Comments on
"Issue Paper Regarding October 2007 Excursion of Refuge Long-Term Concentrations"

Everglades Program Team
August 5, 2008

Introduction

The Issue Paper (IP, Anonymous, 2008) criticizes the compliance methodology as related to the spatial distribution of concentrations, soil accretion, causal connection to loads, and limitations of the historical data used to develop the compliance equations. Many of these concepts have been discussed before at Technical Oversight Committee (TOC) meetings and in Court. The assumptions listed in the document are not listed in the Consent Decree or part of the compliance equations. Our comments here focus on issues raised for the first time by this IP, particularly those related to accretion, spatial variations, and trends..

Assumption 1: Large scale reductions of phosphorus inflows would prevent exceedances.

Although it may seem intuitive that reductions in the amount of a pollutant entering a water body should result in a corresponding improvement in ambient water quality, we have pointed out at TOC that such a relationship may take time to develop. In fact, we would not expect a direct and immediate relationship between phosphorus inputs and water column phosphorus concentrations, particularly in a phosphorus-limited ecosystem such as the Refuge. Excess phosphorus in the water column would be expected to be rapidly assimilated by the biota and the sediments.

Intrusion of canal water containing elevated total phosphorus concentration may have affected total phosphorus concentration at some of the 14 interior sites. Between mid-September and early October 2007, high canal inflows and rainfall increased canal and marsh water stages by more than 30 cm. Along with these elevated inflow rates and stages, canal water in the northwest area of the Refuge intruded more than 2 km into the marsh by October 11. In the northeast area of the Refuge, canal water intruded more than 1.5 km into the marsh. Data analysis as part of our expanded water quality monitoring program has shown that rapid increases in canal water intrusion have been associated with elevated surface water total phosphorus concentrations. The data cited here will be published in the next annual report of that program.

Assumption 2: Using stage in the compliance equation accurately reflects the relationship between marsh water depth and phosphorus concentrations.

The IP implies that the Consent Decree assumed that stage was a surrogate for water depth which, in turn, affects P concentration. This assumption is an over-simplification and is not found in the Consent Decree. The adjustment for stage was included in the compliance equation to reduce variance and increase statistical power. While a hypothetical increase in the Refuge land surface would decrease the water depth at a given stage, it would also tend to decrease flow and P transport from the rim canal to the marsh interior at a given stage. These mechanisms reflect that hydraulic resistance to flow increases with decreasing water depth (Kadlec and Knight, 1996).

Accretion rates in the Refuge interior are likely to be at or below the lower end of the hypothetical range considered in the IP's Table 4 (0.09 to 0.55 ft over the 1978-2007 period). At this low range, no change in the historical compliance determinations is indicated, even if adjustments were warranted. Only the lowest accretion rate considered in the IP's Table 4 is close to being realistic. The IP overlooks significant site-specific data collected in the Refuge and other WCAs by SFWMD contractors and other researchers (Reddy et al, 1994; Robbins et al, 1996; Craft and Richardson, 1998), as well as a broader database of soil measurements from other published studies compiled to support calibration of an integrated soil and water-column phosphorus model for the Everglades (EPGM, Walker and Kadlec, 1996; Kadlec and Walker, 1999). These studies are in close agreement as to the probable ranges of accretion rates. The IP also ignores potential offsetting mechanisms (compaction, oxidation) observed in Refuge soils (Craft and Richardson, 1998) that would reduce the impact of surface accretion on land surface elevation and water depth at a given stage.

The scenarios evaluated in Table 4 correspond to average annual accretion rates ranging from 0.9 m/yr (Refuge historical peat accumulation) to 5.5 mm/yr (measured in STA-1W). These rates are similar to the overall range observed in the above-referenced studies, which generally indicate that accretion rates increase strongly with the degree of nutrient enrichment. The IP implies that rates in the 0.9 to 5.6 mm range apply to the Refuge interior marsh with equal likelihood, which data ignored by the IP indicate is clearly not the case.

While rates approaching 5.5 mm/yr measured in STA-1W may apply to portions of the exterior Refuge marsh, which have been functioning as an STA for decades, rates in the interior are likely to be at or lower than the range considered in Table 4 (0.9 mm/yr). This point is demonstrated by site-specific data overlooked in the IP:

1. At a site in the center of the Refuge sampled in 1991, Craft and Richardson (1998) measured average accretion rates of 0.8 to 1.1 mm/yr, depending on technique.

