Restoration Strategies Science Plan

Detailed Study Plan

Data Integration and Analysis
11/30/2020

Overall Study Plan Summary

The purpose of this Data Integration and Analysis Study (Data Integration Study) is to synthesize and summarize results from the Restoration Strategies Science Plan (RSSP) Studies, and other STA scientific activities, to provide a comprehensive understanding of phosphorus (P) dynamics and factors affecting Everglades Stormwater Treatment Area (STA) reduction performance, and to develop STA design, operation and management guidance to achieve optimal STA performance. To accomplish the Data Integration Study, a number of tasks will be performed, including 1) review and summarize results from RSSP reports and publications as well as other relevant STA reports, 2) review and analyze STA and RSSP study nutrient, biological and ancillary data including: P, nitrogen (N), ions, pH, conductivity, temperature, flow, light, enzyme activity, chlorophyll, plants, animals, and soils, 3) continued development of STA P models and/or development of new models (empirical and deterministic) to support understanding of P dynamics in the outflow regions of the STAs, 4) determine missing relevant information and methods through a data gap analysis and 5) development of a guidance document to provide potential STA design, operation and management strategies to attain lower total phosphorus (TP) discharges to meet the water quality based effluent limit (WQBEL) at the STA outflows. STA scientists will use statistical analyses and modeling strategies to complete these tasks.

Basis for the Project

Key Science Plan Question Study Plan Addresses

- How can internal loading of P to the water column be reduced or controlled, especially in the lower reaches of the STAs?
- How can the biogeochemical or physical mechanisms, including internal flux of P, be managed to further reduce SRP, PP, and DOP concentrations at the outflow of the STAs?

Science Plan Sub-Questions Study Plan Addresses

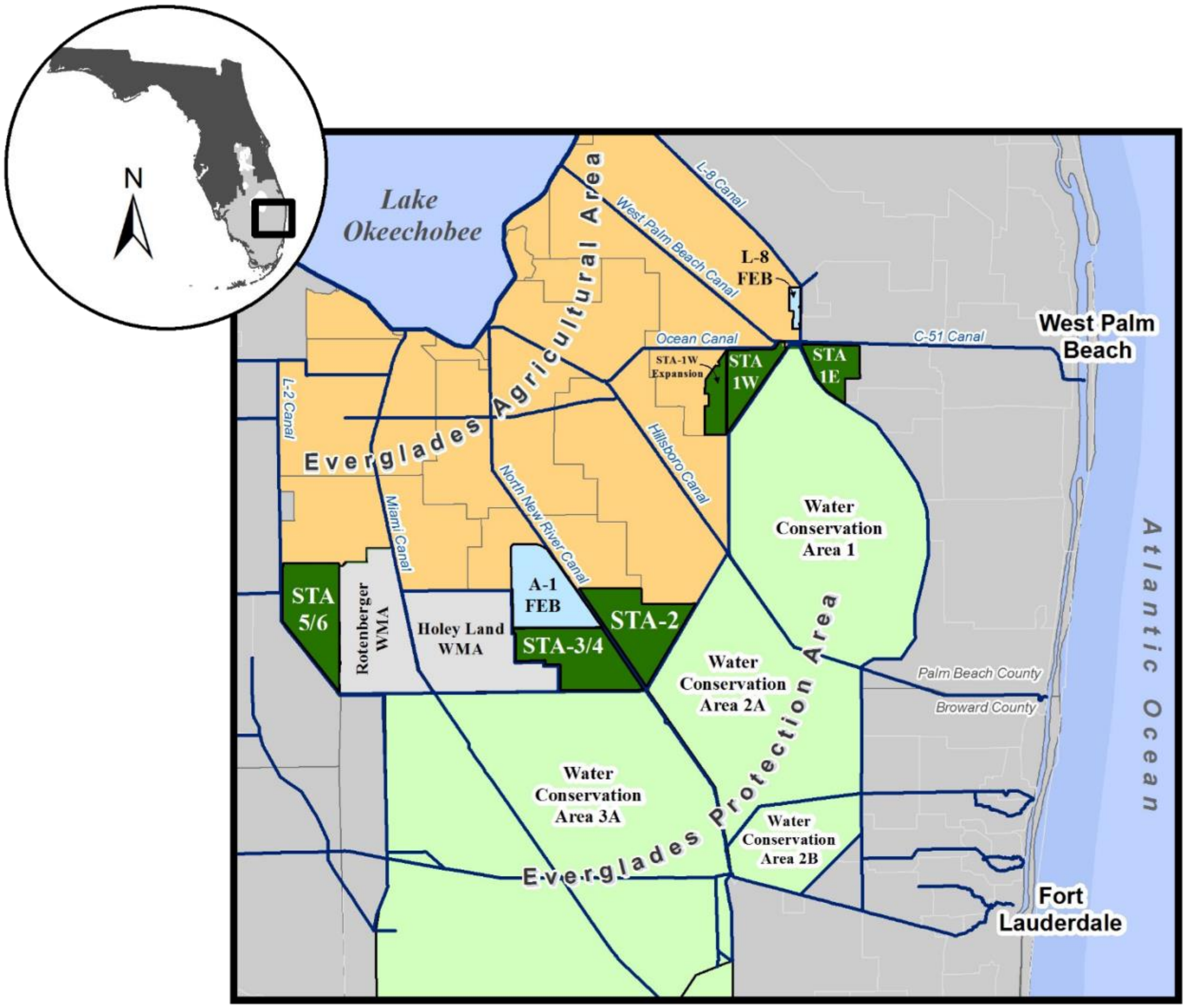
- What are the sources, forms, and transformation mechanisms controlling residual P pools within the STAs, and how do they compare to the natural system?
- What is the role of vegetation in modifying P availability in low P environments, including the transformation of refractory forms of P?
- Are there design or operational changes that can be implemented in the STAs to reduce particulate and dissolved organic phosphorus in the water column?

