Factors Contributing to 2003/4 Exceedance of Interim Phosphorus Levels in the Refuge

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Analysis of Compliance with Interim Levels

- **Study Objective:** Examine factors likely to contribute to excursions & exceedance of the Interim Phosphorus Levels in the Refuge
  - Role of external TP loading into the Refuge
  - Role of error and extraordinary natural phenomena

- **Study Approach:** Examine monthly trends and sources of error as contemplated by the Settlement Agreement
  - Complete data set is the centerpiece
Topics Analyzed by the District

- Circumstances of the 2003/4 events and comparison to past excursions
- Trends in the 14-station data set and their relationship to excursions
- Correlation with external loading, periods of potential marsh penetration and rapid changes in stage
Relevant Refuge Data
Tables 1 and 2

- **Table 1** provides all data for the Refuge since January 1994 for individual stations
  - This table contains original data, not averages.
- **Table 2** summarizes monthly geomeans, stages, interim levels, inflows and TP loads
- Use to examine monthly trends for circumstances of the 2004 events, comparison to past excursions and patterns in the 14-station data set and their relationship to excursions
Circumstances of the 2003/4 Events and Comparison to Past Excursions

- Since monthly sampling began in 1994, there have been 13 excursions; 9 after February 1999.
- Recent Excursions (See Table 2)
  - September 2003 was 0.5 ppb and August 2004 was 2.1 ppb over the Interim Level.
  - Both occurred as stage increased; a pattern often seen in past excursions (see Table 2).
  - August showed higher TP levels than seen typically; top 4 stations were 54, 33, 26 and 20 ppb (Table 1).
  - August followed 3 consecutive months of very low stage in the Refuge; an infrequent event.
Refuge Geomean TP with Interim Levels

- Geomean exceeds Interim Level 9 times in 68 months
- Excursions tend to occur as stage increases.
Patterns in the 14-station Data Set and Their Relationship to Excursions

- In September 2003, stations LOX 3, 4, 7, 10 and 14 were the highest (14 – 10 ppb)
- In August 2004, stations LOX 4, 6, 12, 8 and 16 were the highest (54 – 17 ppb)
- Were these stations high in earlier excursions and what does this tell us about possible causes?
Comparison of Individual Stations to the Monthly Geomean
(Feb 1999 – Sep 2004, compliance dates)

Number of times that the TP concentration at an individual site exceeded the geometric mean.

Mean difference between geometric mean and TP concentration at an individual site when TP concentration exceeded the geometric mean.

Number of times that TP concentration at an individual site exceeded the geometric mean when excursions occurred (9 events).

Mean TP concentration difference between geometric mean and TP concentration at an interior site when the TP concentration exceeded the geometric mean.
Comparison of Individual Stations to Monthly Geomeans
(Feb 1999 – Sep 2004, Compliance dates)

- At least 8 of 14 stations are frequently above the geomean, not just a few high stations; stations 4, 5, 8 and 11 are especially influential to monthly geomeans.

- Stations 3, 4, 8, 11, and 14 are most often associated with excursions; notice that 3, 8, and 11 are centrally located in the Refuge (see map on next slide)
  - In September 2003, stations LOX 3, 4, 7, 10 and 14 were the highest (14 – 10 ppb)
  - In August 2004, stations LOX 4, 6, 12, 8 and 16 were the highest (54 – 17 ppb)

- A mixed pattern, as seen commonly in the past
‘Review of Monthly trends for the 14-Station Mean and Other Relevant Information’

- As noted previously, excursions tend to occur with rising stage, 11 of 13 for POR and 8 of 9 during compliance period (See Table 2).
  - Issue: Rising stage can be associated with two fundamentally different sources of phosphorus
    - External Loading from the peripheral canal
    - Internal Loading from release within the marsh particularly following low water periods
- Explore the correspondence between external loading and periods of potential marsh penetration
- Examine correspondence between rapid changes in stage and the excursions
External Loading and Refuge

Excursions

- Evaluation of earlier excursions by Walker and Kadlec (2003) suggested a correspondence between periods of potential marsh penetration and excursions above the Interim Level
  - Excursions tended to occur early in loading periods
  - Continuing loading does not tend to lead to additional excursions; 1999 is an exception

- Evaluation of existing data provides indirect evidence of relative importance external inputs, internally released P and the predictions of the Interim Level equation
• P loads and spikes are declining
• Marsh average 8.6 ppb for recent 24 months
• Excursions often occur when loads enter the canal
Periods of potential water export (blue) are far more frequent than those of potential marsh penetration (red).
Periods of Potential Water Movement
Into the Refuge Marsh and the Monthly Geomean

