St. Johns River
Water Management District

Michael A. Register, P.E., Executive Director

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DATE: August 9, 2023

TO: Prospective Respondents

FROM: LaDonna Johnson, Associate Procurement Specialist

SUBJECT: Addendum #1 to Request for Proposal #38864, Phosphorus Remediation in the Ocklawaha Prairie Restoration Area

As a result of an inquiry, the following clarifications/changes are provided for your information. Please make all appropriate changes to your proposal.

Question 1: Is there any raw data (water quality or sediment) for the project?

Answer 1:

1) Water quality data is available on our website at http://webapub.sjrwmd.com/agws10/edqt/. The pertinent station names are OFORN and OFEFF.

2) Soil data is provided in the following reports:
    a. Alternative Nutrient Control Treatments within the Upper Ocklawaha River Basin – Prepared by MACTEC September 2005
    b. Upper Ocklawaha Restoration Sites Nutrient Control Feasibility and Design – Final Report Revised February 2003

NOTE: The Request for Proposals Due Date remains 10:00 am, Tuesday, August 22, 2023.

Please acknowledge receipt of this Addendum on the **Proposal Form** provided in the proposal package.

If you have any questions, please e-mail me at ljohnson@sjrwmd.com.

Alternative Nutrient Control Treatments within the Upper Ocklawaha River Basin

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177
Contract No. SE111F0
Work Order No. 56

Prepared by:

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MACTEC Project No.: 6063-04-0022

September 2005

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ANOVA	Analysis of Variance
DO	Dissolved Oxygen
FDEP	Florida Department of Environmental Protection
MACTEC	MACTEC Engineering and Consulting, Inc.
NSD	No significant difference from control
ppm	parts per million
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency

1.0 Introduction

Water quality and riparian wetland habitat in many areas of north central Florida have declined dramatically over the last century. Thousands of acres of former agricultural areas have been acquired by the St. Johns River Water Management District and are being reflooded to provide for restoration of aquatic and wetland habitat and to reduce nutrient loading to adjacent water bodies. Former farms that have already been reflooded have been successfully treated with liquid alum to reduce nutrients. However, in more densely vegetated systems, applications from barges and similar vessels cause significant and unacceptable disturbance to wetland habitats.

Prior to reflooding, nutrient control will be required to restore the 2,550-acre Ocklawaha Prairie property (Figure 1), a former muck farm in the upper Ocklawaha River basin, since elevated concentrations of phosphorus will be discharged if the site is left untreated. The prairie has dense stands of emergent vegetation (Photograph 1), which would preclude chemical application via barge, airboat, Marshmaster™, etc. In addition, liquid alum would not be appropriate for Ocklawaha Prairie due to the tendency of liquid alum to remain on the vegetation, as experienced in the alum application in the Lake Griffin Marsh Flow-Way.

Aerial application appears economically feasible in large vegetated sites, but new application materials need investigation, as discussed in this report. The most promising candidates for aerial application are Baraclear™ pellets (Photograph 2), granular alum (Photograph 3), DinoSoil™, alum residual, and ferric residual (Photograph 4). These five materials are available and may be spread aerially.

Baraclear™ pellets are bentonite-based aluminum sulfate products, which can be combined with various buffering substances. If aerially applied, the pellets would sink in surface water and adsorb phosphorus as they solubilize, according to adsorption work conducted by DB Environmental Laboratories (Year ??). Granular alum is relatively inexpensive and readily available. DinoSoil™, a highly oxidized organic material with high concentrations of humic acids, is being used in south Florida as a pollution abatement tool, though its use to reduce surface water phosphorus concentrations is unproven. Ferric residual is currently being produced by the Lake Washington Water Treatment Plant in Melbourne, Florida. According to recent incubation studies also conducted by DB Environmental Laboratories, ferric residual may sustain its phosphorus binding capacity even under anaerobic conditions. Alum residual is another water treatment plant by-product similar in texture and appearance to the ferric residual. Both residuals are partially-dried sludges.

2.0 Objective

MACTEC Engineering and Consulting, Inc. was contracted by the St. Johns River Water Management District (District) to conduct a field study to compare the phosphorus binding effectiveness of Baraclear™ pellets, granular alum, DinoSoil™, alum residual, and ferric residual treatments in field plots. The compounds were applied to mesocosm plots (Photograph 5), and monitored for 300 days following application to observe nutrient content over time.

3.0 Methods

3.1 Bench Test

In order to prepare for the field trial to compare the nutrient binding properties of these materials, a laboratory range-finding study using Ocklawaha Prairie site water and various concentrations of the five candidate materials was conducted (Table 3-1). The objective of the bench scale study was to develop the application rates for the field trials. Treatment compounds were placed into appropriate beakers and overlying sitewater was added to each vessel (Photograph 6). Unlike other bench scale testing to evaluate the efficacy of these materials for nutrient removal, this test was primarily conducted without sample stirring to more readily simulate field conditions. Total phosphorus, alkalinity and pH were evaluated on Days 0, 1, 2, 5 and 12, following application. At the conclusion of the test, samples from each beaker were filtered and analyzed for dissolved ortho-phosphate.

Table 3-1. Application Rates of Product Used in the Range-Finding Test (g/L)

Compound	High Dose	Medium Dose	Low Dose
Alum Residual	24	12	2
Ferric Residual	24	12	2
Baraclear^{TM}	0.5	0.2	0.1
DinoSoil^{TM}	24	15	6
Granular alum	NA	0.2	0.1

Source: MACTEC, 2005. Created by: JLD Reviewed by: JMR

3.2 Mesocosm Study

The Ocklawaha Prairie study site was selected based upon the following criteria: accessibility, distance from other disturbances, representativeness of the site, homogeneous vegetation, and relatively small elevation changes in topography.

The range-finding study (bench test) results described in the results section were used to eliminate DinoSoil^{TM} from consideration in the field trials. The following chemical amendments were evaluated in the mesocosm study: Granular alum, Baraclear^{TM}, alum residual, and ferric residual. The dosages were based upon results from the bench scale tests, application rates used at other District properties, and best professional judgment of District and MACTEC staff. Dosages used in the mesocosm trials were:

- Granular alum – 0.1 g Al/L + sediment dose*
- Baraclear^{TM} - 0.2 g Al/L + sediment dose*
- Alum residual – 6.5 wet tons/acre
- Ferric residual – 6.5 wet tons/acre

*molar ratio Al:P of 5:1

Additionally, the Baraclear™ and granular alum plots were treated with pelletized dolomitic limestone on February 10, 2005, 190 days after the initial dosing. The ferric residual plots received second and third doses of the ferric compound on February 10, 2005 and February 21, 2005, 190 and 201 days after the initial treatment.

Mesocosm enclosures were constructed in the field using a plastic reinforced fiberglass (Kemlite, Joliet, IL) which was riveted at the seam with sufficient overlap to prevent any substantial horizontal water exchange (Photograph 7). The mesocosm cylinders were fully open at the top and bottom. Enclosure dimensions were approximately 10 feet in diameter. Water depth was used as a blocking variable. Thus, three rows, at varying water depths, contained four treatment plots and a control plot, with applications randomized within rows. The treatment compounds were hand-broadcast into the mesocosms on August 4, 2004 (Photographs 8 and 9). The wetland vegetation at the site and within all of the treatment cylinders was dominated by maidencane (*Panicum hemitomon*).

Granular alum was by far the easiest compound to apply. The granules were relatively smooth and did not stick to each other or to the leaves of the plants (Photograph 10). The Baraclear™ pellets were difficult to apply due to the absorption of ambient moisture, which caused the pellets to disintegrate. The sticky Baraclear™ pieces then stuck to the application, and the leaves of the vegetation, after being broadcast into the plots (Photograph 11). The alum and ferric residuals were fairly difficult to handle because they were initially moist which caused them to “brick-up”. They required a pre-processing step, which in this experiment involved pressing the residual through a 2 mm-mesh screen. The residual compounds stuck to the leaves of the plants in the plots (Photograph 12).

Samples were collected by MACTEC personnel in accordance with the “Standard Operating Procedures for the Collection of Surface Water Quality Samples and Field Data”, published by the District on February 13, 2004.

Water depth was measured in each mesocosm plot to the nearest tenth of a foot using a plastic survey rod. Water depth was measured at three points in each plot on August 4, 6, 9, and 12, 2004. Water depth was measured at one point in each plot on August 19, September 2 and 30, 2004, January 14, February 10 and 21, April 27, and May 31, 2005. Water depth was measured at one point in three randomly selected plots on December 9, 2004. A staff gauge was installed and readings initiated on August 12, 2004. The staff gauge was also read and recorded every site visit thereafter.

Water temperature was measured to the nearest tenth of a degree Celsius (°C). The pH was measured to the nearest hundredth or nearest tenth of a unit. Both temperature and pH were measured using a Thermo Orion 290 A+ meter with a low maintenance pH triode. Dissolved oxygen was measured to the nearest 0.1 ppm using an YSI 55 DO meter. Conductivity was measured to the nearest integer using a YSI model 33 conductivity meter.

Per MACTEC field protocols, field instruments were calibrated and verified at the beginning of each day, prior to use, and verified at the end of each day. Standards used to calibrate the instruments in the laboratory were transported to the field location and used for instrument verification or re-calibration (if necessary).

Water samples were collected using a 1L glass jar attached to a polyvinyl chloride (PVC) pole. Sample bottles, without preservative, were provided by the District. Sample filtration in the field was completed using an ISCO pump which pushed sample through a Pall® Supor-450 filter membrane (0.45 µm)(142mm) held in a Geotech® filter holder. Water samples were stored on ice immediately after sample collection and were transported in less than 24 hours to either the District laboratory or to PPB Laboratories to meet holding time requirements. Samples were analyzed in accordance with USEPA and FDEP standard methods for the analyses of water samples.

All statistical analyses were carried out with Systat for Windows version 11. For each parameter, each treatment type was analyzed for difference from control, as well as differences from each other. Data for each parameter was used only after a trend appeared in the data. If no trend appeared, only the last data point was used. For each parameter, data was broken down by treatment type and tested for normality using a Kolmogorov-Smirnov one sample test. All data sets were then analyzed for significance from control using a one sample t-test. An analysis of variance was run for normally distributed data using an ANOVA test. A Kruskal-Wallis test was used for the analysis of variance of the non-parametric data.

4.0 Results

4.1 Range-finding Bench Test

Ocklawaha Prairie water had sufficient alkalinity to maintain pH above 4.5 at the application levels used in the bench scale study (Granular alum low, Baraclear^{TM} medium, Ferric residual, and Alum residual (Figures 2 and 3; Appendix A).

Granular alum was the most effective at reducing/removing P, followed by the high dose Baraclear^{TM} treatment, followed by the residual treatments (Figures 4 and 5). DinoSoil^{TM} was not only unpredictable, it was also the least effective at reducing P concentrations (Figures 4 and 5). Based upon the results of the bench-scale test, a decision was made to eliminate DinoSoil^{TM} as an experimental treatment for the field trial.

4.2 Mesocosm Study

The mesocosm study was initiated in early August, 2004. Within the month, the first of three large hurricanes blew through the prairie (Figure 6). The subsequent above-average water levels added a complication to the experiment. However, because there was a depth gradient at the site and the treatments were blocked by depth, it was assumed water level fluctuations, as well as chemical dilutions that may have resulted from the hurricanes, would be similar across the blocked plots.

Laboratory results, analyzed over time, indicate Control A (the control plot in the shallowest row) was an outlier for many of the analytes. A decision was ultimately made to exclude Control A data from the analyses.

The plots treated with Baraclear^{TM} and granular alum were overdosed, as indicated by a substantial depression in pH at the outset of the mesocosm study (Figure 7). The pH in the Baraclear^{TM} treatment replicates was still low at the sampling event 4 months after treatments, although the average pH was closer to controls than on previous dates.

A similar trend was observed for alkalinity; alkalinity was significatnely depressed at the outset of the mesacosm study (Figure 8). The field pH and laboratory alkalinity data indicate the supposed buffering capacity of Baraclear^{TM} was not apparent in these field trials. The Ocklawaha Prairie system appears poorly buffered. Although nature's recovery potential is significant, potential toxicity issues (e.g., low pH or high aluminum concentrations in the alum treatments) dictate caution.

On August 19, 2004 (Day 15 of the study) the field notes indicate the vegetation in the granular alum treatment plots was dead (Photograph 13). Algae was present in the Baraclear^{TM} treatments on September 2, 2004, but the macrophytes were dead (Photograph 14). Field notes from May 31, 2005 (day 300) indicate the maidencane was still dead in all of the Baraclear^{TM} and granular alum treatments, but some duckweeds, water hyacinth, and filamentous green algae were present in the plots (Appendix C). The maidencane was unaffected by the application of the residuals and was present in tall, dense (~ 1.5 m) concentrations similar to that found in the control mesocosum plots (Photographs 15 and 16).

Long term steady-state TP levels were significantly reduced by alum residual and Baraclear^{TM} (Figure 9, Table 4.2-1). The granular alum showed a reduction in TP levels that was not significant (Table 4.2-1). The ferric residual treatment showed some effect to day 127, following which more residual was applied, and then there was no effect on TP levels at the end of the study (day 300). Alum residual, Baraclear^{TM}, and granular alum were significantly better at removing total phosphorus from the water than ferric residual (Table 4.2-2).

Treatment effects on dissolved total phosphorus (Figure 10) and dissolved ortho-phosphate (Figure 11) were significantly different from controls for all compounds across all dates (Table 4.2-1). Reductions in dissolved total phosphorus and ortho-phosphate concentrations occurred immediately and were significantly reduced by all treatments. The dissolved total phosphorus and dissolved ortho phosphate concentrations in the four treatment types did not differ significantly from each other (Table 4.2-2).

Total Suspended Solids increased significantly in all treatments in the short-term following start-up (Figure 12). It is assumed this spike was an artifact of the hurricanes since a similar increase was not observed when the plots were re-treated in February, 2005. However, by the end of the study only ferric residual showed a significant increase in suspended solids (Table 4.2-1, Table 4.2-2), although it is worth noting that ferric residual was re-applied two times to the mesocosms—at days 190 and 201.

Due to pH depression, dissolved aluminum significantly increased with Baraclear^{TM} and granular alum through day 29. However, by the end of the second month, aluminum levels had started to decline towards pretest conditions (Figure 13). At the end of the study (day 300), dissolved aluminum was significantly higher than the control in the granular alum, Baraclear^{TM}, and alum residual mesocosms (Figure 14). Alum residual produced the highest dissolved aluminum concentration, which was significantly higher than the Baraclear^{TM} dissolved aluminum concentrations. Granular alum fell somewhere in between and was not significantly different from either treatment type (Table 4.2-2). The ferric residual did not show a significant difference from the control at the end of the study (Table 4.2-1), and was significantly lower in dissolved aluminum than the other three treatment types (Table 4.2-2).

The granular alum and Baraclear^{TM} reduced overall color more than other treatments (Figure 15, Table 4.2-2). The ferric residual treatments had significantly more color than the control and all other treatment types. In general, ferric-phosphate bonds are not particularly stable in the reduced conditions found at this site. However, laboratory studies completed by DB Laboratories indicate ferric residual may sustain its phosphorus binding capacity even under anaerobic conditions. As reported above, ferric residual did bind phosphorus, but not as effectively as some of the other treatment compounds. The ferric residual treatments, despite their darker color, did have unusual algae blooms compared to other plots, indicating the ferric may have had some fertilizing effect on algal producers. Dissolved ferric concentrations were higher than controls in the ferric residual treatments (Figure 16). The DO content was low (generally below 1 ppm) in all treatment plots on all dates.

No significant difference was found between controls and any of the treatment types (or between treatment types) for both chlorophyll *a* content and ammonium concentrations.

Data for each treatment type was used only after a trend appeared in the data. This was usually around day 100, after the initial spike and any artifacts related to the hurricanes, but ranged from day 29 to day 300 (Table 4.2-3). This affects the robustness of certain statistical conclusions. All data was broken down by treatment type and tested for normality using a Kolmogorov-Smirnov one sample test. Only the ferric residual data for dissolved ferric, the ferric residual and Baraclear^{TM} data for color, and the Baraclear^{TM}, granular alum, and alum residual data for ammonium were not normally distributed. However, since 85% of the data was found to be normally distributed, and each parameter had at least one normally distributed data set, all data sets were analyzed for significance from control using a one sample t-test (Table 4.2-1). An analysis of variance was run for the normally distributed data using an ANOVA test. A Kruskal-Wallis test was run for the analysis of variance for the non-parametric data (dissolved ferric, color, and ammonium data) (Table 4.2-2).

Output for all Systat statistical results can be found in Appendix D.

Table 4.2-1. Comparison of Control Group to Each Treatment Type at a 95% Confidence Interval

Treatment Type	**TP**	**TP-D**	**Ortho-PO$_4$**	**Fe-D**	**Al-D**	**Color**	**Alkalinity**	**NH$_4^+$**	**TSS**	**Chlorophyll *a***
Alum Residual	<	<	<	NSD	>	<	NSD	NSD	NSD	NSD
Baraclear^{TM}	<	<	<	<	>	<	>	NSD	NSD	NSD
Ferric Residual	NSD	<	<	>	NSD	>	NSD	NSD	>	NSD
Granular Alum	NSD	<	<	NSD	>	<	NSD	NSD	NSD	NSD

Note: NSD = No significant difference from control

< Parameter significantly lower in treated cells compared with control

> Parameter significantly higher in treated cells compared with control

Table 4.2-2. Comparison of Treatment Types at a 95% Confidence Interval

Treatment Type	**TP**	**TP-D**	**Ortho-PO$_4$**	**Fe-D**	**Al-D**	**Color**	**Alkalinity**	**NH$_4^+$**	**TSS**	**Chlorophyll *a***
Alum Residual	B	A	A	B	A	B	B	A	B	A
Baraclear^{TM}	B	A	A	B	BC	C	A	A	B	A
Ferric Residual	A	A	A	A	C	A	B	A	A	A
Granular Alum	B	A	A	B	AB	C	AB	A	AB	A

Parameters with the same letter are not significantly different. Parameters that do not share the same letter are significantly different. Parameters ranked with an ‘A’ show significantly higher values than those ranked with ‘B’, and so on. All analysis were run using an ANOVA test with a Bonferroni post-hoc test *except* those for dissolved ferric, color, and ammonium. The latter were not normally distributed and the analysis of variance was done using the Kruskal-Wallis test.

Table 4.2-3. Data Range Used in Statistical Analysis for Various Parameters

Parameter	**Date Data Used From**
TP	Day 200
TP-D	Day 100
Ortho-PO_4	Day 100
Fe-D	Day 50
Al-D	Day 200
Color	Day 50
Alkalinity	Last data point only
NH_4^+	Day 50
TSS	Day 29
Chlorophyll *a*	Last data point only

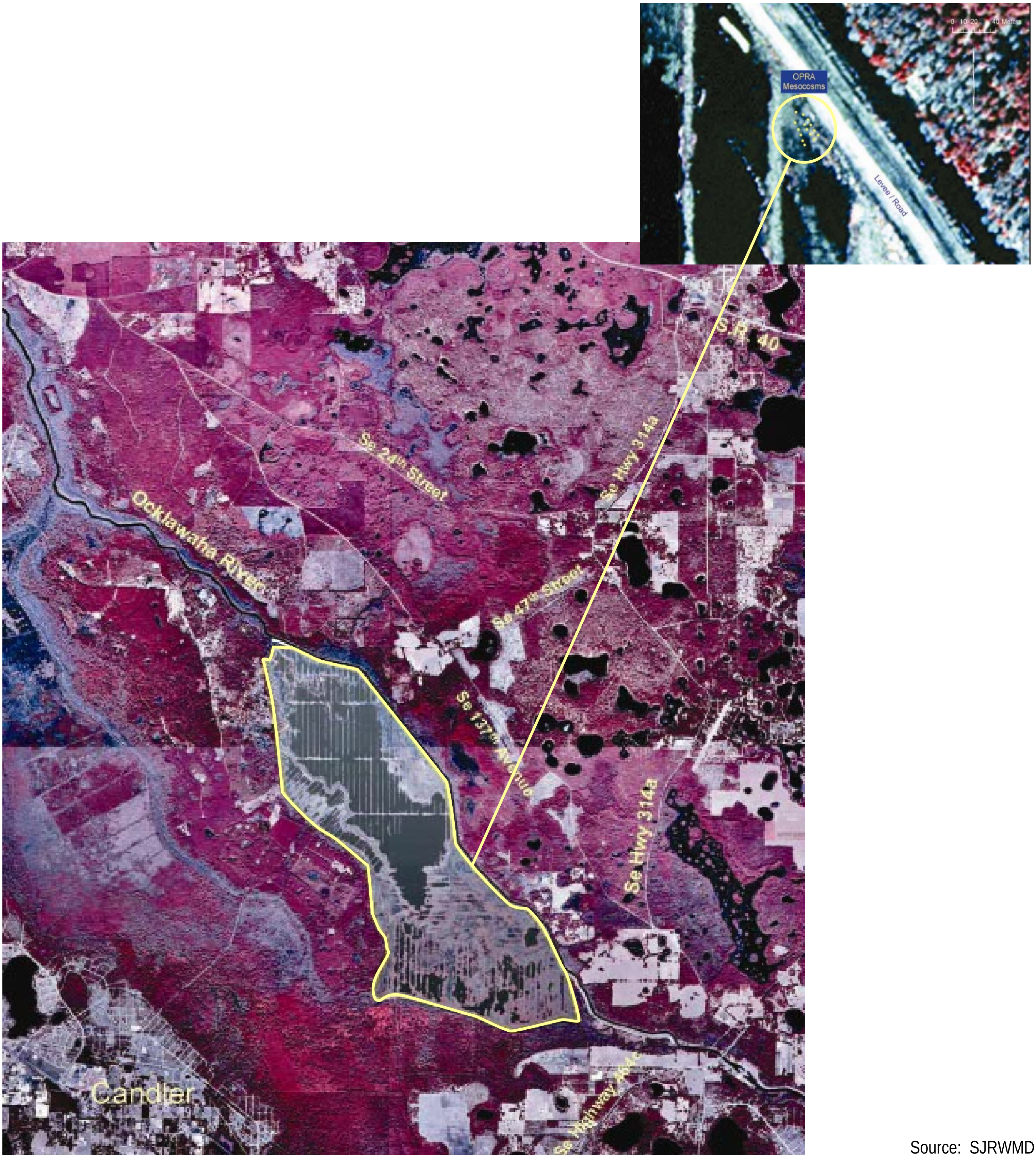
5.0 Conclusions

All of the test compounds reduced phosphorus content in the field trials to some extent. Baraclear^{TM} and alum residual produced a significant reduction in total phosphorus, while all four reduced dissolved total phosphorus and dissolved ortho-phosphate significantly (Table 4.2-1). While it appears the ferric residual reduced total phosphorus significantly less than the other three test compounds, there was no significant difference between treatment types in reduction of dissolved total phosphorus or dissolved ortho-phosphate (Table 4.2-2). The initial treatment dosages for granular alum (0.1 g Al/L) and Baraclear^{TM} (0.2 g Al/L) were too high and the emergent vegetation in those plots was scorched and/or killed with virtually no recovery after one year.

Of the four compounds tested in the field trials, granular alum appears to be the best candidate for aerial application. The granular alum pellets stayed together throughout the application process and penetrated the vegetation. Although Baraclear^{TM} performed almost identically to granular alum, Baraclear^{TM} is a poor candidate for aerial application because the pellets disintegrated as soon as they came in contact with humid air, followed by the dust and particles became sticky, and Baraclear ^{TM} pellets did not penetrate the vegetation. The alum and ferric residuals are poor candidates for aerial application without significant pre-treatment since they are more difficult to handle, requiring a pre-processing step (i.e. crushing or pulverizing), and they are not as effective at phosphorus reduction, which means more compound is required to achieve the desired result. In addition, ferric and alum residuals showed slightly less desirable results in some aspects of phosphorus reduction, color, and dissolved aluminum concentrations.

MACTEC recommends the District eliminate Baraclear^{TM} from consideration and then conduct a cost-benefit analysis with the two residuals versus granular alum. The success criteria for the analysis should be defined in the context of the restoration goals.

Figures



Source: SJRWMD.

