not maintained once target external loading rates have been achieved. The second approach is considered as Performance Measure 1B.

The current consensus goal for the restoration of Lake Okeechobee is to reduce the in-lake concentration of total phosphorus from current levels of approximately 100 µg/L to an ultimate goal of 40 µg/L (SFWMD, 1997). Inherent in the delineation of this target is the expectation that other attributes of the lake currently compromised by eutrophication (e.g., turbidity, chlorophyll *a* concentrations, algal community structure, macrophyte community structure, fish community structure) will be restored to acceptable or more acceptable levels if total phosphorus concentrations in surface water are reduced, and if extreme high and low lake stage events are reduced in their frequency of occurrence as a result of hydrologic restoration projects occurring under CERP.

Primary productivity in lakes often is limited by the availability of a critical nutrient, which most often is nitrogen or phosphorus, or by the availability of light, which may be limited because of absorbance by high concentrations of dissolved organic carbon (DOC), or by reflectance and scattering by suspended particles, including both algae and resuspended sediments. In Lake Okeechobee, limitations on algal growth are complex, and both spatially and seasonally variable, with limitations imposed by light (Phlips et al., 1995a, 1995b, and 1997; see Performance Measure 1C for a discussion of light limitation) and nutrients (Phlips et al., 1995b and 1997; Havens et al., 1999). With respect to nitrogen and phosphorus, the availability of both nutrients may be limiting during different time periods (Schelske, 1989). *In situ* nutrient addition studies conducted by Havens et al. (1996c) indicated that phytoplankton and periphyton in the lake were either nitrogen-limited or co-limited by both nitrogen and phosphorus. The prevailing evidence is that nitrogen is much more limiting in Lake Okeechobee than phosphorus (Havens, 1994). Efforts to control algal productivity by focusing on reducing nitrogen inputs, however, can exacerbate rather than ameliorate eutrophication-related problems (Smith, 1983). Nutrient regimes characterized by excessive or high phosphorus concentrations coupled with low N:P ratios (i.e., nitrogen is limiting), yield competitive advantages to nitrogen-fixing blue-green algae (cyanobacteria) because most fix N (Smith, 1983; Schindler, 1985). Blue-green algae are less available to zooplankton and herbivorous fish as a food resource, and adverse or undesirable changes in the food web can accompany nutrient regime shifts towards N-limitation. Cyanobacterial blooms also lead to aesthetic problems in lakes such as bad odors and taste (Lampert and Sommer, 1997). Indeed, Smith (1983) concluded that even when nitrogen was clearly the limiting nutrient, controlling phosphorus inputs would yield far more favorable results.

For Lake Okeechobee, an empirical analysis of the relationship between chlorophyll a and total phosphorus (TP) (Walker and Havens 1995) indicated that the two variables are unrelated in the central pelagic zone, where light is the limiting factor. In near-shore areas along the western side of the lake, however, there is a strong relationship between chlorophyll and TP. The "risk" of high levels of chlorophyll (blooms) in the near-shore region is near zero when TP is below 30 μg/L, but bloom risk increases rapidly as TP increases from 30 to 60 μg/L, after which it reaches a plateau. At TP above 60 μg/L, nitrogen limitation probably occurs. These results are important because they document that TP may affect algal blooms in the near-shore region, which is most heavily used by fish, wildlife, and for drinking water intakes. The results also demonstrate that, until TP is reduced below approximately 60 μg/L, there may not be a corresponding decrease in blooms, because other factors (nitrogen) limit algal growth. This situation is typical of highly eutrophic lakes with surplus levels of phosphorus in the water column. Until TP is reduced to 40 μg/L or lower, there will continue to be an imbalance of flora and fauna in the lake due to blooms and their by-products (FDEP, 2000).

Although simple regression models based on empirical data do not indicate a significant relationship between total phosphorus and algal blooms in the central pelagic region of the lake, the LOWQM can be used effectively to model blooms and compare their occurrence between alternatives. This reflects the fact that the model takes into consideration other processes that control algal bloom dynamics in the lake, including underwater irradiance and nitrogen limitation.

A target in terms of years to ultimately achieve the water quality goal of 40 μg/L total phosphorus in surface water, following external load reductions, has not been established. However, lake response to an imposed reduction in external loads of phosphorus expectedly will have three phases:

1. An initial phase of very rapid decreases in total phosphorus concentrations (of uncertain magnitude) that are governed largely by the hydraulic residence time of the lake, the magnitude of the external load reduction, and the settling velocity of phosphorus from the water column; followed by
2. A short transitional period leading to the final phase; and
3. A final phase where the rate of response is governed largely by the internal loading of phosphorus from the sediments and the sediment phosphorus turnover rate. During this final phase, the lake

more slowly approaches the final steady state concentration dictated ultimately by the external load.

What will be measured then is the change in temporal response of the response parameter (e.g., total phosphorus or TSS) resulting from different internal loading regimes for a given external load reduction. This can be expressed either as a time series for each internal loading regime series (e.g., Figures 10 and 11), or as the time required for the lake to reach a fraction of the total predicted change in concentration or response between current and long-term (steady state) conditions (Figure 12).

The rationale for this performance measure is based on the following question: Is the amount of time required for the lake to recover sufficiently rapid once external inputs have been reduced? What constitutes a sufficiently rapid time of response is ultimately a management question, and likely one that will be based on the perceived benefit in terms of increase in rate of recovery relative to the cost. Modeling analyses for Lake Okeechobee show that changes in the rate of internal load will influence the response time directly (Pollman, unpublished data). By providing a series of predictions that will show how the response time varies with mitigation option, this study will be establishing the basis for answering the question of what cost will society be willing to bear to accelerate the rate of recovery of Lake Okeechobee as watershed inputs of phosphorus are reduced. For example, the public may be far more willing to incur a large expense for sediment mitigation if the time of response is reduced from hundreds of years to 20 years; if this feasibility study shows, however, that the same level of mitigation and cost is predicted to change the rate of response from only 30 to 20 years, the public's appetite for such an expenditure likely will be greatly diminished. In the first case, the acceptable recovery time would likely be 20 years; in the second case, 30 years may be the acceptable recovery time.

Metric 1A: The metric used will be predicted phosphorus concentrations from the model output. Total phosphorus has been measured by the District continuously at a number of locations in Lake Okeechobee since late 1972 to the present. Locations include both littoral and pelagic stations, and include samples from both the surface and at depth. Sample frequency historically has been at least monthly, with the results reported in milligrams total phosphorus per liter (mg/L).

Target 1A: The target goal is to reduce the response time to changes in the long-term external loading rate. Again, it should be understood that this performance measure of reducing in-lake total phosphorus concentrations to an ultimate goal of 40 µg/L is fundamentally related to reducing external inputs, and that short-term mitigative measures that produce changing internal loads alone will not produce stable changes in total phosphorus concentrations in the lake consistent with the target goal. Mitigating the internal load, however, will reduce the amount of time the lake will require to effectively reach the target goal.

Method 1A: Modeling will focus on two suites of models to predict changes in response time. The principal model used will be the Lake Okeechobee Water Quality Model (LOWQM) developed by James and co-workers (James and Bierman, 1995; Bierman and James, 1995; James et al., 1997; Jin et al., 1998) and recently recalibrated by Tetra Tech (Pollman and Munson, 2000) to account for currently understood levels of atmospheric phosphorus deposition and rates of burial in the sediments. The LOWQM is a 1-box model (Table 1) that can use sediment resuspension and deposition rates from the two other models. Figure 9 summarizes some of the basic input and output features of these models and how the models are inter-linked.

The second suite of models used will be the Lake Okeechobee Internal Phosphorus Loading model developed by Pollman (2000) and the input-output model developed by Walker (2000). Both of these models, which are conceptually much simpler than the LOWQM, will be used to verify whether similar results in terms of response time are predicted. These latter models, however, are not appropriate for evaluating mitigative measures that influence sediment particle resuspension rates without modification to the models, and likely will not be used for all scenario analyses. Both suites of models have been calibrated to Lake Okeechobee.

As discussed previously, protecting the near-shore region against the occurrence of algal blooms is particularly important because it is this region of the lake that is used most heavily by fish and wildlife and for drinking water intakes. Because the LOWQM and the Walker (2000) and Pollman (2000) models are all 1-box models that essentially predict TP concentrations in the pelagic zone of the lake, these predictions need to be related to concentrations in the near-shore and the likelihood or risk of algal bloom occurrence. Havens and Walker (in review) have analyzed the relationship between pelagic and near-shore concentrations of TP and developed a regression model that correlates the two variables as an inverse function of lake stage. The likely frequency of occurrence of algal blooms (40 or 60 μg/L of chlorophyll) can then be related to the predicted near-shore concentrations (Havens and Walker, in review). In addition, because the most of the phosphorus present in the water column is particulate, and because TP correlates closely with TSS (Maceina and Soballe, 1990), the spatially explicit LOHTM model can be used to predict both sediment resuspension rates (when coupled with SWAN) and resultant TP fluxes to and concentrations within the near-shore regions of the lake.

Supplemental modeling may be required to answer specific geochemical questions. In particular, neither of the two suites of models previously described are well-suited for or capable of examining how treating the sediments with alum or calcium additions will reduce the flux of phosphorus across the sediment-water interface. This type of question will be examined using MINEQL+ or MINTEQ2A1. These two models (see Table 1) are thermodynamic equilibrium models that largely have the same fundamental characteristics and thermodynamic databases, differing principally in their user interfaces. These models are capable of predicting porewater inorganic phosphorus concentrations that may be regulated by a controlling mineral phase such as hydroxyapatite, or different iron mineral phases under oxic regimes. The output equilibrium concentrations for porewater phosphorus concentrations can then be input to the LOWQM and LO Internal Phosphorus Loading model to then examine how this type of mitigative measure influences response time.

As Figures 10 and 11 illustrate, the LOWQM and the LO Internal Phosphorus Loading models will be used to predict the expected relationship between changes in the internal load and the resultant response time for a given reduction in external load. Internal load reduction-time response curves can be developed for different loading scenarios other than for the requisite load reduction to achieve the 40 μg/L (ca. 120 to 150 tonnes P/year). Lake Okeechobee Protection Act load reduction schedules and goals through 2015 will be used when available from CERP.

Score 1A: A higher score will be assigned to mitigative measures that equate to a more rapid rate of recovery or response time for a given external load scenario.

3.2.2 Performance Measure 1B: Maximize Reductions in Water Column Phosphorus Concentrations

1B: Maximize Reductions in Water Column Phosphorus Concentrations	
Rationale 1B:	Algal blooms in Lake Okeechobee appear to be limited by the availability of phosphorus when lakewater TP concentrations are below 60 µg/L. The risk of blooms is reduced to a level considered to not cause an imbalance in flora and fauna when lakewater TP concentrations are at or below 40 µg/L (FDEP, 2000). Higher N:P ratios (~30:1) corresponding with TP concentrations at or below 40 µg/L also should help minimize occurrence of cyanobacterial blooms (Havens and Walker, in review) in favor of other, more desirable algal groups (green algae and diatoms).
Metric 1B:	Predicted pelagic lakewater TP concentrations and predicted load reductions required to achieve target concentration goal of 40 µg/L.
Target 1B:	Predict pelagic lakewater TP concentrations of 40 µg/L.
Method 1B:	Quantitative modeling estimate; potential models include LOWQM, Lake Okeechobee Internal Phosphorus Loading model, linked SWAN-LOHTM-LOWQM models. Results of Reddy study also used.
Score 1B:	Higher score means predicted long-term water column phosphorus concentrations are closer to the 40 µg/L target.

Rationale 1B: As described in Performance Measure 1A, one approach towards restoration of Lake Okeechobee is to invoke an active, long-term program of sediment mitigation designed to improve the ability of the lake to permanently retain phosphorus in its sediments (i.e., increase v_{net}). Such a program, if cost effective, would have the advantage of decreasing the magnitude of the reductions in external phosphorus loading rates required to reach the in-lake target phosphorus concentration. This performance measure considers this type of approach. As in Performance Measure 1A, the target concentration is an average TP concentration of 40 µg/L. Performance Measure 1A details the rationale that underlies the focus on reducing in-lake phosphorus concentrations, and why a target value of 40 µg/L has been adopted.

Metric 1B: Two choices of metrics are possible: The first is the predicted $P_{lakewater}$ resulting from different internal loading mitigation strategies coupled with a given external load reduction. The second is the requisite external load reduction necessary to produce the TP target of 40 µg/L for a given long-term mitigation strategy. Total phosphorus concentrations in the lake are currently measured on at least a monthly basis at multiple stations throughout the lake. Units for total phosphorus are mg/L or µg/L.

Target 1B: The target goal is an average concentration of total phosphorus in the pelagic reaches of Lake Okeechobee equal to 40 µg/L.

Method 1B: As mentioned in the discussion of Metric 1B, the analysis can involve two approaches. The first approach focuses on predicting $P_{lakewater}$ resulting from different internal loading mitigation strategies coupled with a given external load reduction. The advantage of this approach is that the District may have specific external load reduction strategies it wishes to evaluate. The effectiveness of a given load reduction coupled with a long-term internal load mitigation strategy can then be predicted and compared to the target goal. The second analytical approach also defines a particular sediment mitigation strategy, but then predicts the requisite external load reduction necessary to produce the TP target of 40 µg/L. This approach has the advantage of defining the external load reductions still required to meet the target for a given long-term internal load mitigation strategy. Although not part of this analysis, the District can then use these latter predictions to fully estimate the cost of restoration.

