DOI-TOC Briefing Paper:
Alternative Operational Strategies to Reduce Refuge Impacts

BACKGROUND

Objective - This briefing paper presents suggested operational approaches that might be adopted to reduce the risk of elevated phosphorus concentrations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). These changes should additionally reduce the risk of excursions beyond interim and long-term total phosphorus levels defined in the Consent Decree. It is important to note that these changes alone are unlikely to achieve our goals of protection and restoration within the Refuge. When compared to construction of major infrastructure additions, these and other operational changes might provide some benefits within a relatively short time frame at relatively modest costs. It is important to consider these operational strategies in the near-term, while STA performance is not yet reliably meeting goals and STA optimization is underway. In the long-term, after STA performance is fully optimized, these strategies can continue to provide an added layer of protection from treatment system disruptions and unusual events.

Timeline - STA-1W became fully operational around June 2000, discharging via pump station G-310 and, to a smaller extent, through pump station G-251. In May 2001, the S-6 pump station discharge was diverted away from the Refuge for treatment by STA-2 and final discharge to WCA-2. This diversion removed a significant source of both water and phosphorus mass loading from the Refuge, and also reduced the demand for water deliveries to WCA-2 through the S-10 gates. The net impacts of this treatment and diversion on refuge hydrology and water quality are not well understood and should be a topic for future hydrologic and water quality modeling analysis. Although the impacts of these changes are not completely understood, it is clear that water quality in the Refuge within the L-39 (Hillsboro) Canal greatly improved following these changes (Figure 1).

Much of STA-1E is now flooded, and STA-1E is nearing or is in a startup status. Soon, the maximum pump capacity discharging to the Refuge will approximately double as pump station S-362, the STA-1E discharge pump station, begins routine operation. Completion of STA-1E represents a significant milestone in the effort to clean up Everglades inflows and restore the Everglades. However, the doubling of instantaneous pumping capacity directed into the Refuge, and the location of the new S-362 discharge adjacent to pristine marsh, coupled with the present reduced efficiency of STA-1W and startup concentration anticipated in proposed permits for STA-1E all serve to heighten concerns about potential increased risk of impact from canal water intrusion. It is, therefore, timely to now consider additional measures that may reduce canal water intrusion and therefore reduce impacts in the Refuge interior.

Conceptual framework - A working hypothesis upon which the proposed operational changes are based is that much of the deleterious impact from pumped stormwater results from intrusion of canal water, often in relatively short-term events. Walker (2004) suggested that these events are analogous to estuarine rising and falling tide events.

Time-series plots of chloride concentration at selected sites in the southern area of the Refuge (Figure 2) are utilized here to examine patterns of canal water intrusion. Chloride concentration provides a useful tracer for canal water movement and mixing because it is, to a close approximation, a conservative material, and because it is elevated in canal water (Figure 2a) and quite low in rain water and rainfall dominated interior sites such as LOX11 and LOX13 (Figure 2b). Patterns of chloride concentration at more impacted sites, LOX12 and LOX14 (Figure 2b), support the hypothesis that canal water does at times intrude into Consent Decree monitoring sites. Qualitative examination of Figure 2b suggests that intrusion may have actually increased in recent years at sites LOX12 and LOX14.

CANDIDATE OPERATIONAL STRATEGIES

This section describes four specific operational strategies that potentially may reduce canal water intrusion and reduce related deleterious impact on the Refuge. Further consideration might identify additional candidate strategies. Prior to implementation, a candidate strategy should undergo a more rigorous evaluation in terms of practical and regulatory constraints, and anticipated positive and negative impacts on the Refuge, other areas of the Everglades, and other stakeholder needs.

➢ More frequent outflow structure water quality sampling

Water quality monitoring at the S-10 and S-39 gates is required by permit conditions. These data are used, however, for a number of non-regulatory purposes. Current sampling relies on grab samples taken at an irregular frequency depending on structure discharge. The sampling protocol at most permitted sites requires grab sampling at least every four weeks, and sampling on the intermediate 2-week date if the structure is flowing on that intermediate date. This protocol results in missing the sampling of many flow events, and results in most samples being collected under no-flow conditions.