Background /Literature Review

The five Everglades STAs (Figure 1) were constructed to reduce TP loads to the Everglades

Protection Area (EPA), which is a key factor for Everglades restoration. Two Flow Equalization Basins (FEBs: A-1 and L-8) were constructed to support P reduction by STAs through attenuation of peak flow events and to reduce STA dry-out..

Figure 1. Map of the STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6) and the FEBs (A-1 and L-8) in relation to the Everglades Agricultural Area, C-139 Basin, EPA, and other landscape features of South Florida



Since inception, the STAs combined have reduced TP loads by 77% and achieved an average outflow TP concentration of 31 µg/L (SFER Chapter 5B, Table 5B-1; Chimney et al. 2020).

Consent orders, associated with Florida Department of Environmental Protection (FDEP) permits for these STAs, established a stringent WQBEL for TP concentration discharged from the STAs into the EPA (FDEP 2012a, 2012b, SFWMD 2012). The Restoration Strategies Regional Water Quality Plan (Restoration Strategies; SFWMD 2012) was established by the South Florida Water Management District (SFWMD or District) to achieve this WQBEL in part through implementation of the RSSP. This RSSP is a framework to develop, implement, and coordinate studies that investigate factors affecting STA treatment performance of P. Results from RSSP studies support the design, operation, and management of STAs to achieve compliance with the WQBEL.

A large amount of data have been collected since the inception of the first STA in 1994 and more recently, with the implementation of the Science Plan (SFWMD, 2013, 2018). Science Plan studies vary in scope and complexity. Of the 17 Studies initiated by the RSSP, 7 have been completed and 10 are ongoing (Table 1). In addition, several new studies are being developed. All studies except for the Data Integration Study, should be completed by the end of 2023. The goal of the Data Integration Study is to develop a comprehensive description of P dynamics and factors affecting Everglades STA performance through reviews and analyses of Science Plan and STA Study reports, publications, and data. The Data Integration Study will synthesize major conclusions of each study, provide information to develop and/or improve current and new phosphorus models, determine any data gaps and provide methods to fill the gaps and ultimately develop a guide for STA design, operation and management to achieve the WQBEL.

This Data Integration Study was developed from the Data Integration Plan (SFWMD et al. 2018), which was a substudy of the Evaluate Phosphorus Sources, Forms, Flux, and Transformation Processes in the Everglades Stormwater Treatment Areas Study (PFlux Study). The Data Integration Plan was developed to synthesize and develop methods to support STA operations and management. The Plan included a table of questions to be evaluated using data from the P Flux Study, the Periphyton-based STA (PSTA) Study, and other Restoration Strategies Science Plan studies related to well performing STAs.

