United States Department of the Interior

U.S. GEOLOGICAL SURVEY
South Carolina Water Science Center
720 Gracern Road, Suite 129
Columbia, SC 29210

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Mr. Ed Eudaly
U.S. Fish and Wildlife Service
Suite 200
176 Croghan Spur Road
Charleston, SC 29407

Dear Mr. EuDaly,

I have completed my review of the "Savannah Harbor Reoxygenation Demonstration Project" report prepared for the Georgia Ports Authority by MACTEC Engineering and Consulting. The report is a summary of the feasibility study for the reoxygenation (ReOx) of the Front River and an analysis of the monitoring data collected prior (7/9-8/6/2007), during (8/7-9/16/2007), and after the demonstration project (9/17-9/26/2007). In addition to reviewing the data presented in the report, I also looked at data from the USGS USACE Dock gage (station 021989733), the USGS Fort Pulaski gage (station 02198980), and the USGS Cooper River gage (station 021720677).

Estuarine systems, such as Savannah Harbor, are constantly integrating changing streamflow, changing tidal conditions, and changing meteorological conditions including wind direction and speed, rainfall, and atmospheric pressure. Dissolved oxygen (DO) in the estuary is responding to these forces in additions to other sources and sinks of oxygen such as tidal exchange, primary productivity, point-source loading, non-point source loading, tidal marsh exchange, rainfall impacts, and benthic demands.

To evaluate the effect of the ReOx injection on the dissolved-oxygen concentration of the Front River, the analysis needs to account for the major forces of DO in the system, such as the 14- and 28-day tidal cycle, to make defensible conclusions on the demonstration project. From my review of the report, the data presented in the report, and limited evaluation of additional data, I found that the analysis in the report did not convincingly isolate the DO effects of the injection system from other factors affecting DO deficit to be able to support a defensible conclusion on the feasibility of the ReOx project.

The monitoring for the ReOx system had three approaches – continuous monitoring at three locations (shallow, mid, and deep in the water column for a total of nine monitors), cross-sectional transects at high and low tide at five locations, and mid-channel longitudinal transects from 14 locations. In the report, there was limited analysis of the continuous monitoring and the majority of the analysis was done on the low-tide cross-sectional and mid-channel longitudinal transects. Six of the longitudinal transects and four of the cross-section transects were the basis for the conclusions presented in the Executive Summary of the report that "…the ReOx system operation reduced the mid-channel average low tide DO deficit along the three-mile target segment by about 0.6 mg/L.." and "…independent cross-channel transect monitoring…showed an average DO deficit reduction of about 0.7 mg/L."

Unfortunately, the limited number of transects and the short duration of the demonstration project did not account for the major influence of the 14- and 28-day tidal cycle which is a major factor in the changing

DO deficit in the estuary. Figure 1 below shows the 15-minute DO deficit[1] and the filtered (daily) DO deficit for the USGS gage at the USACE Dock and tidal range at the USGS Fort Pulaski gage. The data show that there is a large amount of variability in the 15-minute DO deficit data (1.2 to 4.8 mg/L). The data also show that the DO deficit follows the 14- and 28-day cycle of the tidal range. Dissolved-oxygen deficit is low (higher water quality) during neap tides and high during spring tides (lower water quality). The variability in the DO deficit and the influence of the tidal cycles in clearly seen in the data prior, during, and after the operation of the demonstration project.

One of the continuous monitors for the demonstration project was located at the USACE dock and the report states that the USGS data "…matched very closely the data from the deep monitoring zone USACE monitoring station data collected by MACTEC (p. 4-15)."

