INTRODUCTION

The objective of this project is to demonstrate the potential of utilizing alum (aluminum sulfate) injection in a constructed wetland to reduce Phosphorus (P) loads to the Illinois River in order to meet Oklahoma’s Scenic River water quality standard at the Oklahoma/Arkansas state line. The Illinois River basin is identified in Oklahoma’s Nonpoint Source (NPS) Management Program as one of the state’s highest priority watersheds. The development and rehabilitation of wetlands is one of the most economically viable strategies to address NPS P originating from elevated soil P levels. Understanding the capacity of wetlands to mitigate P loss is needed to incorporate wetland design recommendations into the Watershed Management Plan, but more importantly into Oklahoma’s overall NPS program. This is consistent with the 2012 EPA 404(b)(3) project “Method Development to Incorporate Wetland Resources in Watershed Planning Efforts in Oklahoma.”

The Oklahoma Scenic River water quality standard Title 765, Chapter 46, Section 785:46-15-14 of the Oklahoma Water Resources Board Implementation of Oklahoma’s Water Quality Standards states that:

"(2)(C) A three-calendar-month geometric mean concentration shall be determined each month using the total P data from that month together with such data from the preceding two calendar months" "(3)(A) The Aesthetics beneficial use designated for a segment of a Scenic River shall be deemed to be supported with respect to total P if less than 25% of the monthly determinations made in accordance with (b)(2)(C) of this Section exceed 0.037 mg/L total P."

A natural wetland is land characterized by the natural presence of water sufficient to support wetland vegetation and provide a variety of services, such as assimilating pollutants, erosion and sediment control, wildlife habitat, flood protection, recreation, and others. Constructed wetlands are man-made constructed systems designed to approximate natural wetlands to treat wastewater or runoff. The proposed project dramatically improves the wetland P removal efficiency through the use of a passive alum injection system that forms Aluminum Phosphate precipitates that settle and are assimilated in the wetland.

PROJECT OBJECTIVES

1. Determine P removal efficiencies for different alum injection concentrations and settling times using a laboratory-scale settling tube experiment.

2. Using the optimal alum injection concentration and settling time from Objective 1, develop a preliminary design for a constructed wetland located on the former Lake Francis bed that meets the Oklahoma Scenic River water quality standard of 0.037 mg/L directly downstream of Lake Francis.

LABORATORY METHODS

An experiment was conducted to determine the optimal alum concentration and settling time using settling tubes and Illinois River water, which was collected following a 3.8 cm (1.5 in) precipitation event on March 10, 2013 at the No Head Hollow Public Access area near Tahlequah, Oklahoma. The experimental design consisted of:

1. Five alum concentrations: 0.1, 1.0, 2.0, 5.0, 10.0 mg Al/l
2. Four settling times: 12, 24, 36, 48 hours
3. Two replications

The settling tubes were 7.6 cm (3 in) in diameter and 92 cm (36 in) tall clear Polyethylene Terephthalate Glycol-modified (PETG) plastic (Figure 1). Each sampling tube was filled with the Illinois River water and alum, inverted several times, and then placed in the tube stand. At the end of each of the four time periods, a settling tube was drained by collecting five samples at uniform vertical increments of 18 cm using a peristaltic pump. Thus, a total of 40 settling tubes were required.

The samples were filtered with 0.45 um glass fiber filters and frozen. Next, the samples were thawed and analyzed for dissolved reactive P (DRP) using Hach PhosVer3 testing kits and a Hach DR 3900 Spectrophotometer.

LABORATORY RESULTS

Two one-way ANOVAs were performed on the DRP data (Figure 2) to identify differences between means for the settling time and the alum concentration. No significant differences were found between sampling times (p>0.367), and significant differences between at least one mean was found for the alum levels (p<0.001). A Tukey’s multiple comparison test was then performed on the alum levels using an error rate of 0.05, with the results show in Table 1.

Table 1. ANOVA results for column tests. Means with the same letter are not statistically different at the 0.05 level.

<table>
<thead>
<tr>
<th>Alum (mg Al/l)</th>
<th>Sample Number</th>
<th>Mean Dissolved Reactive P Reduction (%)</th>
<th>Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0</td>
<td>33 A</td>
<td>A</td>
</tr>
<tr>
<td>5.0</td>
<td>0</td>
<td>33 A</td>
<td>B</td>
</tr>
<tr>
<td>2.0</td>
<td>0</td>
<td>34 A</td>
<td>B</td>
</tr>
<tr>
<td>1.0</td>
<td>0</td>
<td>30 B</td>
<td>C</td>
</tr>
<tr>
<td>0.1</td>
<td>0</td>
<td>33 C</td>
<td>C</td>
</tr>
</tbody>
</table>

Figure 1. Experimental setup using settling tubes.

Figure 2. Column study results for dissolved phosphorus removal vs. alum concentration and time.

ACKNOWLEDGEMENTS

Special thanks goes to the Oklahoma State University Environmental Science Graduate Program for providing the Public Service of Oklahoma Research Assistantship to Deb Hyde, which made this research possible. In addition, special thanks goes to Dr. Jonathan Fisher at NSU for use of lab equipment and NSU undergraduates Robert Collette, Lauren Trindell, Jordan Peacock and Rachel Taylor for assistance with water testing.

WETLAND DESIGN

Site Location

Lake Francis is located on the Illinois River just downstream of the Oklahoma/Arkansas border near Watts, Oklahoma. The dam was breached in 1992, but remnants of the structure retain some water with 500 acres of former lakebed exposed (Figure 3).

Required P Load Reduction

To determine the total P reduction required to meet this the standard at the Oklahoma/Arkansas state line, US Geological Survey (USGS) flow and P data for 1-2007 through 4-2013 were analyzed for the gage station 07195500 Illinois River at Watts, Oklahoma. Load Estimator (LOADEST), a software program developed by Dr. Robert Runke and the USGS, was used to estimate daily total P load and concentration at the Watts gage station. Using these data, a 67 percent total P reduction on all flow was required to meet the criteria (Figure 3). The criteria can also be met using an 83 percent total P reduction for flow less than 600 cfs, which is approximately baseline.

The injected alum with a 12 hour retention time will provide a 69 percent total P reduction in the wetland. The additional 14 percent reduction required to meet the 83 percent reduction must come from biological uptake and settling of particulate P. Since typical constructed wetland have an expected total P reduction of 30 to 50 percent, the additional 14 percent reduction is plausible. However, a pilot in-situ wetland is recommended to confirm this assumption.

Conceptual Design

Illinois River flow rates less than 600 cfs will be diverted through the wetland and discharged back into the river upstream of the Lake Francis dam (Figure 5). A passive alum injection system will be installed at the inlet of the wetland.

Figure 3. Lake Francis location with the former lake surface shown in blue.

Figure 4. Historical and 67 percent reduction of total phosphorus three-month geometric mean based on daily LOADEST estimates using US Geological Survey data.

Figure 5. Conceptual wetland design with alum injection system.

Wetland Size and Annual Alum Cost

Surface Area = Q x t / d = 800 acres

Total Alum Cost = Q x C x A = $270,000/year

Q = average flow rate < 600 cfs = 300 cfs
d = average depth = 3 feet
A = hydraulic retention time = 12 hours
C = alum injection concentration = 0.10 mg Al/l
A = alum cost = $400/ton