Results of the Data Integration Plan were presented in two reports: Data Integration and Analyses (DB Environmental Inc., 2019) and Data Integration and Synthesis (University of Florida, Florida 2019). The DB Environmental report analyzed several concepts relating to achievable TP flow weighted mean concentration (FWMC) in the STAs including P cycling, internal P loads, P accumulation, and movement in soils. The University of Florida report focused on the relationship of the data values to different regions of the STAs, e.g. submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV) regions process P in different ways. The University of Florida report also documented the development of a spiral model that simulates the major components of P in the STAs. These reports are a starting point for the Data Integration Study.

Table 1. List of Restoration Strategies Science Plan Studies (2013-2020)

	Study Name	Status
1	Operational guidance for FEB and STA regional operation	Completed in 2017
2	Influence of canal conveyance on P concentrations	Completed in 2017
3	Evaluation of sampling methods for TP	Competed in 2017
4	Periphyton based STA performance, design and operational factors	Completed in 2018
5	Evaluation of rooted floating aquatic vegetation	Completed in 2018
6	P forms, flux and transformation processes	Complete in 2020
7	STA water and P budget improvements	Complete in 2020
8	Vegetation inundation depth and duration sustainability	Nearing Completion
9	Soil amendments to control P flux	Ongoing
10	Factors for formation of floating tussocks	Ongoing
11	Effects of faunal species on P cycling in the STAs	Ongoing
12	Improving resilience of submerged aquatic vegetation	Ongoing
13	L-8 FEB operational guidance	Ongoing
14	Periphyton and phytoplankton P uptake and release	Ongoing
15	Biomarker study	Ongoing
16	Data integration study	Initiated 2020
17	P dynamics Study	Approved

Study Plan Tasks

The overall Tasks of this Data Integration Study are:

1) Document Review - develop Report(s) that integrate(s) major findings from STA research and Science Plan studies to define P movement and transformations throughout these constructed wetlands and how the various components interact to support or inhibit P reduction from the water column.
2) Data Analyses - analyze data to support the reports and modeling efforts
3) Modeling - develop and/or update models that describe STA P dynamics at various

functional and spatial scales. Information from RSSP reports and data will be used to enhance existing models and/or create new models.

4) Gap Analysis - create a gap analysis that defines important missing data and methods to fill the gaps through literature and/or statistical methods using Science Plan and/or STA data
5) Guidance Document - develop a guidance document that supports the design, operation, and management of STAs to achieve compliance with the WQBEL.

Hypotheses

The STAs can be managed to achieve WQBEL TP concentrations in the outflow with knowledge and understanding of the different factors and processes that collectively influence STA treatment performance.

Low outflow P concentrations can result from

1. Low hydraulic loads and moderate water levels
2. Low P loads
3. Low inflow P concentrations
4. Healthy emergent and submergent aquatic vegetation and periphyton

Factors that impede low outflow P concentrations

1. Internal (soil) loads
2. Fauna (fish macrofauna and birds)
    a. Excretion
    b. Bioturbation
3. High water depths (including duration aspects)
4. Weather events (hurricanes, droughts)
5. Short circuits

Conceptual Model

Conceptual models were presented in the Data Integration Plan (SFWMD et al. 2018). The more complex conceptual model (Figure 2) was used to develop a matrix to define the direct interactions observed within the various Science Plan studies or assumed based on best professional judgement (Table 2). This conceptual model and matrix will support the analyses and synthesis of Science Plan study reports and data. The goal is to fill each cell of the matrix that designates an interaction with a number, range of numbers or mathematical relationship that describes the interaction. This information can be used for further improvements of models and can be analyzed to suggest the more significant direct relationships and the most significant pathways that affect P dynamics in these STAs.