Ocklawaha River and Prairie	MACTEC	Site Location Map 6063040022 Figure 1

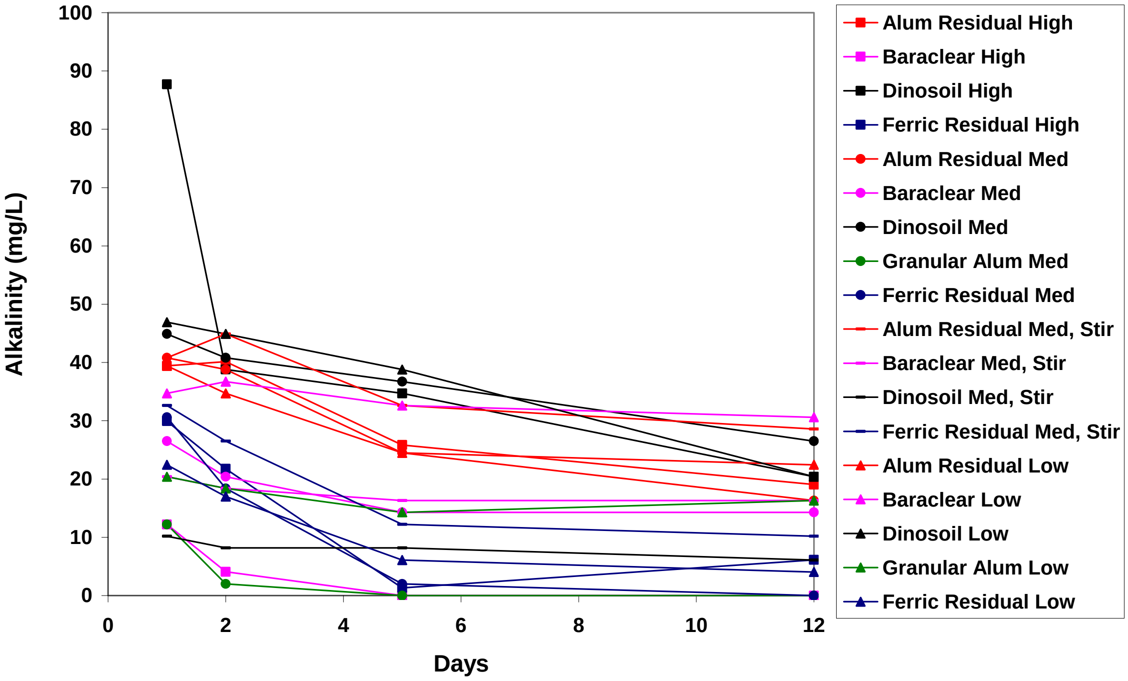


Figure 2. Alkalinity Concentrations in the Range-Finding Bench-Scale Test

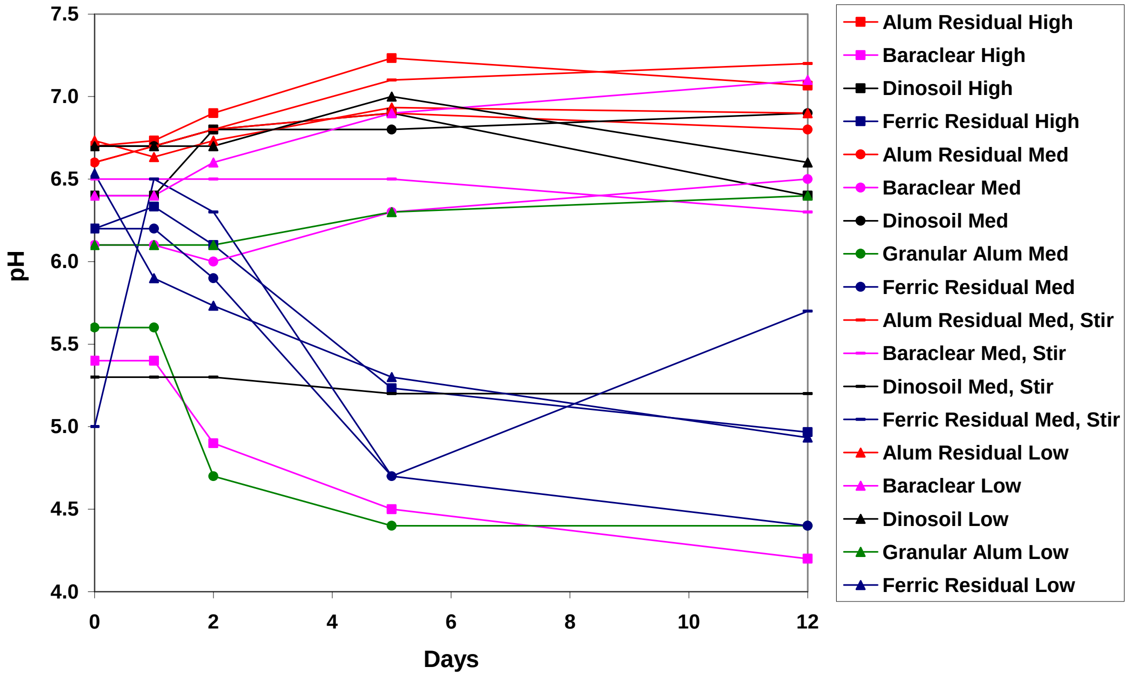


Figure 3. pH Levels in the Range-Finding Bench-Scale Test

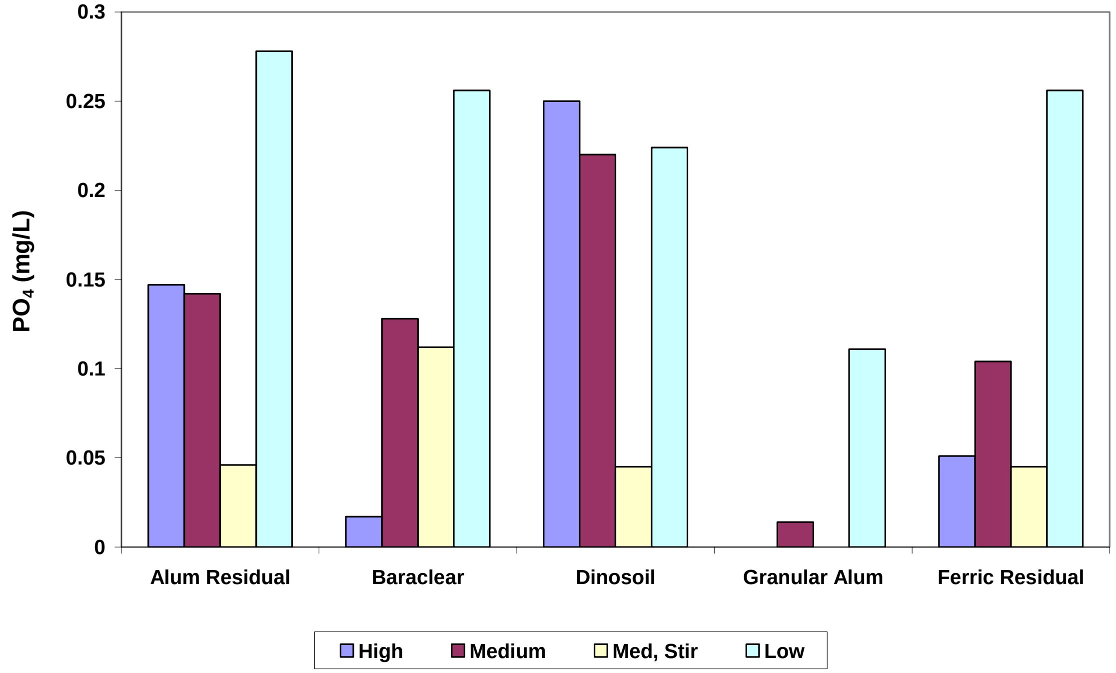


Figure 4. Dissolved Ortho-Phosphate Concentrations at the End of the Range-Finding Bench-Scale Test

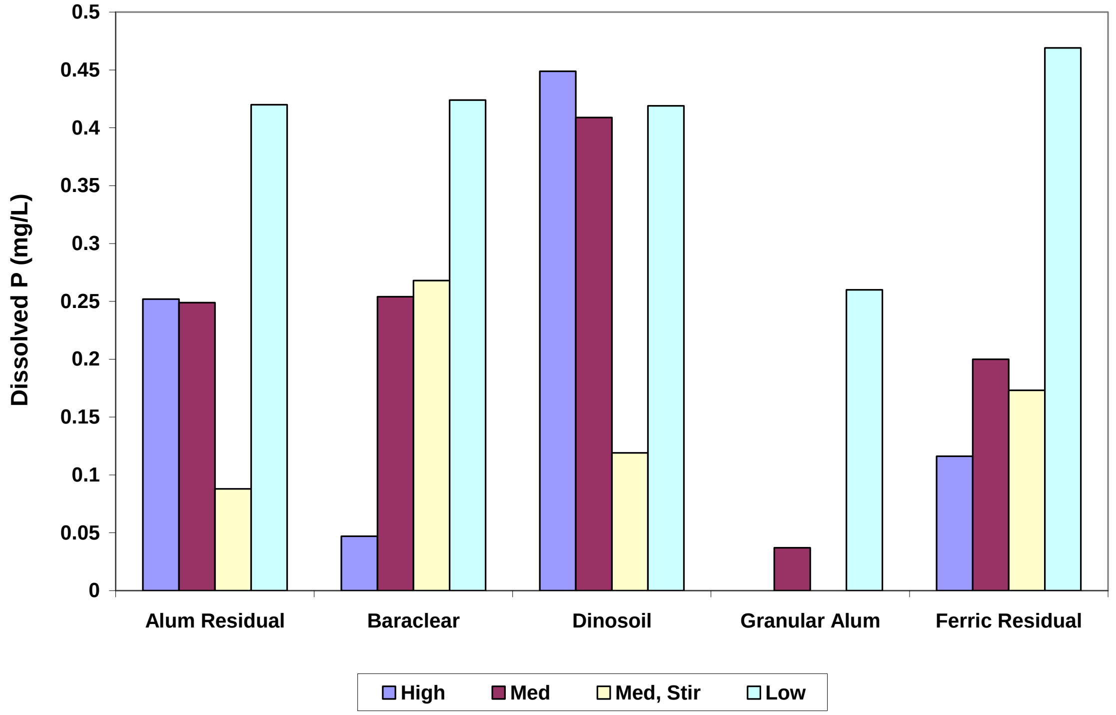


Figure 5. Dissolved Total Phosphorus Concentrations at the End of the Range-Finding Bench-Scale Test

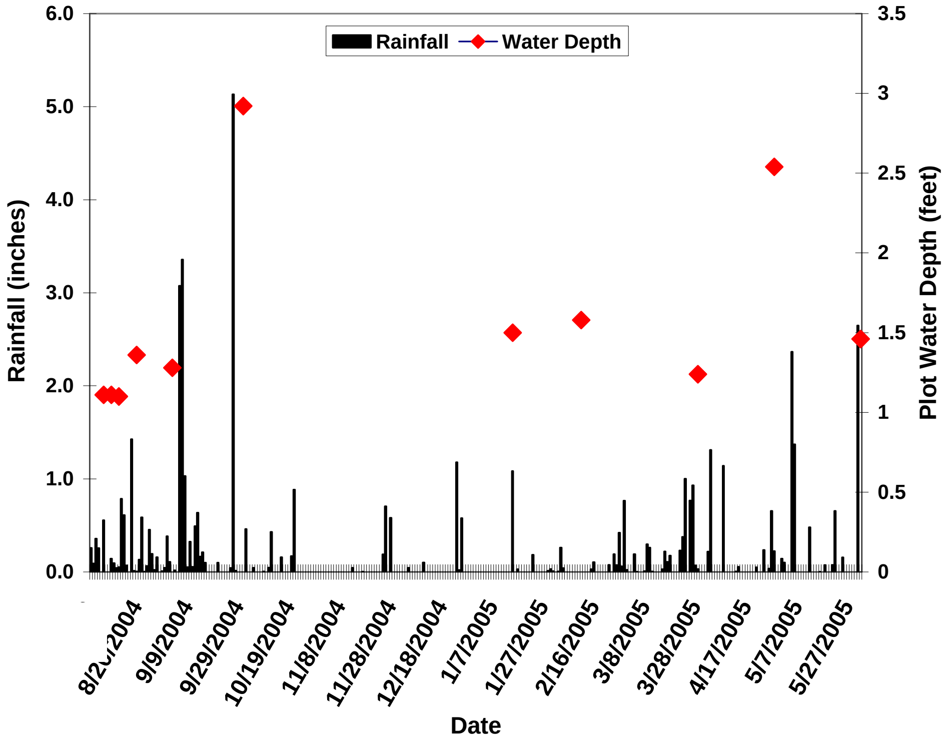


Figure 6. Rainfall and Its Effect on Plot Water Depth in the Ocklawaha Prairie Mesocosm Study.
Note: Hurricanes occurred on August 13 (Charley); September 5 (Frances); September 15 (Ivan); and September 26 (Jeanne).

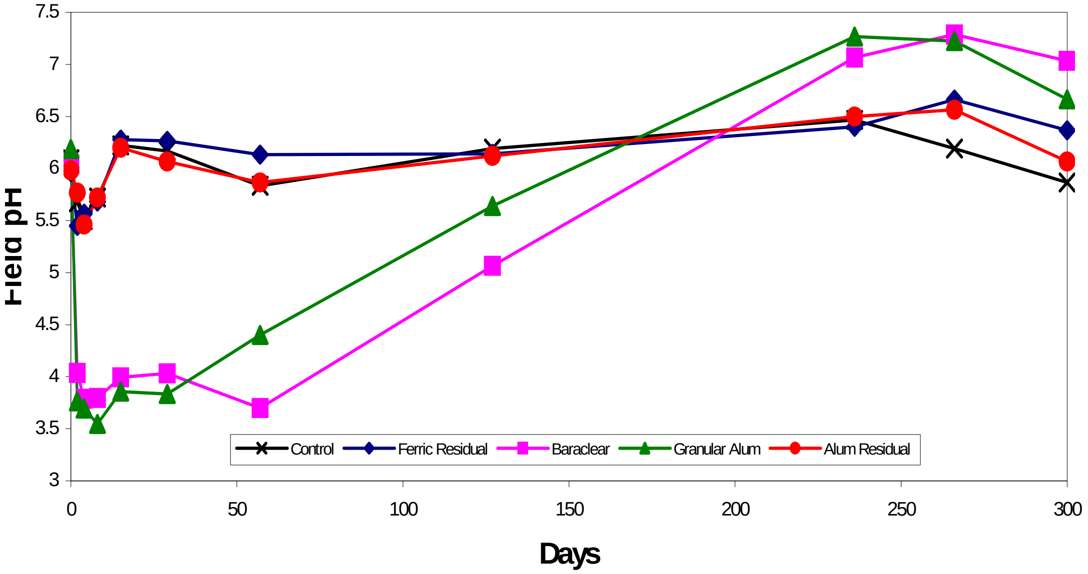


Figure 7. Field pH Data from the Ocklawaha Prairie Mesocosm Study (Average of the Replicates)

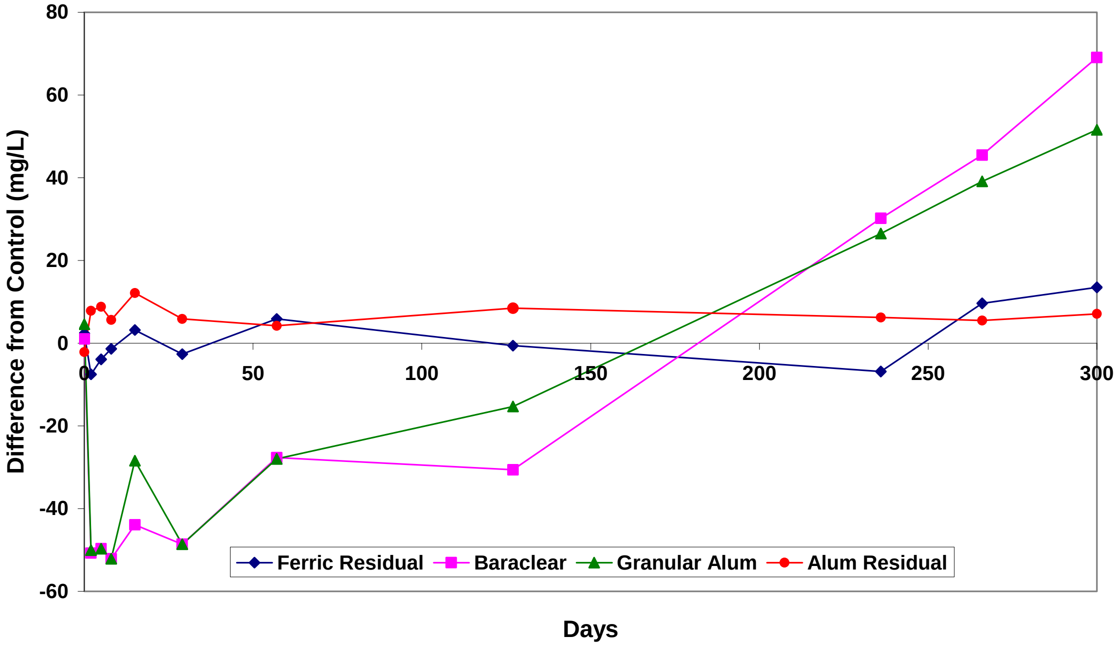


Figure 8. Alkalinity Levels Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

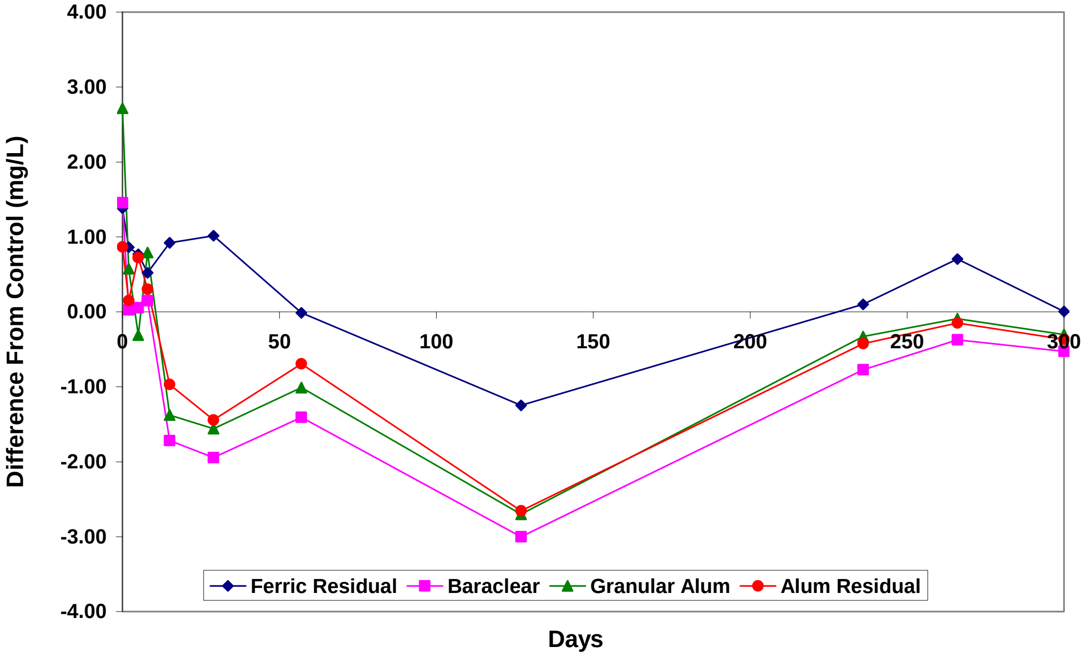


Figure 9. Total Phosphorus Concentrations Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

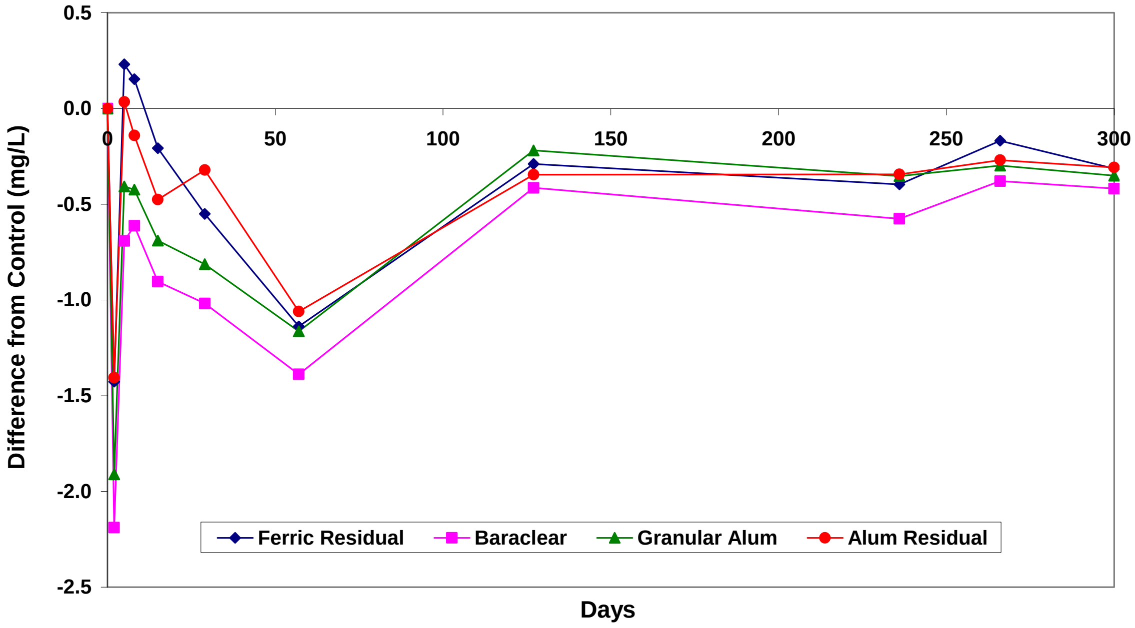


Figure 10. Dissolved Total Phosphorus Concentrations Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

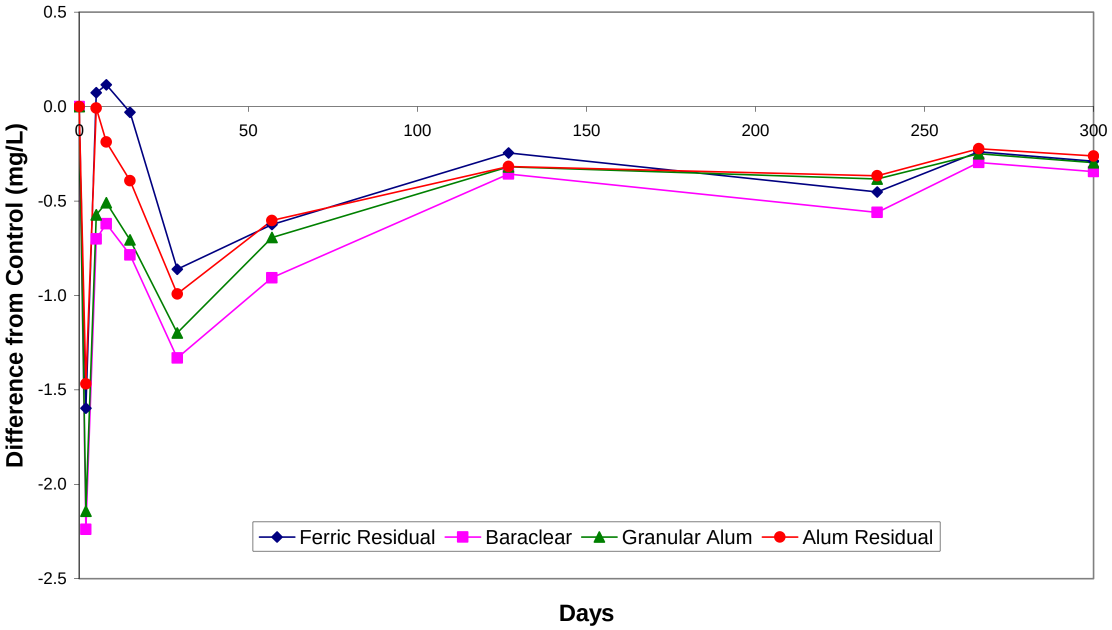


Figure 11. Dissolved Ortho-Phosphate Concentrations Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