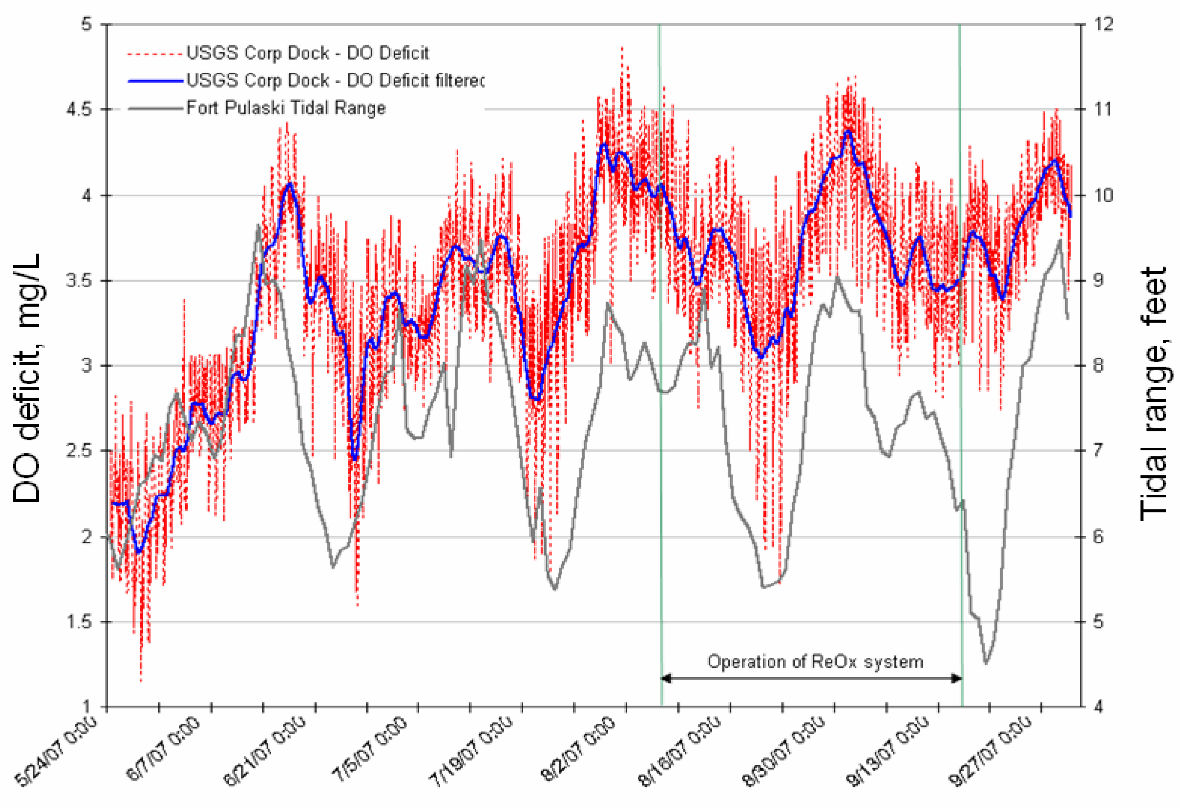

Figure 1. DO deficit, filtered DO deficit, and tidal range for the period May 24 – September 30, 2007.

Figure 2 shows the daily DO deficit values from USACE deep monitoring zone, the USGS USACE Dock gage, and the USGS Cooper River gage at I-526 (Charleston County, SC). The day of the moon phase (from the tide tables in Appendix D) are plotted in figure 2. It is apparent that the two data sets from the USACE Dock monitors have a similar response. The figure also shows that the response of DO deficit to the tidal cycle can also be seen in the Cooper River data. High DO deficits typically occur around the full moon and low DO deficits occur during the quarter moon (waning and waxing moons). This is also seen in the spring and neap tidal ranges and DO deficits in figure 1. During a 28-day cycle there is a strong period of decreasing DO deficits and a strong period of increasing DO deficits.

The challenge in determining the effect of the demonstration project is to determine the amount of the DO deficit variability that is attributable to the oxygen injection. It is clear that the DO deficit is changing but the analysis in the report implies that the change in DO deficit is due to the ReOx operations. For example, on page 4-4 of the report, "After 4 days of reoxygenation the average DO deficit was improved by 0.4 mg/L." One can see from the plots in figures 1 and 2 that the beginning of the demonstration project occurred during a tidal phase when there are improving DO deficit conditions. The question is not how much did the DO deficit improve over 4 day (0.4 mg/L). The question is how much of the decrease in DO deficit of 0.4 mg/L over 4 days is attributable to the ReOx operations. The DO deficit improved by 0.7 mg/L on the Cooper River during the same period and we know that is not attributable to the demonstration project.