From June 1, 2001, to the most recently available DBHYDRO sampling record collected on January 18, 2005, the number of total phosphorus values in DBHYDRO vary from 21 to 63 for these individual sites (see table). This averages from 6 to over 16 samples per year.

Table 1. Total phosphorus sampling history at L-39 structures.

	S-39	S-10A	S-10C	S-10D	S-10E
Number of TP samples in DBHYDRO (6/1/2001 through 1/18/2005)	61	25	21	49	43
Average number of samples per year	16.5	6.7	6.1	13.2	11.6

Data from these sites are used for water quality model calibration and verification, and for loading estimates. Loads of total phosphorus leaving the Refuge are calculated and published each year in the *South Florida Environmental Report* (formerly the *Everglades Consolidated Report*). Because of the frequency of sampling and the fact that most sampling occurs under no-flow conditions, there is considerable uncertainty associated with these load estimates.

Although general spatial and temporal patterns of water quality in terms of total phosphorus and other constituents can be clearly identified from the historic monitoring data collected at structures along the L-39 Levee, the data are not collected at a frequency that supports more detailed studies, including studies targeting development of a better understanding of mechanisms of canal water intrusion. Both SFWMD and Refuge staff have commented that the sampling frequency at these structures results in a high degree of uncertainty in estimates of the concentration time-series.

It is proposed here to initiate a sampling regimen at each of the S-10 gates and at the S-39 gate consisting of flow proportional composite sampling and weekly grab sampling. This enhanced sampling program will result in improved load estimates leaving WCA-1 and entering WCA-2. It will also support model calibration and analysis of canal water intrusion events that transport elevated phosphorus concentrations into the Refuge marsh. Improved understanding of the conditions that lead to intrusion will support future management decisions that optimally protect the Refuge while meeting constraints of water supply and flood control.

- **Improved coordination of inflow pump and outflow gate operations**

It is reasonable to assume that optimal control of outflow gates should be related to real-time pumping and rainfall, and that outflow gate adjustments should be made before significant stage changes have occurred in the Refuge. The desirable speed of reaction to a pumping event can be estimated for specific cases. Consider a situation with the Refuge stage at 15.5 feet (NGVD 29). At this stage, roughly 97,000 acres of the Refuge is inundated (estimated from Fig. 6a in Trimble 1986). If we desire a reaction in gate opening to happen before 0.05 feet of stage change occurs, then the time for 4,850 acre-feet to be pumped into the Refuge provides the critical gate adjustment reaction time. These times are presented in the following table:

Table 2. Relationship between desirable reaction time and total inflow pumping rate at 15.5-foot stage.

Pump rate (cfs)	Time (Days)
500	4.9
1000	2.4
2000	1.2
4000	0.6
8000	0.3

Inflow pump capacity from STA-1W is approximately 4000 cfs. With STA-1E added, capacity approaches 8000 cfs. At these inflow rates it may be impossible to manually operate the outflow gates to coordinate flows during future major storm events. Efficient synchronized operation of the S-10 and S-39 gates and the WCA-1 inflow pumps and structures may necessitate installation of remote operation capability at the S-39 and S-10 gates. It is also recognized that there are significant logistical constraints and organizational obstacles to interagency coordination of operations that must be considered in implementation of this strategy.

- **Delay stage rise until after wet-season rain on Refuge begins**

After examining historic patterns of excursions of the Consent Decree levels, Walker (2004) described mechanisms that may lead to canal water intrusion and circumstances that result in highest probability of excursions (Figure 3). Especially at the beginning of the wet season during rising stages, it is conjectured that phosphorus concentration in the impacted marsh may be elevated by the combination of high phosphorus canal water flowing toward the interior and mixing with water that has elevated concentration due to prior evaporative concentration (distillation) and re-wetting of the soil surface.

It is proposed to consider deferring seasonal increase in stage at the beginning of the wet season to a slightly later time. The objective would be to (1) "rinse" the marsh fringe areas with rainfall for a period of time and either export the initial flush of elevated P water to the rim canal (vs. interior marsh) or allow added time for biotic uptake, and (2) collect rainwater in the interior to a slightly higher water surface elevation (stage) which should counter canal water intrusion (e. g. inflowing tide analogy). Under this operational scheme, the S-10 and/or S-39 gates would operate to hold Refuge stage constant during the first major storm event of the wet season. After interior stage had risen (e.g. 0.2 feet at the 1-9 gage), operations would return to normal.