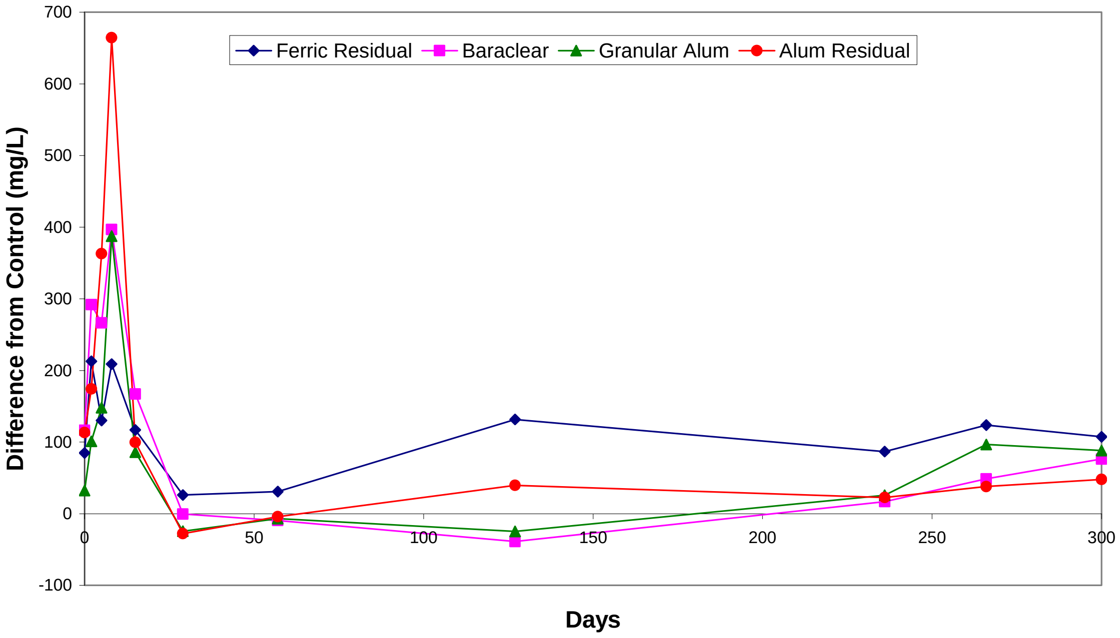


Figure 12. Total Suspended Solids Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

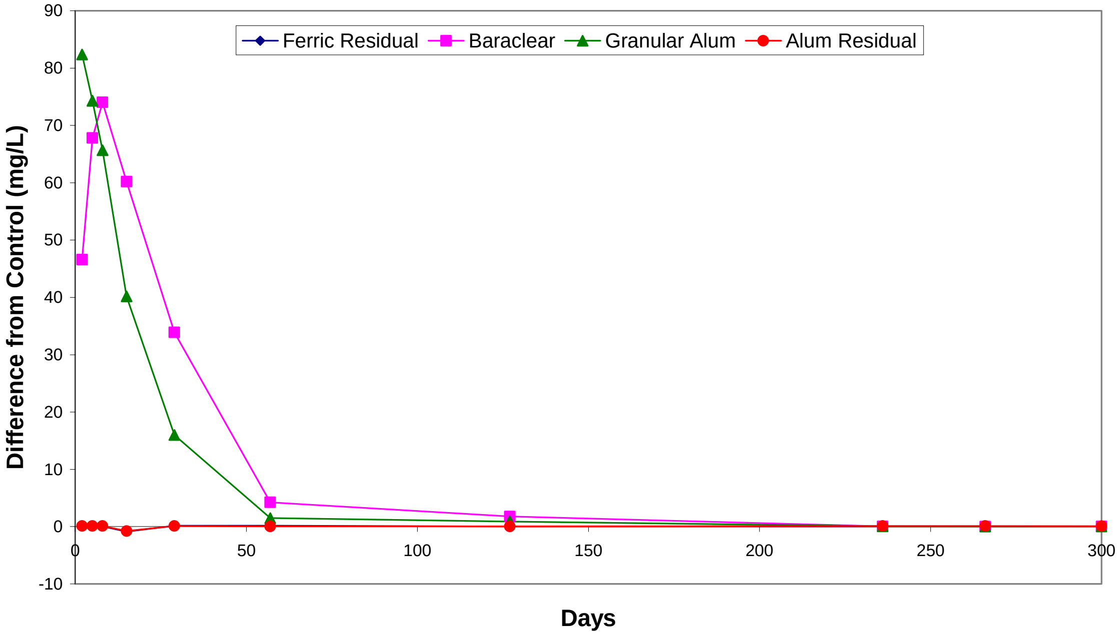


Figure 13. Dissolved Aluminum Concentrations Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

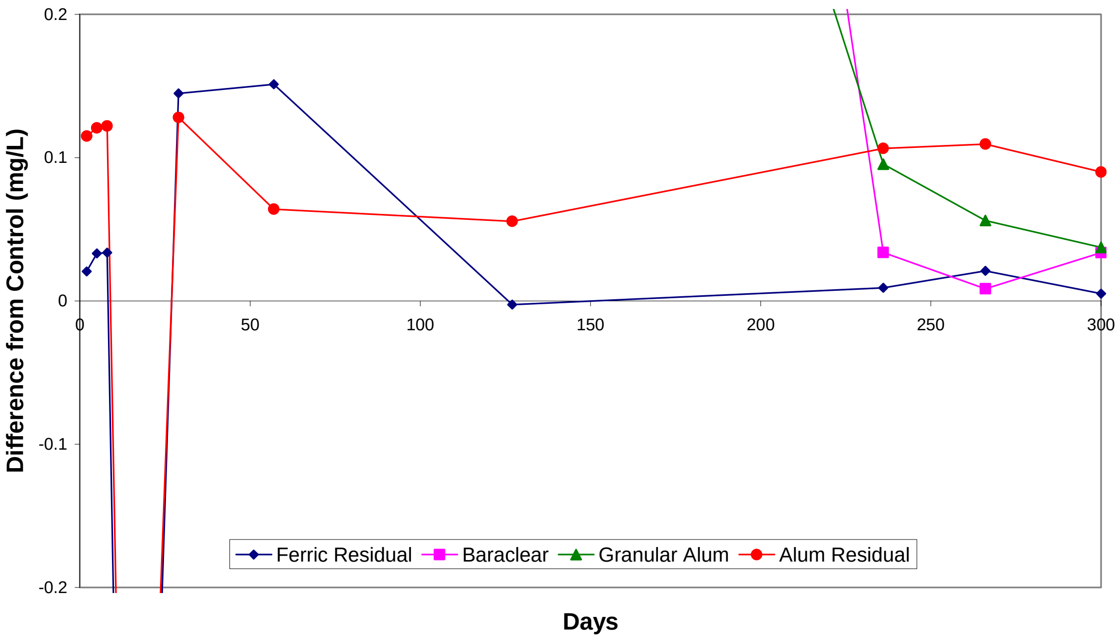


Figure 14. **Dissolved Aluminum Concentrations, Excluding Spikes, Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.**

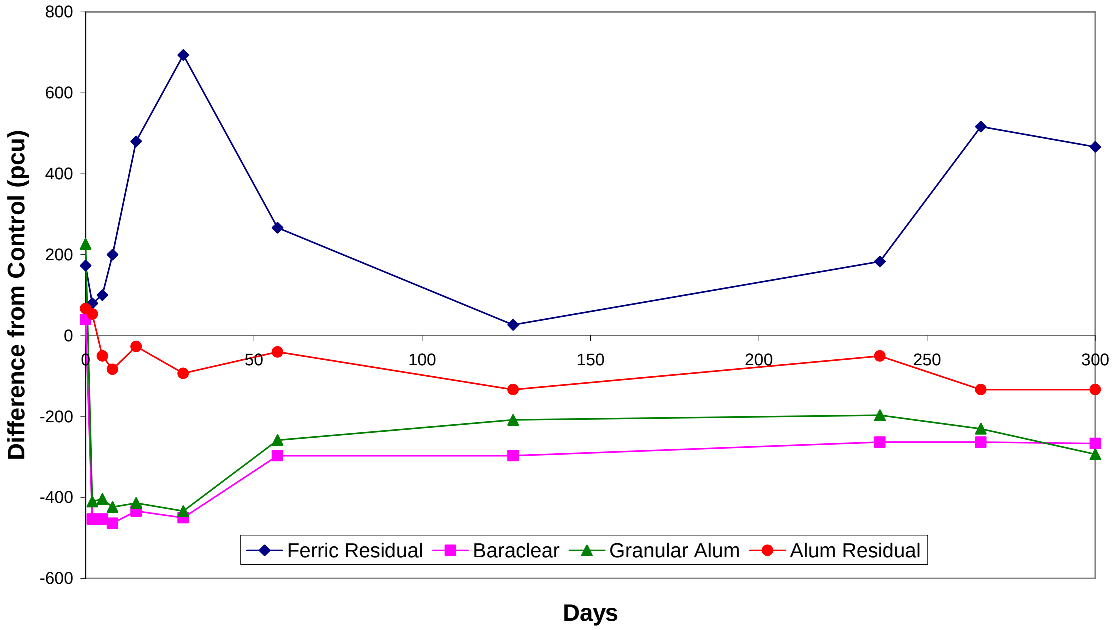


Figure 15. **Water Color Units Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.**

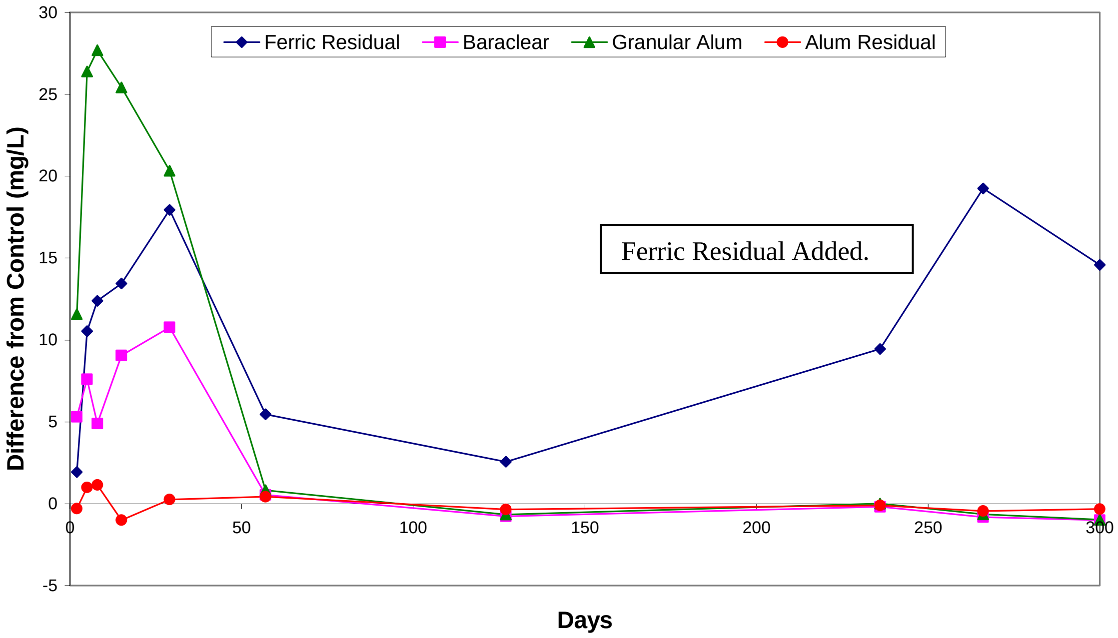


Figure 16. Dissolved Ferric Concentrations Expressed as Difference from Controls in the Ocklawaha Prairie Mesocosm Study.

Photographs

Photograph 1. High Grass during mesocosm construction period

Photograph 2. Baraclear^{TM} pellets

Photograph 3. Granular Alum Residual

Photograph 4. FerricResidual and Alum Residual

Photograph 5. Mesocosm plots at Ocklawaha Prarie

Photograph 6. Bench Scale Study Prior to Field Application

Photograph 7. Structure of mesocosm

Photograph 8. Hand broadcasting amendment into mesocosm

Photograph 9. Hand Broadcasting amendment into Mesocosm

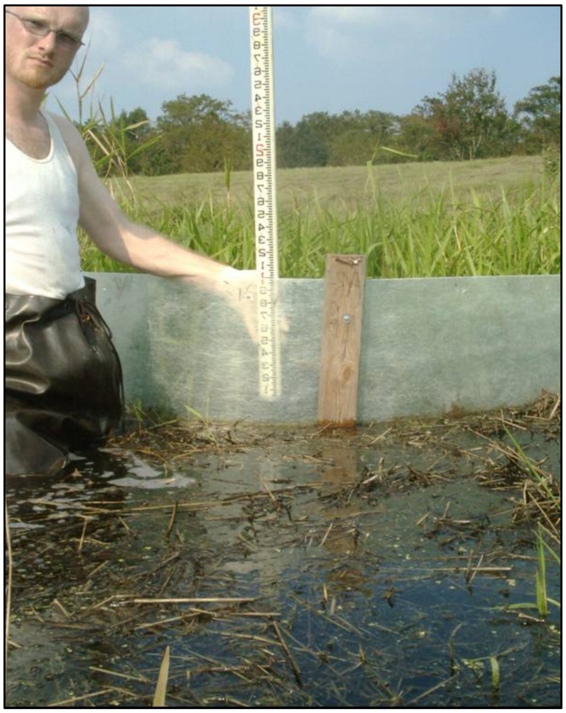
Photograph 10. Mesocosm Vegetation after Granular Alum Application

Photograph 11. Mesocosm Vegetation after Baraclear^{TM} pellets Application,

Photograph 12. Mesocosm Vegetation after Residual Application

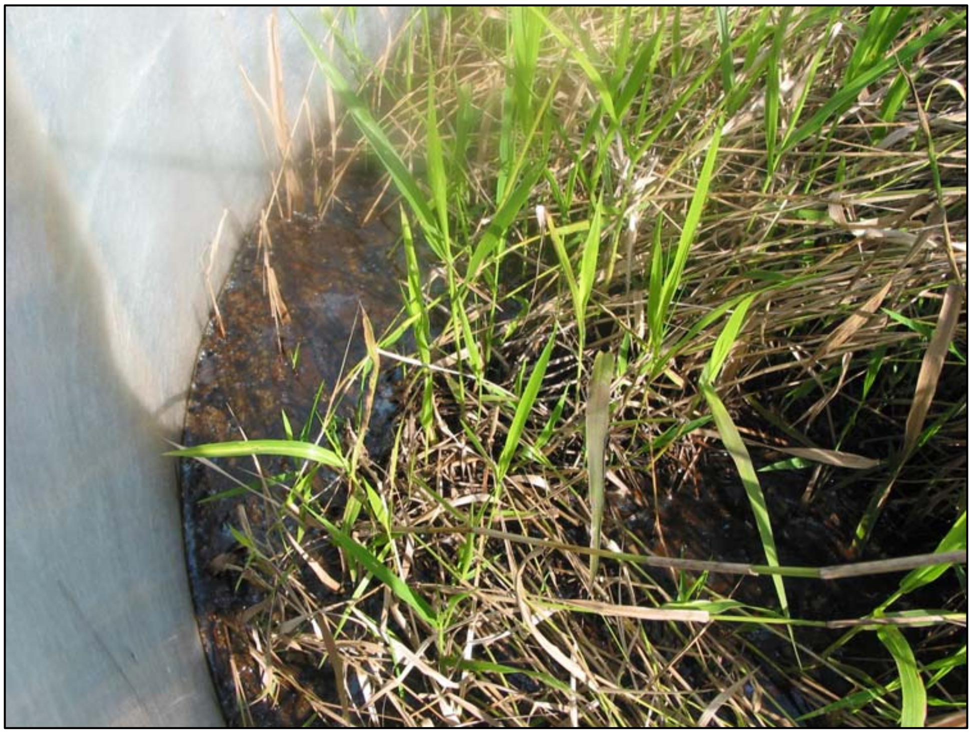
Photograph 13. 57 Days After Being Overdosed with Granular Alum, Ocklawaha Prairie Mesocosm Study

Photograph 14. 57 Days After Being Overdosed with Baraclear^{TM}, Ocklawaha Prairie Mesocosm Study



Photograph 15. 57 Days After Being Dosed with Alum Residual, Ocklawaha Prairie Mesocosm Study

Photograph 16. Vegetation in a Control Plot on Day 57, Ocklawaha Prairie Mesocosm Study



Photograph 17. Algal Sheen in Ferric Residual Treatment on Day 12

Photograph 18. Geotech pump and P Meter.

Photograph 19. Geotech pump and P Meter.

APPENDIX A

Lab Data from the Range-Finding Test

Table A-1. Ocklawaha River Data from Laboratory Range-Finding Test, July 2004.

Compound	Treatment	Dose Description	Dose g/L	19-Jul Diss PO4 mg/L	19-Jul Diss Total P mg/L	19-Jul Total P mg/L	19-Jul P (a) mg/L	7-Jul Total P mg/L	7-Jul pH	8-Jul pH	9-Jul pH	12-Jul pH	19-Jul pH	8-Jul Alkalinity mg/L	9-Jul Alkalinity mg/L	12-Jul Alkalinity mg/L	19-Jul Alkalinity mg/L
Alum Residual	A	low	6	0.163	0.301	0.334	0.02	0.78	6.7	6.7	6.8	7.1	7.1	44.9	40.8	28.6	34.7
	B1	med	12	0.142	0.249	0.301	0.15	0.235	6.7	6.6	6.7	6.9	6.8	53	38.8	26.5	16.3
	B2	med, stir	12	0.046	0.088	0.276	0.222	0.354	6.6	6.6	6.7	6.8	6.8	20.4	24.5	18.4	16.3
	C	high	18	0.13	0.228	0.271	0.264	0	6.7	6.7	6.8	6.9	6.9	40.8	38.8	24.5	16.3
	AA	low	4	0.174	0.32	0.363	0.134	0.97	6.7	6.7	6.8	7.1	7.2	40.8	44.9	32.6	28.6
	AAA	low	2	0.278	0.42	0.462	0	0.31	6.8	6.8	6.9	7.3	7.3	42.8	49.0	40.8	34.7
	CC	high	20	0.134	0.247	0.275	0.111	0	6.8	6.8	7.0	7.4	7.0	38.8	32.6	16.3	10.2
	CCC	high	24	0.147	0.252	0.293	0.003	0.316	6.6	6.6	6.8	7.0	6.9	36.7	38.8	20.4	12.2
Ferric Residual	A	low	6	0.153	0.337	0.381	0.17	0.45	6.5	6.5	6.3	6.1	5.4	32.6	30.6	12.2	8.2
	B1	med	12	0.104	0.2	0.245	0.085	0.212	6.2	6.2	6.0	5.1	4.7	26.5	16.3	4.1	2.0
	B2	med, stir	12	0.045	0.173	0.735	0.218	0.189	5.0	5.0	4.9	4.7	4.7	8.2	4.1	2.0	2.0
	C	high	18	0.067	0.131	0.173	0.336	0.046	6.2	6.2	5.9	4.7	4.4	30.6	18.4	2.0	0
	AA	low	4	0.189	0.308	0.367	0.042	0.367	6.5	6.5	6.3	6.2	5.7	32.6	26.5	12.2	10.2
	AAA	low	2	0.256	0.469	0.505	0.241	0.368	6.6	6.6	6.5	6.5	6.4	40.8	36.7	26.5	18.4
	CC	high	20	0.063	0.169	0.219	0.101	0.28	6.2	6.2	5.9	4.7	4.3	24.5	14.3	2.0	0
	CCC	high	24	0.051	0.116	0.169	0.02	0.271	6.2	6.2	5.9	4.5	4.2	24.5	14.3	0	0
Baraclear™	A	low	0.1	0.256	0.424	0.578	0	0.215	6.4	6.4	6.6	6.9	7.1	34.7	36.7	32.6	30.6
	B1	med	0.2	0.128	0.254	0.425	0.046	0.019	6.1	6.1	6.0	6.3	6.5	26.5	20.4	14.3	14.3
	B2	med, stir	0.2	0.112	0.268	0.671	0.049	0.091	6.5	6.5	6.5	6.5	6.3	20.4	18.4	16.3	16.3
	C	high	0.5	0.017	0.047	0.052	0.013	0.274	5.4	5.4	4.9	4.5	4.2	12.2	4.1	0	0
Granular alum	A	low	0.1	0.111	0.26	0.457	0.016	0.016	6.1	6.1	6.1	6.3	6.4	20.4	18.4	14.3	16.3
	B1	med	0.2	0.014	0.037	0.052	0.023	0.049	5.6	5.6	4.7	4.4	4.4	12.2	2.0	0	0
Dinosoil™	A	low	6	0.224	0.419	0.5	0.196	0.408	6.7	6.7	6.7	7.0	6.6	46.9	44.9	38.8	20.4
	B1	med	15	0.22	0.409	0.553	0.381	0.08	6.7	6.7	6.8	6.8	6.9	44.9	40.8	36.7	26.5
	B2	med, stir	15	0.045	0.119	0.286	0.042	0.28	5.3	5.3	5.3	5.2	5.2	10.2	8.2	8.2	6.1
	C	high	24	0.25	0.449	0.551	0.297	0.417	6.4	6.4	6.8	6.9	6.4	87.7	38.8	34.7	20.4

Note: (a) = P measured with handheld P Spectrometer.

Source: MACTEC, 2005.
Created by: JLD Reviewed by: SEB, JMR

APPENDIX B

Raw Data

August 4, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Ca-T mg/L	Fe-T ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	27	960	86	66.6	0.012	0.071	585	25.8	10800	38.9	29.7	-0.2	-2.3	16.8	1.4	6.28	26.4	6.05	0.3	271	
Control-B	29	400	48	53.6	0.012	0.043	266	20.2	7790	32.8	30.1	3.7	1.5	1.4	1.7	2.58	25.9	5.9	0.5	207	
Control-C	30	480	42	52.2	0.006	0.015	200	20.4	9120	49.2	47.8	10.8	2.6	1.1	1.7	2.4	26.8	6.32	0.5	212	
FeR-A	60	800	222	57	0.014	0.051	1610	23.8	10800	37.2	30.3	1.6	-4	13.5	1.4	4.81	26.3	6.04	0.4	256	
FeR-B	31	640	66	52	0.007	0.067	346	20	9280	25.4	21.3	0.4	-0.6	4.6	1.6	4.64	26.6	5.95	0.5	230	
FeR-C	28	400	101	56.8	0.005	0.043	179	23.1	7240	50.8	46.7	6.6	-1.7	4.6	1.6	2.17	26.7	5.91	0.5	236	
BARA-A	75	560	287	53.6	0.012	0.21	1450	23.4	13200	98.6	94.5	17.4	0.9	11.7	1.6	4.86	26.3	5.94	0.5	248	
BARA-B	65	480	136	45.7	0.01	0.06	567	18.4	10400	61.4	58.7	8.5	0	6.4	1.6	4.64	26.4	6.08	0.4	260	
BARA-C	27	400	61	62.5	0.008	0.023	316	24.3	7830	17.7	15	3.3	0.3	6.8	1.4	2.34	26.1	6.1	0.4	215	
GA-A	39	960	95	72.8	0.017	0.287	467	27.4	18500	89.1	78.2	12.4	-1.4	14.6	1.6	8.54	26.9	6.4	0.5	269	
GA-B	33	640	91	47.8	0.015	0.049	338	18.6	9760	19.5	15.4	-2	-1	6.8	1.4	4.74	26.2	6.22	0.4	191	
GA-C	11	400	46	51.9	0.016	0.019	164	20.6	6490	27	25.6	3.5	-0.1	0	1.7	2.34	25.5	5.94	0.6	230	
AlR-A	65	560	222	41.8	0.014	0.056	1720	19.1	8290	28.3	25.6	3.5	-0.1	6.1	1.5	3.08	25.3	5.87	0.4	207	
AlR-B	50	640	185	52.1	0.011	0.042	378	21	11700	38.5	34.4	7.2	-1.2	2.8	1.6	4.25	26.6	5.81	0.4	260	
AlR-C	32	320	68	58.3	0.008	0.034	170	23.1	8900	64.1	61.4	12.3	0.8	5.3	1.6	2.74	26.4	6.27	0.6	236	

Source: PPB Laboratories, Gainesville, FL.