The models used for the predictive analyses are described in detail in Performance Measure 1A. Predicted lakewater TP concentrations will be predicted as a function of time using as time series inputs information on sediment mitigation throughout the period of time simulated. Changes in water quality over time as a result of each alternative will be estimated using the LOWQM and the Lake Okeechobee Internal Phosphorus Loading models, or if appropriate for the alternative evaluated, the linked SWAN – LOHTM – LOWQM models. The results of the K.R. Reddy study titled *Potential Impacts of Sediment Dredging on Internal Phosphorus Load in Lake Okeechobee* (Reddy et al., 2000) will also be used in this evaluation to assist in understanding the movement of phosphorus into the water column from newly-exposed sediments that are unearthed by dredging. Post-removal sediment concentrations of phosphorus that are anticipated to exist following dredging will be included in the modeling effort (in conjunction with the Reddy data). Although the pilot dredging study is designed on a small scale, the results will be able to be used to assess the ability of dredging to effectively remove phosphorus-containing sediment.

Score 1B: A higher score means predicted long-term water column phosphorus concentrations are closer to 40 µg/L target.

3.2.3 Performance Measure 1C: Maximize TSS Reductions in the Short Term and Long Term

1C: Maximize TSS Reductions in the Short Term and Long Term	
Rationale 1C:	The submerged aquatic macrophytes community is adversely impacted by reductions in light transparency in the near-shore zone. Light transparency in pelagic Lake Okeechobee appears to be largely a function of the concentration of resuspended , non-algal material in the water column, with generally smaller contributions from algae. This material (tripton) is the largest contributing fraction to total suspended solids in the lake.
Metric 1C:	Predicted total suspended solids (TSS) concentrations (mg/L) in lakewater. TSS will then be used to compute the light extinction coefficient, k_e. Compliance with FAC 62-302.
Target 1C:	The critical light extinction coefficient required to protect the submerged aquatic macrophyte community.
Method 1C:	Simulation of spatially resolved changes in TSS concentrations using SWAN-LOHTM. Predicted TSS will then be used to predict changes in k_e and the critical depth capable of supporting submerged aquatic macrophytes
Score 1C:	Two scores will be given – one for the short-term and one for the long-term; higher scores means greater TSS reductions, and an increase in the maximum water depth able to support submerged aquatic vegetation in the near-shore zone (i.e., improved light transparency).

Rationale 1C: In general, the term "turbidity" is used to describe the overall clarity of the water column, with clarity inversely related to turbidity. Turbidity, which originates from suspended particles in the water, is quantified by measuring the amount of light scattered by these particles. High turbidity results in lower light transmission through the water column and, as a result, can reduce the extent of submerged aquatic macrophytes and favor the dominance of cyanobacteria. Cyanobacteria are favored in turbid conditions due to their buoyancy and low light requirements (Reynolds, 1987). Turbidity also detracts from the aesthetic condition of the lake and hence impairs recreational uses such as swimming and boating.

The turbidity or clarity of a waterbody is one of the best measures of use impairment. The optical (light transmitting) properties of the lake are determined both by turbidity and dissolved color derived from decomposing organic matter. Turbidity is closely correlated with suspended solids and derives from the levels of phytoplankton, inorganic silt and clays, and suspended calcium carbonate present. Because of higher filtration, disinfection, and possible advanced treatment requirements, high levels of turbidity increase potable water treatment costs.

Of particular importance in Lake Okeechobee is the hypothesized relationship between turbidity and the stability of the submerged aquatic macrophyte community in the near-shore zone of the western part of the lake. High turbidity translates into lower light levels along the bottom and is believed to have resulted in large declines in the submerged aquatic macrophytes community (Havens et al., 1999). Steinman et al. (1997) conducted photosynthesis-irradiance studies on the charophyte populations in Lake Okeechobee and concluded that irradiance was the major reason why charophyte biomass is both low and had declined in the mid-1990's. The occurrence (or absence) of charophytes has particular significance to Lake Okeechobee because of its possible role influencing internal loading. Because of their ability to both take up phosphorus and to stabilize sediments, Steinman et al. (1997) concluded the occurrence of charophytes could be important particularly in the southern end of Lake Okeechobee where sedimentary concentrations of labile phosphorus are high. As a result, the presence of charophytes could help reduce the rate of occurrence of cyanobacterial blooms in the lake, although this effect is expected to be both localized and seasonal.

Metric 1C: The standard measure of turbidity is determined by the scattering of light and is reported in Nephelometric Turbidity Units (NTUs). Turbidity in a given lake typically is closely correlated with total suspended solids (TSS), which characteristically are measured by collecting the suspended material on a filter and weighing the collected mass relative to the volume filtered. Units for TSS are mg/L. Optical properties also can be reported either as the Secchi disk depth (m) or an extinction coefficient (the absorption of light, m^{-1}). Because the SWAN-LOHTM-LOWQM models predict TSS explicitly, the metric of choice will be TSS.

Target 1C: The specific performance measure goal or target is difficult to enumerate precisely at this time. The overall goal is to reduce turbidity or suspended solids in the near-shore zone of the lake such that sufficient light transparency exists to support an active, viable population of submerged aquatic macrophytes. In other words, the performance measure will be defined by establishing the critical light extinction coefficient, $k_{e,critical}$, that is required to protect the submerged aquatic macrophyte community. Stepwise regression analysis of seasonally-averaged tripton and chlorophyll *a* data derived from Phlips et al. (1995a) clearly show that the light extinction coefficient, $k_{e,}$ in the pelagic zone is related to ambient concentrations of tripton (nonalgal solids), and that chlorophyll *a* has virtually no influence (Figure 14). Moreover, the largest fraction of TSS in the pelagic water column originates from resuspended sediment (compare time series plots for inorganic suspended solids and chlorophyll *a* concentrations presented by James et al. (1997)). Somewhat similar results were obtained by Limno-Tech (1993) using a different approach to partition the contributions of color, chlorophyll a, and “residual factors” (i.e., components contributing to light absorbance and scattering not included by measuring chlorophyll a and color). Their analyses demonstrated that the largest component of light attenuation was derived from the residual fraction, although chlorophyll a always accounted for at least one-third or more of total light extinction, and concluded that wind-driven resuspension may be the principal factor controlling light attenuation in Lake Okeechobee. In the near-shore environment, light attenuation typically may be more a function of color and chlorophyll a than resuspended material (Havens, personal communication).

The District is currently developing empirical relationships between light extinction in Lake Okeechobee and suspended solids concentrations. The light extinction coefficient in turn can be used to calculate the depth of the euphotic zone. For phytoplankton, this depth often corresponds to the depth of 1% surface light intensity (Lampert and Sommer, 1997). For submerged aquatic vegetation, the critical depth is a function of the daily requirement of “irradiance-saturated” photosynthesis, which apparently varies based on environmental factors such as temperature and the distribution of biomass between roots and shoots, but is likely significantly less (i.e., greater light transmission) than the photosynthetic compensation depth for algae (Zimmerman and Alberte, 1991). For seagrasses, the critical depth appears to require 10 to 20% daily average surface irradiance (Fourqurean and Zieman, 1991; Kenworthy et al., 1991; Moore, 1991). Ongoing studies by the District relating light transmission to the productivity of the submerged aquatic vegetation community are expected to help define $k_{e,critical}$.

Methods 1C: Changes in TSS resuspension fluxes owing to, for example, changes in lake stage, or changes in the physical properties of the sediments (e.g., critical shear stress), will be predicted using the linked SWAN–LOHTM models. The spatial resolution of the SWAN-LOHTM models will enable computations of changes in TSS in the near-shore zone to be computed directly. For each sediment mitigation scenario, TSS concentrations will be calculated as a function of space and time. A complicating variable in the analysis will be possible changes in surficial sediment chemistry in the pelagic zone following mitigation. These changes will be related to how external loads are managed in the lake during and, in particular, following mitigation. Predicting changes in sediment properties over time will require a process-oriented model such as the LOWQM that includes sediments explicitly; for this study, however, only the single box version of the model will be available and the SWAN-LOHTM-LOWQM models are not linked in a manner to provide direct feedback from LOWQM to SWAN.

Score 1C: Because there is a possibility that short-term impacts on TSS, particularly in the immediate vicinity of construction areas, may be substantially different from long-term impacts, two scores will be given to separate out these two very different situations. The same metric and method will be used to generate results and scores for both the short and long term. Higher scores will be assigned to those mitigative measures that yield greater TSS reductions and, accordingly, increasing light transparency and thus an increase in the maximum water depth able to support submerged aquatic vegetation in the near-shore zone. Both the short and long term results and scores will be reported.

3.2.4 Performance Measure 1D: Minimize Algal Blooms

1D: Minimize Algal Blooms	
Rationale 1D:	Reductions in water column total phosphorus concentrations are necessary to either minimize or eliminate the occurrence of algal blooms, and cyanobacterial blooms in particular.
Metric 1D:	Total phosphorus concentrations; TN:TP ratio.
Target 1D:	Total phosphorus concentration of 40 μg/L in lakewater; TN:TP > 30.
Method 1D:	Predict total phosphorus concentrations and compare results to 40 mg/L “threshold” phosphorus concentrations using same models as described in Goal 1A. Use LOWQM to predict changes in relative abundance of green algae, cyanobacteria, and diatoms. Use LOWQM to predict steady state N:P.
Score 1D:	Higher score means lower incidence of blooms.

Rationale 1D: As described in performance measure 1A, algal productivity in Lake Okeechobee is generally nitrogen-limited (Schelske, 1989; Havens, 1994, Havens et al., 1996b). Because phosphorus concentrations are excessively high, and because nitrogen concentrations are generally limiting, the nutrient regime in Lake Okeechobee favors the formation of blooms by nitrogen-fixing cyanobacteria, particularly in the near-shore reaches where light limitation imposed by wind-wave induced resuspended sediments is less severe than in the pelagic reaches of the lake (Walker and Havens, 1995). These organisms outcompete other algal species under such conditions precisely because their ability to fix atmospheric nitrogen enables them to satisfy their nutritional requirements when dissolved nitrogen concentrations are otherwise limiting. In addition, their buoyancy favors them in such a light climate.

Cyanobacteria are less available to zooplankton and herbivorous fish as a food resource, and adverse or undesirable changes in the food-web can accompany nutrient regime shifts towards N-limitation. Cyanobacterial blooms also lead to aesthetic problems in lakes such as bad odors and taste (Lampert and Sommer, 1997). Indeed, Smith (1983) concluded that, even when nitrogen was clearly the limiting nutrient, controlling phosphorus inputs would yield far more favorable results towards lake restoration, and controlling nitrogen inputs alone could exert a deleterious effect by creating higher selective pressures favoring cyanobacteria blooms. As noted earlier, the empirical analyses of the relationship between chlorophyll *a* and total phosphorus conducted by Walker and Havens (1995) suggest that, once water column TP concentrations are reduced to below ca. 50 – 80 µg/L (open lake and north near-shore zone, respectively), algal standing crop is directly related to ambient TP concentrations. Moreover, Walker and Havens (1995) demonstrated that the risk of algal blooms in the critical near-shore zone of Lake Okeechobee increased with phosphorus concentrations when TP concentrations were between 30 and 60 µg/L The importance of reducing phosphorus is also evident in results reported by Seip (1994) and Sas (1989).

Metric 1D: Historically in Lake Okeechobee, algal standing crop or biomass has been measured indirectly by analyzing for the indicator pigment chlorophyll *a* as a surrogate for algal biomass. Of concern in Lake Okeechobee, however, are not only algal biomass or chlorophyll *a* levels, but also the algal speciation or community structure. In particular, a shift in dominance from diatoms to cyanobacteria is deemed problematic. Because algal community structure (particularly with respect to the proliferation of cyanobacteria) is related to the relative concentrations of total nitrogen and phosphorus, the metric will include predicted TN:TP ratios as well.

Target 1D: Walker and Havens (1995) established empirically that the frequency of algal blooms (defined by chlorophyll *a* concentrations in excess of 40 µg/L) reached a maximum level of likelihood of occurrence when water column concentrations of TP exceed 60 µg/L. When water column concentrations of TP declined below 40 µg/L, the likelihood of bloom occurrence dropped significantly such that no blooms generally occurred in either the north or south near-shore zones below TP concentrations of 30 to 35 μg/L. Thus an overall target phosphorus concentration goal of 40 μg/L translates directly to a goal of reducing the risk of algal blooms (defined as chlorophyll *a* concentrations in excess of 40 μg/L) in the near-shore regions of the lake.

In a review of the literature on the relationship between cyanobacterial dominance and N:P ratios, Smith and Bennett (1999) presented results from a number of studies that indicate that non-cyanobacterial species tend to be dominant at TN:TP ratios > *ca.* 29:1, and nitrogen-fixing cyanobacteria tend to be dominant at TN:TP ratios < *ca*. 14:1, although the evidence supporting the applicability of that ratio is not unilaterally consistent. Thus, the target goal for TN:TP ratios will be 30:1.