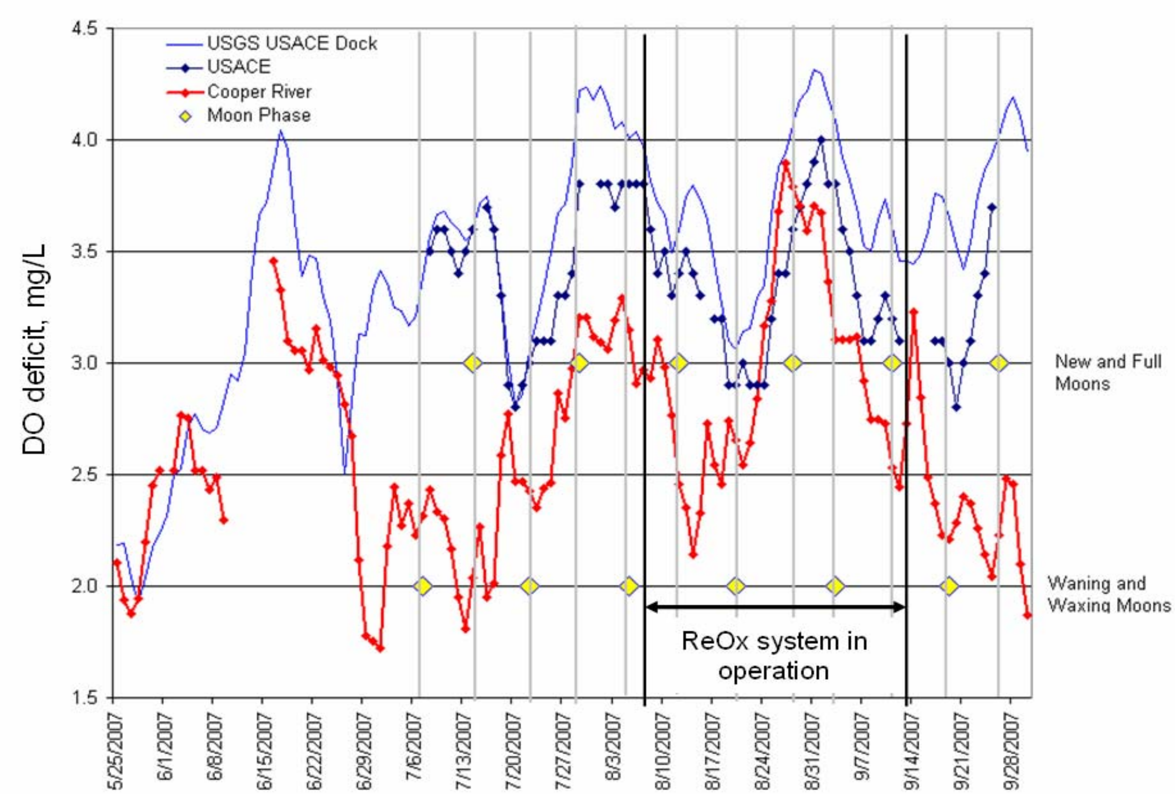

Figure 2. Daily DO deficit from the USGS USACE Dock gage, MACTEC USACE deep zone monitoring, and the average DO deficit for the 39 days before and 39 day of the demonstration project.

Accounting for the DO deficit variability caused by the tidal cycle is a critical aspect in the design of a data collection program and the analysis of the data. It appears that the majority of the low tide transects measured during the demonstration project occurred during the tidal phase of decreasing DO deficits. Figure 3 shows the 15-minute DO deficit and daily DO deficit and the approximate dates of the low tide cross-section and mid-channel transects. The 15-minute data is presented to show the temporal variability in the DO deficit. Depending on the length of time to measure the points of the transects, conditions in the Front River can change substantially (0.5 to 1.0 mg/L). It needs to be noted the transect dates shown in figure 3 are presented only to give a sense of the range of the 15-minute data and the timing in the DO deficit cycle in the tidal cycle. The results given in the Executive Summary are *averaged* deficits from either the five cross-section transects (0.7 mg/L impact, table 4-2) or the 3 mile grid average of the mid-channel transects (0.6 mg/L impact, table 4-1). As seen in figure 3, there was a large portion of the cycle of increasing DO deficits from August 22 to September 3 where there was not a low tide transect. (There were two high tide transects during this period but these were not used in the analysis.) Transects were not measured during the tidal phase when the DO deficit would be higher that the initial measurement at the beginning of the demonstration project. The analysis presented for these low-tide averaged transects are probably more a result of 14- and 28-day tidal cycle than the demonstration project.

One would expect that the DO deficit would improve from the initial start up of the ReOx demonstration project, August 7, until about August 28, based the timing of the tidal cycle (fig. 3-blue trace DO deficit