August 6, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	95	800	408	66.9	0	0.077	2360	120	33.3	16300	6350	285.4	175	-65.6	-86.6	131.4	1.3	7.42	0.925	3.78	26.9	5.72	0.3	393	
Control-B	65	400	206	49.3	0.018	0.067	748	19.6	24.5	10700	1950	121.9	73.8	-35.8	-44.1	48.7	1.3	3.26	0.665	0.734	26.3	5.85	0.4	300	
Control-C	45	560	223	50.7	0	0.074	293	49	21.8	12900	3670	98.9	76.4	-10.6	-20.1	41.7	1.4	3.55	3.87	3.82	26.8	5.46	0.5	300	
FeR-A	65	640	542	38.4	0	0.154	1580	67.7	25.5	66400	5690	152.2	90.8	-44.4	-58.7	87.6	1.2	4.81	0.633	0.67	26.1	5.15	0.3	386	
FeR-B	50	640	207	38.7	0	0.105	1100	83	23.8	34600	5910	80.1	56.7	-13.6	-19.5	25.9	1.4	4.47	0.994	1.44	25.6	5.55	0.4	358	
FeR-C	120	400	533	50.3	0.008	0.139	580	14	28.3	30800	2620	87	48.7	-33.5	-37.8	40.7	1.2	3.52	0.384	0.442	27.6	5.65	0.3	343	
BARA-A	240	30	785	0	0.017	0.956	191000	84500	69.6	26100	9920	32.6	21.7	-3.8	-11.7	22.8	1.2	4.49	0.031	0.112	27.4	3.99	0.4	2830	
BARA-B	100	30	408	0	0	0.489	126000	46000	52.6	16000	6360	42.8	30.5	-9.4	-10.8	30.4	1.2	3.23	0.05	0.122	26.2	3.99	0.7	1400	
BARA-C	120	20	326	-2.29	0.014	0.134	50300	9340	37.9	15600	8050	44.7	27.1	-10.9	-17.8	16.8	1.3	2.58	0.004	0.032	25.9	4.13	0.5	1144	
GA-A	55	80	485	0	0.022	0.603	132000	96700	80.7	37900	23900	62.2	37	-20.7	-25.4	43.5	1.1	6.12	0.16	0.447	26.8	3.7	0.8	1859	
GA-B	80	60	201	0	0.017	0.17	76900	57800	49.6	18600	10800	35.7	21.4	-8.2	-17.7	15.5	1.3	3.61	0.08	0.342	27.8	3.78	0.4	1187	
GA-C	39	70	261	0	0	0.28	99800	92800	45.6	12900	8460	78.5	64.2	-2	-10.2	41.1	1.3	2.21	0.135	0.309	27.9	3.81	0.4	1788	
AlR-A	180	560	657	47.7	0	0.192	9720	139	26.4	11100	1790	107.4	58.3	-37.6	-51	53.4	1.2	3.62	0.532	0.594	26.2	5.7	0.4	343	
AlR-B	50	640	149	59.6	0	0.057	4590	173	23	10900	2750	64.9	48.5	-6.5	-8.2	15	1.5	3.44	1.1	1.2	25.3	5.92	0.5	365	
AlR-C	130	400	360	66.1	0.025	0.079	10200	136	31.6	13800	3010	107.4	44.6	-55.2	-68	28.5	1.3	3.61	0.765	0.82	25.8	5.68	0.4	358	
Dupe-1	95	720	513	45.2	0	0.151	6640	126	24.7	10200	1610	72	39.3	-29.9	-38.5	41.7	1.1	3.44	0.412	0.517					
Wetland	65	400	190	54.5	0.024	0.04	233	18.2	31.3	8170	1580	79.6	53.3	-12	-19	20.6	1.5		0.248	0.314					

Source: PPB Laboratories, Gainesville, FL.

August 9, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	55	70	510	62.9	0	0.071	2750	111	30.3	14000	5140	244	168.3	-41.4	-65.6	133	1.3	5.82	2.6	2.63	25.3	5.56	0.1	290	
Control-B	75	600	263	48.7	0.021	0.147	850	21.5	22.9	8100	1720	121.6	76.6	-38.9	-46.9	56.1	1.3	2.38	0.572	0.614	25.1	5.6	0.1	252	0.17
Control-C	65	400	166	50.7	0.018	0.068	325	27	23.1	9870	3560	66.3	54.2	-5.5	-10.5	16.8	1.5	2.76	0.854	0.92	26.4	5.35	0.1	300	0.15
FeR-A	180	600	472	48.2	0.028	0.115	1910	79.6	26.2	34700	17600	71.7	47.2	-15.4	-27.8	38.4	1.2	3.9	0.861	1.18	25.4	5.6	0.1	334	
FeR-B	70	700	323	42	0.026	0.102	1000	76.1	22.8	30900	12900	110.1	89.6	-5.6	-16.9	36.8	1.4	3.42	0.933	1.18	25.1	5.52	0.3	298	0.89
FeR-C	65	500	239	47.1	0.016	0.242	435	16.6	23.2	32300	9040	114.8	98.4	-3.1	-6.6	51.8	1.4	2.69	0.566	0.635	25.8	5.58	0.1	288	0.12
BARA-A	270	60	713	0	0	2.46	162000	106000	93	28300	18400	36	23.7	-9.8	-13.1	19.2	1.2	2.53	0.037	0.127	26.3	3.74	0.1	1620	
BARA-B	180	40	337	0	0	0.965	78700	54400	65.7	14800	1310	47.2	30.9	-12.5	-19.1	21.4	1.3	1.36	0.002	0.047	26	3.73	0.4	1656	0.02
BARA-C	190	40	393	0	0.004	0.503	88800	43100	70.1	24200	11000	72	45.4	-22.7	-24.4	34.7	1.3	3.98	-0.003	0.052	26.1	3.9	0.3	1560	0.01
GA-A	190	100	651	0	0	2.39	94200	82000	122	54400	47500	56.1	33.6	-17.3	-22.8	43.3	1.1	3.24	0.238	0.474	26.8	3.74	0.5	1860	0.12
GA-B	75	100	317	0	0.011	0.108	56000	49500	66.1	27700	21300	29.2	16.9	-10.2	-15.5	17.1	1.2	1.86	0.047	0.277	26.8	3.81	0.1	1260	0.06
GA-C	23	90	119	0	0.006	0.64	94500	91500	67.4	23300	18300	54.3	44.1	-8.3	-8.5	39.2	1.2	1.68	0.136	0.329	25.7	3.54	0	1440	0.05
AlR-A	220	500	554	51	0	0.548	9640	132	30.7	11900	2930	112.1	64.4	-37.7	-52.9	54.3	1.2	3.04	0.562	0.649	25.3	5.47	0.1	300	
AlR-B	370	400	909	59.2	0.013	0.15	19200	158	42.2	24400	3980	135.8	90.8	-45.4	-48.9	69.4	1.3	4.57	0.91	1.06	25.9	5.41	0	222	
AlR-C	95	450	269	65.3	0.016	0.081	4210	145	28.2	10200	4000	96.5	47.4	-43.7	-54.6	16.6	1.5	2.27	0.645	0.697	25.1	5.51	0.1	270	0.021

Source: PPB Laboratories, Gainesville, FL.

August 12, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	110	1000	392	64.5	0	0.051	4770	150	37.2	15300	4740	152.5	109.6	-24.7	-34.6	66.8	1.3	4.96	2.25	2.36	24.8	5.69	0.2	259	
Control-B	45	500	107	48.1	0	0.034	242	42.2	22.2	5900	1740	36	31.9	0.6	-0.9	-2.1	1.8	1.76	0.657	0.715	24.8	5.84	0.2	210	
Control-C	190	500	345	56.2	0	0.062	1020	60.3	25.6	9540	2020	157	116.1	1.9	14.1	63.5	1.4	2.17	0.583	0.65	24.7	5.63	0.2	220	
FeR-A	190	900	777	56.4	0.008	0.098	3150	139	31.2	43600	18600	108	75.3	-23.7	-38.2	47	1.3	2.94	0.733	0.88	24.7	5.68	0.2	300	
FeR-B	170	700	329	46.6	0.003	0.08	1100	103	24.8	30200	13100	128.4	103.8	-12.1	-18.9	59.3	1.4	2.44	0.898	0.995	24.7	5.64	0.3	250	
FeR-C	80	500	199	49.4	0	0.078	209	13	24.8	28300	11100	142.8	122.3	12.3	-1.3	47.5	1.5	2.08	0.574	0.635	25.1	5.73	0.2	230	
BARA-A	600	30	1132	0	0.009	0.264	178000	95000	137	43500	14300	51.6	33.2	-13.6	-19.4	34.2	1.2	3.68	-0.005	0.068	25.2	3.9	0.3	2200	
BARA-B	140	50	325	0	0.007	1.59	73000	58700	82.5	12600	5120	31.3	19	-7.6	-12.5	11.7	1.3	1.16	-0.003	0.076	24.8	3.77	0.3	1500	
BARA-C	200	30	411	0	0.018	0.074	87500	68500	78.7	10200	903	6.5	4.4	2	-2.2	7.5	1	1.5	0.008	0.066	24.8	3.72	0.4	1490	
GA-A	120	80	1375	0	0	2.99	114000	70800	148	65700	48900	113.2	60	-31.8	-39.6	57.1	1.2	5.5	0.09	0.281	24.6	3.49	0.5	1510	
GA-B	180	80	346	0	0.02	0.144	59300	48100	78.8	28900	19300	44.9	26.4	-14	-21.8	23	1.2	1.8	0.068	0.218	24.4	3.56	0.4	1000	
GA-C	65	70	119	0	0.003	0.533	87100	78300	85.4	25000	20500	47.5	37.3	-9	-8.4	41.7	1.1	0.97	0.174	0.276	24.8	3.59	0.2	1190	
AlR-A	280	450	567	48.8	0	0.074	23100	288	31.5	13900	2350	150.2	117.5	-9.1	-33.8	63.5	1.4	2.58	0.387	0.496	24.7	5.92	0.2	240	
AlR-B	1300	400	1776	56.2	0.004	0.076	18000	97.3	46.1	23300	4370	92.4	63.7	-23	-30.2	55.5	1.2	2.62	0.534	0.675	24.8	5.71	0.3	240	
AlR-C	85	400	328	68.3	0.003	0.104	2520	135	27.8	8940	2360	98.2	49.1	-37.4	-48.1	29.4	1.3	1.6	0.377	0.453	24.8	5.54	0.3	260	
Marsh	45	350	113	59.8	0	0.277	124	-12	31.3	7420	2070	128.4	99.7	-17.8	-20.1	42.7	1.4	1.02	0.245	0.301	25.5	5.82	0.4	220	

Source: SJRWMD.

August 19, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	60	960	155	56.8	0.001	0.048	434	75.6	22.4	10200	3380	19	12.2	-0.5	-0.5	1.8	1.6	4.96	3.06	1.7	26.1	6.29	0.3	285	0.63
Control-B	26	480	69	46.5	0	0.057	154	1800	20.3	6910	3430	17.8	14.8	0.8	-0.3	1.6	1.6	2.72	0.976	1.15	25.5	6.27	0.3	252	0.72
Control-C	18	480	38	41.3	0	0.021	72.2	24	16.8	7100	2330	12.2	11.2	2.5	0.2	0.5	1.7	2.24	0.799	0.902	24.9	6.11	0.3	238	0.101
FeR-A	130	1280	202	43	0	0.196	348	37.4	23	57100	18600	28.9	24.8	3.8	0.1	4.8	1.6	3.75	0.721	0.8	24.7	6.31	0.3	366	0.059
FeR-B	85	960	136	44.2	0	0.078	382	61.8	21.4	38200	16200	26.8	22.7	0.7	1.9	1.1	1.7	4.33	1.42	1.08	25.1	6.2	0.5	324	0.4
FeR-C	80	640	173	54	0	0.061	269	32.6	26.4	34600	14200	26.7	22.6	2.1	1.4	1.1	1.7	2.12	0.431	0.575	25.5	6.32	0.3	348	0.41
BARA-A	200	40	376	0	0	4.74	93200	64800	98.8	21200	14000	15.3	11.2	2.5	0.2	18.7	1	0.885	0.146	0.099	26	4.02	0.3	2496	0.05
BARA-B	100	60	121	0	0	1.23	67200	55700	87.8	22600	15000	3.6	1.6	-0.5	-1.9	2.5	1	0.72	0.16	0.149	25.5	3.96	0.4	1980	0.0033
BARA-C	95	40	165	0	0	0.72	77800	62900	79	13300	6800	4.5	3.2	-1.4	-0.4	5	1	0.681	0.002	0.119	25.4	4	0.5	1860	0.026
GA-A	140	80	275	0	0	4.13	54500	41800	115	46100	41400	7.3	3.2	-1.1	-3.7	5	1	1.15	0.284	0.339	26.3	3.8	0.5	1200	0.11
GA-B	85	60	127	0	0	0.851	42500	38300	71.1	29500	22700	12.1	7	-1.2	-1.8	6.7	1.2	1.46	0.103	0.37	25.6	3.91	0.5	1740	0.23
GA-C	28	60	16	46.4	0.01	1.67	49900	43200	78.5	24600	20800	9	7	-1.2	-1.8	8.9	1.1	0.696	0.156	0.301	28.3	3.86	0.2	1320	0.153
AlR-A	60	480	178	46.1	0	0.09	924	141	17	5590	1680	18.7	14.6	2.9	-1.1	6.1	1.4	1.38	0.498	0.565	25.5	6.24	0.3	276	0.29
AlR-B	55	480	104	56.4	0	0.193	1450	184	21.4	11600	2000	22.1	20.1	6	0.7	6.4	1.5	1.7	0.584	0.628	25.6	6.25	0.3	306	0.091
AlR-C	45	400	178	65.6	0	0.044	1900	148	25.1	8510	1960	26.9	18.8	-5.9	-3.7	11.7	1.3	1.45	0.405	0.458	25.4	6.11	0.2	312	0.37
Wetland																					27	6.12	0.3	238	

Source: SJRWMD.

September 2, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	34	720	119	56.9	0	0.01	417	89.8	22.4	8820	3130	82	64.3	-4.1	-3.1	38.1	1.4	5.52	1.17	2.45	26.3	6.2	0.3	227	0.049
Control-B	34	480	224	47.1	0	0.018	142	35.3	18.2	6720	2040	74.6	61.5	-3.9	-3	31.2	1.4	3.22	1.88	1.23	27.8	6.2	0.2	206	0.1565
Control-C	38	480	138	50.1	0	0.007	133	38.5	19.3	7110	2680	123.2	106.2	-9.6	-4.1	66.3	1.3	2.2	0.873	1.01	26.2	6.1	0.1	258	
FeR-A	330	1280	333	45.6	0	0.084	609	445	26.6	76900	26500	287.8	246.9	-34.3	-8.8	182.1	1.3	5.6	0.652	0.795	26.7	6.3	0.1	412	0
FeR-B	160	1120	145	39.9	0.014	0.047	247	62.1	21	45400	15200	134	113.6	-22.2	-4	74.2	1.3	3.56	0.556	0.591	26.5	6.3	0.2	299	0.277
FeR-C	130	1120	143	52.4	0.011	0.07	221	38.3	28.7	49300	19200	169.1	132.3	-25.6	-18	104.1	1.3	2.02	0.338	0.324	27.5	6.2	0.1	227	0.238
BARA-A	170	30	315	0	0	2.68	58600	44300	101	17400	13300	25.4	20.2	4.7	-5.9	15.5	1.3	0.788	0.035	0.082	27.6	4	0.3	1751	0.0098
BARA-B	27	30	77	0	0	11.1	34600	29200	83.5	15200	12900	12.1	4.9	-3.7	-4.8	5.2	1.1	0.58	0.098	0.146	26.6	4	0.2	1483	0.082
BARA-C	45	30	150	0	0	0.886	45000	28300	80.7	16200	13200	31.4	16.1	-13.6	-16.3	15.2	1.2	0.93	0.002	0.079	26.4	4.1	0.2	1390	0.0293
GA-A	150	40	262	0	0	70	17600	9890	104	39700	34300	21.1	8.8	-8.8	-11.1	13.1	1	1.55	0.006	0.309	27.2	3.9	0.2	1442	0.121
GA-B	100	40	159	0	0	0.328	16700	11300	67.5	22600	20200	22.1	4.7	-14	-17.2	10.1	0.8	1.29	0.276	0.302	26.5	4	0.2	1339	0.036
GA-C	55	60	49	0	0.004	2.55	34300	26900	74.5	19700	13600	12.8	7.7	-3.3	-3.5	7.6	1.2	0.616	0.25	0.309	27.9	3.6	0.3	1133	0.196
AIR-A	110	360	268	51.5	0	0.024	8270	174	24	8970	2550	103.3	91.4	-0.5	-5.3	51.2	1.4	2.02	0.371	0.387	27	6.2	0.3	256	0.401
AIR-B	45	480	96	52.4	0.002	-0.007	1490	204	22.2	9460	2960	183.6	171.7	-7	3	91.2	1.4	0.606	0.503	1.7	27.8	5.8	0.4	227	0
AIR-C	50	320	96	59.5	0.006	0	1000	117	23.3	7700	2330	233.3	200.9	-39.9	-1.4	81.9	1.4	1.18	0.281	0.309	26.3	6.2	0.2	309	0.0261
Wetland																					29.3	6.1	0	216	

Source: SJRWMD.

September 30, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	16	320	25	26.9	0.005	-0.009	119	17.6	8.58	3020	957	87.5	82.4	16.2	-1.1	8.5	1.6	2.13	0.919	1.26	27	5.8	1	103	0.45
Control-B	13	320	19	25.7	0.005	0.064	8.9	10.9	8.08	3680	1030	33.5	32.4	4.3	2.5	2.5	1.6	1.98	0.922	1.01	29.3	5.8	1	92.7	0.2
Control-C	14	320	21	29.7	0.004	-0.009	14.1	19.1	10	3520	1250	23.4	21.7	2.2	-0.2	6.8	1.5	1.06	0.901	1.85	28.2	5.9	1.2	92.7	0.68
FeR-A	55	640	61	36.6	0	0.046	24.9	18.8	14	24500	11000	51.6	44.7	10.2	9.3	6.7	1.6	2.21	0.488	0.422	28.7	6.2	0.2	144.2	0.44
FeR-B	38	400	54	32	0.006	0.004	9.6	8.7	10.7	11200	2900	53.1	50.6	9.7	3.7	16	1.5	1.18	0.162	0.208	25	6	0.4	82.4	0.18
FeR-C	32	720	38	32.1	0	0.004	31	471	13.2	20800	5910	35.4	33.7	6	6.6	10.7	1.5	1.13	0.212	0.245	26.7	6.2	1	103	0
BARA-A	8.5	20	5	0	0	-0.009	7970	8270	28.3	2370	1620	0.8	0.8	1.2	-0.7	1.5	1	0.048	0	0.033	30.2	3.8	2.8	566.5	0.1
BARA-B	6.9	25	8	0	0.003	-0.005	2440	2390	21.3	2230	1320	7.2	7.2	1.1	1	4.7	1.3	0.132	0.007	0.063	27.5	3.7	3	309	0.11
BARA-C	9	25	19	0	0	-0.009	2470	2080	21.2	2960	2110	5.3	5.3	2	1.3	1.7	1.5	0.159	0.009	0.03	29.5	3.6	1	206	0.01
GA-A	11	50	22	-0.82	0.022	0.008	179	134	19.9	1990	2120	159.1	155	37.3	-1.5	29.9	1.6	0.515	0.141	0.206	27.3	4.7	9.1	231.75	0.17
GA-B	16	120	7	0	0	-0.003	266	108	15.3	3530	2720	12.5	11.7	2.3	-0.9	1.3	1.6	0.858	0.514	0.566	26.1	4.9	0.8	123.6	0.41
GA-C	3.1	15	10	0	0	-0.009	4800	4310	31	1670	1060	17.6	15.9	6.5	0	1.5	1.6	0.156	0	0.028	29.5	3.6	6.9	339.9	0.01
AIR-A	9.4	320	18	28.8	0.004	0.012	108	141	8.1	2930	1480	48.4	45.9	7.7	1.3	7.3	1.6	0.888	0.322	0.376	28.4	5.7	0.6	72.1	0.1
AIR-B	9.5	280	17	31.4	0.005	0.01	112	63.2	9.84	4370	1830	43.8	40.8	5.3	1.1	9.9	1.5	1.08	0.422	0.512	27.2	5.8	1.5	82.4	0.33
AIR-C	7.6	240	13	35.5	0.001	0.005	93.8	33.1	11.6	3540	1400	40.5	39.2	4.6	1.4	4.3	1.6	0.513	0.181	0.221	27.1	6.1	2	103	0.16
Marsh																					29.9	6	2		

Source: SJRWMD.

December 9, 2004 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	5.9	280	33	32.2	0.009	0.04	42.4	39.2	10.5	1810	847	83.1	79.9	5.5	2.6	8.1	1.6	0.992	0.324	0.431	19.1	6.3	0.7	107	0
Control-B	22	240	82	26.2	0.007	0.084	56	30.4	9.3	3650	729	65.9	58	-7.3	-0.4	12.1	1.6	1.15	0.283	0.365	18.8	6.1	0.9	112	0.03
Control-C	4.5	400	14	36.4	0.008	0.155	56	34.1	13.7	2740	1380	37.3	33	-4.3	-2.1	8	1.5	5.11	0.453	0.517	18.5	6.17	0.4	133	0.48
FeR-A	149	320	157	29.5	0.01	0.035	102	29.2	18.5	54800	3650	113.3	110.6	25.6	-1.1	27.1	1.5	2.29	0.141	0.172	18.4	6.05	0.3	133	0.03
FeR-B	154	320	332	32.5	0.021	0.021	136	38.3	19.6	42400	3570	135.3	114.8	-8.8	-1.7	20.5	1.6	2.86	0.149	0.151	18.5	6.27	0.4	153	0.08
FeR-C	65	400	50	30.2	0.03	0.013	31.2	21.8	14.9	13400	3640	80.7	73.9	-4.6	-0.8	19.6	1.5	0.497	0.078	0.132	18.9	6.1	0.6	133	0.44
BARA-A	1	15	10	0	0	-0.003	5840	5250	41.1	457	169	34.8	34.8	10	0.1	18.4	1.4	0.051	0.007	0.022	17.8	4.2	5.2	612	0
BARA-B	3.6	25	10	1.12	0	0.01	208	86	22	1250	423	25	24.2	5.7	-0.5	11.3	1.4	0.185	0.01	0.028	17.9	5.5	1.5	357	0.02
BARA-C	1.6	30	8	1	0	0.008	185	87.1	20.3	602	258	17.1	15.5	0.6	-1.4	0	1.7	0.148	0.018	0.03	18.7	5.5	1.4	367	0.01
GA-A	10	160	44	24.5	0.008	0.009	334	154	19.2	1100	659	19.7	18.7	2.5	0	0	1.7	0.425	0.078	0.156	22.9	6.3	2.6	204	0.08
GA-B	4.4	160	20	23.5	0.007	0.107	330	141	10.3	598	256	33.4	31	1	-0.8	14.5	1.4	0.797	0.04	0.478	19.7	6.5	0.8	153	0.32
GA-C	0.82	15	6	0	0	0.007	3040	2510	36.9	483	263	16.1	15.2	3.8	-0.6	10.9	1.3	0.062	0.029	0.033	18.8	4.12	5.8	347	0
AIR-A	11	160	60	30.3	0.005	0.041	284	89.8	9.87	2700	483	43.3	41.6	3.3	-2.7	8	1.6	0.36	0.018	0.082	17.6	5.97	1	112	0.05
AIR-B	13	200	166	35.9	0.006	0.021	549	94.8	15	6760	607	55	48.6	-6.3	-3.1	11.8	1.5	0.609	0.046	0.082	18.7	6.2	0.4	133	0.08
AIR-C	3.7	200	37	53.1	0.005	0.029	251	78.8	14.4	4160	1040	26.1	24.1	-1.7	0	7.5	1.5	0.459	0.088	0.122	18.5	6.2	1.5	133	0.13
Marsh	13	160	184	29.7	0.005	0.052	904	15.6	23.6	5660	674	18.1	16.8	0.1	-2.2	9.3	1.4	0.747	0.088	0.106	19	6.2	2	143	0.01

Source: SJRWMD.