One potential “rule-of-thumb” that could be used as a basis for an operational rule would be to release water during a drainage basin storm event such that rainfall dominates net inflow to the Refuge. Neglecting evapotranspiration and groundwater recharge, this is:

$$V_{in} - V_{out} < A\,R / 12 \qquad (1)$$

where V_{in} is pumped stormwater inflow volume (acre-ft), V_{out} is outflow volume through structures (acre-feet), R is Refuge rainfall (inches), and A is Refuge inundated area (acres). Rearranging this inequality provides the outflow management rule that at all times during a storm event in the early wet season

$$V_{out} > V_{in} - (A\,R / 12) \qquad (2)$$

Prior to adopting this or a similar altered operational strategy, several factors would need to be fully considered:

- Feasibility – Capacity of the outflow structures is a constraint that should be considered. For example, avoidance of 0.2 feet of stage rise when 1/3 of the Refuge (roughly 50,000 acres) is inundated would require the release of 10,000 acre-feet of water. Over a 10-day period, this would require a 500 cfs release. This is well within the capacity of the outflow structures.
- Water quality in WCA-2 or the Eastern Hillsboro Canal – It is not anticipated that this operational change would have a significant effect on downstream water quality. However, these impacts should be quantified prior to implementation of this strategy.
- Ecological impacts – Impacts on Refuge plant and animal communities should be analyzed prior to implementation.
- Relationship to regulation schedule – It is not envisioned, at this time, that this candidate strategy will require amending or deviating from the Refuge regulation schedule. In order to be implemented as quickly as possible, operations proposed here must be shown to be consistent with the current regulation schedule (Neidrauer 2004). Future consideration of regulation schedule revision should consider additional operational alternatives as described here.

➢ Re-distribution of flows through the S-10 gates

Four gated structures, S10A, C, D, and E deliver water from the Refuge to WCA-2. Historically, total annual flow through these gates (Figure 4a) has varied depending on basin rainfall, water management decisions, and infrastructure changes such as the 2001 diversion of the S-6 pump station discharge. Although the total flow via the S-10 gates must be consistent with a number of constraints including the Refuge and other regulation schedules, the distribution of flow among the gates is not prescribed. The pattern of utilization of the 4 gates has varied (Figure 4b). The S-10E gate was constructed by the State of Florida to provide water to western WCA-2. After the S-10E began discharging in 1985, this additional volume of canal water was delivered to WCA-2 from the western portion of the L-39 Canal. Since mid 1997, these deliveries to WCA-2 using the S-10E have stopped. Since 1997, the S-10A and C gates have delivered slightly more of the volume of discharge than was the case in years when the S-10E was used.

Distribution of flow through the S-39 and individual S-10 gates may influence Refuge marsh water quality. Water quality monitoring in the headwater area of the gates reveals a gradient of total phosphorus often exists from the highest values at the more western S-10E and S-10D, to lowest values at the more eastern S-10A (Figure 1). That is, it appears from water quality monitoring data, that the S-10D discharges more pumped stormwater while the S-10A discharges more rainwater drawn for the Refuge interior. This observed pattern implies that preferentially discharging from the S-10D might reduce impact on the pristine areas of the refuge by bypassing more stormwater south into the already impacted area of WCA-2. The Refuge's hydrodynamic and water quality model will be used, when available, to evaluate alternative gate operation scenarios that may be more protective of pristine Refuge areas. Further analyses associated with this candidate strategy must estimate not only the positive impact on the Refuge, but also quantify any negative impact on WCA-2.

It has also been suggested that intensive field studies associated with controlled gate opening events might support better understanding. Such studies should be considered as soon as practical. When STA-1E becomes fully operational, this proposed strategy should be reexamined and adapted to fit this new condition.

CONCLUSIONS AND ADDITIONAL RECOMMENDATIONS

Operational strategies selected within constraints to reduce water quality impacts and enhance restoration may provide timely benefits without necessitating large financial investments. Although such strategies are unlikely to provide more than a small part of needed improvements, further investigation of these strategies is clearly warranted. It is important to now pursue these strategies aggressively because recent performance of STA-1W has been degraded, and total phosphorus concentration in discharges from STA-1W and STA-1E in the near future are unlikely to be close to the 10 ppb goal.