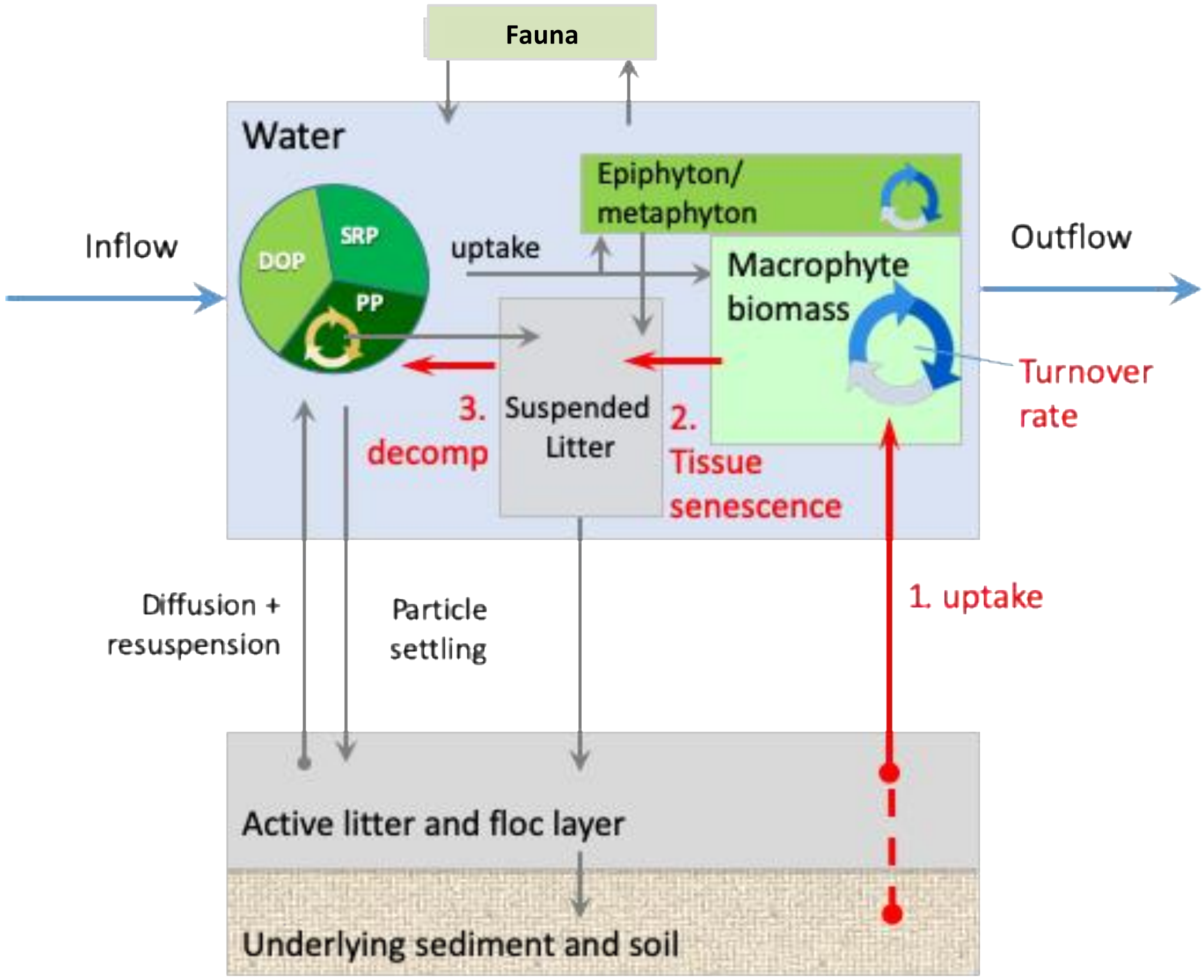


Figure 2. Conceptual model of phosphorus transformations and movements in the STAs

Table 2. Matrix of direct interactions (represented as an X, either through movement of P, affecting the movement of P, or affecting water conditions), from the major components (see descriptions below) identified within the STAs and the STA conceptual model (Figure 2)

From\To	Topo	Velocity	Water Depth	Water column Phosphorus	EAV	SAV	PERI	Fauna	Litter	Floc	RAS	Pre STA Soil	Outflow
Inflow		X	X	X									
Topography		X	X		X	X		X		X	X		
Velocity			X		X	X	X		X	X	X	X	X
Water Depth		X			X	X	X	X	X	X	X		X
Water column Phosphorus					X	X	X		X	X	X		X
EAV	X	X		X		X	X	X	X		X	X	
SAV	X	X		X			X	X	X		X	X	
PERI				X	X	X		X	X	X			
Fauna	X			X	X	X	X		X	X	X	X	
Litter	X			X			X			X			
Floc	X			X			X				X		
RAS	X			X								X	
Pre STA Soil				X							X		
Outflow		X	X										

Inflow	Flow into the STAs Primarily occurring at structures Transports P, creates velocity near structures, increases water column depth (head) which affects downstream flow and velocity.
Topo	Topography (Topo) includes large scale features (remnant farm roads, and canals that were not removed) and small scale microtopography such as holes, and mounds from plant growth, organic matter accumulation.