March 28, 2005 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	NA	400	25	27.4	0.018	0.0813	96.2	55.5	11.5	3060	1160	NA	NA	NA	NA	NA	NA	1.61	0.935	1.03	19.5	6.6	0.9	125	0.59
Control-B	NA	400	16.5	20.4	0.0143	0.0243	41.9	35.5	7.45	1720	1070	NA	NA	NA	NA	NA	NA	0.933	0.601	0.643	19.4	6.3	0.7	99	0.254
Control-C	NA	300	15	26.3	0.0164	0.0316	69.6	49.5	10.3	2680	1140	NA	NA	NA	NA	NA	NA	1.03	0.552	0.604	19.9	6.5	1.3	130	0.453
FeR-A	NA	400	70.7	5.43	0.0203	0.161	177	60.4	12.6	20700	3780	NA	NA	NA	NA	NA	NA	0.604	0.0459	0.119	19.6	6.1	0.4	139	0.01
FeR-B	NA	800	156	30.1	0.0372	0.105	167	61.5	19.2	48100	24200	NA	NA	NA	NA	NA	NA	1.72	0.28	0.48	20.5	6.9	0.7	210	0.218
FeR-C	NA	400	81	14	0.0203	0.094	150	33.1	14.6	22500	3700	NA	NA	NA	NA	NA	NA	0.918	0.0462	0.0834	19.7	6.2	0.9	129	0.046
BARA-A	NA	60	36.5	34.6	0.0084	0.00582	221	30.7	44.4	2370	1090	NA	NA	NA	NA	NA	NA	0.136	0.00267	0.0292	20.9	6.6	0.7	450	0.006
BARA-B	NA	100	26	59	0.00982	0.421	998	95.4	26.9	2440	834	NA	NA	NA	NA	NA	NA	0.252	0.0284	0.0555	19.7	7.1	2.6	349	0.02
BARA-C	NA	100	35	67	0.0122	0.472	615	103	29.3	1840	815	NA	NA	NA	NA	NA	NA	0.241	0.0181	0.0587	20.9	7.5	4.9	350	0.026
GA-A	NA	200	59.3	62.5	0.00978	0.0809	465	186	22.8	3930	1270	NA	NA	NA	NA	NA	NA	0.584	0.105	0.196	25.7	7.5	11.5	249	0.052
GA-B	NA	200	42.5	56	0.0117	1.02	854	181	18.3	3170	1380	NA	NA	NA	NA	NA	NA	1.15	0.466	0.576	20.7	7.2	3.4	189	
GA-C	NA	60	22.7	31	-0.00462	0.0139	204	46.8	34.3	3260	709	NA	NA	NA	NA	NA	NA	0.224	0.00754	0.0401	22.1	7.1	6.5	320	0.01
AIR-A	NA	300	17.5	22.1	0.0102	0.0348	241	179	7.81	1770	744	NA	NA	NA	NA	NA	NA	0.619	0.299	0.388	19.3	6.4	1.5	109	0.231
AIR-B	NA	300	18.5	31.6	0.0136	0.0362	291	150	11.8	3070	1180	NA	NA	NA	NA	NA	NA	0.613	0.209	0.275	20.1	6.5	0.8	190	0.173
AIR-C	NA	300	79	35	0.0134	0.0297	490	118	12.4	6110	1080	NA	NA	NA	NA	NA	NA	0.443	0.122	0.176	20	6.6	2.6	135	0.101
Marsh	NA	300	37.5	33	0.0153	0.0277	155	26.2	12.7	3300	1450	NA	NA	NA	NA	NA	NA	0.539	0.168	0.229	20.3	6.4	4.5	115	0.134

Source: SJRWMD.

April 27, 2005 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	16.7	300	54	25.1	0.0138	0.0425	114	64.6	11.5	3150	819	NA	NA	NA	NA	NA	NA	0.939	0.356	0.427	20.5	5.93	2.87	60	0.59
Control-B	8.8	300	12.5	14.7	0.00834	0.0228	53.9	42.2	8.03	1810	992	NA	NA	NA	NA	NA	NA	0.676	0.322	0.389	20.8	6.17	0.91	70	0.46
Control-C	9.3	400	10.7	26.9	0.0131	0.00684	70	47	11.7	3450	1380	NA	NA	NA	NA	NA	NA	0.807	0.295	0.417	20.2	6.47	1.36	90	0.42
FeR-A	166	1000	154	26.9	0.0533	0.0965	210	96.9	24.7	81700	39100	NA	NA	NA	NA	NA	NA	1.44	0.0667	0.35	20.4	6.61	0.7	120	0.08
FeR-B	130	800	123	28.2	0.0225	0.0678	134	66.6	21.7	40900	16000	NA	NA	NA	NA	NA	NA	1.67	0.108	0.228	19.2	6.7	0.33	180	0.06
FeR-C	269	800	129	36.2	0.0189	0.0674	102	33.2	22.5	52200	6220	NA	NA	NA	NA	NA	NA	1.23	0.0342	0.126	21.6	6.67	1.5	140	0.07
BARA-A	17.2	60	44.5	52.7	0.00721	0.000997	743	32.2	44.6	5680	262	NA	NA	NA	NA	NA	NA	0.373	0.00731	0.0216	21.7	7.12	3.02	400	0.03
BARA-B	11.1	100	64	65.7	0.004	0.0197	667	56.6	25.4	3560	190	NA	NA	NA	NA	NA	NA	0.502	0.018	0.0194	21.2	7.12	2.14	170	0.05
BARA-C	24.9	100	72.7	80.5	0.00618	0.00578	562	70.4	26.4	3110	651	NA	NA	NA	NA	NA	NA	0.228	0.0122	0.0303	24.2	7.62	4.68	250	0.07
GA-A	31.6	150	176	80.8	0.00791	0.0263	342	127	25.6	1970	559	NA	NA	NA	NA	NA	NA	0.536	0.013	0.0411	23.1	6.52	5.2	120	0.03
GA-B	18.1	150	82.7	59.6	0.00346	0.0514	468	141	19.5	2600	754	NA	NA	NA	NA	NA	NA	0.842	0.152	0.239	22.6	8.06	2.67	140	0.21
GA-C	14.9	60	66	39.3	0.00692	0.0126	406	34.2	33.2	4250	321	NA	NA	NA	NA	NA	NA	0.572	0.0102	0.034	22.7	7.09	1.3	220	0.07
AIR-A	3.3	150	12.5	18	0.0133	0.0134	309	184	8	1050	469	NA	NA	NA	NA	NA	NA	0.312	0.133	0.203	19.7	6.34	0.8	70	0.17
AIR-B	51.5	250	80	29.5	0.01	0.0078	583	162	13.5	5940	983	NA	NA	NA	NA	NA	NA	0.942	0.0818	0.116	20	6.67	3.08	90	0.11
AIR-C	16.4	250	56	31.4	0.00725	0.0163	302	116	13.5	4590	754	NA	NA	NA	NA	NA	NA	0.521	0.0429	0.0817	22.4	6.68	1.3	60	0.42
Marsh	15.8	250	36.7	20.7	0.00634	0.0249	83.3	31.2	11.5	4540	756	NA	NA	NA	NA	NA	NA	0.664	0.0429	0.0788	24.5	6.24	1.08	90	0.01

Source: SJRWMD.

May 31, 2005 – Ocklawaha Prairie Laboratory Data

	Turbidity ntu	Color cpu	TSS mg/L	Alkalinity mg/L	NOx-T mg/L	NH4-T mg/L	Al-T ug/L	Al-D ug/L	Ca-T mg/L	Fe-T ug/L	Fe-D ug/L	Chl-a mg/m3	Chl-a_Corr mg/m3	Chl-b mg/m3	Chl-c mg/m3	Phaeo-Corr mg/m3	Chl a:Phaeo ratio	TP-T mg/L	PO4-D mg/L	TP-D mg/L	Field Water Temp deg C	Field pH	Field DO mg/L	Field Conductivity umhos/cm	Field Phosphorus
Control-A	NA	400	34.5	16.2	0.0174	0.0333	71.1	39.4	10.4	2970	1040		21.6				1.5	0.541	0.153	0.228	22.7	5.9	0.6	88	NA
Control-B	NA	400	20	8.21	0.0105	0.0253	49.3	25.5	7.65	2480	1220		54				1.55	0.791	0.301	0.385	23.5	5.6	0.4	88	NA
Control-C	NA	400	27.5	25.5	0.0162	0.0386	48.7	28	12.5	3800	1720		60.4				1.57	1.19	0.417	0.565	23.4	6.1	5	132	NA
FeR-A	NA	1000	178	22.7	0.0392	0.0867	214	48.4	22.6	74000	29500		235				1.61	0.934	0.0594	0.177	24.2	6.3	0	176	NA
FeR-B	NA	800	91.4	34.3	0.0371	0.144	107	28.6	24.6	41900	8930		52.4				1.62	1.04	0.116	0.206	23.2	6.5	0.3	187	NA
FeR-C	NA	800	124	34	0.0301	0.0779	75.7	18.6	22.8	56600	9720		142				1.6	1.01	0.0333	0.1	23.6	6.3	0.2	220	NA
BARA-A	NA	100	71.3	83.3	0.0173	0.0243	2370	42.9	28	5590	512		182				1.43	0.563	0.00727	0.041	25.5	7	3	187	NA
BARA-B	NA	150	181	85	0.0146	0.0299	3140	64.2	21	7150	519		251				1.47	0.645	0.0267	0.0767	26.9	7.1	3.3	253	NA
BARA-C	NA	150	47.5	89.4	0.0115	0.0686	1070	74.1	18.9	1320	381		127				1.5	0.186	0.0104	0.0515	23.4	7	1.5	275	NA
GA-A	NA	70	210	97.8	0.0108	0.0563	257	55.7	30.7	1840	370		86.9				1.61	1.12	0.00673	0.0468	29.7	6.3	12	187	NA
GA-B	NA	150	104	57.9	0.00957	0.0384	271	84.8	17.2	2200	821		129				1.53	0.732	0.165	0.25	26.7	6.6	6	154	NA
GA-C	NA	100	22	49.7	0.0086	0.0291	437	51.8	20.2	2260	295		122				1.5	0.214	0.0159	0.0745	25	7.1	6.3	275	NA
AIR-A	NA	300	34	20.1	0.0113	0.0277	339	138	8.77	2680	1080		40.5				1.53	0.534	0.141	0.221	23.5	6	0.4	110	NA
AIR-B	NA	300	100	29.6	0.0118	0.0226	510	121	14.9	4830	1320		169				1.51	0.651	0.0819	0.136	23.6	6	0.2	110	NA
AIR-C	NA	200	80.9	22.2	0.0145	0.0313	509	91.1	10.8	5160	1030		68.4				1.45	0.682	0.0683	0.146	23.4	6.2	0.3	132	NA
Marsh	NA	250	478	38.7	0.0158	0.0939	1840	22	18.7	5680	570		116				1.46	0.593	0.0395	0.0757	25	6	4.7	154	NA

Source: SJRWMD.

APPENDIX C

Copy of field notebook

APPENDIX D

Statistical Results from Systat

Statistical results from Systat.

Total Phosphorus

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.196          0.462

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.123          1.000

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.173          0.744

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.233          0.181
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =       0.269
95.00% CI              =      -0.103 to 0.641
SD                  =       0.484
t                   =       1.668
df                  =           8
p-value             =       0.134


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      -0.557
95.00% CI              =      -0.787 to -0.328
SD                  =       0.299
t                   =      -5.601
df                  =           8
p-value             =       0.001


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      -0.241
95.00% CI              =      -0.567 to 0.085
SD                  =       0.424
```

t = -1.708
df = 8
p-value = 0.126

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = -0.314
95.00% CI = -0.510 to -0.119
SD = 0.254
t = -3.708
df = 8
p-value = 0.006

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
444 case(s) deleted due to missing data.

Dep Var: VALUE N: 36 Multiple R: 0.646 Squared multiple R: 0.418

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	3.260	3	1.087	7.654	0.001
Error	4.543	32	0.142		

Durbin-Watson D Statistic 1.787
First Order Autocorrelation 0.056
COL/

ROW TREATMENT$
  1 AlR
  2 BARA
  3 FeR
  4 GA
Using least squares means.
Post Hoc test of VALUE
Using model MSE of 0.142 with 32 df.

Matrix of pairwise mean differences:

	1	2	3	4
1	0.000			
2	-0.243	0.000		
3	0.584	0.827	0.000	
4	0.073	0.316	-0.510	0.000

Bonferroni Adjustment.

Matrix of pairwise comparison probabilities:

	1	2	3	4
1	1.000			
2	1.000	1.000		
3	0.015	0.000	1.000	
4	1.000	0.507	0.043	1.000

Dissolved Phosphorus

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   =

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)


The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000      0.150          0.730

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000      0.150          0.744

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000      0.193          0.265

The following results are for:
```

```
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable       N-of-Cases      MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000       0.168          0.499


T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =      -0.292
95.00% CI             =      -0.387 to -0.197
SD                    =       0.150
t                     =      -6.758
df                    =          11
p-value               =       0.000


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =      -0.447
95.00% CI             =      -0.509 to -0.385
SD                    =       0.097
t                     =     -15.963
df                    =          11
p-value               =       0.000


The following results are for:
   TREATMENT$   = GA
```

```
One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean              =      -0.305
95.00% CI           =      -0.435 to -0.176
SD                =       0.204
t                 =      -5.184
df                =          11
p-value           =       0.000


The following results are for:
   TREATMENT$   = AlR

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean              =      -0.317
95.00% CI           =      -0.366 to -0.268
SD                =       0.077
t                 =     -14.209
df                =          11
p-value           =       0.000


ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
   AlR, BARA, FeR, GA
432 case(s) deleted due to missing data.

Dep Var: VALUE   N: 48   Multiple R: 0.419   Squared multiple R: 0.176

Analysis of Variance
```

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	0.186	3	0.062	3.127	0.035
Error	0.873	44	0.020		

```
*** WARNING ***
Case         29 is an outlier      (Studentized Residual =       3.468)

Durbin-Watson D Statistic        1.637
First Order Autocorrelation      0.175
COL/
ROW TREATMENT$
  1  AlR
  2  BARA
  3  FeR
  4  GA
Using least squares means.
Post Hoc test of VALUE
Using model MSE of 0.020 with 44 df.

Matrix of pairwise mean differences:
```

	1	2	3	4
1	0.000			
2	-0.130	0.000		
3	0.025	0.155	0.000	
4	0.011	0.142	-0.013	0.000

```
Bonferroni Adjustment.

Matrix of pairwise comparison probabilities:
```

	1	2	3	4
1	1.000			
2	0.170	1.000		
3	1.000	0.059	1.000	
4	1.000	0.106	1.000	1.000

Dissolved ortho-Phosphate

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable     N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000       0.145          0.812

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable     N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000       0.187          0.314

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable     N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000       0.134          0.979

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable     N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            12.000       0.188          0.298
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean              =      -0.307
95.00% CI         =      -0.385 to -0.228
SD                =       0.123
t                 =      -8.630
df                =          11
p-value           =       0.000


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean              =      -0.389
95.00% CI         =      -0.462 to -0.316
SD                =       0.115
t                 =     -11.690
df                =          11
p-value           =       0.000


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean              =      -0.312
95.00% CI         =      -0.396 to -0.229
SD                =       0.132
```

t = -8.225
df = 11
p-value = 0.000

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 12 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = -0.292
95.00% CI = -0.344 to -0.240
SD = 0.081
t = -12.436
df = 11
p-value = 0.000

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
432 case(s) deleted due to missing data.

Dep Var: VALUE N: 48 Multiple R: 0.326 Squared multiple R: 0.106

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	0.068	3	0.023	1.743	0.172
Error	0.576	44	0.013		

Durbin-Watson D Statistic 2.091
First Order Autocorrelation -0.054

Dissolved Fe

```
TEST FOR NORMALITY

The following results are for:
  TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

 Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

  VALUE            15.000      0.248          0.014

The following results are for:
  TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

 Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

  VALUE            15.000      0.189          0.159

The following results are for:
  TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

 Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

  VALUE            15.000      0.186          0.176

The following results are for:
  TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

 Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

  VALUE            15.000      0.131          0.785
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =    10263.567
95.00% CI             =     4150.067 to 16377.067
SD                    =    11039.552
t                     =        3.601
df                    =           14
p-value               =        0.003


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =     -447.500
95.00% CI             =     -797.083 to -97.917
SD                    =      631.265
t                     =       -2.746
df                    =           14
p-value               =        0.016


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =     -287.300
95.00% CI             =     -744.020 to 169.420
SD                    =      824.729
t                     =       -1.349
```

```
df                 =         14
p-value              =       0.199


The following results are for:
   TREATMENT$   = AlR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                 =    -159.100
95.00% CI              =     -395.248 to 77.048
SD                   =     426.428
t                  =      -1.445
df                 =         14
p-value              =       0.170
```

KRUSKAL-WALLIS

```
Categorical values encountered during processing are:
TREATMENT$ (4 levels)
   AlR, BARA, FeR, GA

Kruskal-Wallis One-Way Analysis of Variance for 60 cases
Dependent variable is VALUE
 Grouping variable is TREATMENT$

    Group      Count   Rank Sum


  AlR           15     409.000
  BARA             15     296.000
  FeR           15     795.000
  GA            15     330.000

Kruskal-Wallis Test Statistic =       34.666
Probability is        0.000 assuming Chi-square distribution with 3 df
```

Dissolved Al

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.162          0.886

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.142          1.000

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.163          0.881

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            9.000      0.202          0.403
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      11.750
95.00% CI             =      -5.674 to 29.174
SD                  =      22.668
t                   =       1.555
df                  =           8
p-value             =       0.159


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      25.328
95.00% CI             =       4.975 to 45.680
SD                  =      26.477
t                   =       2.870
df                  =           8
p-value             =       0.021


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      62.972
95.00% CI             =      17.728 to 108.216
SD                  =      58.860
t                   =       3.210
```

df = 8
p-value = 0.012

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 9 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = 101.950
95.00% CI = 79.352 to 124.548
SD = 29.399
t = 10.403
df = 8
p-value = 0.000

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
444 case(s) deleted due to missing data.

Dep Var: VALUE N: 36 Multiple R: 0.707 Squared multiple R: 0.501

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	44440.759	3	14813.586	10.689	0.000
Error	44349.731	32	1385.929		

Durbin-Watson D Statistic 1.143
First Order Autocorrelation 0.411
COL/
ROW TREATMENT$

1 AlR
2 BARA
3 FeR
4 GA

Using least squares means.

Post Hoc test of VALUE

Using model MSE of 1385.929 with 32 df.

Matrix of pairwise mean differences:

	1	2	3	4
1	0.000			
2	-76.622	0.000		
3	-90.200	-13.578	0.000	
4	-38.978	37.644	51.222	0.000

Bonferroni Adjustment.

Matrix of pairwise comparison probabilities:

	1	2	3	4
1	1.000			
2	0.001	1.000		
3	0.000	1.000	1.000	
4	0.201	0.238	0.038	1.000

Alkalinity

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE             3.000      0.341          0.283

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE             3.000      0.315          0.471

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE             3.000      0.194          1.000

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE             3.000      0.285          0.782
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                 =      13.478
95.00% CI            =     -13.853 to 40.810
SD                   =      11.002
t                    =       2.122
df                   =           2
p-value              =       0.168


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                 =      69.045
95.00% CI            =      52.086 to 86.004
SD                   =       6.827
t                    =      17.517
df                   =           2
p-value              =       0.003


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                 =      51.612
95.00% CI            =     -18.991 to 122.214
SD                   =      28.421
t                    =       3.145
```

df = 2
p-value = 0.088

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = 7.112
95.00% CI = -24.663 to 38.887
SD = 12.791
t = 0.963
df = 2
p-value = 0.437

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
468 case(s) deleted due to missing data.

Dep Var: VALUE N: 12 Multiple R: 0.883 Squared multiple R: 0.779

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	8026.687	3	2675.562	9.396	0.005
Error	2278.083	8	284.760		

*** WARNING ***
Case 7 is an outlier (Studentized Residual = 3.025)

Case 9 is an outlier (Studentized Residual = -2.618)

Durbin-Watson D Statistic 2.329
First Order Autocorrelation -0.201
COL/
ROW TREATMENT$
1 AlR
2 BARA
3 FeR
4 GA
Using least squares means.
Post Hoc test of VALUE
Using model MSE of 284.760 with 8 df.

Matrix of pairwise mean differences:

	1	2	3	4
1	0.000			
2	61.933	0.000		
3	6.367	-55.567	0.000	
4	44.500	-17.433	38.133	0.000

Bonferroni Adjustment.

Matrix of pairwise comparison probabilities:

	1	2	3	4
1	1.000			
2	0.012	1.000		
3	1.000	0.023	1.000	
4	0.072	1.000	0.146	1.000

Chlorophyll a

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            3.000      0.184          1.000

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            3.000      0.195          1.000

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            3.000      0.274          0.927

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            3.000      0.318          0.443
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      86.000
95.00% CI           =    -137.738 to 309.738
SD                  =      90.067
t                   =       1.654
df                  =           2
p-value             =       0.240


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =     129.667
95.00% CI           =     -32.114 to 291.447
SD                  =      65.126
t                   =       3.449
df                  =           2
p-value             =       0.075


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                =      55.667
95.00% CI           =      -1.863 to 113.196
SD                  =      23.159
t                   =       4.163
```

df = 2
p-value = 0.053

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 3 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = 35.333
95.00% CI = -138.846 to 209.513
SD = 70.117
t = 0.873
df = 2
p-value = 0.475

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
468 case(s) deleted due to missing data.

Dep Var: VALUE N: 12 Multiple R: 0.546 Squared multiple R: 0.298

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	15136.667	3	5045.556	1.133	0.392
Error	35612.000	8	4451.500		

Durbin-Watson D Statistic 2.736
First Order Autocorrelation -0.497

Total Ammonium

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000      0.178          0.231

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000      0.355          0.000

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000      0.432          0.000

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000      0.296          0.001
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =       0.024
95.00% CI              =      -0.020 to 0.067
SD                     =       0.078
t                      =       1.180
df                     =          14
p-value                =       0.258


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =       0.025
95.00% CI              =      -0.068 to 0.118
SD                     =       0.167
t                      =       0.579
df                     =          14
p-value                =       0.572


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =       0.052
95.00% CI              =      -0.095 to 0.200
SD                     =       0.267
t                      =       0.758
```

```
df                =        14
p-value               =       0.461


The following results are for:
   TREATMENT$   = AlR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =      -0.022
95.00% CI               =      -0.044 to 0.001
SD                    =       0.040
t                   =      -2.094
df                =        14
p-value               =       0.055


KRUSKAL-WALLIS

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
   AlR, BARA, FeR, GA

Kruskal-Wallis One-Way Analysis of Variance for 60 cases
Dependent variable is VALUE
 Grouping variable is TREATMENT$

    Group      Count   Rank Sum


  AlR           15     372.500
  BARA            15     393.500
  FeR           15     594.500
  GA            15     469.500

Kruskal-Wallis Test Statistic =        6.609
Probability is        0.085 assuming Chi-square distribution with 3 df
```

Total Suspended Solids (TSS)

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE           18.000      0.116          0.840

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE           18.000      0.160          0.258

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE           18.000      0.152          0.340

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases     MaxDif  Lilliefors Probability (2-tail)

   VALUE           18.000      0.190          0.086
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 18 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =       84.444
95.00% CI             =       47.973 to 120.916
SD                    =       73.341
t                     =        4.885
df                    =           17
p-value               =        0.000


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 18 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =       15.667
95.00% CI             =      -18.342 to 49.675
SD                    =       68.388
t                     =        0.972
df                    =           17
p-value               =        0.345


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 18 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                  =       25.722
95.00% CI             =      -10.496 to 61.941
SD                    =       72.832
t                     =        1.498
```

df = 17
p-value = 0.152

The following results are for:
TREATMENT$ = AlR

One-sample t-test of VALUE with 18 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean = 19.389
95.00% CI = -6.707 to 45.485
SD = 52.476
t = 1.568
df = 17
p-value = 0.135

ANOVA

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
AlR, BARA, FeR, GA
408 case(s) deleted due to missing data.

Dep Var: VALUE N: 72 Multiple R: 0.394 Squared multiple R: 0.155

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TREATMENT$	56546.944	3	18848.981	4.162	0.009
Error	307940.333	68	4528.534		

Durbin-Watson D Statistic 1.776
First Order Autocorrelation 0.103
COL/
ROW TREATMENT$

1 AlR
2 BARA
3 FeR
4 GA

Using least squares means.

Post Hoc test of VALUE

Using model MSE of 4528.534 with 68 df.

Matrix of pairwise mean differences:

	1	2	3	4
1	0.000			
2	-3.722	0.000		
3	65.056	68.778	0.000	
4	6.333	10.056	-58.722	0.000

Bonferroni Adjustment.