Method 1D: The primary method of evaluation will be to predict total phosphorus concentrations in the lake and compare the results to the 40 μg/L "threshold" total phosphorus concentration. The models used will be the same as those described in the methods for subgoal 1A. Evaluating N:P ratios requires a model that explicitly includes both N and P dynamics. Currently, only one model is available to predict both nutrient forms in Lake Okeechobee – the LOWQM. Nitrogen concentrations will be calculated based on N loading rates supplied by the District, but we will not be able to predict changes in internal resupply of nitrogen resulting from different sediment mitigation scenarios. Thus, only steady state computations of N:P will be computed, and these arguably are related to long-term external loading rates only, and not to short-term mitigative measures. In addition to nutrient concentrations, the LOWQM has the ability to predict the relative abundance of three different algal groups (green algae, cyanobacteria, and diatoms).

Score 1D: As in performance measure 1B, a higher score will be assigned to mitigative measures that equate to a more rapid rate of recovery or response time for a given external load scenario. A higher score will equate to a lower expected incidence of algal blooms.

3.2.5 Performance Measure 1E: Minimize Exceedances of Water Quality Standards in the Short Term and Long Term

1D: Minimize Exceedances of Water Quality Standards in the Short Term and Long Term	
Rationale 1E:	Resuspension of sediment has the potential to impact water quality in both the short and long term.
Metric 1E:	Estimated chemical concentrations of constituents of concern in the water column based on available surface water and bulk sediment chemistry data.
Target 1E:	No exceedances of FAC 62-302 in the short or long term
Method 1E:	Review of existing sediment and water quality data and comparison to screening criteria. In addition, concentrations of constituents will be predicted by LOHTM as a function of simulated resuspended sediment concentrations, and from the results of the pilot dredging study (i.e. bench-scale test data, in-lake monitoring data, CDF/treatment data).
Score 1E:	Two scores will be given – one each for short and long term; higher scores means fewer predicted exceedances.

Rationale 1E: Lake Okeechobee is a Class I Surface Water Body for Potable Water Supply, and as such is subject to FDEP's Florida Administrative Code (FAC) 62-302 water quality criteria for a potable water supply (see Appendix IV for a list of applicable criteria). In addition, the FDEP has established a list of constituents that must be monitored in all waters discharged to Lake Okeechobee. These constituents are listed in the Lake Okeechobee Operating Permit (LOOP); any applicable conditions in effect at the time of implementation of an alternative will be met (i.e., no exceedances of LOOP criteria).

Resuspension of sediment is possible under a variety of sediment management options. Some sediment management alternatives have potential to cause chemicals in sediment to be released into the water column in the short and/or long term. (For example, review of relevant case studies could reveal that typically TSS can be expected to increase by x% within some distance from the dredge head.) Some sediment management alternatives could require the treatment of water and discharge back into the lake or other waters. The cost for treatment of water could be prohibitive depending on the pre-treatment water quality and the criteria that would need to be achieved.

Metric 1E: Estimated chemical concentrations of constituents of concern in the water column based on available surface water and bulk sediment chemistry data and relevant case studies. Actual concentrations (in either mg/L or μg/L) of chemicals in surface water and sediment will be assessed based on existing data and samples gathered during the Lake Okeechobee sediment Pilot Dredging Study. Depending on the type and quality of data from the pilot study, additional characterization data may be needed from elsewhere throughout the lake, as appropriate.

Target 1E: No exceedances of FAC 62-302 or the Lake Okeechobee Operating Permit (where applicable) in the short or long term, either through direct in-lake remedial construction activities or through the potential discharge of treated water returned to the lake or other waters. Alternatively, there may be allowable exceedances within a certain distance from the potential work sites as long as there are no exceedances at a sentinel point of compliance (POC); this would be agreed to by FDEP in a variance on an Environmental Resource Permit (ERP).

Method 1E: Existing sediment and water quality data and relevant case studies will be reviewed in advance by the District, BBL, and the FDEP. If sediment concentrations are found to be present at levels of concern above screening criteria provided in the Sediment Quality Assessment Guidelines (McDonald, 1994), or surface water concentrations are found to exceed FAC- 62-302, then additional sediment and surface water sampling/monitoring would be recommended for inclusion in the Pilot Dredging Study or as a separate characterization study if the pilot study data were considered to insufficient to represent conditions across the remainder of the lake. If there are exceedances of the screening criteria described, then a wider characterization of sediments/surface water may be warranted to improve the reliability of the evaluation of alternatives. Otherwise evaluations of an alternative’s effectiveness, implementability, and cost could be hindered by a significant degree of uncertainty in regard to the level of engineering controls and treatment/disposal required.

In addition, if enough data are available, the relationships between the constituents of concern and both mud type and spatial location within a particular sediment-type zone can be assessed. These relationships will allow prediction of the resulting concentration of a toxicant produced by a particular sediment remediation activity. The LOHTM has the ability to predict both concentrations of resuspended sediment in the water column, and the concentration of toxicants associated with the resuspended material. Based upon estimated short-term or pulsed sediment resuspension rates owing to the mitigative activity, the LOHTM will be used to predict flux rates and durations of chemical release. There is, however, a need to refine the method of estimating short-term sediment resuspension rates. Available data and applicable case studies will be used to assess the impacts of a given alternative on water quality. The outcome of this FS process may be to recommend the need to collect additional water quality data.

Score 1E: Because there is a possibility that short-term impacts on water quality, particularly in the immediate vicinity of construction areas, may be substantially different from long-term impacts, two scores will be given to separate out these two very different situations. The same metric and method will be used to generate results and scores for both the short and long term. Scores will be assigned based on the number of exceedances of FAC-62-302; higher scores will be assigned to those mitigative measures that produce fewer predicted exceedances. Both the short- and long-term scores will be reported.

3.2.6 Performance Measure 1F: Minimize Downstream Impacts

1F: Minimize Downstream Impacts	
Rationale 1F:	Lake Okeechobee is connected ecologically and hydrologically to most of south Florida.
Metric 1F:	Estimates of water quality parameters at lake outlets.
Target 1F:	Targets for other parameters in Goal 1.
Method 1F:	Water quality modeling; results will be compared to ultimate goal of 40 µg/L TP.
Score 1F:	Higher score means net positive impacts.

Rationale 1F: The current consensus goal for the restoration of Lake Okeechobee is to reduce the in-lake concentration of TP from current levels of approximately 100 µg/L to an ultimate goal of 40 µg/L (SFWMD, 1997). Lake Okeechobee is connected ecologically and hydrologically to most of south Florida. Changes in the quality of water leaving the lake could have a direct impact on the water quality, wildlife habitat, and recreational and commercial opportunities in downstream areas. Special attention will also be paid to potential impacts on specific CERP activities, including the quality of water delivered to downstream stormwater treatment areas (STAs), the Indian River Lagoon, and the St. Lucie estuary; as well as any impacts on future aquifer storage and recovery (ASR) well implementation over the next 30 years. Improving water quality in Lake Okeechobee (with regard to the other parameters listed in Goal 1) will clearly benefit downstream areas. In addition, alternatives should not create new problems and associated cost increases (such as greater need for treatment of potable water supply) for local water treatment plants.

Metric 1F: The water quality parameters listed in Goal 1 (phosphorus, TSS, algal bloom incidence, and short- and long-term water quality standards) will be estimated for water leaving the lake.

Target 1F: Performance measure targets for the other parameters in Goal 1, as applicable, at the lake outlet points. In addition, preferred alternatives will not degrade downstream water supply in any way or significantly increase additional costs/problems (e.g., treatment of water supply).

Method 1F: For each alternative evaluated, an estimate of water quality can be made for major outlet point around the lake using model predictions for targets under other Goal 1 performance measures. Results will be compared to the TP target of 40 μg/L.

Score 1F: A score of 5 will indicate net positive impacts; 3 will indicate no expected impact; and 1 will indicate net negative impacts. For example, if levels of total phosphorus in water leaving the lake are estimated to decrease from current in-lake levels of approximately 100 μg/L, the result would be a net positive impact and the alternative would earn a score of 4 or 5, depending on the degree of reduction.

3.3 Goal 2: Maximize Engineering Feasibility and Implementability

3.3.1 Performance Measure 2A: Maximize Technical Reliability

2A: Maximize Technical Reliability	
Rationale 2A:	Proven technologies minimize performance risks and Operation and Maintenance (O&M) costs.
Metric 2A:	Degree to which a technology is demonstrated as reliable and effective.
Target 2A:	High reliability and low O&M costs.
Method 2A:	Qualitative evaluation of information and data from case studies and other projects; quantitative assessment of O&M costs.
Score 2A:	Higher score means technologies used are reliable and have lower O&M costs.

Rationale 2A: The use of proven technologies minimizes performance risks (e.g., project delays) and O&M costs over the life of a project. These long-term O&M costs include monitoring, operation, maintenance, and component replacement costs for elements of the alternative that have a design life of less than 50 years.

Metric 2A: The degree to which a technology has been demonstrated as reliable and effective over the long term at other sediment management sites will be qualitatively evaluated. The evaluation will also quantitatively consider the O&M costs developed within Goal 3B.

Target 2A: There is no specific target, but alternatives that use technologies with demonstrated long-term reliability (lesser degree of technical problems associated with the construction and operation of the technology), and lower O&M costs are preferable.

Method 2A: A qualitative evaluation will be conducted using long-term performance data for a given technology implemented at other projects, along with review of relevant case studies. Reliability evaluations will focus upon potential additional costs and project delays resulting from technical problems associated with the technology. This evaluation will also include a quantitative assessment of O&M and component replacement costs for the alternative. Representative examples of the reliability aspects of this goal include:

- The estimated percent of the working day that a dredge may be actually removing sediment is in part, a reflection of its mechanical reliability. For example, there may be a large base of experience that indicates a commonly available hydraulic dredge used to remove the entire sediment thickness may be operational 70% of a 24-hour workday. However, the base of information used to assess the operability of a newly developed dredge to selectively remove a thin layer of sediment may be less significant in terms of its breadth and depth and hence an availability of 40% may be more appropriate for this application. While the difference in on-line percentages would be reflected in the overall cost for sediment removal, a removal alternative using equipment with less operation history may be viewed as less reliable. However, if the design and operational aspects of the newly developed equipment are straightforward and use components of other well developed technologies, the equipment may be judged as more reliable, rather than less. Again this will be an engineering judgment based on available information and experience.

- Concerns of the long-term reliability of a chemical treatment such as alum could be reflected in the need to repeat the application on a periodic basis throughout the life of an alternative. This would be reflected in the component replacement aspects of the O&M costs for the alternative.

- The potential need to augment an alternative with other technologies to ensure effectiveness of the actions taken would also be considered under this goal. This could include the potential need to apply a chemical treatment (such as alum) following sediment removal operations if removal alone was not considered to be completely effective.

Score 2A: A higher score means a technology has been proven reliable in other projects, and has lower O&M needs and costs over the long term.

3.3.2 Performance Measure 2B: Maximize Technical Scalability

2B: Maximize Technical Scalability	
Rationale 2B:	Technologies proven on a similar large scale of sediment management/remediation will reduce performance risks.
Metric 2B:	Degree to which a technology used at a similar scale; ease of scale-up for a technology not proven at similar scale.
Target 2B:	Technology proven for a sediment management/remediation project of similar large scale.
Method 2B:	Evaluation of case studies and Lake Okeechobee-specific study projects.
Score 2B:	Higher score means a technology has been proven for sediment management/remediation on a scale similar to Lake Okeechobee, or can be successfully/easily scaled-up from a smaller-scale application.

Rationale 2B: Alternatives that employ technologies that have been proven at other sediment management/remediation sites on a scale similar to that contemplated for Lake Okeechobee will reduce performance risks.

Metric 2B: The degree to which a technology within a given alternative has been used at a similar scale and/or the relative ease with which the technology implemented at a smaller scale can be scaled-up to meet the requirements of the Lake Okeechobee project.

Target 2B: Alternatives that use technologies proven successful at a scale similar to the Lake Okeechobee project, or that can be easily scaled-up to the Lake Okeechobee requirements, are preferable.

Method 2B: A quantitative and qualitative evaluation of performance and monitoring data from other applicable projects (i.e., case studies). This evaluation will include data from a range of sediment management projects (e.g., navigation, remediation, restoration projects for lake, river and coastal sites). For example, scaling-up a removal alternative that uses large hydraulic cutterhead dredges capable of removing 20,000 to 40,000 cubic yards per day would be considered less complicated than scaling-up removal using a special purpose hydraulic dredge such as the PNEUMA® Pump. This dredge was developed in Italy and has a reported range in production capacity of approximately 1,000 to 6,000 cubic yards per day (assuming 20 hours of dredging time per day). The scaling will also take into consideration the Lake Okeechobee-specific dredging studies that are being conducted by EA Engineering (pilot scale) and Reddy (bench scale). To the extent that data are available from EA's pilot dredging study, it may be possible to develop scale-up information. This information would include critical elements of sizing and removal production for the newly developed dredge-head that is being implemented during this study. The results from the Reddy bench scale study may provide some technical insight as to the movement of P into the overlying water column and the assimilative P capacity of the sediment as a function of the depth dredged. This information would assist in evaluating the scaling of equipment that may be necessary to effect the removal of a thin layer of sediment as many types of dredges are limited in their ability to accomplish this without significant over-dredging.