Velocity	Water movement, affected by structure flow rate, topography, and wind, affects particle resuspension/settling, sloughing of periphyton, uprooting and movement of litter, SAV, recently accreted soils (RAS), EAV, Soil, (respectively under increasing strength primarily due to storm events) .
Water column Phosphorus	P in the STA's water column. Source of P for plants (SAV and Periphyton primarily), storage of P from animal excretion, plant exudation, resuspended particulate and dissolved P from litter, flow, RAS and Soils, water depth
Water Depth	Depth of water in the STAs. It can affect plants. If it is too shallow, plants can die through desiccation or too deep can lead to plant die-off, uprooting and tussock formation. It can affect fauna movement and feeding (indirectly affecting prey distribution). It affects velocity and turbulence which affects resuspension of floc and RAS. Need to include the duration aspect as well.
EAV	Emergent aquatic vegetation (EAV) are rooted plants whose shoots extend throughout the water column. The rigidity and density of the shoots can reduce velocity resulting in enhanced settling of PP. The reduced velocity can reduce the potential for SAV to be scoured. Under dense conditions, EAV produces light-limitation which can reduce SAV growth. Roots uptake P which can be transferred to the shoots and leaves. P and other nutrients can be exuded which may result in periphyton community accumulation that can retain the P or break it down. The process of root uptake could produce, through transpiration, a movement of water from the water column into the RAS. Plant exudate may end up in the water column. Plant death results in organic litter. Plant tussocks can detach from soil and create floating wetlands which can damage surrounding vegetation increase suspended material, create short circuits, block structures.
SAV	Submerged aquatic vegetation (SAV) can reduce P from the water column directly or from soils (if rooted). If the plant is floating (FAV), severe light limitation may occur in the water column thereby affecting SAV health and sustainability. When dense, SAV can affect water velocity. If the shoots and leaves have enough structural integrity periphyton can grow on the surfaces. Exudates to the water column and litter from sloughing and death can be a source of P to the water column. High rates of photosynthesis can produce H_30 which may support abiotic mineralization of DOM and may cause plant death. Photosynthesis can shift the water column pH (as high as 12) removing CO_2 and shifting $CaCO_3$ to $CaPO_4$ and Ca analogs that can trap PO_4 in particulate form that settles out to the soils as marl particles.
PERI	Periphyton (PERI) is the microbial component attached to plants that can reduce P by uptake and can act like SAV and reduce P through increased $CaPO_4$

	coprecipitation. These microbes produce exoenzymes that can cleave organic nutrients for uptake. In addition to algae, periphyton includes bacterial and fungal components that can break down dissolved and organic matter. Under more extreme nutrient depleted conditions, periphyton may effectively sequester nutrients, creating a tight P cycle through the microbial loop.
Fauna	Fauna can be seasonal and/or ephemeral. Fauna can store significant amounts of nutrients. Birds can be a source through excretion or sink through predation and flying out of area before excretion. Fish and birds can affect SAV through herbivory. Fish, alligators and macrofauna can affect litter, floc, soil and RAS (see below) through bioturbation. Excretion to the water column can be significant..
Litter	This accumulated dead plant material may provide surface for periphyton growth. Mineralization of nutrients in litter may be sent to water column and floc. Decomposed litter becomes floc.
Floc	This is accumulated mineralized litter. It may provide surface for periphyton growth. Mineralization of nutrients may be sent to water column and floc and sediments. Aged floc becomes RAS.
RAS	Recently accreted soils (RAS) are developed from consolidated Floc through diagenesis. This material is harder to resuspend than floc. Potential mineralization results in more release of nutrients. Burial of RAS is a long-term reduction storage component.
Pre- STA Soils	Pre-STA soils have been primarily affected by agricultural activities resulting in high nutrient content, which can be released into the water column through diffusion, potential resuspension and mineralization. Not all STAs were constructed on previously farmed soil, therefore those Pre-STA soils may not be high in nutrient content.
Outflow	Outflow is regulated by structures, . Outflow or lack of outflow can affect water depth. It can affect local velocity upstream of structure resulting in increased particulate resuspension.

Detailed Study Plan Description and Experimental Design

The study will be carried out in several workorders to accomplish one or more of the tasks or portions of a task Including report reviews, high level data analyses, model development, gap analyses and guidance (Table 3).