Matrix of pairwise comparison probabilities:

	1	2	3	4
1	1.000			
2	1.000	1.000		
3	0.030	0.019	1.000	
4	1.000	1.000	0.065	1.000

Color

```
TEST FOR NORMALITY

The following results are for:
   TREATMENT$   = FeR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases      MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000       0.221          0.047

The following results are for:
   TREATMENT$   = BARA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases      MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000       0.275          0.003

The following results are for:
   TREATMENT$   = GA

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases      MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000       0.137          0.697

The following results are for:
   TREATMENT$   = AlR

Kolmogorov-Smirnov one sample test using normal(0.00, 1.00) distribution

  Variable      N-of-Cases      MaxDif  Lilliefors Probability (2-tail)

   VALUE            15.000       0.155          0.448
```

```
T-TEST

The following results are for:
   TREATMENT$   = FeR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =      292.000
95.00% CI               =      169.841 to 414.159
SD                    =      220.590
t                    =       5.127
df                    =          14
p-value                =       0.000


The following results are for:
   TREATMENT$   = BARA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =    -277.333
95.00% CI               =    -302.837 to -251.830
SD                    =      46.054
t                    =     -23.323
df                    =          14
p-value                =       0.000


The following results are for:
   TREATMENT$   = GA

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                   =    -237.333
95.00% CI               =    -284.333 to -190.333
SD                    =      84.871
t                    =     -10.830
```

```
df                =          14
p-value              =       0.000


The following results are for:
   TREATMENT$   = AlR

One-sample t-test of VALUE with 15 cases
Ho: Mean = 0.000 against Alternative = 'not equal'

Mean                 =     -98.000
95.00% CI              =     -136.776 to -59.224
SD                     =      70.020
t                     =      -5.421
df                =          14
p-value              =       0.000


KRUSKAL-WALLIS

Categorical values encountered during processing are:
TREATMENT$ (4 levels)
   AlR, BARA, FeR, GA

Kruskal-Wallis One-Way Analysis of Variance for 60 cases
Dependent variable is VALUE
 Grouping variable is TREATMENT$

    Group       Count   Rank Sum


  AlR           15     543.500
  BARA            15     205.500
  FeR           15     793.000
  GA            15     288.000

Kruskal-Wallis Test Statistic =       46.580
Probability is        0.000 assuming Chi-square distribution with 3 df
```

Upper Ocklawaha Restoration Sites Nutrient Control Feasibility And Design

Ocklawaha Prairie Restoration Site

Final Report
(Revised)

February 2003

Submitted to:

St. Johns River
Water Management District

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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the St. Johns River Water Management District (District) under Contract No. SE620AA to evaluate methods of reducing the release of dissolved phosphorus from organic soils associated with restoration sites in the Upper Ocklawaha Basin. Three separate sites are evaluated as part of this contract: Sunnyhill Farms, Ocklawaha Prairie, and Long Farm. The work efforts outlined in this report address the Ocklawaha Prairie Restoration Site only.

Each of the three restoration sites consists of former wetland areas which were drained and used for muck farming operations prior to the early 1920s. Previous data collection and research performed by the District in similar areas has indicated that the organic soils at these sites exhibit a strong potential for long-term release of sediment phosphorus resulting from draining, cultivation, and desiccation of the hydric soils combined with decades of periodic fertilizer applications. The primary objective of this study is to evaluate the use of chemical amendments, either to exposed soils in a solid state or directly into the overlying water column in a liquid state, to inactivate soil phosphorus and improve the net phosphorus retention of the flow-way areas.

A digital orthophoto quad (1 m resolution) of the Ocklawaha Prairie Site is given in Figure 1-1 based upon 2000 imagery performed by the USGS. The Ocklawaha Prairie site is a 2550-acre area which is bisected by approximately 6 miles of the historic Ocklawaha River. The site is located approximately 9 miles southeast of Ocala, 7 miles northeast of Belleview, and 3 miles northeast of Candler, Florida. In the early 1900s, the historic floodplains and wetlands were drained for agricultural use by constructing a bypass canal around the site. In the 1970s, the bypass canal was enlarged and designated as Canal-231. The canal enlargement resulted in a substantial lowering of water levels within the Ocklawaha Prairie, effectively isolating the historic riverbed

Figure 1-1. Location Map for the Ocklawaha Prairie Restoration Site.

and floodplains from the primary flow channel. The natural meandering stream was replaced with a deep straight channel along the northeast edge of the site, and the natural channel and adjacent floodplains were converted to agricultural muck.

The primary restoration efforts at the Ocklawaha Prairie site involve re-establishment of the natural channel and adjacent wetlands, with secondary goals including improvement of water quality, restoration of fish and wildlife habitat, expansion of flood storage, and enhanced recreational opportunities. However, concern has been raised that a high level of nutrient release may occur in the previous agricultural areas after flooding. The work efforts outlined in this report are designed to evaluate this potential and recommend mitigative actions to reduce the level of release. All of the work efforts performed by ERD outlined in this report were conducted in the area outlined on Figure 1-1.

Only a limited amount of previous historical data is available for the wetland soils located at the Ocklawaha Prairie site. The results and conclusions presented in this report are based primarily on field monitoring and laboratory analyses performed by ERD. Field investigations included: (1) multiple site visits to the Ocklawaha Prairie site to review current system characteristics; (2) collection of composite surface water samples to evaluate water quality impacts from addition of selected soil amendments; and (3) collection of sediment core samples to investigate general soil characteristics and quantify soil phosphorus speciation. Laboratory efforts included: (1) laboratory jar tests to evaluate water quality impacts on surface water resulting from addition of selected coagulants; (2) chemical analyses for raw and treated surface water samples collected from the site; and (3) general characterization studies and chemical speciation of core samples collected by ERD.

A variety of metal salts have been utilized in previous research activities for inactivation of phosphorus release from lake sediments and flooded soils. The three most common soil amendments referenced in the literature are metal salts of aluminum, calcium, and iron. The work efforts outlined in this report specifically address the use of aluminum- and calcium-based amendments since phosphorus associations with these metals are stable under the wide range of redox potentials anticipated in rehydrated soils and floodplains under normal operating conditions.

Although iron-based salts have the ability to retain phosphorus in soils and sediments under certain conditions, iron-phosphorus bonds which are formed are only stable under oxidized conditions, becoming unstable as the sediments and overlying water column become reduced. Since reduced conditions are anticipated within the soils of the site throughout much of the year, iron-based salts were not considered as part of this evaluation. Therefore, the work efforts outlined in this report deal exclusively with the use of aluminum and calcium based coagulants for phosphorus inactivation.

This report is divided into six separate sections for presentation and discussion of project results. The first section provides an introduction to the report and summarizes work efforts performed by ERD. Field and laboratory methodologies and procedures are discussed in Section 2. The results of field and laboratory investigations performed by ERD are summarized in Section 3. Potential application methods and costs for inactivating phosphorus release from the organic soils are presented in Section 4. Summary and conclusions of the work efforts are included in Section 5. Listed references are provided in Section 6.

SECTION 2

FIELD AND LABORATORY METHODS AND PROCEDURES

Field and laboratory investigations were performed by ERD to assist in evaluating proposed amendments, and in determining phosphorus soil inactivation requirements within the Ocklawaha Prairie site. Details of these activities are provided in the following sections.

2.1 Field Procedures

2.1.1 Sediment Collection

Sediment monitoring was performed at the Ocklawaha Prairie site by ERD during October 2001 and March 2002. Locations of the sediment monitoring sites are indicated on Figure 2-1. A total of 30 monitoring sites were selected at the Ocklawaha Prairie site in a relatively uniform grid pattern. Slight variations from a uniform grid pattern were necessary in some areas due to accessibility problems resulting from areas of dense vegetation, farm ditches, and berms. Geographic coordinates of the sediment sample sites, referenced as UTM NAD83 coordinates, are provided in Table 2-1. Based on an overall area of 2550 acres at the Ocklawaha Prairie site, each of the 30 collected soil samples represented approximately 85 acres of the site.

Sediment samples were collected at each of the 30 monitoring sites using a stainless steel split-spoon core device which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the top 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 30 monitoring sites. The polyethylene

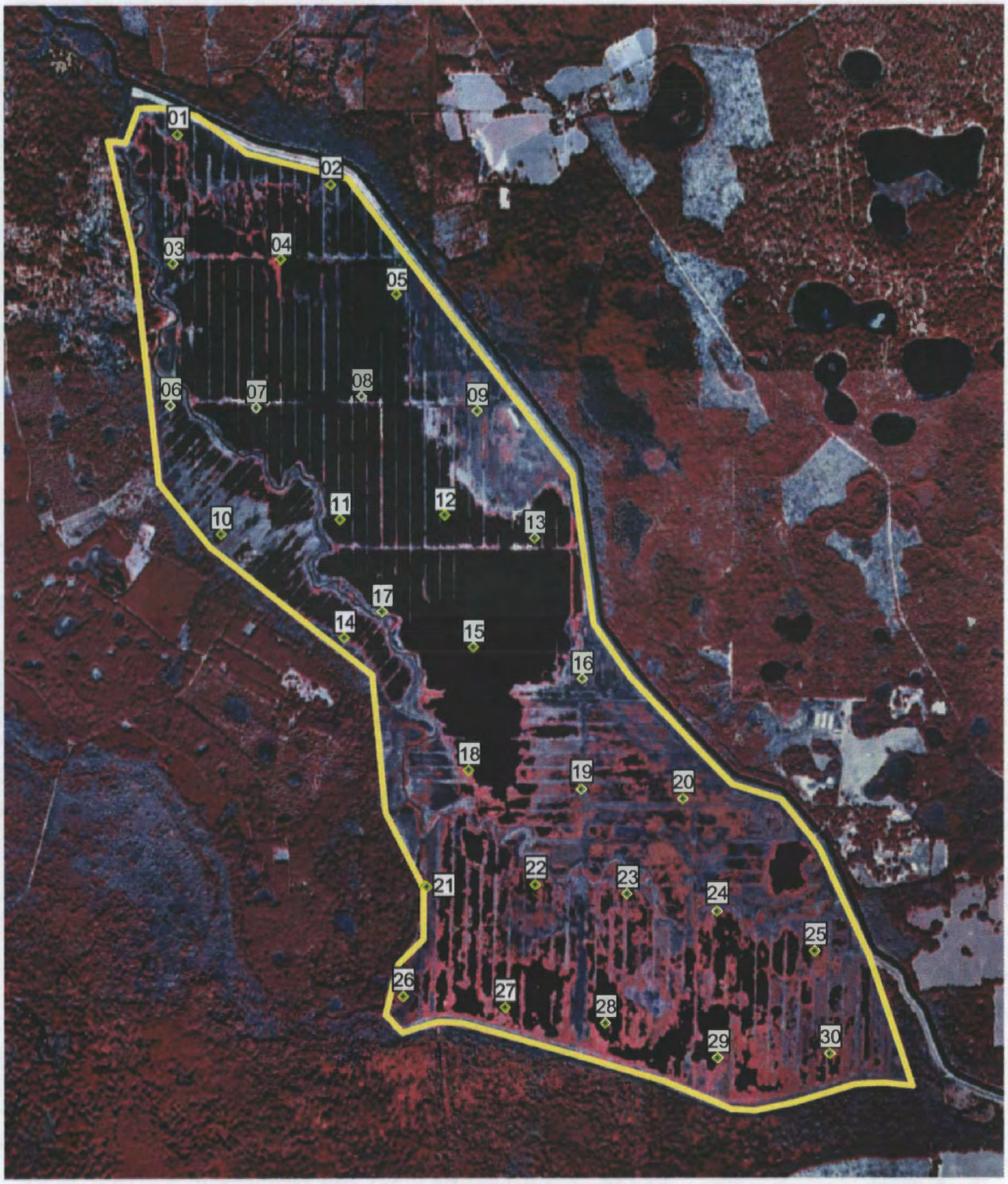

Figure 2-1. Location of Sediment Monitoring Sites at the Ocklawaha Prairie Restoration Site.

containers utilized for storage of the collected samples were filled completely so that no air space was present in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

TABLE 2-1

LOCATIONS OF OCKLAWAHA PRAIRIE SEDIMENT SAMPLING SITES

SITE	X	Y	SITE	X	Y
1	407,746.3	3,223,220.1	16	409,995.9	3,220,192.0
2	408,603.6	3,222,941.5	17	408,891.1	3,220,566.3
3	407,721.2	3,222,502.2	18	409,370.6	3,219,683.4
4	408,323.2	3,222,526.5	19	409,991.0	3,219,575.0
5	408,971.4	3,222,331.1	20	410,554.9	3,219,522.5
6	407,704.9	3,221,713.5	21	409,126.9	3,219,035.6
7	408,183.5	3,221,700.2	22	409,738.8	3,219,043.2
8	408,775.9	3,221,762.0	23	410,245.9	3,218,991.7
9	409,415.7	3,221,681.4	24	410,741.6	3,218,893.3
10	407,986.3	3,220,998.5	25	411,276.6	3,218,671.6
11	408,655.1	3,221,078.2	26	409,008.7	3,218,421.3
12	409,239.3	3,221,102.7	27	409,571.1	3,218,359.8
13	409,734.2	3,220,975.1	28	410,125.4	3,218,270.4
14	408,679.1	3,220,422.4	29	410,745.2	3,218,075.4
15	409,395.4	3,220,368.5	30	411,358.3	3,218,099.7

2.1.2 Collection of Composite Surface Water Samples

Composite surface water samples were collected from the Ocklawaha Prairie site during August 2002 to assist in evaluating water quality impacts associated with addition of aluminum-based amendments to the water column of the cells. Subsamples were collected from multiple sites to form a single composite sample. Locations of surface water collection sites are indicated on Figure 2-2.

Equal volumes of surface water collected at each site were combined to produce an overall composite surface water sample for laboratory testing. The collected composite sample was placed in a polyethylene container and returned (on ice) to the ERD laboratory for further evaluation. Due to the neutral to slightly acidic pH characteristics of the Ocklawaha Prairie soils, the use of calcium-based soil amendments seems unlikely; therefore, laboratory jar testing was conducted using only alum.

2.2 Laboratory Procedures

2.2.1 Sediment Testing

Each of the 30 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-2.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 35 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

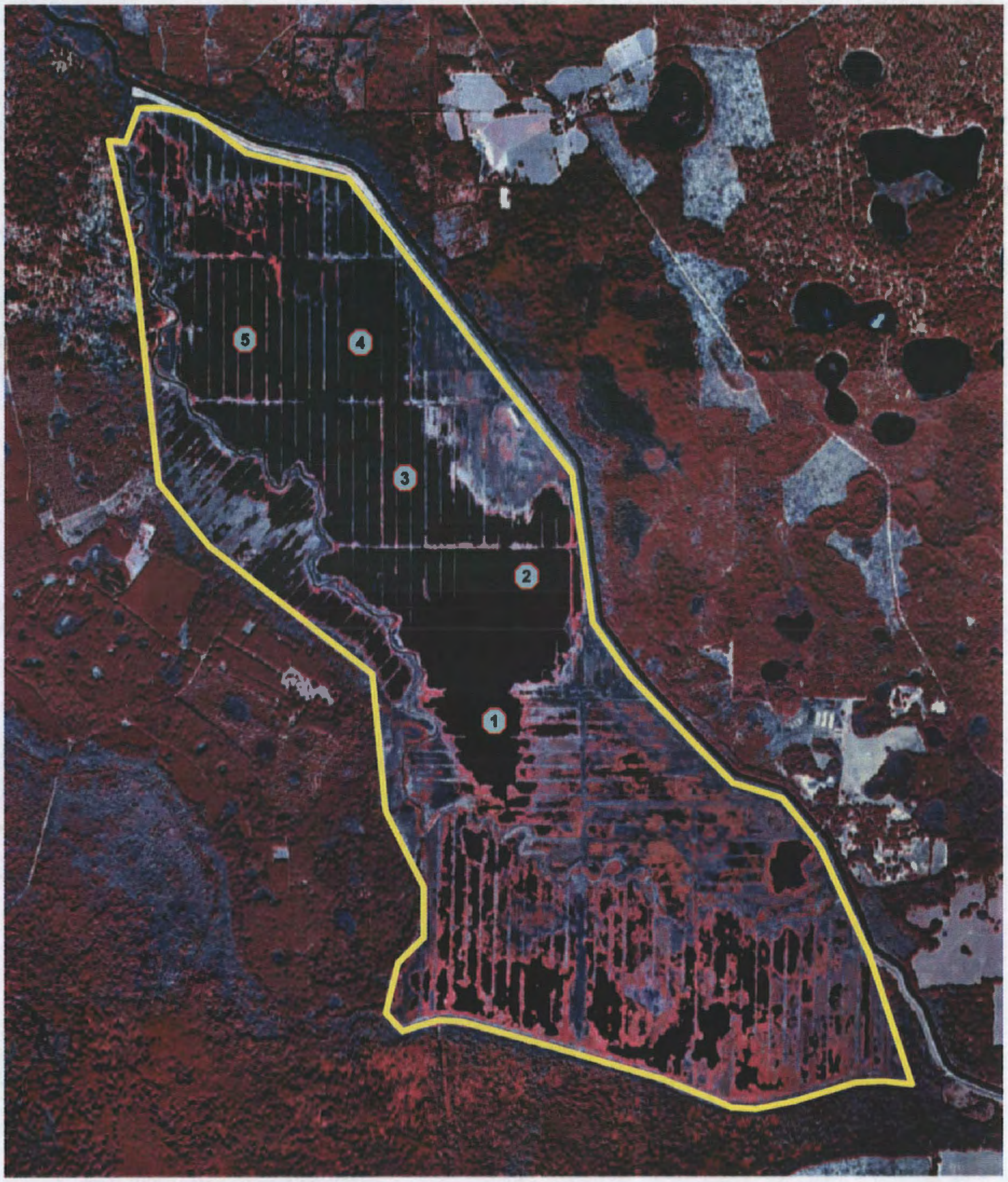

Figure 2-2. Location of Surface Water Collection Sites at the Ocklawaha Prairie Restoration Site.

TABLE 2-2

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3/3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1/1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1/1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1/2	0.005 mg/kg

REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphorus bounding is given in Figure 2-3.

For purposes of evaluating release potential, ERD typically assumes that potentially available inorganic phosphorus in soils/sediments, particularly soils which exhibit a significant potential to develop highly reduced conditions below the sediment-water interface, is represented by the sum of the soluble inorganic phosphorus and easily exchangeable phosphorus fractions (collectively termed saloid-bound phosphorus), plus iron-bound phosphorus, which can become solubilized under reduced conditions. Aluminum-bound phosphorus is generally considered to be unavailable in the pH range of approximately 5.5-7.5 under a wide range of redox conditions.

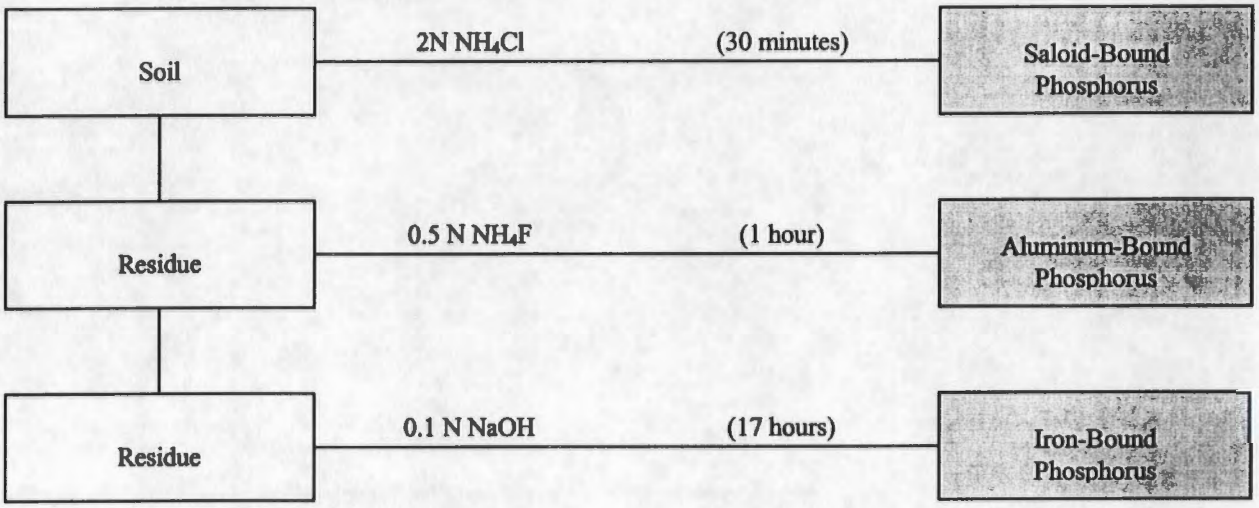

Figure 2-3. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

2.2.2 Jar Test Procedures

A series of laboratory jar tests were conducted on the composite surface water sample collected from the Ocklawaha Prairie site. The laboratory jar tests were performed using only aluminum- based coagulants, since the use of calcium-based coagulants seems unlikely at this site.

Alum-based laboratory jar tests were conducted on the composite surface water sample in individual polycarbonate containers using a sample volume of two liters for each test. Jar testing was conducted at alum doses of 5, 7.5, 10, 12.5, 15, and 20 mg Al/liter on the composite surface water sample to evaluate a wide range of potential application doses.

To begin each jar test, the appropriate amount of alum was added to a 2-liter water sample contained in a polycarbonate beaker. Following addition of the alum, the mixture was agitated for approximately 60 seconds. Measurements of pH were conducted initially in the raw sample approximately one minute after addition of the selected alum dose. If the pH of the sample was less than 5.5 after one minute, lime was added gradually until a minimum pH value of 5.5 was attained. The amount of lime required to raise the pH to this level was recorded. Additional measurements of pH were conducted at periods of one hour and 24 hours after addition of the alum coagulant to document changes in pH which typically occur after alum addition. In general, minimum pH levels in alum treated water typically occur within one hour after addition of the coagulant. The pH value of the treated water continues to increase steadily following the addition of the alum for a period of approximately 24 hours. The alum treated samples were then allowed to settle for 24 hours, simulating settling processes which would occur within the water column of the flow-way. At the end of the 24-hour settling period, the clear supernatant was decanted from each jar test container for subsequent laboratory analyses.

2.2.3 Laboratory Analyses

Each of the samples generated during the laboratory jar test procedures were analyzed for a wide variety of chemical constituents, including general parameters, chlorophyll-a, nutrients, aluminum, and calcium. A summary of analytical methods and detection limits for laboratory analyses conducted by ERD on each of the generated jar test samples is given in Table 2-3.

TABLE 2-3

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED ON JAR TEST SAMPLES

MEASUREMENT PARAMETER	METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters		
Hydrogen Ion (pH)	EPA-83[2], Sec. 150.1/Manf. Spec.[3]	NA
Specific Conductivity	EPA-83, Sec. 120.1/Manf. Spec.	0.1 µmho/cm
Alkalinity	EPA-83, Sec. 310.1	0.5 mg/l
Color	EPA-83, Sec. 110.3	1 Pt-Co Unit
Turbidity	EPA-83, Sec. 180.1	0.1 NTU
T.S.S.	EPA-83, Sec. 160.2	0.7 mg/l
Biological Parameters		
Chlorophyll-a	SM-18[4], Sec. 10200 H.3	0.1 mg/m^3
Nutrients		
Ammonia-N (NH_3-N)	SM-18, Sec. 4500-NH_3 G.	0.01 mg/l
Nitrate + Nitrite (NO_x-N)	EPA-83, Sec. 353.3	0.01 mg/l
Organic Nitrogen	Alkaline Persulfate Digestion[5]	0.03 mg/l
Orthophosphorus	SM-18, Sec. 4500-P E.	0.001 mg/l
Total Phosphorus	Alkaline Persulfate Digestion[5]	0.001 mg/l

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Subject to manufacturer's specifications for test equipment used.
4. Standard Methods for the Examination of Water and Wastewater, 18th Ed., 1992.
5. FDEP-approved method.

SECTION 3

RESULTS

The results of field and laboratory investigations performed by ERD to assist in evaluating proposed amendments and determining phosphorus soil inactivation requirements within the Ocklawaha Prairie Restoration Site are presented in the following sections.

3.1 Soil Types

A summary of soil types at the Ocklawaha Prairie Restoration Site is given in Figure 3-1 based upon information provided by SJRWMD. The area of the Ocklawaha Prairie site evaluated in this report is highlighted for identification purposes. The dominant soil types at the Ocklawaha Prairie site are Tomoka Muck, followed by Terra Ceia Muck, which together occupy a majority of the site. Perimeter areas of the site contain Bluff Sandy Clay, Holopaw Fine Sand, and Anclote Sand.

3.2 Historical Soil Characterization Studies

A limited amount of historical soil characterization data was obtained from SJRWMD based upon soil samples collected on May 18, 1998 at four separate locations in the Ocklawaha Prairie. Locations of the sediment/soil sampling sites are indicated on Figure 3-2 based upon information provided by SJRWMD. Two of the sample sites are located in the extreme southwest and southeast portions of the site, with an additional two sites located in the northeast and northwest portions of the site.