Score 2B: A higher score means that the technology has been successfully implemented on a scale similar to the Lake Okeechobee project, or that the technology can be readily scaled-up to the Lake Okeechobee requirements.

3.3.3 Performance Measure 2C: Maximize Equipment and Material Availability

2C: Maximize Equipment and Material Availability	
Rationale 2C:	To reduce performance risks, materials, equipment, and skilled workers must be readily available to meet project requirements.
Metric 2C:	Availability of materials, equipment, and skilled workers; length of lead times for obtaining equipment or materials.
Target 2C:	Widely and readily available materials, equipment, and skilled workers.
Method 2C:	Qualitative requirements identified in cost estimate; availability in marketplace assessed.
Score 2C:	Higher score means necessary and critical elements are widely and readily available.

Rationale 2C: In order for a technology to be feasible and implementable, all materials, equipment, and skilled workers must be available (in an appropriate amount of time) to meet the project schedule and requirements.

Metric 2C: The availability of materials, equipment, and skilled workers will be assessed on a regional, national, and international basis. Length of lead times to obtain critical materials and equipment will also be evaluated.

Target 2C: Readily available equipment, materials, and skilled workers in sufficient quantities, and in an appropriate time frame, to meet project requirements.

Method 2C: A qualitative evaluation will be conducted to assess the availability, within the local, national, and international construction marketplaces of equipment, materials, and workers required for an alternative. As part of this assessment, local and national contractors, manufacturers, and suppliers will be contacted regarding the availability of required materials, equipment, and skilled workers. For dredging-related equipment, the search would be conducted on an international basis using the annual directory of dredge owners and operators published in the *International Dredging Review.* The evaluation will also consider the potential limitations the Jones Act may place on foreign-supplied specialized equipment. For example, the Japanese-made Oozer dredge may not be available within the United States due to restrictions contained this Act. The evaluation will also consider lead times required for obtaining critical materials, equipment, and other components of the alternative. An example of this consideration includes the time necessary to fabricate project-specific dredges if the marketplace inventory and current demands exceed the potential needs of a Lake Okeechobee removal project. Finally, the evaluation will consider the availability of land necessary to implement the alternative, including short-term construction support areas and the potential for long-term land needs such as sediment disposal areas.

Score 2C: A higher score means that more of the necessary and critical elements of an alternative are widely and readily available.

3.3.4 Performance Measure 2D: Maximize Permanence

2D: Maximize Permanence	
Rationale 2D:	Permanent technologies minimize long- and short-term performance risks.
Metric 2D:	Degree to which a technology has proven long-term success.
Target 2D:	A permanent solution.
Method 2D:	Qualitative case study comparisons. Weather events modeled using linked SWAN-LOHTM models
Score 2D:	Higher score means the alternative is less susceptible to disturbance and more likely to retain its effectiveness over time.

Rationale 2D: Alternatives that use technologies that can be characterized as "permanent" or approaches to minimize long- and short-term performance risks including the potential impacts of sediment transport due to normal wind/wave action or rare events (hurricanes) are desirable. Given the magnitude of financial resources and significant amount of time to implement an alternative, the potential that the positive impacts of an alternative could be negated by sediment transport or by an extreme weather event is an important consideration. In addition, if an alternative entails removing sediment from the lake and placing it in either a temporary or permanent disposal area on land, steps to prevent the phosphorus or other constituents in the sediment from returning to the lake specifically or the watershed in general will be taken.

Metric 2D: The degree to which an alternative uses technologies or approaches with a successful history of long-term performance will be evaluated. This includes the degree to which the effectiveness of the technologies or approaches may be susceptible to the effects of normal wind/wave action or rare events, such as a hurricane.

Target 2D: Because lakes function over the long-term as net sinks of phosphorus and internally produced organic matter, no mitigative approach can offer a truly permanent solution (i.e., not requiring continued maintenance or intervention in the lake) to reducing internal loading, even if the fundamental morphometry of Lake Okeechobee is changed so that that the areal zone of net sediment accretion is radically reduced and sediment deposition is highly focused within a comparatively small area. Moreover, the long-term effectiveness of any technology will be influenced directly by the external loading regime of phosphorus to the lake. However, approaches can be evaluated with respect to which offer the most optimal effectiveness over time for any given scenario. More specifically, the target here is to ensure that the efficacy of a method is not severely compromised by sediment resuspension induced either by normal wind-wave activity or by infrequent (but still likely) events such as hurricanes.

Method 2D: A qualitative evaluation will be conducted by comparing the technologies or approaches used within an alternative with case study results from other projects with similar components. The case study results used in this evaluation could include monitoring results (i.e., physical, chemical, and/or biological data) and general observations regarding long-term performance. The evaluation would also include an assessment of the hydrodynamic impacts of wind/wave action and extreme weather events using the linked SWAN-LOHTM models. This approach would examine both the depth applied and critical shear stress of material used in armoring or capping the sediments. Erosion losses of material would then be simulated for given wind-wave events using SWAN-LOHTM.

Score 2D: A higher score means the alternative is less susceptible to disturbance and more likely to maintain its effectiveness over time.

3.3.5 Performance Measure 2E: Minimize On-Shore Land Use Needs and Conflicts

2E: Minimize On-Shore Land Use Needs and Conflicts	
Rationale 2E:	On-shore land needs could displace current land use activities, possibly affecting the local economy and increasing project costs. Must not conflict with land needs of other projects.
Metric 2E:	Acres of on-shore property needed.
Target 2E:	Minimize short- and long-term land losses.
Method 2E:	Quantitative; engineering estimate of on-shore land needs and time frame.
Score 2E:	Higher score means less on-shore land is needed for a shorter time.

Rationale 2E: Some alternatives are likely to require on-shore facilities to support in-lake operations. The potential need for on-shore land to support an alternative is an important consideration as it could potentially displace current land use activities. This has the potential to negatively impact the local economy and in turn, may increase project costs if the acquisition or leasing of land is necessary. Other ongoing projects (CERP, in particular) may have land use needs of their own (for stormwater treatment areas, wetland reclamation, aquifer storage and recovery projects, tributary dredging, etc.), and the implementation of any sediment management alternative must not conflict with the needs of those other projects.

Metric 2E: The primary metric is the acreage of on-shore property required by a given alternative. This includes both long-term and short-term losses. The short-term losses include the time that construction support areas would be required in terms of years.

Target 2E: Minimizing short- and long-term loss of on-shore acreage. This includes minimizing the duration of short-term land losses.

Method 2E: A quantitative engineering estimate for the acreage of on-shore land required by a given alternative would be developed. This would include both permanent land loss and short-term land loss required to support construction. The evaluation will also identify the length of time (years) that the construction support areas would be required.

Score 2E: A higher score means less on-shore land needed, and the duration of short-term land use is minimized.

3.3.6 Performance Measure 2F: Satisfy Permitting Requirements

2F: Satisfy Permitting Requirements	
Rationale 2F:	Environmental Resource Permit (ERP) issued by the Florida Department of Environmental Protection (FDEP) is required.
Metric 2F:	Compliance with four primary issues and no impact on water supply.
Target 2F:	Receive an ERP from the FDEP.
Method 2F:	Predicted chemical concentrations in lakewater and sediment.
Score 2F:	Yes/No – 5 means permit issued, 1 means permit not issued.

Rationale 2F: Any alternative implemented as a result of this project will require one over-arching permit issued by the Florida Department of Environmental Protection in conjunction with the USACE, the Florida Game & Fresh Water Fish Commission, and the Florida Division of State Lands. This permit, known as the Joint Environmental Resource Permit (ERP) (Part IV, Chapter 373 F.S. - Authorization to use State-Owned Submerged Lands/Federal Dredge and Fill Permit), provides for multi-agency review of a single permit application and covers most all of the considerations required to implement an alternative within the lake. The only uncertainty at this time is whether or not a separate National Pollutant Discharge Elimination System (NPDES) permit would perhaps be required as well for any alternative involving an effluent discharge to the lake or other waters. As of the time of this writing, the FDEP did not expect a NPDES permit would be required.

Metric 2F: Metrics for assessing permit compliance will include:

- Degree of assurance that permit requirements can be achieved with minimal number of variances and mitigative measures;
- Estimated chemical concentrations of constituents of concern in the water column based on available surface water and/or bulk sediment chemistry data. Sources of data can include existing monitoring data, actual concentrations (in either milligrams or micrograms per liter) of chemicals

in surface water and sediment sampled during the Lake Okeechobee sediment dredging pilot study, and actual concentrations from samples collected elsewhere throughout the lake, as appropriate;

- Estimated number of expected wetland acres that could be impacted;
- Estimated number of and types of listed or endangered species that could be impacted and estimated time frames for recovery or recolonization; and
- Estimated number of acre feet that could be lost for storage or flood control under an alternative such as capping or land disposal, where added material might have the potential to reduce cross sectional area. Estimated area needed to provide compensatory storage and practicability of providing for such mitigated storage.

Target 2F: Issuance of the joint ERP permit will be based on achieving the following targets:

- Ability to comply with FAC-62-302 surface water quality criteria for Class I Potable Water Supply both in lake during any remedial construction activities as well as in staging and support zones that may be required to manage sediments and water. No exceedance of FAC-62-302 in the short or long term, either through direct "in lake" remedial construction activities and/or through the potential discharge of treated water returned to the lake. Alternatively, allowable exceedances within a certain distance from the potential work sites and no exceedances at a sentinel point of compliance (POC) as agreed to by FDEP in a variance on the ERP;
- Ability to comply with FAC-62-777 soil quality criteria in the event that sediments will need to be managed, sold, and/or disposed of outside the lake;
- Absence of impacts to jurisdictional wetlands and/or mangroves;
- Minimal adverse effects to listed or endangered species and habitats;
- No reductions in cross-sectional area of surface water body and/or surrounding land required for flood control management without providing for compensatory storage or mitigation elsewhere; and
- Agreement with the Division of State Lands regarding ownership of any materials that could be potentially sold for profit, if applicable.

Variances for certain parameters are possible and mitigation of wetlands can be considered, however, there can be no impacts to the water supply.

Method 2F: Methods for assessing permit compliance will include:

- Existing sediment and water quality data will be reviewed in advance by the District, BBL, and the FDEP. If sediment concentrations are found to be present at levels of concern above screening criteria provided in the Sediment Quality Assessment Guidelines (McDonald, 1994), and/or surface water concentrations are found to exceed FAC- 62-302, then additional sediment and surface water sampling/monitoring would be recommended for inclusion in the pilot dredging study or a separate characterization study. The data reviewed from the pilot study will be assessed for representativeness of the remainder of the lake. If there are exceedances of the screening criteria described, then a wider characterization of sediments/surface water may be warranted to improve the reliability of the evaluation of alternatives. Otherwise evaluations of an alternative's effectiveness, implementability, and cost could be hindered by a significant degree of uncertainty in regard to the level of engineering controls and treatment/disposal required;
- A desktop assessment of wetland nature and extent will be conducted using National Wetland Inventory (NWI) maps and other data to estimate the potential impacts of alternatives on wetlands or other sensitive habitats;
- Coordination efforts with FWC, USFWS, and others to assess the status and locations of listed and endangered species in and near Lake Okeechobee; review of the work done through the Florida Natural Areas Inventory (FNAI, 2000) and the Multi-Species Recovery Plan for South Florida (USFWS, 2000);
- Preliminary discussions will be advanced with the Florida Division of State Lands by the District, to address potential issues that could arise in the event that sediments extracted from the Lake could be sold for profit or otherwise reused; and
- Each alternative will be evaluated with respect to its potential to reduce cross-sectional area of a surface water body and/or land-based water storage area managed for flood control. Compensatory storage needs and the practicability of options available to provide such storage elsewhere will be assessed.

Score 2F: Alternative evaluation scores will range from a 5 (high probability of receiving an ERP) to a 1 (low probability of receiving an ERP).

3.4 Goal 3: Maximize Cost Effectiveness

3.4.1 Performance Measure 3A: Minimize Construction Costs

3A: Minimize Construction Costs	
Rationale 3A:	Funding for implementing an alternative may be limited; therefore, cost of an alternative is an important consideration.
Metric 3A:	Estimated cost for the alternative, in dollars.
Target 3A:	Least cost possible to achieve goals.
Method 3A:	Quantitative engineering cost estimate.
Score 3A:	Higher score means lower cost for the alternative.

Rationale 3A: The construction costs for an alternative can generally be thought of as the short-term project costs. Although there is no pre-determined cost for achieving the project goals, the cost to implement an alternative is an important consideration due to potential limitations in available funding.

Metric 3A: The estimated cost in terms of dollars required to construct the alternative. The time to construct the alternative is also a metric, as the project costs will be presented on a Net Present Value (NPV) basis. This will facilitate a comparison of alternatives with differing costs and implementation timeframes against a consistent baseline. The NPV costs will be developed using the discount rate recommended by the federal Office of Management and Budget (OMB). The current discount rate currently recommended by OMB in their Circular A-94 is seven percent. The cost estimates will also recognize an annual inflation rate for construction activities that span more than one year in length. The inflation rate will be estimated using the rate of increase in the federal Gross Domestic Product deflator for the period of construction, up to six years. For projects that span more than six years, the rate of inflation for the sixth year will be carried through the remaining years of the project.