This paper has not exhaustively examined all operational strategies that may be beneficial. Future consideration should, for example, be given to the possibility of coordinating discharge from STA-1W and STA-1E in an effort to minimize intrusion. Both modeling and monitoring will support this deliberation. Before implementation of any of the candidate strategies presented here, consideration should be given to the adequacy of the monitoring network and models for assessment of the success or failure of the strategy.

Adaptive management is dependent on monitoring and analysis. The initial analyses presented here would not be possible without the legacy of monitoring that is available. As we move forward in efforts to protect and restore the Everglades it is essential that monitoring and modeling efforts continue, and in some cases expand, to support the best management decisions within constraints of practicality and budget.

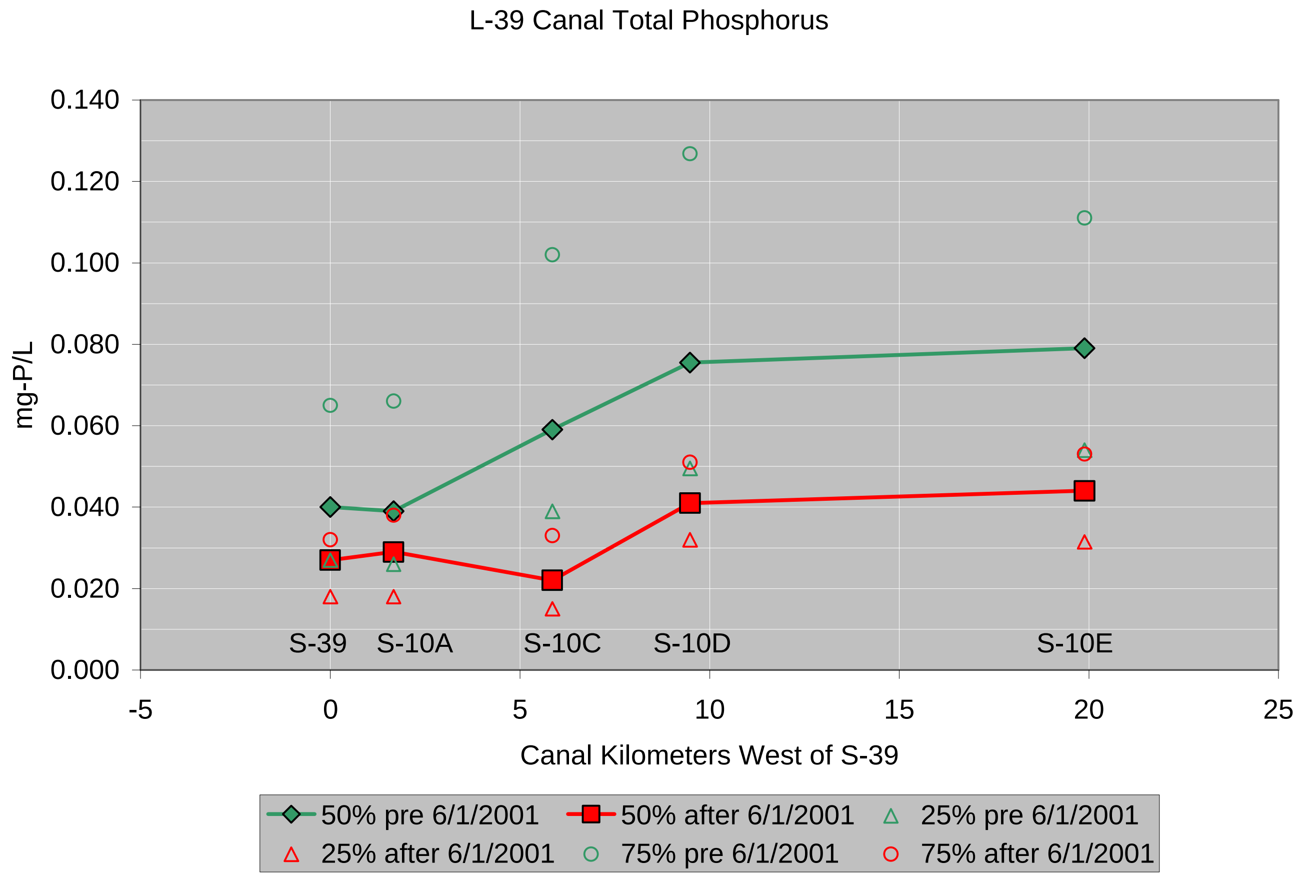

Figure 1. Historic patterns of total phosphorus concentration along the L-39 Canal measured at outflow structures. The figure presents the 50 percentile (median), 25 percentile (1st quartile), and 75 percentile (3rd quartile) for sampling prior-to and after diversion of the S-6 pump (data from DBHYDRO).

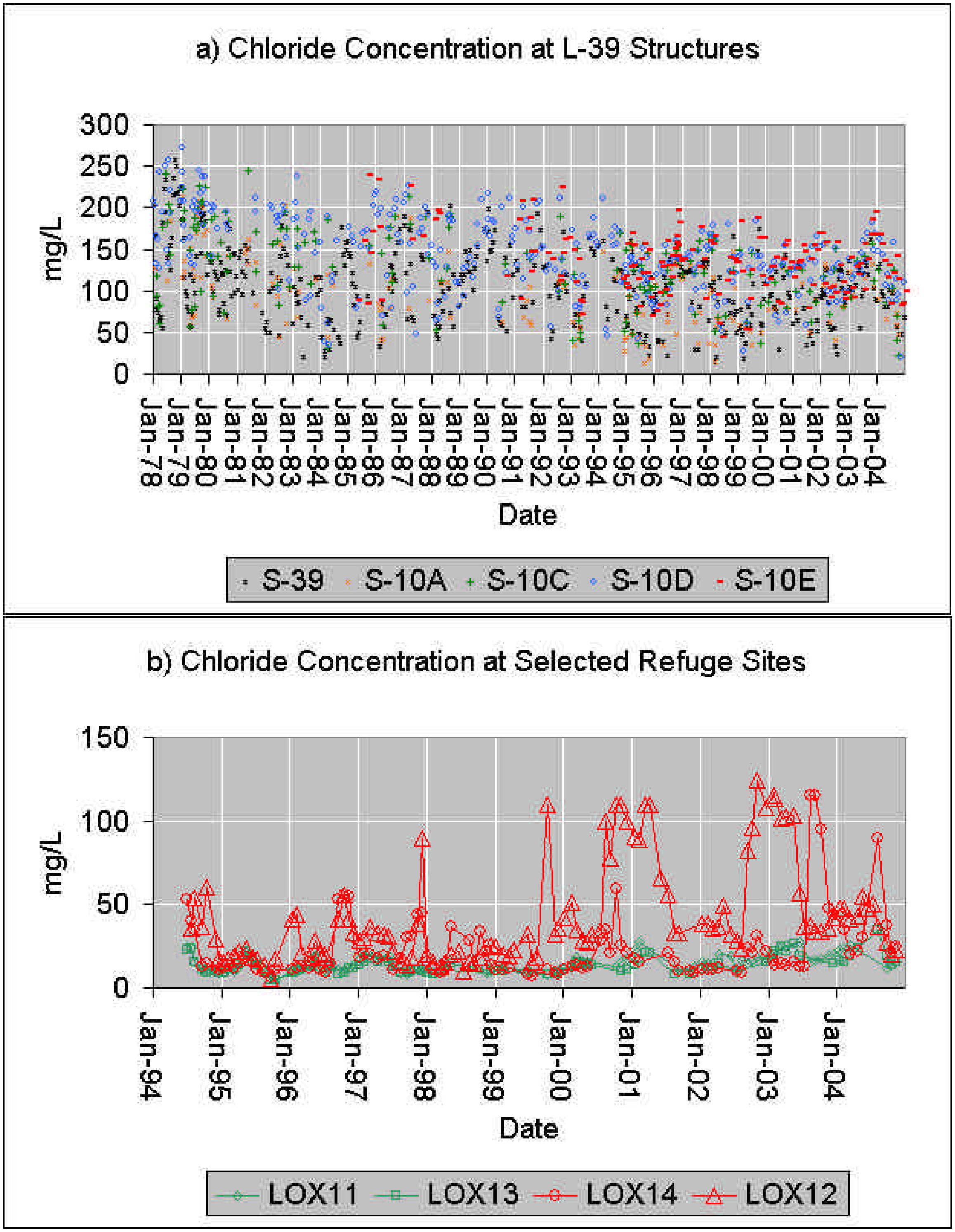

Figure 2. Time series plots of chloride concentration at (a) 5 outflow structures along the L-39 Levee, and (b) at two sites relatively unimpacted by intrusion (LOX 11 and 13), a moderately impacted (LOX 14), and a more heavily impacted site (LOX 12). All sites are in the southern area of the Refuge (data from DBHYDRO).