2. In studies funded by SFWMD, Robbins et al. (1996) reported accretion rates ranging from 4.2 to 0.7 mm/yr along a transect sampled by Reddy et al. (1994) in 1991 starting adjacent to the rim canal just north of S-6 and extending east across the center of the Refuge for a distance of approximately 15 km. At the four sites most representative of the interior marsh (> 1 km from the rim canal), the accretion rates averaged 1.9 mm/yr and ranged from 0.7 to 3.2 mm/yr.

3. The latter results reflect cumulative surface soil deposition of 2-9 cm over a 29-year period[1]. These measurements are likely to over-estimate the rate of rise in land surface elevation (the relevant metric in the IP's analysis). As observed by Craft and Richardson (1998), soils tend to compact as they accumulate, particularly in areas that periodically

[1] Soil accretion rates typically are measured by collecting vertical cores and identifying the depth with maximum Cesium 137 content. That isotope is a marker for radioactive atmospheric deposition caused by testing of nuclear weapons in the early 1960s, and peaked around 1963. That depth approximates the cumulative soil accretion between 1963 and the date of sample collection. Most of the available data are from cores collected in 1991 and therefore reflect approximately 29 years of soil accumulation, similar to the duration to the 1978-2007 period considered in the IP calculations. The measured phosphorus contents of the accumulated soils were used in calibrating the STA design model (Walker, 1995).

dry out such as the Refuge interior. Along the Refuge transect analyzed by Robbins et al. (1996), soil bulk densities below the 29-year marker (from 2-9 cm down to a maximum of 30 cm) averaged 1.4 to 2.4 times higher than densities measured above the marker (Reddy et al, 1994, pp. 3-10 to 3-12). Adjusting for compaction yields a mean estimate of 1.1 mm/yr, similar to values measured by Craft and Richardson (0.8 to 1.1 mm/yr) and to the lowest value evaluated in the IP (0.9 mm/yr).

4. Aside from compaction, oxidation of the soil would further decrease the rate of increase in land surface elevation for a given level of surface accretion. That mechanism is more difficult to quantify, however.

The intermediate accretion rate derived in IP Table 3 (0.29 feet over 30 years or 2.9 mm/yr) also is unrealistically high. The error results from applying the wrong data to the wrong model which, even if it were appropriate for this application, has not been calibrated to the Refuge. The STA design model (Walker, 1995) cited in testimony (Walker, 2005) and misused in Table 3 predicts water column concentration and net accretion of soil phosphorus. Rebuttal testimony acknowledged that, while the model had not been calibrated to the Refuge, conclusions regarding percentage changes in phosphorus accretion under different management scenarios were insensitive to the calibration (10 m/yr settling rate). In contrast, the IP results in Table 3 are proportional to the assumed yet un-calibrated settling rate.

The STA design model does not predict accretion of soil mass or soil volume, as attempted in Table 3. A related model (EPGM, Walker and Kadlec, 1996) would have been more relevant, but its application still would have required specifying an un-calibrated settling rate and ignoring spatial and temporal distribution of water column concentrations in the Refuge.

The calculations in Table 3 also rely heavily on an assumed soil phosphorus content (250 mg/kg), no references for which are cited. Based upon soils data from each WCA published in the above-cited references, the EPGM calibration shows that soil phosphorus contents in recently accreted peat (above the 1963 Cs-137 marker) ranges from about 500 mg/kg at unenriched sites to 1500 mg/kg at enriched sites (Walker and Kadlec, 1996, Figure 7). Even if all of the other questionable assumptions in the Table 3 were valid, under-estimation of phosphorus content by at least a factor of two causes over-estimation of soil accretion in Table 3 by at least a factor of two.

At the assumed bulk density of 0.1 g/cm^3, the 30-year accreted soil volume (3.5 inches or 0.29 ft) corresponds to an annual average soil mass accretion rate of 296 g/m^2 per year. This rate compares with mean measured rates at the 4 Refuge interior sites (Robbins et al, 1996) ranging from 44 to 65 g/m^2 per year, depending on computation technique. This rate also compares with an overall range of ~50 g/m^2 per year at less enriched sites to ~400 g/m^2 per year at highly enriched marsh sites in the Everglades (Walker and Kadlec 1996, Figure 7). Robbins et al. (1996) noted that these estimates of soil mass accretion rates (g/m^2 per year) are more precise than volumetric estimates (mm/yr) because they are less sensitive to the sampling depth interval. These comparisons further indicate that the intermediate scenario derived in Table 3 and evaluated in Table 4 (0.29 feet) is unrealistic.