Target 3A: Sediment management alternatives that achieve the project goals at the least cost are preferable.

Method 3A: Quantitative engineering cost estimate based on equipment, manpower, materials, land purchase (if necessary), treatment/disposal (if necessary), and duration required to implement a given alternative using widely accepted methods. The estimates will be based on standardized unit cost data (e.g., Means tables), experience at similar sites or with similar technologies, and professional engineering judgement. The estimate will also include indirect cost items such as engineering design, permitting, and engineering support during construction. The estimated construction costs will be presented on a NPV basis using a discount rate of 7% and an annual inflation rate as described in metric 3A. Revenue streams that could offset construction costs would be considered separately under performance measure 3C, "Maximize benefits (material reuse)."

Score 3A: A higher score means lower NPV cost for construction.

3.4.2 Performance Measure 3B: Minimize Operation and Maintenance Costs

3B: Minimize Operation and Maintenance Costs	
Rationale 3B:	O&M costs can extend out over 50 years; lower costs over this extended time frame are preferable.
Metric 3B:	Cost estimates over a 50-year O&M period.
Target 3B:	Lowest O&M cost possible.
Method 3B:	Quantitative engineering cost estimate.
Score 3B:	Higher score means lower O&M costs.

Rationale 3B: O&M costs can, in general terms, be considered long-term project costs. Although there is no current target for O&M costs, because O&M costs can be very high for large, complex, and long-term projects, alternatives that achieve the project goals but do not require funding of long-term or complex maintenance activities are considered preferable. O&M costs include components such as long-term monitoring of alternative effectiveness, maintenance of equipment or infrastructure, maintenance or repair of remedial components such as capping material (if capping were to be implemented), and the labor, engineering, data collection and analysis, and other required resources or activities. Similar to construction cost estimates, the estimated long-term O&M costs are a quantitative measure of the financial resources required to maintain each alternative over time, and are thus useful in conducting a comparative analysis of various sediment management alternatives. Coupled with other performance measures, O&M costs can be an indicator of long-term effectiveness and permanence of an alternative, considering how much investment is needed to maintain an alternative's effectiveness at reducing internal phosphorus loading over time.

Metric 3B: The metrics include NPV cost estimates for a 50-year period of O&M. This includes costs for O&M and component replacement where applicable.

Target 3B: The lowest O&M cost possible to achieve goals is preferable.

Method 3B: A quantitative engineering cost estimate will be developed. The cost estimate will focus on post-construction monitoring, reporting, operating and maintenance activities and include equipment, manpower, and materials. The costs will be presented on a NPV basis for a 50-year period. The estimate will use a discount rate of seven percent and an annual inflation rate, as described in metric 3A.

Score 3B: A higher score means lower O&M costs. The costs for O&M and component replacement will be presented on a NPV basis given the time-value of money, the differing nature of the life-cycle costs for the range of alternatives, and the need to compare these alternatives against a consistent baseline, in this case today's dollar.

3.4.3 Performance Measure 3C: Maximize Benefits (Material Reuse)

3C: Maximize Benefits (Material Reuse)	
Rationale 3C:	Materials produced during alternative implementation may generate revenue streams that could offset capital or O&M costs.
Metric 3C:	Revenue in terms of dollars and timing.
Target 3C:	Generation of significant early and long-lasting revenue.
Method 3C:	Engineering cost estimate for potential revenue stream.
Score 3C:	Higher score means greater, earlier revenue.

Rationale 3C: Some alternatives may generate materials (i.e. dredged material) that could be reused or sold to generate revenue (e.g., building materials, fill/soil, soil amendments, etc.). The revenue from these operations could be used to offset capital and/or O&M costs associated with implementing an alternative.

As discussed in performance measure 2F, compliance with FAC-62-777 and agreement with the Division of State Lands regarding ownership of any materials to be potentially sold for profit would be required prior to the generation of any revenue stream.

Metric 3C: The revenue in terms of dollars and the timing (start date and duration in years) of the revenue-generating activities are the important metrics.

Target 3C: Alternatives that create the possibility for generating significant revenue are preferable. Revenue streams that can be developed early in the project and last for a significant period of time are also preferable.

Method 3C: An engineering cost estimate for the magnitude and timing of the potential revenue stream would be developed based on the potential marketability of the material. This would be based on available case study information and would be highly dependent on the technical approach for generating revenue. Only options estimated to be feasible and generate a reasonable reliable revenue stream will be considered.

Score 3C: A higher score means greater revenue would be generated by an alternative. The earlier the revenue stream is produced will also be reflected in a higher score.

3.5 Goal 4: Maximize Environmental Benefits

All of the environmental performance measures discussed in Goal 4 are focused on the potential long-term benefits of lowering phosphorus concentrations in the water of Lake Okeechobee. The ultimate goal is to improve water quality within the lake and thereby enhance the social and ecological functions of the lake within the larger human and environmental complex of south Florida. These performance measures are designed to assess how successful a given alternative would be in achieving that ultimate goal. There is a recognition that, in order to reach the long-term goal, there may be some negative impacts to the ecosystem and surrounding region in the short term; however, alternatives that are most likely to eliminate, avoid, or minimize those negative impacts will be favored over those that may produce unacceptable impacts. For example, alternatives will focus primarily on addressing phosphorus-laden sediments within the pelagic zone. This focus will allow the design of the alternatives to clearly avoid the sensitive littoral zone and to have minimal, if any, short-term impacts on the near-shore zone (see Figure 4 for definition of zones). Wildlife protection experts will be included in the design and implementation of any alternative in order to protect the unique and diverse populations in Lake Okeechobee.

3.5.1 Performance Measure 4A: Maximize Benefits to Wetland Vegetation in Littoral Zone

4A: Maximize Benefits to Wetland Vegetation in Littoral Zone	
Rationale 4A:	Nuisance plants crowd out beneficial, native plants that are attractive to waterfowl, fish, and other organisms reliant upon the littoral zone.
Metric 4A:	Tons of phosphorus transported into littoral zone.
Target 4A:	Decrease phosphorus flux into the littoral zone.
Method 4A:	Quantitative estimates of phosphorus transport into the littoral zone.
Score 4A:	Higher score means greater decrease in phosphorus and likely improvement in plant community structure.

Rationale 4A: Cattail *(Typha spp.)* and torpedograss *(Panicum repens)* tend to form rank, monotypic stands that are both unattractive and have no food value to waterfowl. Cattail and torpedograss have largely replaced the more valuable (as a source of food and brood cover) spike rush *(Eleocharis spp.)* and other annual plant communities that historically supported large numbers of dabbling ducks in the littoral zone of the lake (Walsh et al., 2001). Cattail has rapidly expanded in the littoral zone, especially along edges of boat trails and natural flow paths. This is thought to reflect effects of phosphorus inputs from the pelagic zone, much as in the Everglades (Newman, et al., 1996).

Resident waterfowl species, such as the Florida mottled duck (*Anas fulvigula fulvigula),* the wood duck (*Aix sponsa*)*,* and the fulvous whistling duck (*Dendrocygna bicolor*) use the lake during the spring and summer for brood-rearing and molting. Lake Okeechobee is especially important to the endemic mottled duck during drought years when the prairies (where most mottled ducks nest) become dry and the lake constitutes the largest area of suitable brood-rearing habitat in south Florida. During fall and winter, these species share the lake with as many as 20 species of migratory waterfowl. These include large numbers of ring-necked ducks (*Aythya collaris*), and blue- and green-winged teal (*Anas discors* and *A. crecca carolinensis* respectively) in the littoral areas. As much as 40% of the entire Atlantic flyway population of ring-necked ducks may winter on Lake Okeechobee in a given year and under optimal conditions (Walsh et al., 2001).

Vegetated littoral zones also provide important habitat for fish, in particular for small forage fish taxa and the juvenile stages of larger species that use the littoral zone both as a refuge from predators and as a foraging area (Werner et al., 1983; Rozas and Odum, 1988). In Lake Okeechobee, surveys by Chick and McIvor (1994) documented a high biomass and diversity of fish in the littoral zone, with distinct fish assemblages occurring in different plant communities (Havens et al., 2000). Fry et al. (1999) also documented that a variety of fish may begin life in the lake's littoral zone and then migrate out into deeper water as they grow in size and "move up" the food chain.

Metric 4A: Tons of phosphorus transported into the littoral zone (based on long-term model simulations) under the various alternatives.

Target 4A: Decrease phosphorus in the pelagic zone sediments, and therefore, to the littoral zone. As phosphorus transport decreases, plant communities are expected to respond favorably, which will benefit waterfowl and other wildlife. In addition, reductions in cattail *(Typha spp.)* would be expected, although other factors, such as water depth, play a key role in determining community structure.

Method 4A: Quantitative estimate based on modeled phosphorus flux to area; qualitatively estimate changes in plant community.

Score 4A: A higher score means greater decrease in phosphorus. Interval scale scoring based on the percentage increase or decrease in the base amount of phosphorus.

3.5.2 Performance Measure 4B: Maximize Benefits to Submerged Aquatic Vegetation

4B: Maximize Benefits to Submerged Aquatic Vegetation	
Rationale 4B:	Submerged aquatic vegetation (SAV) plays a critical role in the ecological functioning of Lake Okeechobee. Existing beds of SAV in near-shore zones should be protected from disruption, and conditions improved to allow lakeward expansion of SAV abundance and diversity. The multiple benefits of SAV include trapping of suspended solids; stabilization of the sediment bed via the root mass; wave attenuation and reduction in water velocity and sediment shear stress; uptake of phosphorus (competes with water-borne phytoplankton); and provision of habitat for epiphytic algae, macroinvertebrates, fish, wading birds, waterfowl and other wildlife.
Metric 4B:	Distance between construction zone and existing areas of SAV (to protect existing beds in the short term), and critical light extinction coefficient (to promote SAV expansion in the long term, as described in performance measure 1C).
Target 4B:	400 meter buffer zone; restoration plan if SAV destruction cannot be avoided; achievement of critical light extinction coefficient target set forth in performance measure 1C.
Method 4B:	Comparison of spatial extent of existing SAV with areas likely to be impacted by an alternative to determine if 400-meter buffer zone would be violated during implementation. If an alternative unavoidably impacts SAV, then the alternative's restoration plan would be evaluated. Predicted level of achievement against performance measure 1C would be considered in evaluating potential for an alternative to improve conditions favorable to SAV growth and expansion over the long term.
Score 4B:	5 means a low probability of short-term impacts and high potential for improved conditions in the long term; 3 means an alternative is not likely to destroy or encroach on SAV and is likely to improve conditions for SAV in the long term; and 1 means a high probability of short-term destruction of SAV and/or minimal long-term expansion of SAV.

Rationale 4B: Submerged aquatic vegetation plays a critical role in the ecological functioning of aquatic systems such as Lake Okeechobee, and thus needs to be managed (i.e., protected) to maintain or increase SAV abundance and ecological value to the system. SAV beds increase the structural complexity of shallow water habitats, which support a greater richness of macroinvertebrate, fish, and wildlife species than deeper waters or shallow waters lacking SAV (Ayvazian et al., 1992; Bain and Boltz, 1992; Furse and Fox, 1994; Randall et al., 1996; Rozas and Odum, 1987; Warren and Vogel, 1991). In addition to supporting near-shore foodwebs and other functionally-linked biological complexes, rooted SAV beds attenuate wave energy and water velocities, which can stabilize the sediment bed by increasing solids deposition and reducing sediment shear stresses (Vermaat et al., 2000). SAV also plays a role in phosphorus dynamics and the assimilative capacity of lakes as roots uptake phosphorus from sediments, and as epiphytic algae, *Chara,* and submerged macrophytes compete favorably with phytoplankton for phosphorus in the water column (Burkholder et al., 1990; Carrigan and Kalff, 1982; Havens and Schelske, 2000; Steinman et al., 1997).

Similar to observations in other shallow lakes (Moss et al., 1996) and the Everglades (Browder et al., 1994), the extent and community structure of SAV in Lake Okeechobee have been linked to lake stage and degree of irradiance through the water column (Havens et al., 2000; Havens 1999), among other factors. The relatively high lake stage (e.g., >15 ft NGVD) in place through much of the 1990s contributed to a significant decline in SAV as underwater irradiance decreased in the near-shore zones due to high water levels and long hydroperiods (Hopson and Zimba, 1993) and increases in sediment transport into the near-shore areas as a result of wind/wave-induced resuspension (Havens et al., 2000). Starting in 1999 and continuing into 2001, lake stage has decreased due to a planned operational recession of levels, low input (drought) conditions, and water supply (usage). Field studies conducted before, during, and after recession have shown a dramatic return of SAV in near-shore zones, dominated in most cases by *Chara* (indicative of successional transition), but including more beneficial plants such as *Vallisneria, Scirpus sp.,* and *Potamogeton sp.* (SFWMD, 2001). By the end of the 2000 growing season, SAV was observed within approximately 17,000 hectares of the near-shore zones (SFWMD, 2000d).