A summary of historical sediment/soil characteristics at the Ocklawaha Prairie Restoration site is given in Table 3-1. Each of the collected samples was analyzed for particle size distribution, percent solids, moisture content, TOC, and selected species of nitrogen and phosphorus. Soils collected at the site were found to be relatively well-graded, with approximately 50% of the soil

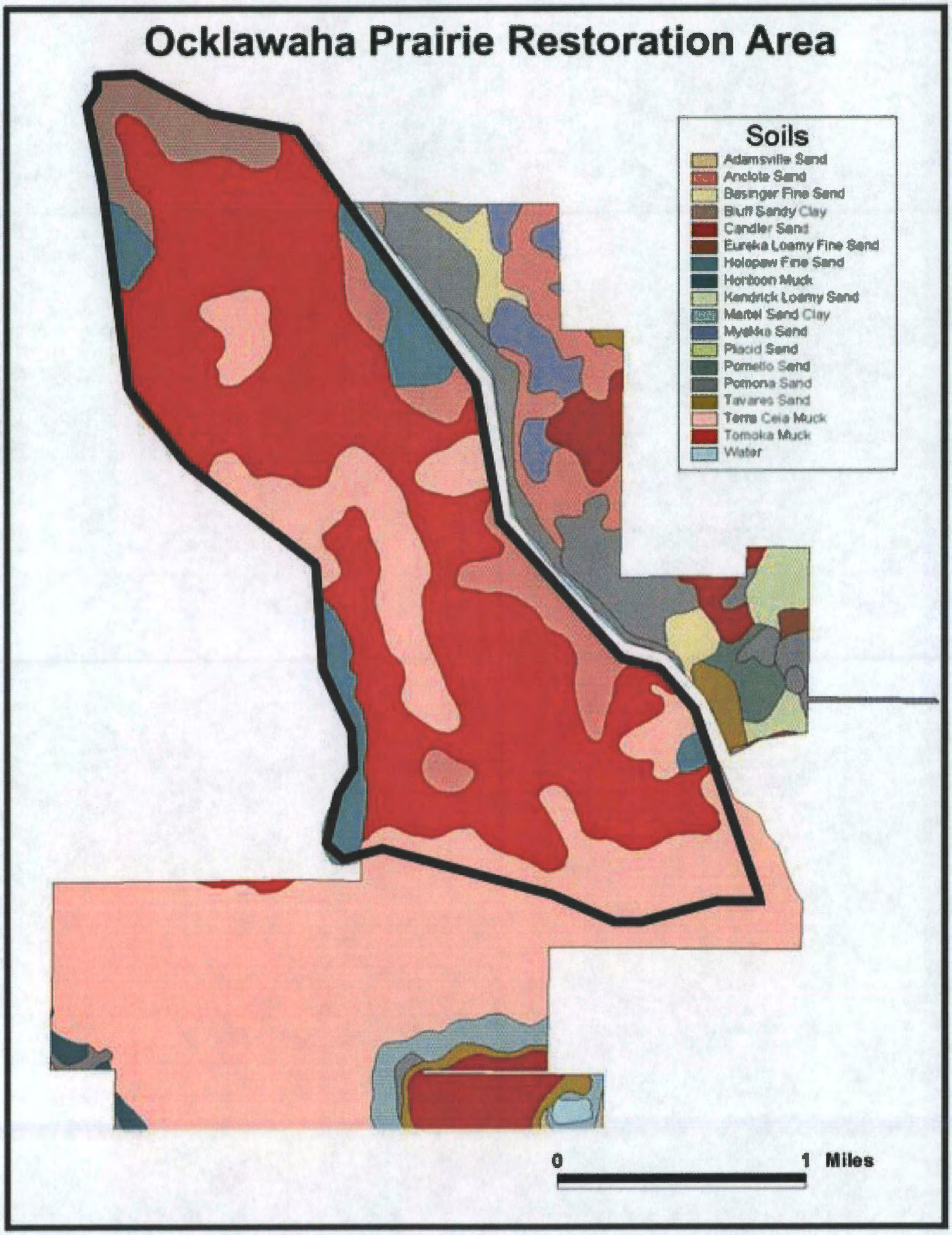

Figure 3-1. Soils in the Ocklawaha Prairie Restoration Area (Source: SJRWMD).

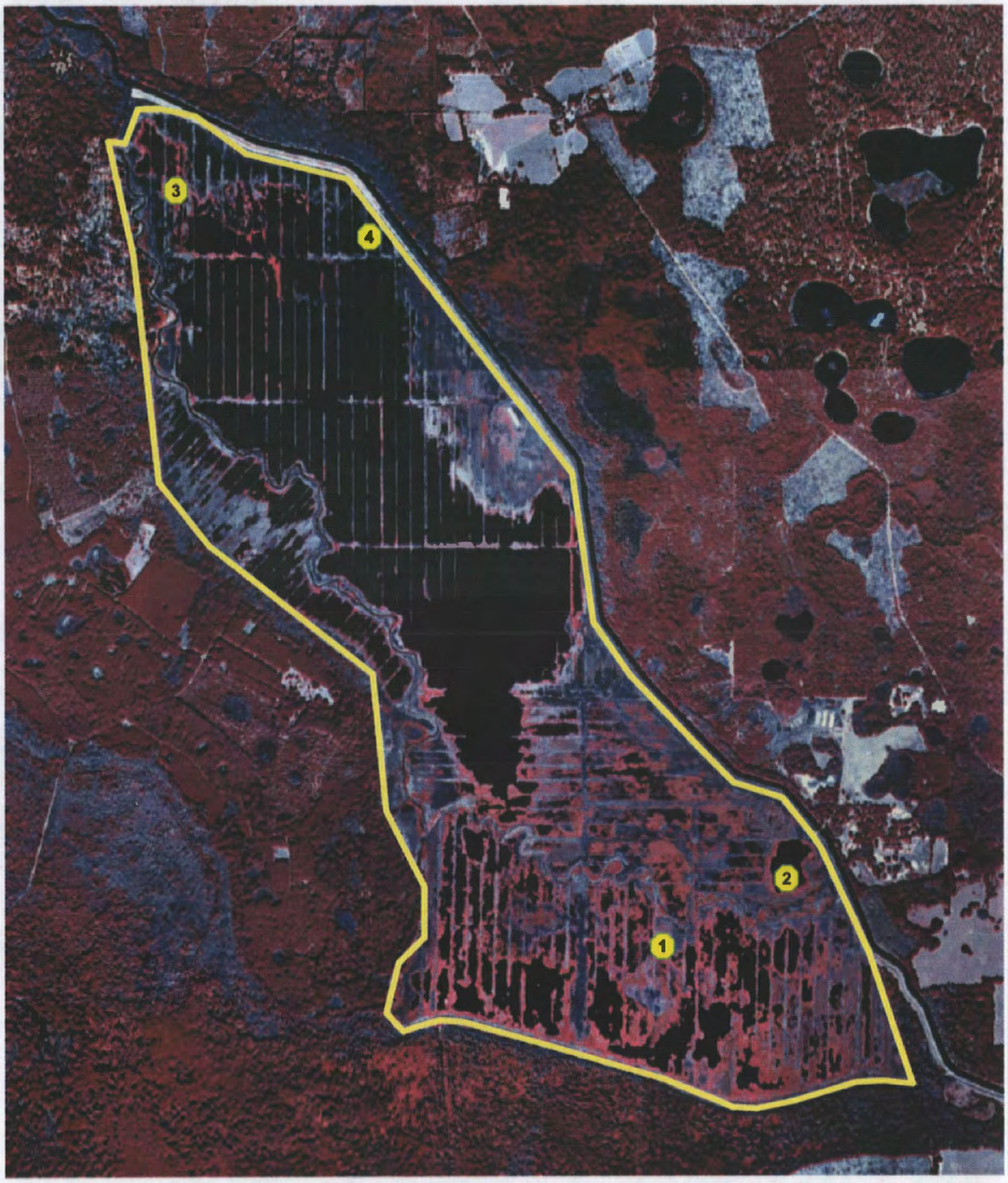

Figure 3-2. Location of SJRWMD Soil Sampling Sites during 1998.

particles less than 0.25 mm and 50% of the particles greater than 0.25 mm. Soils collected in the 1998 characterization study were also found to be relatively high in total nitrogen as well as total phosphorus.

TABLE 3-1

SUMMARY OF HISTORICAL SEDIMENT/ SOIL CHARACTERISTICS AT THE OCKLAWAHA PRAIRIE RESTORATION SITE

PARAMETER	UNITS	SITE					MEAN VALUE
		1	2	3	3-DUP	4	
Sediment Particle Size (%<0.063 mm)	% dry wt	19	18	16	14	23	18
Sediment Particle Size (%<0.063-0.125 mm)	% dry wt	12	7	8	10	10	9
Sediment Particle Size (%<0.125-0.25 mm)	% dry wt	14	11	14	13	11	13
Sediment Particle Size (%<0.25-0.5 mm)	% dry wt	19	13	15	21	16	17
Sediment Particle Size (%<0.5-2.0 mm)	% dry wt	22	22	21	23	21	22
Sediment Particle Size (%>2.0 mm)	% dry wt	13	30	26	20	22	22
Percent Solids	%	30.4	30.3	27.5	28.9	29.1	29.2
Moisture Content	%	69.6	69.7	72.5	7.1	70.9	70.8
TOC	mg/kg dw	420,000	350,000	380,000	430,000	440,000	404,000
Ammonia-N	mg/kg dw	170	170	92	97	93	124
NO_x-N	mg/kg dw	0.66	0.65	0.73	0.69	0.69	0.68
Ortho-P	mg/kg/dw	27	55	41	31	58	42
Total N	mg/kg dw	19,000	16,000	18,000	20,000	8,000	18,200
Total P	mg/kg dw	1,400	1,300	1,200	1,400	1,200	1,300

NOTE: Soil samples collected by SJRWMD on 5/18/98

3.3 Existing Soil Characterization

3.3.1 General Soil Characteristics

A summary of general characteristics of soil samples collected from the Ocklawaha Prairie site is given in Table 3-2. Measured values are provided for each of the 30 soil samples for moisture content (%), organic content (% of dry weight), soil density (g/cm^3), and pH. In general, soils collected from the Ocklawaha Prairie site are characterized by elevated moisture contents, ranging from approximately 20.3-78.5%. Measured moisture contents in the soils of the Ocklawaha Prairie site are similar to characteristics measured in soils at the Sunnyhill Restoration Site.

An isopleth map of soil moisture map for the Ocklawaha Prairie Restoration site is given in Figure 3-3. Areas of elevated soil moisture content, with values exceeding 60-70%, are present in central portions of the Ocklawaha Prairie site in the general area of the historical river bed which meandered through the site. In general, soil moisture contents appear to decrease with increasing distance from the historic channel.

A relatively high degree of variability is apparent in soil organic contents within the Ocklawaha Prairie site, with measured values ranging from 9.2-79.8%, and an overall mean of 40.5%. Values of soil organic content measured at the Ocklawaha Prairie site are similar to values measured at the Sunnyhill site. Isopleths of soil organic content at the Ocklawaha Prairie site are presented in Figure 3-4. In general, elevated soil organic contents are present in central portions of the site near the vicinity of the historic river bed.

Measured soil densities at the Ocklawaha Prairie site are indicative of soil characteristics ranging from sand to muck type soils. The lowest soil density measured at the site is 1.08 g/cm^3. This value suggests primarily muck type soils, with a low amount of inorganic soil particles. The highest soil density measured at the site is 2.16 g/cm^3, suggesting a significant amount of inorganic soil particles, such as fine sand, in combination with muck soils. The relatively low mean soil density of 1.43 g/cm^3 for the site is consistent with highly organic soils combined with a low percentage of inorganic soil particles.

TABLE 3-2
GENERAL CHARACTERISTICS IN THE TOP 0-10 cm LAYER OF SOIL/SEDIMENT SAMPLES COLLECTED FROM THE OCKLAWAHA PRARIE RESTORATION SITE

SITE	MOISTURE CONTENT (%)	ORGANIC CONTENT (% dry wt)	SOIL DENSITY (g/cm^3 wet basis)	SOIL pH
1	42.0	17.5	1.72	7.11
2	45.1	31.7	1.56	7.30
3	58.4	33.2	1.42	7.17
4	58.0	41.4	1.37	7.64
5	63.2	41.4	1.32	7.57
6	66.1	46.2	1.27	7.11
7	73.7	53.7	1.18	7.40
8	51.9	38.0	1.45	7.54
9	39.2	23.4	1.70	7.39
10	66.9	54.4	1.23	7.77
11	57.8	42.9	1.36	7.44
12	72.3	75.8	1.10	7.66
13	60.5	50.6	1.29	7.28
14	51.5	31.5	1.50	7.19
15	78.5	74.0	1.08	7.48
16	34.9	15.9	1.82	7.21
17	38.5	9.2	1.84	7.64
18	63.5	48.8	1.28	7.12
19	48.5	27.0	1.56	7.10
20	57.5	33.2	1.43	7.17
21	46.5	24.0	1.61	7.67
22	68.3	58.3	1.20	7.09
23	56.2	31.0	1.45	6.89
24	51.7	26.5	1.53	6.95
25	66.9	53.0	1.23	7.09
26	20.3	2.7	2.16	7.65
27	42.3	20.4	1.69	7.39
28	62.8	54.2	1.26	7.52
29	73.8	79.8	1.08	7.30
30	69.8	74.1	1.12	7.36
Mean	56.2	40.5	1.43	7.35

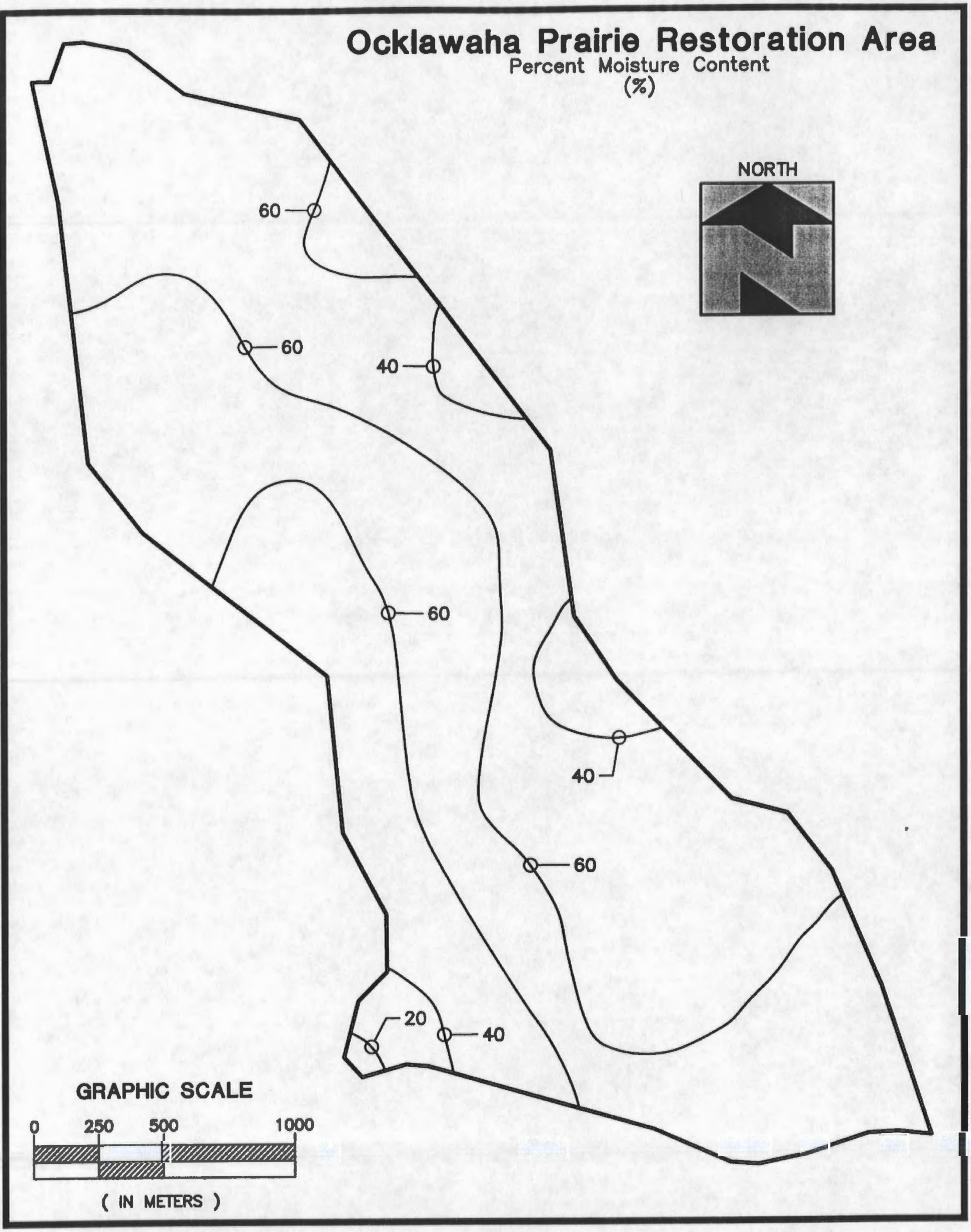

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Figure 3-3. Isopleths of Soil Percent Moisture Content in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

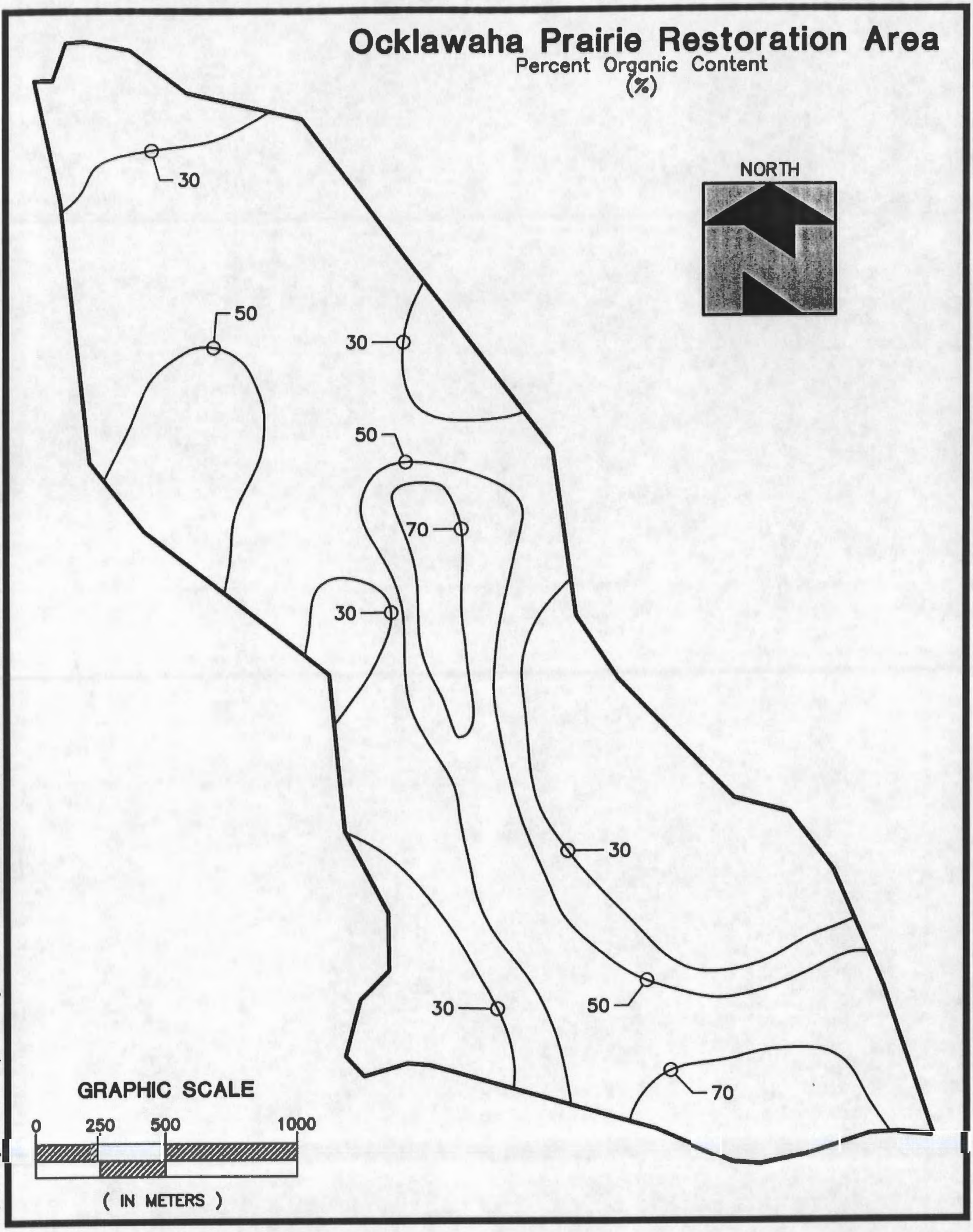

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Figure 3-4. Isopleths of Soil Organic Content in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

Soil pH values at the Ocklawaha Prairie site are approximately neutral, with measured values ranging from 6.89-7.77. The overall mean soil pH value of 7.35 suggests relatively neutral soil characteristics.

3.3.2 Nutrient Concentrations

A summary of nutrient concentrations in soil samples collected from the Ocklawaha Prairie site is given in Table 3-3. Measured values are provided for both nitrogen and phosphorus in terms of μg/cm^3 on a wet weight basis. In general, total nitrogen concentrations in the Ocklawaha Prairie soils were found to be somewhat variable, with measured nitrogen contents ranging from approximately 1458-8582 μg/cm^3, with an overall mean of 5650 μg/cm^3. Nitrogen concentrations in soils at the Ocklawaha Prairie site appear to exhibit less variability between sites than observed at the Sunnyhill site.

Measured total phosphorus concentrations in soils from the Ocklawaha Prairie site were also found to be variable, with measured values ranging from approximately 91-874 μg/cm^3, and an overall mean of 458 μg/cm^3. This value is approximately 21% greater than the mean value measured at the Sunnyhill site.

An isopleth map of soil nitrogen content in the top 10 cm of the Ocklawaha Prairie site is given in Figure 3-5, with contours expressed in terms of μg total nitrogen/cm^3. Elevated total nitrogen concentrations are present in northeastern portions of the site along with south central portions. Nitrogen concentrations appear to be lowest along the west side of the site.

An isopleth map of soil phosphorus content in the top 10 cm of the Ocklawaha Prairie site is given in Figure 3-6. Similar to the trends exhibited by nitrogen, soil total phosphorus concentrations appear to be greatest in northeast and southeast portions of the site.