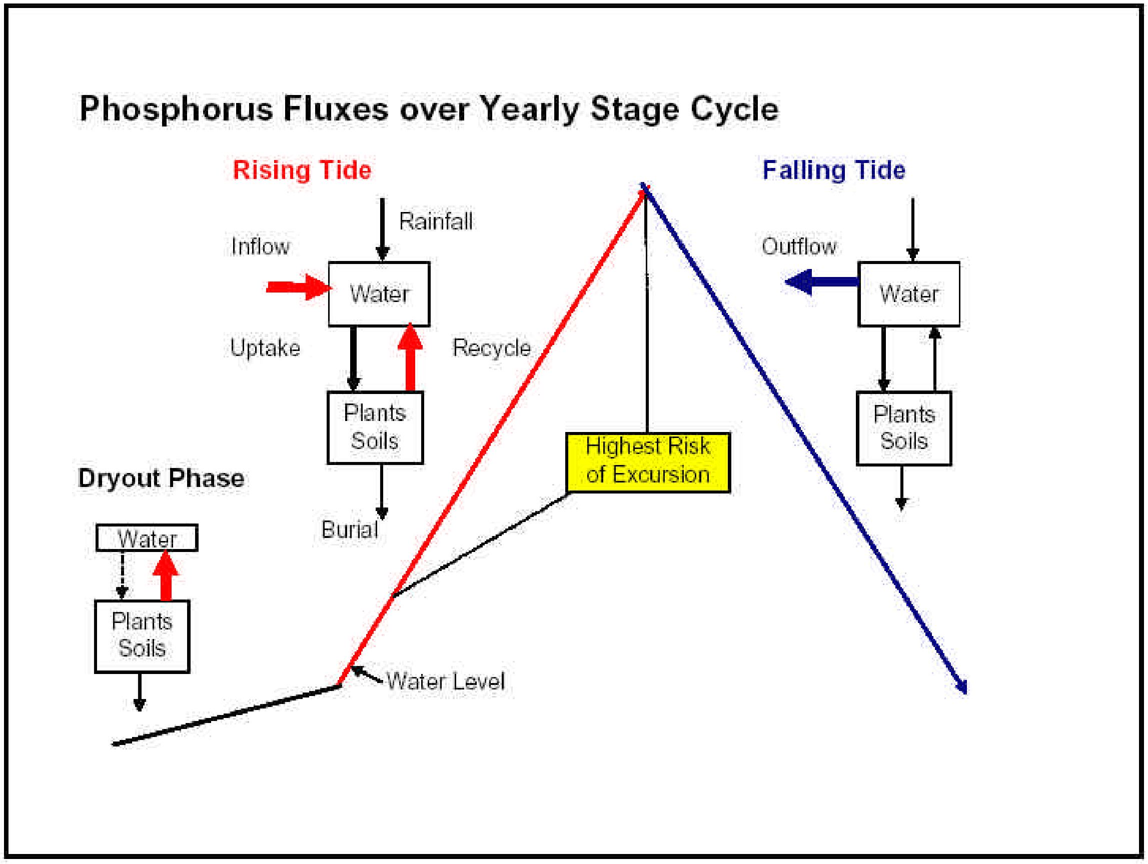

Figure 3. Conceptualization of mechanisms of canal-interior phosphorus exchange, cycling, and excursion risk (Walker 2004).