- Marsh penetration is only associated with excursions in roughly one-half of input episodes.
External Loading and Refuge

Excursions

- Statistical correlation between monthly loads and geomeans explains only 0 to 4% of the variation in the geomean using lags of 0 to 4 months (3 month lag was highest)
- The direct, short-term correspondence of canal imports on the marsh is inconsistent.
- Huge loads in the September 2004 did not produce an excursion (see Table 2).
- Conclusion: Loading influences are complex and occur over periods longer than monthly.
External inputs might lead to gradual, long-term TP increases in marsh and increase the likelihood of excursions.

*Is there evidence that the P climate getting worse in the Refuge?*

**Examine** -

- long-term trends in monthly geomeans
- trends in individual stations
- changes in the frequency or magnitude of excursions
Geomean TP Concentration in the Refuge
(Feb. 1999 – Sep. 2004, Compliance Dates)

- Although more time is needed to confirm a trend, TP in the water column of the marsh has decreased over the compliance period.
- Long-term average remains less than 10 ppb; 8.6 for the last 24 months
External Loading and Refuge

Excursions

- *Is there evidence that the P climate getting worse in the Refuge?*
  - No upward trend is evident in geomeans over last six years
  - No upward trend is evident in data from individual stations
    - Six stations show a significant declining trend
  - No upward trend in evident in magnitude or frequency of excursions
    - Excursions average 1.2 ppb for the POR and 1.2 ppb for the compliance period
    - No evident change in the frequency of excursions
  
- For Settlement Agreement compliance stations, there is no evidence that marsh P climate is getting worse.
Loading and 2003/4 Excursions

- For September 2003, role of external loading is uncertain.
- For the August excursion, external loading could not have entered the marsh.
  - P levels were very high for two months preceding excursion when external inputs could not have entered the marsh due to stage differential.
  - Ability of the Interim Level equation to accurately predict P levels during rapid changes in stage could also have been a contributing factor.
- Sources for the internally-generated P increases for August are not known.
Aspects of Error

- **Context of variability.**
  - For a given month, the Interim Level has a 10% probability of being exceeded based on the derivation statistics of the Settlement Agreement.
  - For a given 12-month period, this probability produces a 23% chance that an exceedance will occur based solely the variability of measurement, assuming the equation works well over the range of variation in Refuge ecology.

- **Does the Interim Level equation predict P levels accurately when Refuge stage increases rapidly?**
  - A data summary follows looking at this aspect.
  - Internal loading might sometimes interfere.
Compliance and Marsh Levels

<table>
<thead>
<tr>
<th>Geomean &gt; Interim Level</th>
<th>Geomean &lt; Interim Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excursions Above Interim Levels</strong></td>
<td><strong>In Compliance with Interim Levels</strong></td>
</tr>
<tr>
<td>Marsh levels going down</td>
<td>Marsh levels going down</td>
</tr>
<tr>
<td>Marsh levels going up</td>
<td>Marsh levels going up</td>
</tr>
</tbody>
</table>

| Stage < Previous Month | Stage > Previous Month |
Compliance and Change in WCA-1 Marsh Levels

- Marsh levels going down
- Marsh levels going up

Excursions

Above Interim Level
Below Interim Level

In Compliance

Stage Change from Previous Month (feet)
Stage < Previous Month
Stage > Previous Month

GeoMean minus Interim Limit (ppb)
Preliminary Conclusions from the District

• Analysis of data from across Refuge stations suggests many simultaneous factors, such as external P loading and uncertainty in the compliance equation, may contribute to Refuge excursions.

• The combination of factors underlying the 0.5 ppb excursion of September 2003 is not certain.

• The ability of the Interim Level equation to predict P accurately during a period of rapidly rising stage with high P concentrations from an antecedent dry period is likely to have been a primary factor in the 2.1 ppb excursion of August 2004.

• Influences of external loading are complex and long-term.
Preliminary Conclusions from the District (Continued)

• A decreasing trend in phosphorus levels was found for the Refuge compliance station geomeans and there are no P data demonstrating marsh enrichment at any of the individual compliance stations.

• The ability of the compliance equation to predict P concentrations accurately during rapid increases in stage was a contributing factor in 2003/4 exceedance.

• Little additional information is available for TOC to attempt to establish causation over that evaluated in 2003.

• A better use of time and resources is to implement recommendations agreed to in 2003.