Given the critical importance of SAV in the system's physical stability, phosphorus dynamics, and biological functioning, any sediment management alternative considered for Lake Okeechobee must not negatively impact the apparent improvements in SAV extent and diversity, especially in the north, west, and southern near-shore zones (see Figure 4 for map of ecological zones). In addition to Performance Measure 1C (reduce TSS), this performance measure is needed to protect existing SAV from physical disturbance or destruction in the short term (during implementation of an alternative) and, ideally, improve conditions favorable to community diversification and lakeward expansion of SAV over the long term.

Metric 4B: The short-term metric for this performance measure is distance between areas known to support SAV and where an alternative may be implemented. The objective is to prevent physical disruption or destruction of SAV from migrating sediment plumes or other impacts or, to the extent possible, improve conditions to enhance substrate for establishment of SAV. If an alternative cannot prevent disruption/destruction, then it must include mitigative measures to reestablish SAV in affected areas to functionally equivalent levels. The metric for long-term expansion of SAV is performance measure 1C regarding TSS concentrations and light transmission to the sediment bed.

Target 4B: Performance measure 1C (maximize TSS reductions) under Goal 1 will use modeling results to set a maximum target TSS concentration and light extinction coefficient that are assumed favorable for increased establishment of SAV over the long term. In the short term, the target for this performance measure is to prevent the physical disturbance or destruction of existing SAV beds due to implementation of an alternative. Thus, in addition to long-term improvements that may result from achieving performance measure 1C, the short-term target for this performance measure is no potentially disruptive alternative is to be implemented within 400 meters of known SAV beds. The distance of 400 meters is admittedly relatively arbitrary, but thought to be a buffer zone sufficiently large enough to mitigate the effects of resuspended sediment plumes or other stressors that may migrate from a construction zone into areas containing SAV. Further, in the event an alternative must destroy existing SAV beds to achieve some greater overall benefit (e.g., removal, capping, or treatment of underlying sediment), then such alternatives must include a specific plan that will result in either the restoration of existing beds or establishment of SAV beds with a greater spatial extent and functional benefit to the ecosystem.

Method 4B: Using District maps of known SAV distribution (see Figure 4 and SFWMD, 2000d), alternatives will be evaluated as to where they are likely to be implemented (assumed to be primarily in the pelagic zone) and whether construction would directly impact SAV or encroach within 400 meters of known SAV. Alternatives that can improve near-shore conditions (e.g., improve water quality and/or substrate in the short-term) and be implemented without disrupting or encroaching upon SAV will be favored over alternatives that adversely impact SAV. Alternatives that unavoidably impact SAV will be further evaluated to determine the sufficiency of mitigative measures and the probability for success of SAV restoration plans. For example, plans would be evaluated on their ability to successfully and quickly restore spatial extent of SAV or, based on habitat equivalency analysis (HEA) or some comparable method and associated data (if available), restoration of the functional equivalent of destroyed/degraded SAV within the disrupted area or elsewhere within Lake Okeechobee. An alternative's likelihood of improving conditions for expansion of SAV over the long-term will be considered under performance measure 1C.

Score 4B: A score of 5 indicates a low probability that an alternative would adversely impact SAV in the short-term, and high probability that conditions needed to support expansion of existing SAV would improve over the long term. A score of 3 indicates an alternative or its effects (e.g., resuspension of sediment) are not likely to destroy or encroach on SAV and are likely to improve conditions for SAV in the long term. A score of 1 indicates a high probability of short-term disruption or destruction of SAV and/or minimal long-term expansion of SAV.

3.5.3 Performance Measure 4C: Maximize Benefits to Fish and Aquatic Invertebrate Communities

4C: Maximize Benefits to Fish and Aquatic Invertebrate Communities	
Rationale 4C:	Lake Okeechobee supports recreational and commercial fisheries with an annual value exceeding $200 million. As a food resource, aquatic invertebrates are integral to the quality of these fisheries and the quality and health of the entire lake ecosystem.
Metric 4C:	Probability for impacts (positive or negative) on habitat quality and, to the extent data or estimates are available, population structure of important sport fish species and the species composition, absolute abundance, relative abundance, absolute biomass, relative biomass, diversity, and evenness of distribution of fish and aquatic invertebrate communities.
Target 4C:	Alternatives should benefit or improve fish and aquatic invertebrate communities and their habitats in the long term, and should minimize short-term disruption or degradation of existing healthy or other known communities and associated habitats.
Method 4C:	Review available lake data and relevant case studies to assess each alternative's potential impacts (positive and/or negative) on habitat quality and the species composition and structure of fish and aquatic invertebrate communities.
Score 4C:	5 means high probability for enhancement of community structures/habitats. 3 means no net impact is expected. 1 means a high probability of unacceptable adverse impacts.

Rationale 4C: Lake Okeechobee supports world-renowned largemouth bass (*Micropterus salmoides*) and black crappie (*Pomoxis nigromaculatus*) recreational fisheries. The lake's commercial bream fishery provides employment and a food resource for a large area of south Florida. These fisheries together contribute more than $200 million per year to local economies (Warren, 2001).

Fish community studies conducted by FWC have documented productive and diverse fish communities, especially in vegetated habitats (Bull et al., 1991; 1995), and show that species composition, relative abundance, and relative biomass vary by habitat type and season. Similarly, Warren et al. (1991; 1995) showed that the species composition and structure of aquatic invertebrate communities, which are integral food resources for juvenile and adult sport fish, varied substantially by habitat type. For example, mud sediments in the northern region of Lake Okeechobee (north of lat. 27° 05.00) were found to support an insect and crustacean community especially important to the diet of black crappie. The lake's sand and peat sediment habitats and the unconsolidated mud zone of the central pelagic region (see Figure 4) did not support this same community, or supported a similar assemblage in substantially lower numbers (Warren et al., 1991). However, the peat and sand sediment habitats were found to support the most diverse sediment-associated communities. Hydrilla (*Hydrilla verticilata)* and eelgrass (*Vallisneria americana*) supported the highest quality phytomacrofauna, such as the grass shrimp (*Palaemonetes paludosus*), which is an important food item in the diet of largemouth bass. According to Havens and Schelske (2000), current conditions of invertebrate and fish communities in Lake Okeechobee are consistent with high internal loading of phosphorus. For example, a high rate of eutrophication is evident in the relative abundance of Oligochaeta (segmented worm), which rose from 24.2% in 1969-70 to 73.7% in 1990-91 (Warren et al., 1995). While management of lake sediments provides an opportunity to beneficially mitigate or reverse these conditions and trends, alternatives also should be evaluated as to their potential to adversely impact what is regarded as a healthy fish community (in all sampled habitats) and healthy aquatic invertebrate communities in vegetated, peat, sand, and north lake region mud habitats. Similarly, sediment management alternatives should be evaluated for their potential to impact the vegetative and benthic habitats that support these healthy fish and invertebrate communities.

Metric 4C: Based on available data, sediment management alternatives will be evaluated qualitatively as to their probability for impacts (positive or negative) on habitat quality and, to the extent possible, population structure of important sport fish species and the species composition, absolute abundance, relative abundance, absolute biomass, relative biomass, diversity, and evenness of distribution of fish and aquatic invertebrate communities.

Target 4C: Sediment management alternatives employed in Lake Okeechobee should, in the long term, benefit or improve fish and aquatic invertebrate communities and their habitats. In the short term, alternatives should minimize disruption or degradation of existing healthy or other known communities and associated habitats.

Method 4C: Lake Okeechobee data will be reviewed to assess each alternative's potential impacts to habitat quality and the species composition and structure of fish and aquatic invertebrate communities. To the extent available, pre- and post-construction fish and aquatic invertebrate data from other shallow, eutrophic lakes where organic sediments have been removed, capped, chemically treated, or otherwise addressed will be reviewed. Site-specific and case-study information will then be used to assign a relative score to estimate the predicted level of benefit or degradation of communities and habitats. Using Lake Okeechobee data, FWC may develop and make available detailed information (e.g., metrics and targets) for each habitat type that is determined to be important for maintenance of healthy fish and aquatic invertebrate communities.

Score 4C: A score of 5 means a high probability for enhancement of habitat quality and community composition and structure; a score of 3 means no net impact is expected; and a score of 1 means a high probability of unacceptable adverse impacts.

3.5.4 Performance Measure 4D: Minimize Negative Impacts to the Manatee

4D: Minimize Negative Impacts to the Manatee	
Rationale 4D:	The manatee is listed as an endangered species; availability of foraging habitat is crucial.
Metric 4D:	Probability that an alternative would impact (improve or degrade) habitat/forage requirements.
Target 4D:	Increase in desirable native plant forage species (i.e., SAV).
Method 4D:	Assess alternatives' potential to enhance/degrade forage habitat.
Score 4D:	5 means a high probability for positive impacts on the habitat and forage requirements; 3 means an estimated no net impact is expected; and 1 means a high probability of habitat/forage loss.

Rationale 4D: The West Indian Manatee *(Trichechus manatus)* has been on the federal endangered species list since 1967 and is protected by the Endangered Species Act, the Marine Mammal Protection Act and the Florida Manatee Sanctuary Act. Manatees and their habitats are continually threatened by human activities, such as habitat loss for residential and commercial purposes, increased turbidity from upland urbanization activities, pollution from sewage discharge and stormwater runoff, aquatic recreational and commercial activities, and alterations of natural hydrology (USFWS, 2000).

Manatees depend on areas with access to natural springs or manmade warm water refugia, access to areas with vascular plants and freshwater sources (USFWS, 2000). The South Florida Ecosystem region, including Lake Okeechobee and the Everglades, is home to the most resident manatee populations and transient migrants in Florida (USFWS, 2000), and due to the warm water (manatees prefer water warmer than 20 degrees Celsius), some of the highest winter aggregations occur in south and central Florida (USFWS, 1996).

The availability of foraging habitat throughout the manatee's range is crucial to recovery of the species. Although the Multi-Species Recovery Plan for South Florida (USFWS, 2000) identifies the need for more studies regarding manatee food habits, it is known that in South Florida, manatees prefer areas with available SAV. Manatees feed on a variety of submerged, emergent, or floating aquatic plant species (see Hurst and Beck, 1988; and Smith, 1993 for a complete review), may also feed on algal complexes attached to rocks, pilings, or dams (Reynolds, 1981), and may occasionally eat fish or invertebrates while feeding on floating or submerged vegetation (Powell, 1978; Smith, 1993). In Lake Okeechobee, manatees depend primarily on *Potamogeton spp.* (pond weeds)*, Najas guadalupensis* (southern naiad)*, Pontederia cordata* (pickerelweed), *Ceratophyllum demersum* (coontail), *Sagittaria spp.*, and *Cabomba spp.* (fanwort) (Walsh et al., 2001).

Metric 4D: Probability that an alternative would impact habitat and forage requirements for manatees in Lake Okeechobee. Clearly, this performance measure will be closely tied to the metric for performance measure 4B, maximize benefits to SAV, since manatees rely on SAV for food. Short-term impacts to manatees during construction of a particular alternative will be considered in the development and approval process for the ERP, discussed in performance measure 2F, which requires there be minimal adverse effects to endangered species.

Target 4D: The target is to maintain or increase desirable forage species such as *Potamogeton spp.* (pond weeds)*, Najas guadalupensis* (southern naiad)*, Pontederia cordata* (pickerelweed), *Ceratophyllum demersum* (coontail), *Sagittaria spp.*, and *Cabomba spp* (fanwort). (Walsh et al., 2001). The target defined in performance measure 4B, that no alternative will be implemented within 400 meters of known SAV beds in order to prevent physical disturbance or destruction of existing SAV beds, will protect the specific SAV species manatees rely upon.

Method 4D: As described in the methods for performance measure 4B, alternatives that can be implemented without disrupting or encroaching upon SAV or that can improve conditions (e.g., provide better substrate) will benefit the manatee in the long run and will be favored over alternatives that adversely impact SAV. As described earlier, impacts to the manatee in the short run will be addressed in the development and approval of the ERP.

Score 4D: A score of 5 means a high probability for enhancement of habitat and forage required by the manatee, a score of 3 means an estimated no net impact is expected, and a score of 1 means a high probability of habitat/forage loss.

3.5.5 Performance Measure 4E: Minimize Negative Impacts to the Alligator

4E: Minimize Negative Impacts to the Alligator	
Rationale 4E:	The alligator is a protected species; the greatest threat to its long-term survival is habitat loss.
Metric 4E:	Important measures include acreage and distribution of *Eleocharis* marshes and elevated nesting substrate (islands, berms, and tussocks within permanently flooded emergent marsh)
Target 4E:	Increase available nesting, juvenile, and adult habitat in littoral zones.
Method 4E:	FWC habitat suitability indices (HSI), nest surveys, spring night-light surveys/trend analyses, and case studies will be used to assess an alternative's potential to impact/enhance habitat.
Score 4E:	5 means a high probability for enhancement of suitable habitat; 3 means an estimated no net impact is expected; and 1 means a high probability of unacceptable adverse impacts.

Rationale 4E: The American alligator (*Alligator mississippiensis*) is a protected species, and the greatest threat to its long-term survival is habitat loss (Ashton and Ashton, 1985). Nest building occurs during the months of June and July, above the water line in marshes or on high ground close to the water's edge, in dense stands of cattail (*Typha ssp.*) and *Phragmites ssp.* The apparent criteria are height above water line, proximity to water line, and both density vegetation height (required for concealment of the nest). On Lake Okeechobee, appropriate areas include Observation Shoal, the berm along the north shore, agricultural lands in the southern portion of the lake, and North Lake Shoal; these areas have high nest densities, and low rates of nest flooding. At an approximate length of 3', juvenile alligators move to *Eleocharis* marshes, and are supported by a high diversity of invertebrates. Appropriate water quality and littoral zone vegetation mosaics are required in order to provide a heterogeneous habitat that supports both juvenile survival and the high biomass of fish and turtles that dominate the diet of adult alligators.