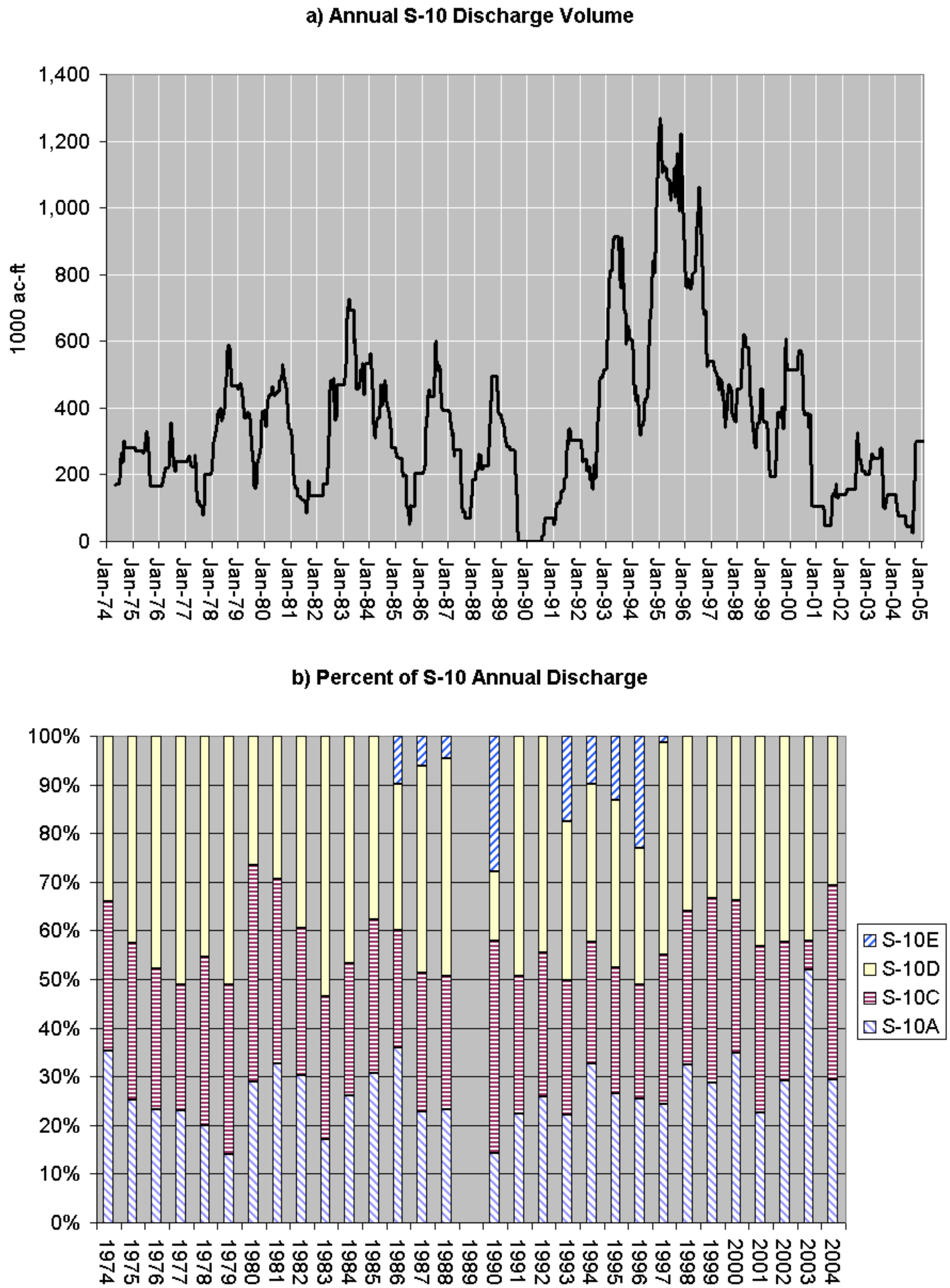

Figure 4. Discharge through the S-10 gated structures over the available period-of-record (data from DBHYDRO). (a) One year rolling total volume, and (b) percent of calendar year discharge volume by gate.

CITATIONS

Neidrauer, C. J. (2004). "Water Conservation Area Regulation Schedules." *available at* <http://www.sfwmd.gov/org/ema/toc/archives/082604/wca_schedules_082604.pdf>.

Trimble, P. (1986). "South Florida Regional Routing Model." *Technical Publication 86-3*, South Florida Water Management District, West Palm Beach, FL.

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