1) Document Review.
2) Data Analyses
3) Modeling
4) Gap Analysis

5) Guidance Document

Table 3. Workorder contracts currently underway as part of the Data Integration Study and Tasks supported

Work order number	Title	Description	Study Plan Task(s) supported
Agreement 4600004075	Data Integration and Analyses: Water, Vegetation and Soil Relationships in the Everglades Stormwater Treatment Areas	Evaluation of soil water and SAV content relationships	2. Data Analyses
460004012-WO05	Integration of DB Environmental Microbiological Studies in Wetlands and Stormwater Treatment Areas of South Florida	Compile and synthesize periphyton research on STAs, WCAs, and Everglades conducted in the past 20 years	1. Document Review 2. Data Analyses
4600004016 -WO05	Comparison of Stormwater Treatment Areas and Water Conservation Area-2A Transect Water Quality Data	Compare and contrast water quality along transects of STAs and WCA2A	1. Document Review 2. Data Analyses
4600004014 -WO05	Data Integration and Analysis: Development of Simulation Models for Everglades Stormwater Treatment Areas (STAs)	Biogeochemistry and CASM model development Phase I. interaction development Phase II. Unit model and CASM demonstration model development Phase III. Tank in Series and CASM model development	1. Document Review 2. Data Analyses
TBD	TBD	Gap Analyses	4. Gap Analyses
TBD	TBD	Guidance Documentation	5. Guidance Document

Detailed Study Plan/ Methods

The goal of this study is to compile and synthesize the large quantity of information attained through the 16 plus studies that have been conducted through the RSSP and other pertinent previously attained STA scientific information. Methods to compile and synthesize the information will rely to a large extent on best professional judgement of Consultant and District Scientists working on the STAs. In addition, numerous analytical, mathematical, and water quality methods shall be used to quantify key components, relationships and processes that affect P reduction in the STAs as a whole and specific flowways in particular such that each flowway and STA can be managed to attain the WQBEL. A guidance document will use these key components, relationships and processes to provide a list of tools and directions for STA design, operation, and management to support and maintain performance to attain the WQBEL. There are five major tasks in this study including 1) Document Review, 2) Data Analyses, 3) Modeling, 4) Gap Analysis, 5) Guidance Document (Table 4).

Table 4. Timeline of Study Plan tasks

Task #	Task	FY2021	FY2022	FY2023	FY2024
1	Document review	X	X		
2	Data Analysis	X	X	X	
3	Modeling	X	X	X	
4	Gap Analyses		X	X	
5	Guidance Document			X	X

Detailed Study Plan Tasks

1) Document Review

Science Study leads will provide final reports and publications from the peer reviewed literature that contain significant results that affect P dynamics in the STAs. The study leads will provide a summary of the major findings to the District's Data Integration Study Lead. The Data Integration Study Lead will compile these publications and summaries and provide them for use by Consultants to develop summary reports of aspects of RSSP including soil, microbial, plant, transect, biogeochemistry and modeling.

2) Data query and historical data analysis

All study data are submitted by the study leads for inclusion in the ERDP or Morpho Data bases. After QA/QC of these data with appropriate qualifications, the District Data Integration Study Lead will review the data to determine if further evaluation by the integration study is warranted. Three specific items will be considered: 1) relationship of the data to water column P concentrations, 2) use of the data to define P reduction rates, community metabolism and P transformations, and 3) use to fill in direct effects matrix.

A set of workorders may be developed for further data analyses. Data will be analyzed primarily by flowway or cell but also may be analyzed among flowways or cells. Analyses may include but are not limited to correlation, T-Test, regression, logistic regression, Principal Components, ANOVA.

3) <u>Modeling</u>

The interaction matrix (Table 1) will be used to support development and/or advancement of new or existing models and to support data gap analyses (see below). In addition to tank-in-series models, spatial scale models will be evaluated to consider spatial scale effects of vegetation, vegetation management, soil, soil management, fauna and fauna management, topography and topographic management.

4) <u>Gap analyses</u>

Completed matrices will be evaluated to determine if significant interactions are missing. Sensitivity analyses from various STA models will be used to determine the importance of specific interactions to the P reduction processes within the STAs. If deemed important and no direct STA data exists for the interaction, various methods will be applied to add the interaction. These may include peer reviewed literature, short term experiments, interpolation or other mathematical methodologies. The method used will be described in the final Gap analysis report.

5) <u>Guidance Document</u>

The study lead along with District scientists and consultants will use the information compiled in the four tasks above to develop a document to provide design, operation, and management guidance for STA performance to achieve the WQBEL. This will likely cover scenarios that are applicable to subsets of flowways based on but not limited to: inflow water quality, vegetation status, topography, water depth, soil quality, hydraulic loading, weather events, and fauna.

Literature Cited

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