Metric 4E: Appropriate measures of the habitat quality include acreage and distribution of elevated nesting substrate (islands, berms, and tussocks within permanently flooded emergent marsh), acreage and distribution of *Eleocharis* or *Typha* marshes, pounds/species/acre of invertebrates, and pounds/acre of fish and turtles. Successful use of the habitat is measured by percent flooded nests (a negative metric), total number of alligator nests, and stable or increasing trends in numbers for all size classes of alligator.

Target 4E: Increase available nesting, juvenile, and adult habitat for the American Alligator (*Alligator mississippiensis*) in the littoral zones of Lake Okeechobee (Walsh et al., 2001).

Methods 4E: The FWC conducts ongoing nest surveys. Alligator abundance and size class distribution is determined from ongoing FWC spring night-light surveys and trend analyses. To the extent available, these data will be used to assess an alternative's potential to impact/enhance habitat.

Score 4E: A score of 5 means a high probability for enhancement of suitable habitat for the alligator; a score of 3 means an estimated no net impact is expected; and a score of 1 means a high probability of unacceptable adverse impacts.

3.5.6 Performance Measure 4F: Minimize Negative Impacts to the Okeechobee Gourd

4F: Minimize Negative Impacts to the Okeechobee Gourd	
Rationale 4F:	The Okeechobee gourd is a federally endangered species; critical habitat needs protection.
Metric 4F:	Number and location of Okeechobee gourd sites potentially impacted by an alternative.
Target 4F:	Increase suitable habitat for the Okeechobee gourd and, at a minimum, do not disturb or negatively impact areas known to support the Okeechobee gourd.
Method 4F:	Alternatives evaluated for their potential to create or impact known existing critical habitats; new mapping survey needed of areas potentially impacted by alternative implementation.
Score 4F:	Higher score (up to 5) means an increase in suitable habitat; alternatives that require actions in near-shore areas, the Kreamer, Torry, or Ritta Islands, or near the rim canal would be given a low score (1).

Rationale 4F: The Okeechobee gourd, which was placed on the federal list of endangered species in 1993, is a vine that was common in the extensive pond apple (*Annona glabra*) forest that once grew south of Lake Okeechobee (Small, 1922). As early as 1930, at least 95 percent of the pond apple forests had been destroyed (Small, 1930), and pond apple now persists only as scattered trees or small stands around Lake Okeechobee and in the Everglades.

The survival of the Okeechobee gourd in South Florida is threatened by the present-day water-regulation practices in Lake Okeechobee and the continued expansion of exotic vegetation in the lake (United States Fish and Wildlife Service [USFWS], 2000). In the most recent surveys, the species was found to be present at 11 sites along the southeastern shore of Lake Okeechobee, including Torry Island, Ritta Island, Kreamer Island, Bay Bottom Dynamite Hole Island, South Shore Dynamite Hole Island, and the southern shore of the Lake Okeechobee Rim Canal (Walters et al., 1992; Walters and Decker-Walters, 1993). The documented population of Okeechobee gourd around the southeastern shore of Lake Okeechobee is strongly associated with Torry muck, a soil formed in the extensive pond apple forests that once surrounded Lake Okeechobee. However, successful growth and reproduction of the gourd under cultivation suggests that the species can grow in a wider range of soils (USFWS, 2000).

Around Lake Okeechobee, the gourd is frequently associated with alligator nests. These disturbed sites provide areas where competition is reduced, and the areas are elevated, which promotes the growth of elderberry, button bush, and other erect bushes and shrubs.

Recovery of the Okeechobee gourd may require special emphasis on protection and management of Ritta Island. In the most recent habitat survey, this was the only site in Lake Okeechobee that supported what appeared to be more mature plants. Plants at other sites around the lake appeared to be transitory and in poor health (USFWS, 2000). Other potential recovery actions would involve physical alteration of the environment, entailing either removal of levees or mounding of organic material to provide substrate at appropriate elevations (USFWS, 2000). Mounding of organic soil on Torry and/or Ritta islands could be part of a restoration plan for those islands and could provide a safeguard against prolonged periods of high water (USFWS, 2000).

Metric 4F: The number and locations of surveyed Okeechobee gourd sites located in areas that could be considered for implementing a given alternative.

Target 4F: Take no action that will disturb or otherwise negatively impact current habitat of the Okeechobee gourd and, if possible, create or enhance habitat that could support the gourd. Kreamer, Torry, and Ritta islands and the southern rim canal are the areas supporting current populations (FDEP, 2001; USFWS, 2000). In addition, alternatives should not disturb or negatively impact the Okeechobee gourd at other transient sites that are currently not well understood or mapped, but generally are located within the near-shore zones of the lake (FDEP, 2001).

Method 4F: Alternatives will be evaluated for their potential to impact known existing critical habitats for the gourd or create/enhance additional habitat. Prior to initiating any sediment management activity, a new Okeechobee gourd survey would need to be developed within the activity area to determine if critical habitat would be impacted.

Score 4F: For the purposes of this study, alternatives that would require actions in near-shore areas, the Kreamer, Torry, or Ritta Islands, or near the rim canal would be given a low score (1) relative to this performance measure. Higher scores (up to 5) indicate an alternative is expected to create or enhance suitable habitat and have no negative impacts.

3.5.7 Performance Measure 4G: Minimize Negative Impacts to the Snail Kite and Wading Birds

4G: Minimize Negative Impacts to the Snail Kite and Wading Birds	
Rationale 4G:	The endangered snail kite and wading birds depend on critical habitat in Lake Okeechobee.
Metric 4G:	Qualitative assessment of nesting/nursery and forage quality.
Target 4G:	Expansion or no net impact on the habitat or forage base of the snail kite or wading birds.
Method 4G:	Available data will be used to estimate the likelihood of benefits (or impacts) from a given alternative.
Score 4G:	5 means a high probability for positive effects on critical habitat/forage; 3 means an estimated no net impact is expected; and 1 means a high probability of unacceptable adverse impacts.

Rationale 4G: Sight-foraging birds such as the endangered Snail Kite (*Rostrhamus sociabilis*), herons (Family Ardeidae), and probe-foraging birds such as the endangered wood stork (*Mycteria americana*) and the ibises (Family Threskiornithidae) depend on shallow, relatively clear, and sparsely vegetated aquatic habitats for forage. On Lake Okeechobee, such habitat was historically dominated by sparse *Eleocharis* ssp. and *Panicum* ssp. High turbidity and dense growths of cattails (associated with either increased water depth, increased P, or both), water lily, lotus, and *Hydrilla* prevent sight-foraging wading birds from accessing forage prey. Southern willow (riparian habitats) and bulrushes (littoral zones), which each have been displaced by Melaleuca and cattails respectively, are also desirable as nesting habitat for a variety of aquatic birds including snail kites. An additional benefit provided by an increased/enhanced littoral zone would be increased frequency of recommended minimum buffer distances between nesting and foraging sites and human disturbances. The recommended minimum buffer distance for wading birds is 100 m and for snail kites is 75 m (Walsh et al., 2001).

The Snail Kite is uniquely adapted to rely almost exclusively on the apple snail (*Pomacea paludosa*) for its dietary requirements. This renders the Snail Kite extremely dependent on the availability of apple snails in sufficient populations to support foraging (several other species include the apple snail in their diets as well). In turn, the apple snail is dependent upon shallow wetland habitat with long hydroperiods and a water surface not obstructed by dense vegetation. The apple snail inhabits emergent vegetation and can breathe underwater through gills or extend a siphon to breathe air directly through lung-like structures. It spends a majority of its time at or near the water surface, and its eggs are deposited a few inches above the water surface on plant stems. When they hatch they must enter water immediately and adults must live near a permanent source of water (Lodge, 1994).

Thus, nesting, forage, and cover requirements of the Snail Kite and wading birds include water clarity, native plant communities in densities that do not obstruct sight-foraging ability, and water levels or hydroperiods favorable to prey items such as the apple snail.

Metric 4G: Given the number of factors that determine the quality and abundance of habitat and forage base needed to support the Snail Kite and wading birds, the metric for this performance measure is a qualitative assessment of nesting/nursery and forage quality. Note that apple snails are very dependent on water level and hydroperiod, which cannot be significantly impacted by any sediment management alternative (see performance measure 5D).

Target 4G: The target for this performance measure is that an alternative is to improve or, at a minimum, have no net impact on the habitat or forage base of the Snail Kite or wading birds.

Method 4G: Based on available data, case studies, and any other relevant information, the likelihood of benefits (or impacts) from a given alternative will be estimated on a simple probability scale. Factors to be considered include water clarity, native plant community structure, plant densities as a function of potential to obstruct sight-foraging ability, and water levels or hydroperiods favorable to prey items such as the apple snail.

Score 4G: A rating of 5 means a high probability for positive impacts (benefits/enhancements) on the habitat and forage base of the Snail Kite and wading birds, a rating of 3 means an estimated no net impact is expected, and a rating of 1 means a high probability of unacceptable adverse impacts.

3.6 Goal 5: Maximize Socioeconomic Benefits

3.6.1 Performance Measure 5A: Maximize Regional Socioeconomic Benefits

5A: Maximize Regional Socioeconomic Benefits	
Rationale 5A:	The socioeconomic effects on the lives of the region's citizens is an important consideration when evaluating project alternatives.
Metric 5A:	Data on economic activity and employment, customized to the Lake Okeechobee region.
Target 5A:	No effect or a beneficial socioeconomic effect.
Method 5A:	Defining and tracking dominate economic activities and employment in the entire region and sub-regions using two digit SIC codes and sales tax data.
Score 5A:	Higher score means an increase in combined economic and employment levels.

Rationale 5A: “Socioeconomic Status refers to the combined influence of income, occupation, education, material possessions, cultural tastes, and prestige on social ranking” (Bidwell and Vander Mey, 2000). Although we are not concerned with “status” in this project, the definition provides guidance. The “influence of income, occupation, [and] education, ...” must be taken into account when assessing socioeconomic effects. This project will focus on income and occupation because the time frame of most sediment management alternatives is too short to greatly effect education levels.

The Central and Southern Florida Project Comprehensive Project Review Study (Restudy; USACE, 1999a) identifies six economic activities as being potentially affected by Everglades water management activities. The Restudy focuses on the entire Everglades region and the long-term effects of construction expenses and changes in water levels and water quality on all of south Florida, while this feasibility study is primarily concerned with the relatively short-term effects of sediment management activities on Lake Okeechobee and the immediate surrounding area. It is necessary though to maintain a common basis among all the economic analyses carried out in District-sponsored projects; therefore, this study will use four of the six economic sectors identified in the Restudy as guides in choosing economic activities. Specifically, the focus will be on the agriculture, commercial navigation, recreation, and commercial and recreational fishing sectors.

These four measures alone, however, are not sufficient to fully define the economic and employment effects in the region surrounding Lake Okeechobee. That region, for purposes of this analysis, is composed of Glades, Hendry, Martin, and Okeechobee counties and the western-most portion of Palm Beach County. The 1998 Florida Statistical Abstract (Bureau of Economic and Business Research, 1998) indicates that while approximately 44% of the region's employment is in the agricultural/forestry/fishing sector, the retail, service, and manufacturing sectors constitute an additional 44%. These sectors are not adequately covered by the four items identified from the Restudy and any measure of socioeconomic impact to the region would be incomplete without considering them.

Metric 5A: Data on economic activity and employment will be collected by relevant 2-digit Standard Industrial Classification (SIC) codes to measure changes in the volumes of dollar flows and number of jobs caused by each alternative. Current year estimates for each selected SIC category will be obtained from Claritas, Inc., an economic data company that has provided data to commercial, retail, industrial, and advertising companies and governmental entities for over 25 years. Claritas, Inc. collects data from state and federal governmental sources, established financial clearing houses such as Nielsen and Dun & Bradstreet, industry trade associations, and single sector data sources such as NDS Business Facts and InfoUSA. The data are collected, edited, cross-referenced, and cross-checked, and then segmented into useful geographical subdivisions. The data will be customized to the Okeechobee region based on zip code or municipal geographical definitions, whichever is more specific.

These data will be augmented by retail, commercial, and property tax data from the State Department of Revenue, through the Bureau of Economic and Business Research. Three to five years of historical data will be gathered and matched to the current year SIC data. While the exact SIC codes have not yet been selected, the following table (Table 5) presents relevant examples, many of which will ultimately be included in the analysis.