Because accretion rates are known to increase with phosphorus load, adjusting the Refuge Levels for accretion would provide a means for achieving compliance by increasing phosphorus loads to the marsh. Should TOC consider this adjustment concept further, it should also consider adjusting the Levels for differences in sampling methodology (buckets dropped from helicopter vs. marsh-based sampling with extreme care to exclude particles).

Assumption 3: The "Clean 3" sites are the three least impacted stations in the Refuge.

The current spatial distribution of concentrations is irrelevant to the compliance test specified in the Consent Decree. Data from the clean 3 sites (LOX 5, 6, and 16) had the lowest geometric mean concentrations during the baseline period. In deriving the test, limitations of the historical data were acknowledged and there was no assumption that those same sites would also have the lowest concentrations in the future. Given the expected changes in the spatial and temporal distribution of inflows as a consequence of STA construction and operation, the spatial distribution of concentrations may well have changed, but that fact would not impact the validity and applicability of the compliance equation.

Given the high variability of concentrations at the Refuge interior sites and limitations of the historical data, the power for detecting significant spatial, temporal, or stage-related variations is low. The fact that statistically significant relationships could not be detected in various subsets of the data using highly simplistic empirical models is not unexpected and cannot be used as a basis for stating that they do not exist. Their presence or absence would not change the agreed-upon compliance equation or the assumptions upon which it is based.

Assumption 4: The strong inverse relationship between stage and phosphorus forming the basis for the compliance equation was real and would remain constant.

Our data analyses leads us to agree that the Refuge marsh water column total phosphorus concentration may have decreased over the 1999-2007 period (IP, Figure 3). However, specific causes cannot be differentiated with the available information. For example, interpretation of apparent trends in the marsh over the past decade is complicated by decreases in precipitation and consequent decreases in Refuge inflow volume.

Despite the October 2007 excursion and the fact that interim treatment goals of the Consent Decree have not been consistently achieved, there has been both a lower inflow total phosphorus concentration and phosphorus load relative to the 1979-1998 period (IP, Figure 2) and fewer excursions for the Interim and Long-Term Levels. Following near completion of repairs to STA-1 West, monthly flow weighted mean concentrations in STA discharges recently have decreased (STA-1 East < 30 ppb since May 2007, STA-1 West < 40 ppb since January 2008, DBHYDRO data).

Assumption 5: A model built to predict month-to-month changes in phosphorus concentrations could be based on a data set without month-to-month data.

This section of the IP is an attack on the Consent Decree equation – a disagreement which has been covered well in the past.

References

Anonymous. 2008. Analysis of the October 2007 excursion of the long-term phosphorus levels for the Refuge, May 8, 2008.

Craft, C.B. and C.J. Richardson. 1998. Recent and long-term organic soil accretion and nutrient accumulation in the Everglades. Soil Sci. Soc. Am. J., 62:834-843.

Kadlec, R.H. and R.L. Knight. 1996. Treatment wetlands, Lewis Publishers.

Kadlec, R.H. and W.W. Walker. 1999. Management models to evaluate phosphorus impacts on wetlands, *In* Phosphorus biogeochemistry in subtropical ecosystems, pp. 621-642, K.R. Reddy, G.A. O'Connor, and C.L. Schelske (eds.). Lewis Publishers.

Reddy, K.R., W.F. DeBusk, Y. Wang, and S. Newman. 1994. Physico-chemical properties of soils in Water Conservation Area 1 (WCA-1) of the Everglades, prepared for SFWMD, Soil and Water Science Department, University of Florida.

Robbins, J.A., X. Wang, and R.W. Rood. 1996. Sediment core dating, Semi-Annual Report, September 1995-January 1996. prepared for SFWMD, Contract Number C-5324, U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Great Lakes Environmental Research Laboratory.

Walker, W.W. 1995. Design basis for Everglades Stormwater Treatment Areas. Water Resources Bulletin, 31:6711-685.

Walker, W.W. 2005. Direct and rebuttal testimony before the Special Master, August 2005.

Walker, W.W. and R.H. Kadlec. 1996. Model for simulating phosphorus concentrations in waters and soils downstream of Everglades Stormwater Treatment Areas", prepared for U.S. Department of the Interior. http://www.wwwalker.net/epgm