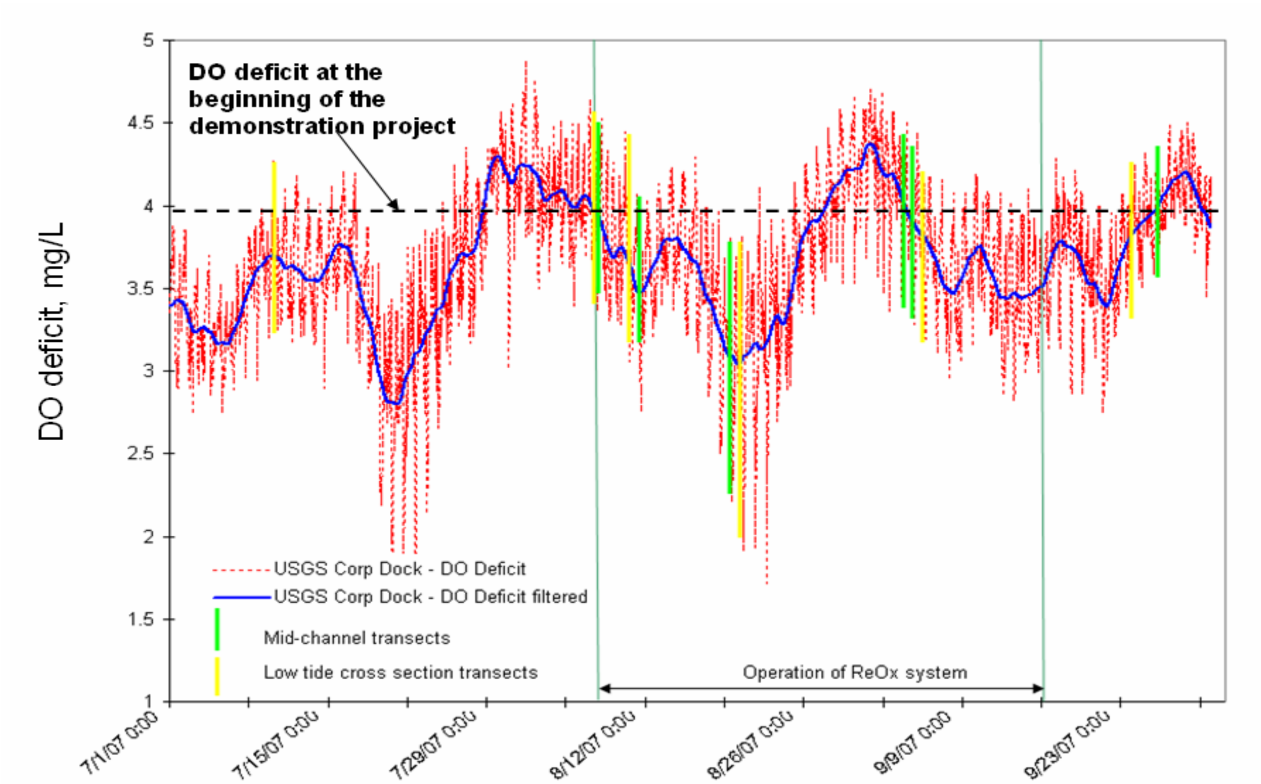

Figure 3. Daily and 15-minute DO deficit and periods of low tide mid-channel and cross-section transects.

filtered). Likewise, one would expect the DO deficit to worsen sometime between August 28 and September 5 (fig. 3). If you review the plots of the DO deficit time series data and the average daily values in figures 4-2.1 through 4-2.3 of the report, you will find this is true for 8 of the 9 continuous monitors located at the continuous monitoring sites (shallow, mid, and deep in the water column). At the GPA site, 1.5 miles upstream of the ReOx injection location, DO deficits equal to or worse than the initial conditions were recorded between August 28 and September 3 for the three monitors. At the Barge site, located at the point of ReOx injection, the mid and deep continuous monitors recorded daily DO deficit equal to or greater than the initial conditions between August 30 and September 1. The shallow monitor did not record DO deficits greater than the beginning of the ReOx injection. At the USACE site, located 0.4 miles downstream of the ReOx injection location, DO deficits greater than the initial value occurred between August 28 and September 3 for the three monitors. (The shallow monitor was missing data at the ReOx start up and the initial values were computed from measurements on August 1.)

It is interesting to note that the only location where the worsening DO deficit condition due to the tidal cycle did not exceed the initial DO deficit level was at the surface location of ReOx injection of supersaturated DO of over 120 mg/L (Report, p. 3-4). At the continuous monitoring sites 1.5 miles upstream and 0.4 miles downstream, the DO deficit during the full moon was worse than the initial DO deficit at the start up of the ReOx injection system. I cannot say with certainty that the ReOx demonstration system did not have any effect, beyond the immediate injection site, on the DO of the Front River. However, the data and discussion in the report did not present a defensible quantification of contribution of the ReOx injection to the dynamic DO variability of the system. None of the information reviewed supports the conclusion the ReOx system had a substantial impact on DO in the Front River.

The data and discussion presented in this letter is based on a review of the report and limited evaluation of the data at USGS gaging station 021720677, 021989733, and 02198980 and not a thorough analysis of the data collected during the ReOx demonstration project. Please call me at (803) 750-6140 or pconrads@usgs.gov if you have any questions or need additional information.

Sincerely,

Paul A. Conrads
Hydrologist

Cc: Bill Bailey, U.S. Army Corps of Engineers, Savannah District

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[1] Tidal range and dissolved-oxygen deficit were computed from the field measurements of the physical parameters. Tidal range is calculated from water level and is defined as the water level at high tide minus the water level at low tide for each semi-diurnal tidal cycle. Dissolved oxygen and water temperature are inversely related and highly correlated. Dissolved oxygen deficit (DOD) is defined as the difference between the actual dissolved-oxygen (DO) concentration and the saturated DO concentration. The computed variable, DOD, is derived using an algorithm that assumes a constant barometric pressure (U.S. Geological Survey, 1981, Technical Memorandum 81.11, Reston, Va.).