Table 5 – SIC Codes for Alternative Analysis

Sector	SIC Code	Business Description
Agriculture		
	01	Agricultural Production – Crops
	02	Agricultural Production - Livestock
	07	Agricultural Services
	08	Forestry
Fishing and Tourism (recreation & recreational fishing from the Restudy)		
	09	Fishing, Hunting, and Trapping
	44	Water Transportation
	45	Transportation by Air
	58	Eating and Drinking Places
	70	Hotels and Other Lodging Places
Retail Trade		
	52	Bldg. Mat'rl/Garden Sup./Mob'l Homes
	53	General Merchandise Stores
	54	Food Stores
	55	Auto Dealers and Gas Service Stations
	56	Apparel and Accessory Stores
	57	Home Furniture/Furnishings/Equip.
	59	Misc. Retail
Service		
	72	Personal Services
	73	Business Services
	75	Auto Repair, Services, and Parking
	76	Misc. Repair Services
	78	Motion Pictures
	79	Amuse. & Recr. Serv. (ex. Movies)
	80	Health Services
	86	Membership Organizations
	87	Engin./Acct./Res./Manag./Related Services
	88	Private Households
	89	Misc. Services
Manufacturing		
	20	Food and Kindred Products
	24	Lumber & Wood Products (ex. Furniture)
	26	Paper & Allied Products
	28	Chemicals & Allied Products
	31	Leather & Leather Products
	32	Stone, Clay, Glass, & Concrete Products

Target 5A: Alternatives that either do not affect or have a beneficial effect on regional socioeconomics are preferred.

Method 5A: The economic and employment data will be collected for each sector for the year 2000. A simple correlation matrix will be created, containing all relevant two-digit SIC industries. Coefficients will be based on historical sales tax data, while the Statistical Package for the Social Sciences (SPSS) will be used to estimate coefficients and growth trends. The correlation matrix will provide for a quantitative assessment of the region's socioeconomic strength in terms of the economic activity and employment levels of the region's salient commercial, industrial, and retail activities. When the 2001 economic and employment data become available, the matrix will be recalibrated.

The key output from the correlation matrix will be base projections of the Lake Okeechobee region's economic and employment levels (the composite of the economic sectors and SIC activities included) if no sediment management activities were undertaken. To the degree that they are useful, estimates can also be extracted for each of the economic sectors (e.g., agriculture, fishing and tourism, retail trade), as well as total estimates.

These base projections of the economic activity that might be expected with no sediment management activities will also factor in general population growth, state economic growth, and inflation estimates. In addition, because of the use of historical tax data, the base projections will not be simple totals of each sector; rather, sector interrelationships will be calculated so that the economic interactions in the Lake Okeechobee region (as defined above for this study) will be taken into account.

The data used to construct the correlation matrix must be highly specific to the Lake Okeechobee region. County-based data will not support an accurate calculation of the factors included. This can be easily understood by noting that the Belle Glade area represents perhaps 10% of Palm Beach County's total population and economic activity. The data used will be zip code-level data (or municipal where possible) allowing a concise estimate of the region's socioeconomic activity.

An additional benefit of using zip code-level data is that economic sub-regions of the Lake Okeechobee region can be defined and modeled. As a result, the evaluation of alternatives can be specific to given sub-regions showing, for example, that “Alternative A” has a large effect on the Clewiston area but no effect on the area around the City of Okeechobee. This flexibility will be useful in performance measure 5B, discussed below, and in other ways as the project proceeds.

When the final sediment management alternatives are ready for socioeconomic evaluation, the likely impact of each alternative on the primary and secondary economic activities will be identified. For example, the primary effect, defined as the projected local expenditures associated with the alternative (e.g., temporary housing, local purchase of construction materials and services, etc.), will be identified first. Then, any secondary effects on current local commercial activities such as tourism, transportation, and agriculture will be estimated. These estimates will be used to adjust the data in the correlation matrix, and new economic and employment projections will be calculated for each alternative. Each alternative's likely effects on economic and employment activity will be compared to the no-action base case estimate to define that alternative's estimated impact.

Implicit in this evaluation is the effect of an alternative on land use. If, for example, land around the lake is needed for staging equipment or dewatering sediment, this change in use will be reflected in shifts in employment from the base scenario (i.e., two gas stations and one restaurant close in the geographic area supporting the staging or dewatering).

Score 5A: The absolute and percentage measures of the effects of each alternative will be calculated and reported along with a score of 1-5. Higher scores will indicate a net increase in combined economic and employment levels. Depending on the alternative evaluated, it may be possible to separate out short- and long-term economic effects. In those instances, two scores will be reported using the same scale, method, and metric for each analysis.

3.6.2 Performance Measure 5B: Minimize Environmental/Social Inequities

5B: Minimize Environmental/Social Inequities	
Rationale 5B:	Alternatives should distribute any negative or positive impacts equally across the citizens of the affected area.
Metric 5B:	Data on economic activity and employment, customized to the Lake Okeechobee region.
Target 5B:	Uniform distribution of economic/environmental impacts.
Method 5B:	Defining and tracking dominate economic activities and employment in the entire region and sub-regions using two digit SIC codes and sales tax data.
Score 5B:	Higher score means impacts distributed evenly.

Rationale 5B: "[Environmental equity is] an ideal of equal treatment and protection for various racial, ethnic, and income groups under environmental statutes, regulations, and practices applied in a manner that yields no substantial differential impacts relative to the dominate group..." (University of Michigan, 1997). An important aspect of minimizing regional socioeconomic impacts is to attempt to distribute any negative or positive impacts equally across the citizens of the affected area.

As discussed in rationale 5A, the Lake Okeechobee region is composed of several population concentration areas (centering on the cities of Okeechobee, Indiantown, Pahokee, Belle Glade/South Bay, Clewiston, and Moore Haven) and the Brighton Indian Reservation; a possible total of seven sub-regions. Using zip code-level data, the final number of sub-regions will be determined by analysis of the socioeconomic data. Each of these sub-regions will have differing socioeconomic characteristics. Regardless of the socioeconomic differences, to the extent possible, negative or positive impacts, that cannot in some way be mitigated, should be distributed as evenly as possible across the various geographical sub-regions.

Metric 5B: The economic activity correlation matrix described in performance measure 5A will be employed to measure environmental equity. Because the correlation matrix will define socioeconomic sub-regions, it can be used to calculate the economic and employment scores for those sub-regions as well as for the entire area. The sub-region scores can be used to identify areas of potential environment/social inequity.

Target 5B: Alternatives that have uniform economic/environmental impacts across the region are preferred.

Method 5B: After the correlation matrix is specified and the base "business as usual" projections for the region as a whole are made, sub-region matrices will be defined and base projects for the sub-regions will be generated. In a manner similar to the assessment of the region as a whole, the negative or positive effects of each alternative will be determined. The impact of each alternative on each sub-region will be measured. The target, as stated above, will be that any negative effects that cannot be otherwise mitigated (or positive effects) will be evenly distributed across the geographic region.

Score 5B: The absolute and percentage measures of the effects of each alternative will be calculated and reported along with a score of 1-5. Higher scores will indicate that impacts are distributed evenly across sub-regions.

Note: Because this project is a feasibility study where sediment management options/alternatives are being evaluated on the basis of technical merit, environmental justice, per se, is not included as a performance measure. However, if or when the District and other interested parties select an alternative for sediment management and begin the planning stages for implementation, the District will conduct a detailed environmental justice analysis specific to the selected alternative at that time, if required.

3.6.3 Performance Measure 5C: Maximize Community Acceptance

5C: Maximize Community Acceptance	
Rationale 5C:	Community acceptance is an integral component of the project. A high degree of community acceptance could lower the potential for legal challenge.
Metric 5C:	Estimated degree of community acceptance and potential for legal challenge.
Target 5C:	High degree of community acceptance and low potential for legal challenge.
Method 5C:	Qualitative assessment of implementation of outreach plan and analysis of comments received; potential for legal challenge assessed through review of applicable cases and comments received.
Score 5C:	Higher score means greater degree of community acceptance and lower potential for legal challenge.

Rationale 5C: Community acceptance or buy-in to the process of selecting an alternative is an important component of this project and will be a function of the degree of public and interagency involvement, as well as the attention given to comments submitted throughout the project. As such, an active outreach effort is an integral component of the project and will be used to ascertain community and interagency acceptance. An indirect measure of community and interagency support and the overall implementability of an alternative is the potential for a legal challenge. Given the potential size and complexity of alternatives to reduce internal loading of phosphorus in Lake Okeechobee (many of the alternatives for reducing the internal loading of phosphorus in Lake Okeechobee could be precedent setting in terms of their size and scope) and the diverse nature of the stakeholder groups, the potential for legal actions may be present for all alternatives considered within the feasibility study.

Metric 5C: The estimated degree of public and interagency acceptance for an alternative, and the potential for legal challenge.

Target 5C: Alternatives with a high degree of community/interagency acceptance and a low potential for legal challenge are preferable.

Method 5C: A qualitative rating of public and interagency acceptance will be assigned to each alternative based on feedback provided through the outreach process and the potential for legal challenge. The outreach process, designed to encourage public and interagency participation in the development of the

Lake Okeechobee Sediment Management Feasibility Study, is described in detail in the Public and Interagency Outreach Plan (November, 2000). Highlights of the outreach plan include the public and interagency staff meetings planned during each project task, use of the project web site (www.sfwmd.gov/org/wrp/wrp_okee/projects/sedimentmanagement.html), and publication of periodic fact sheets. The process for "getting the word out" about the public and interagency meetings begins 60 days prior to the meetings and includes direct mailings, newspaper ads, targeted e-mails and phone calls, and postings on the project web site. Comments and inquiries received from participants at the meeting along with input gathered throughout the process will be entered into a database, then analyzed and used directly to determine how best to address the problem of internal phosphorus loading. Public and interagency acceptance is a key criterion that will be used to evaluate the various sediment management options, and the nature of comments, inquiries, and input gathered during the process will be useful in judging the relative level of community acceptance. The potential for legal challenge will be assessed for each alternative by reviewing current and/or prior legal challenge(s) to actions taken or contemplated for Lake Okeechobee, or for similar lakes or restoration approaches.

Score 5C: A higher score means a greater degree of community acceptance and a lower potential for legal challenge.

3.6.4 Performance Measure 5D: No Impacts on Water Supply and Lake Operations

5D: No Impacts on Water Supply and Lake Operations	
Rationale 5D:	Lake Okeechobee plays a critical role in water supply for all of south Florida, and management of lake levels is optimized to produce multiple benefits.
Metric 5D:	Lake stage, in feet.
Target 5D:	No adverse effect on water supply or lake operations (maintain 12'-15' lake stage).
Method 5D:	Measurement of potential impacts on water supply against requirements outlined in appropriate reports and schedules.
Score 5D:	Higher score means no adverse impact.

Rationale 5D: Lake Okeechobee plays a critical role in providing water to all of south Florida. Water levels in Lake Okeechobee are managed for multiple purposes, including water supply, flood control, navigation, and environmental protection. Operational guidelines are optimized to the extent possible to benefit natural resources of the lake and restore natural hydroperiods and flows without adversely impacting flood control, water supply, or navigation. The largest use of water from the lake is agricultural, primarily in the Everglades Agricultural Area, and also along the St. Lucie Canal and Caloosahatchee River. In addition, a major utility company draws water from the St. Lucie Canal, small communities obtain water from the C-43 Canal and the Caloosahatchee River, and the M Canal and the L-8 Canals provide water to the City of West Palm (see Figure 1). Water obtained directly from the lake is used by five small urban communities around the lake. Water from the lake also provides aquifer recharge for the coastal communities of south Florida during prolonged droughts. Water from the lake is also important for sustaining ecological function in the Water Conservation Areas and Everglades National Park, and sufficient flows must be provided to the St. Lucie and Caloosahatchee estuaries in the dry season to prevent excessive salinity that is harmful to biotic communities (SFWMD, 1997). An adequate supply of lakewater for agricultural, potable water, and ecological purposes must be maintained. Alternatives cannot create conflicts with the implementation of water supply development options outlined in the LEC Plan (SFWMD, 2000c).

Metric 5D: Lake stage, in feet.

Target 5D: No adverse effect on the water supply, operation of Lake Okeechobee, and maintenance of lake stage between 12 and 15 feet. Preferred outcome of an alternative would maintain lake stage and other operational parameters within the most current regulations/strategies as developed in the SWIM plan, LORSS, CERP, and the LEC Plan. In addition, alternatives should cause no reduction in the level of certainty from the LEC Plan (1 in 10 drought year level of certainty).

Method 5D: Alternatives will be evaluated for their potential impact on water budget for lake storage requirements, minimum lake levels, and the environmental needs of the water conservation areas, the Everglades, and downstream estuaries. The water management requirements as governed by the most updated version of the SWIM Plan (SFWMD, 1997), LORSS (USACE, 1999b), the District's LEC Plan (SFWMD, 2000c), and the minimum flows and levels (MFLs) as discussed in the Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer report (SFWMD, 2000a) will serve as the basis of measurement.

Score 5D: Higher score means no adverse impact on water supply or lake operations.

3.7 Summary

Table 3 summarizes the goals, performance measures, and potential impacts for evaluation of sediment management alternatives. The goals are to maximize water quality improvements, maximize engineering feasibility and implementability, maximize cost effectiveness, minimize environmental impacts, and minimize socioeconomic impacts. In Task 4, Evaluation of Alternatives, all the potential sediment management alternatives will be evaluated with regard to what extent they can achieve the five overall goals. Results of the evaluation process will be passed on to the District, who, with input from the public and other agencies, will balance the relative positives and negatives of each alternative and then select the best overall course of action for addressing internal loading of phosphorus in Lake Okeechobee.