TABLE 3-3
NUTRIENT CONCENTRATIONS IN THE TOP 0-10 cm OF SOIL SAMPLES COLLECTED FROM THE OCKLAWAHA PRAIRIE SITE

SITE	TOTAL NITROGEN ($\mu g/cm^3$ wet weight)	TOTAL PHOSPHORUS ($\mu g/cm^3$ wet weight)
1	6243	597
2	8483	852
3	2144	214
4	5148	325
5	1458	95
6	2070	135
7	3199	240
8	7335	393
9	8582	705
10	7203	496
11	5583	506
12	6016	265
13	6837	423
14	6333	459
15	4343	251
16	6236	591
17	2654	167
18	7240	788
19	7460	536
20	6722	507
21	6616	580
22	6433	496
23	5268	461
24	6180	692
25	6627	578
26	1687	91
27	5927	315
28	6919	874
29	5904	778
30	6665	331
Mean	5650	458

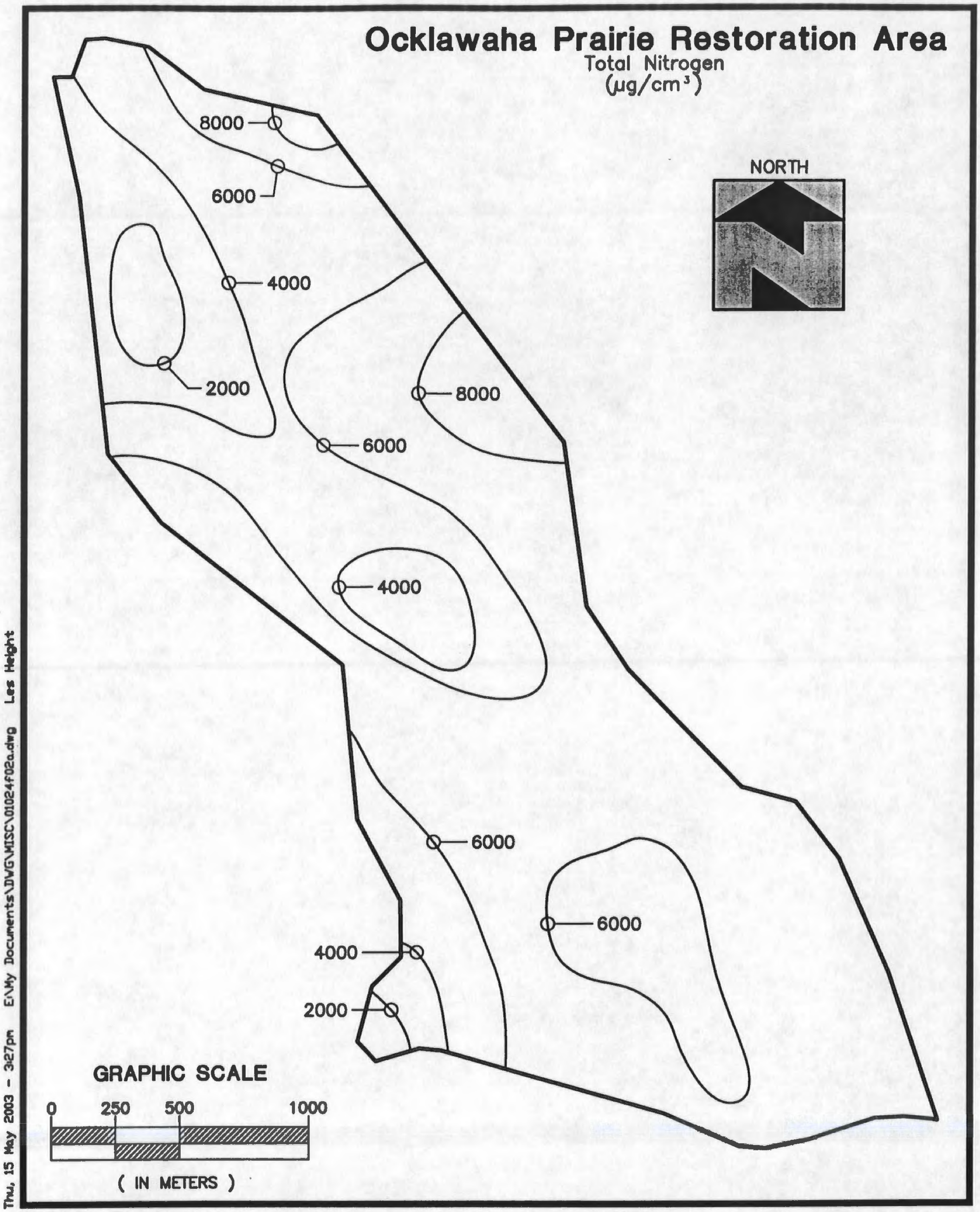

Figure 3-5. Isopleths of Soil Nitrogen Concentration in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

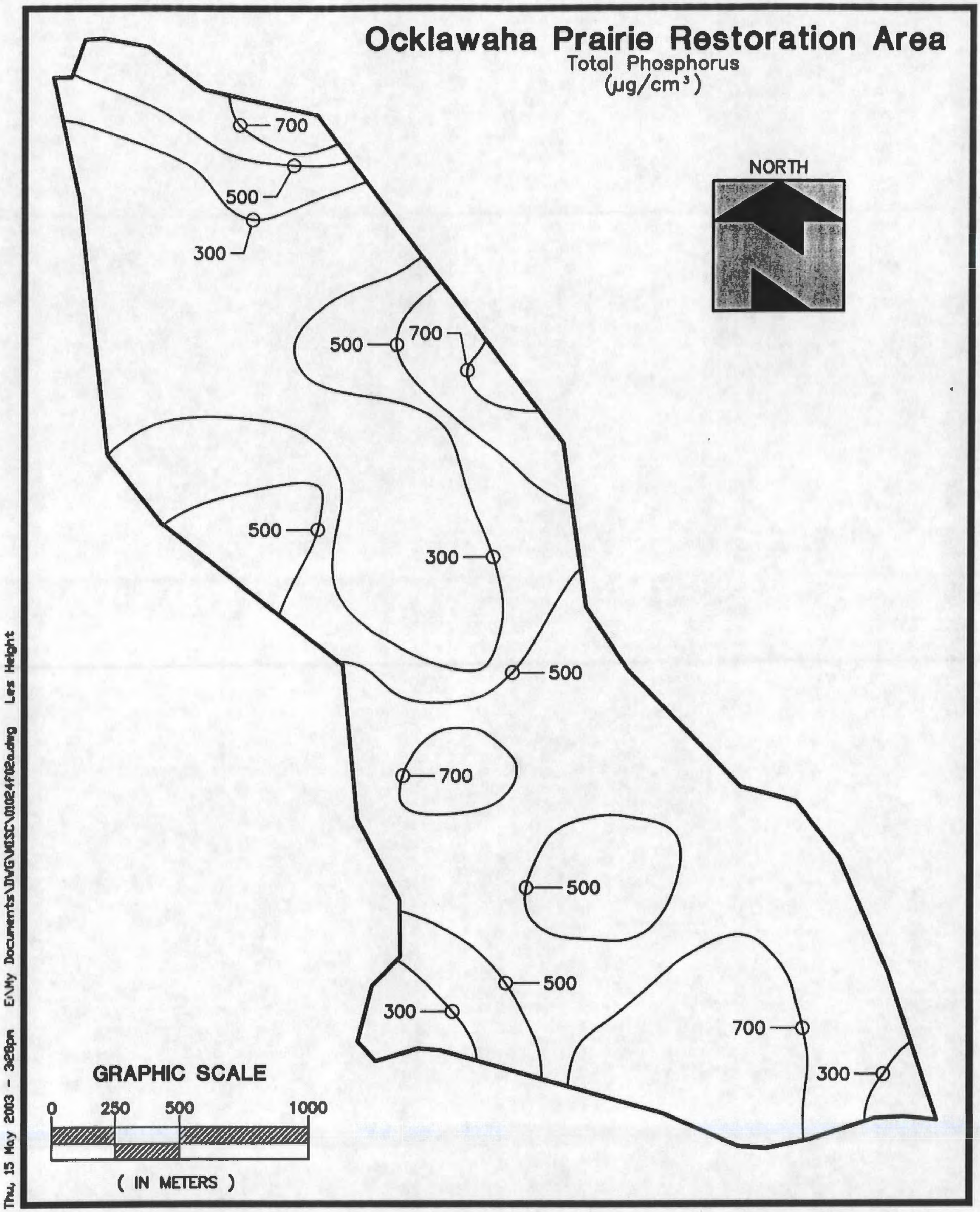

Figure 3-6. Isopleths of Total Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

3.3.3 Sediment Phosphorus Speciation

As discussed in Section 2.2.1, each of the 30 collected core samples was carried through the Chang and Jackson speciation procedure to fractionate inorganic soil phosphorus. The Chang and Jackson procedure allows speciation of sediment phosphorus into saloid-bound phosphorus (soluble plus easily exchangeable), iron-bound phosphorus, and aluminum-bound phosphorus. Saloid-bound phosphorus and iron-bound are considered to be potentially available for release into the overlying water column, while aluminum-bound phosphorus is typically considered to be inert and stable under all conditions of redox potential.

A summary of sediment speciation in soil samples collected from the Ocklawaha Prairie site is given in Table 3-4. Measured concentrations are provided for saloid-bound phosphorus, iron-bound phosphorus, and aluminum-bound phosphorus. Estimates of total available phosphorus, defined as saloid-bound plus iron-bound phosphorus associations, are also provided in Table 3-4. All concentrations for phosphorus species are provided in terms of µg phosphorus/cm^3 (µg P/cm^3) of soil on a wet basis.

As seen in Table 3-4, a relatively high degree of variability is apparent in saloid-bound phosphorus fractions measured at the Ocklawaha Prairie site. Saloid phosphorus concentrations range from 1.2 µg/cm^3 to more than 13 µg/cm^3 at the soil monitoring sites. The overall mean saloid phosphorus concentration at the site is 5.7 µg/cm^3 which is similar to the value measured at the Sunnyhill site (6.0 µg/cm^3).

Isopleths of saloid-bound phosphorus in soils at the Ocklawaha Prairie site are presented in Figure 3-7. Areas of elevated saloid-bound phosphorus concentrations are present along the eastern and southern portions of the site.

As seen in Table 3-4, a high degree of variability is also present in iron-bound phosphorus associations in soil samples collected from the Ocklawaha Prairie site. Iron-bound phosphorus concentrations range from approximately 0.9 µg/cm^3 to 100 µg/cm^3, with an overall mean of 39.9 µg/cm^3. This value is approximately 2.6 times greater than the mean iron-bound association measured at the Sunnyhill site (15.2 µg/cm^3).

TABLE 3-4
SEDIMENT PHOSPHORUS SPECIATION IN THE TOP 0-10 cm LAYER OF SOIL SAMPLES COLLECTED FROM THE OCKLAWAHA PRAIRIE SITE

SITE	SALOID-BOUND ($\mu g/cm^3$ wet)	Fe-BOUND ($\mu g/cm^3$ wet)	AVAILABLE P ($\mu g/cm^3$ wet)	Al-BOUND ($\mu g/cm^3$ wet)	PERCENT AVAILABLE P (%)
1	5.3	100	106	40.7	17.7
2	3.7	27.2	30.9	19.1	3.6
3	6.5	14.8	21.3	17.6	9.9
4	2.2	29.8	32.0	19.1	9.9
5	4.5	18.1	22.6	3.7	23.7
6	3.3	8.4	11.6	8.4	8.6
7	5.1	13.3	18.4	36.3	7.7
8	2.6	31.2	33.7	28.6	8.6
9	6.3	48.9	112	55.9	15.9
10	3.9	41.3	45.3	56.0	9.1
11	3.7	44.0	47.7	113	9.4
12	1.6	11.2	12.8	23.6	4.8
13	2.7	45.3	48.0	57.2	11.4
14	2.3	46.2	48.5	53.5	10.6
15	4.0	16.2	20.2	39.0	8.0
16	6.5	49.6	56.0	52.5	9.5
17	2.6	77.0	79.6	0.8	47.7
18	1.2	74.5	75.7	185	9.6
19	2.1	34.6	36.7	103	6.8
20	1.2	53.8	55.0	27.7	10.9
21	3.0	50.9	53.8	41.2	9.3
22	3.1	36.9	40.0	44.5	8.1
23	3.1	52.1	55.3	67.5	12.0
24	4.3	99.2	104	112	14.9
25	4.4	40.1	44.6	61.9	7.7
26	3.2	0.9	4.1	3.2	4.6
27	3.7	29.1	32.8	27.9	10.4
28	3.3	54.3	57.6	92.0	6.6
29	13.3	38.3	51.6	150	6.6
30	1.7	9.7	11.4	33.4	3.5
Mean	5.7	39.9	45.6	52.5	10.9

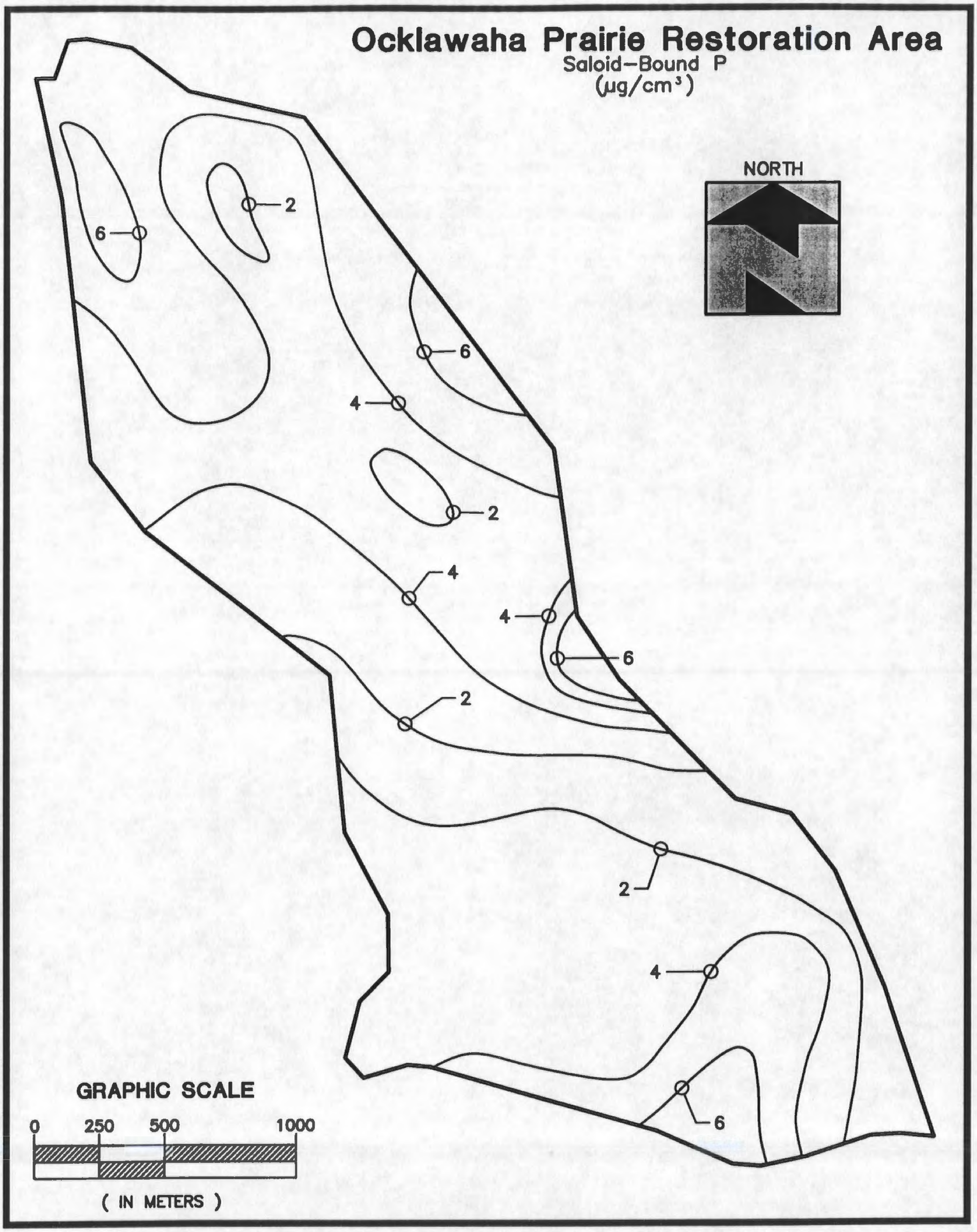

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Figure 3-7. Isopleths of Saloid-Bound Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

A graphical representation of isopleths of iron-bound phosphorus in the Ocklawaha Prairie site is given in Figure 3-8. Iron-bound phosphorus associations in the soils at the Ocklawaha Prairie site appear to be greatest in northwestern and south central portions of the site.

Estimates of total available phosphorus in soils collected at each of the 30 monitoring sites are provided in Table 3-4, by summing the measured saloid-bound phosphorus and iron-bound phosphorus associations at each monitoring site. As seen in Table 3-4, estimates of total available phosphorus are substantially less variable than either the saloid-bound or iron-bound fractions individually. Estimated total available phosphorus values range from approximately 4.1-112 μg/cm^3, with an overall mean concentration of 45.6 μg/cm^3. The overall mean total available phosphorus concentration of 45.6 μg/cm^3 at the Ocklawaha Prairie site is approximately twice the total available phosphorus measured at the Sunnyhill site (21.1 μg/cm^3).

Isopleths of total available phosphorus in the top 10 cm of the Ocklawaha Prairie site are presented in Figure 3-9. Total available phosphorus in the soils appears to be greatest in northwestern and south central portions of the site. The isopleths of total available phosphorus presented in Figure 3-9 are used as a guide for evaluating chemical amendment requirements and preparing cost estimates for phosphorus inactivation at the Ocklawaha Prairie site.

Aluminum-bound phosphorus associations are also summarized in Table 3-4. A relatively high degree of variability is apparent in aluminum bonding between the 30 different soil sites, with aluminum-bound phosphorus concentrations ranging from approximately 0.8-185 μg/cm^3. The overall mean aluminum-bound phosphorus concentration of 52.5 μg/cm^3 is substantially greater than aluminum-bound associations measured in the Lake Griffin Flow-way (21.5 μg/cm^3), the Sunnyhill site (19.9 μg/cm^3), or the Long Farm site (13.8 μg/cm^3).

Isopleths of aluminum-bound phosphorus in the top 10 cm of the Ocklawaha Prairie site are presented in Figure 3-10. Aluminum-bound phosphorus associations appear to be greatest in central and south central portions of the site.

Calculations of the percentage of available phosphorus are also provided in the final column of Table 3-4. These values reflect the percentage of total soil phosphorus, based upon the total phosphorus values presented in Table 3-3, which is considered to be available based upon

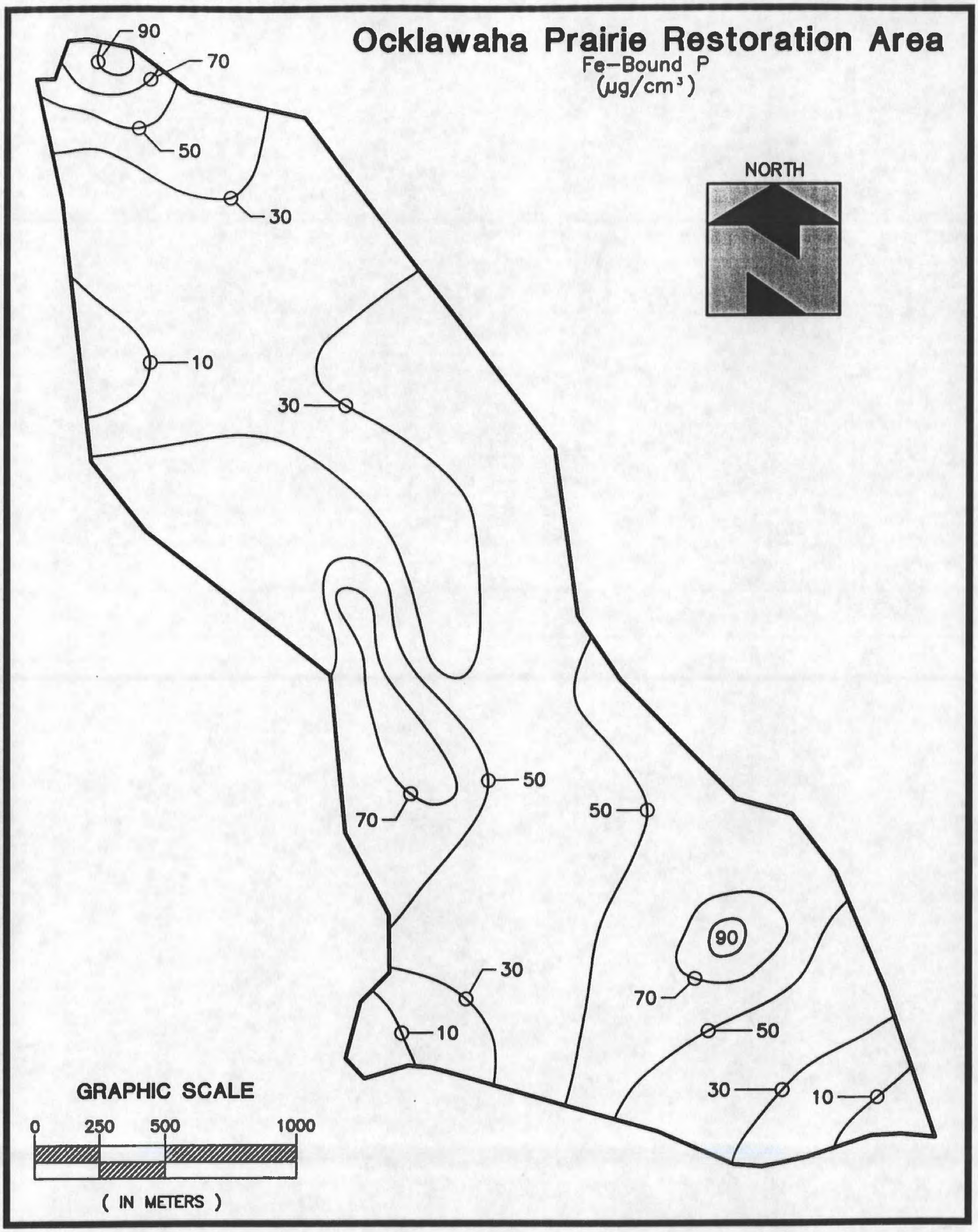

Figure 3-8. Isopleths of Iron-Bound Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

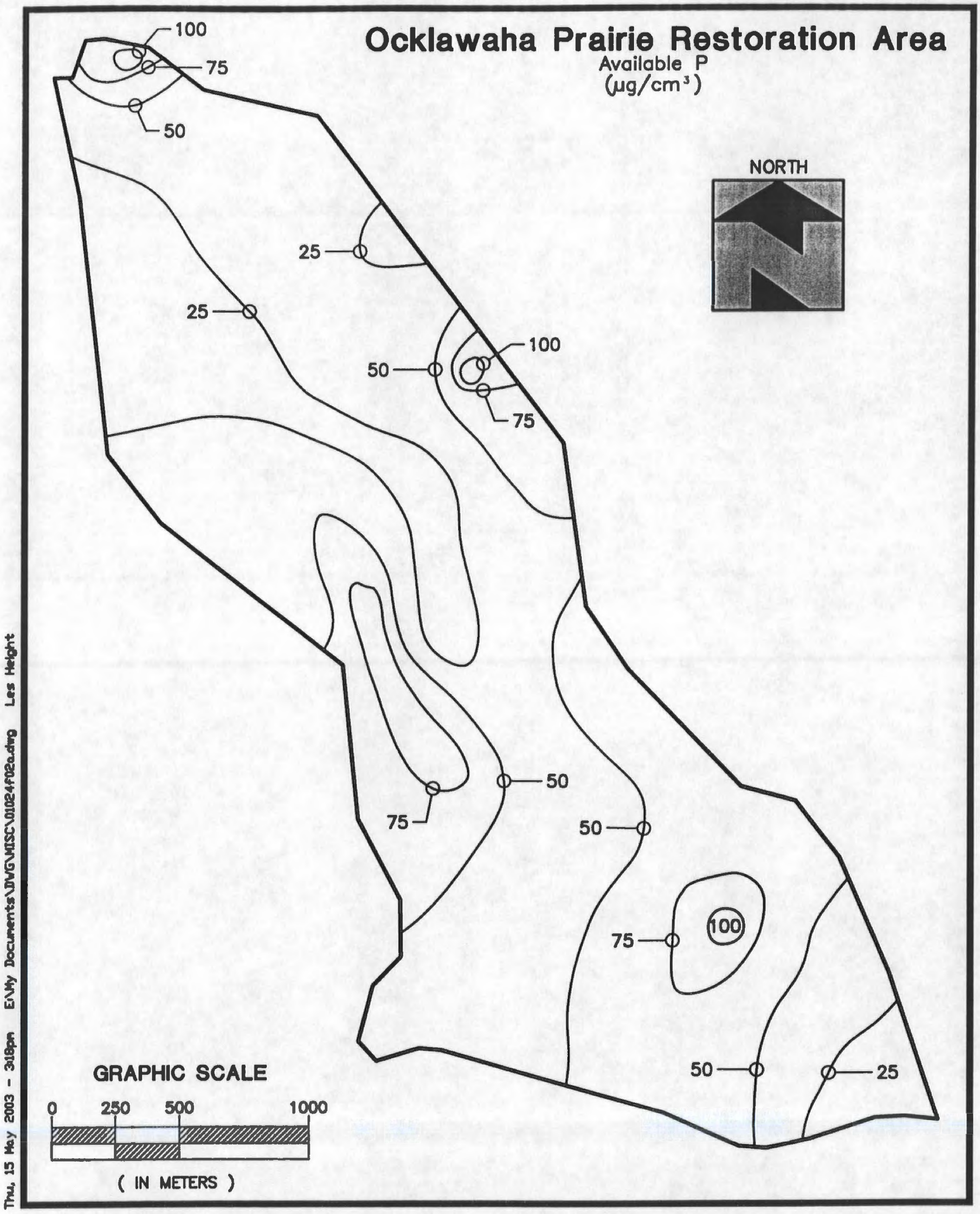

Figure 3-9. Isopleths of Available Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

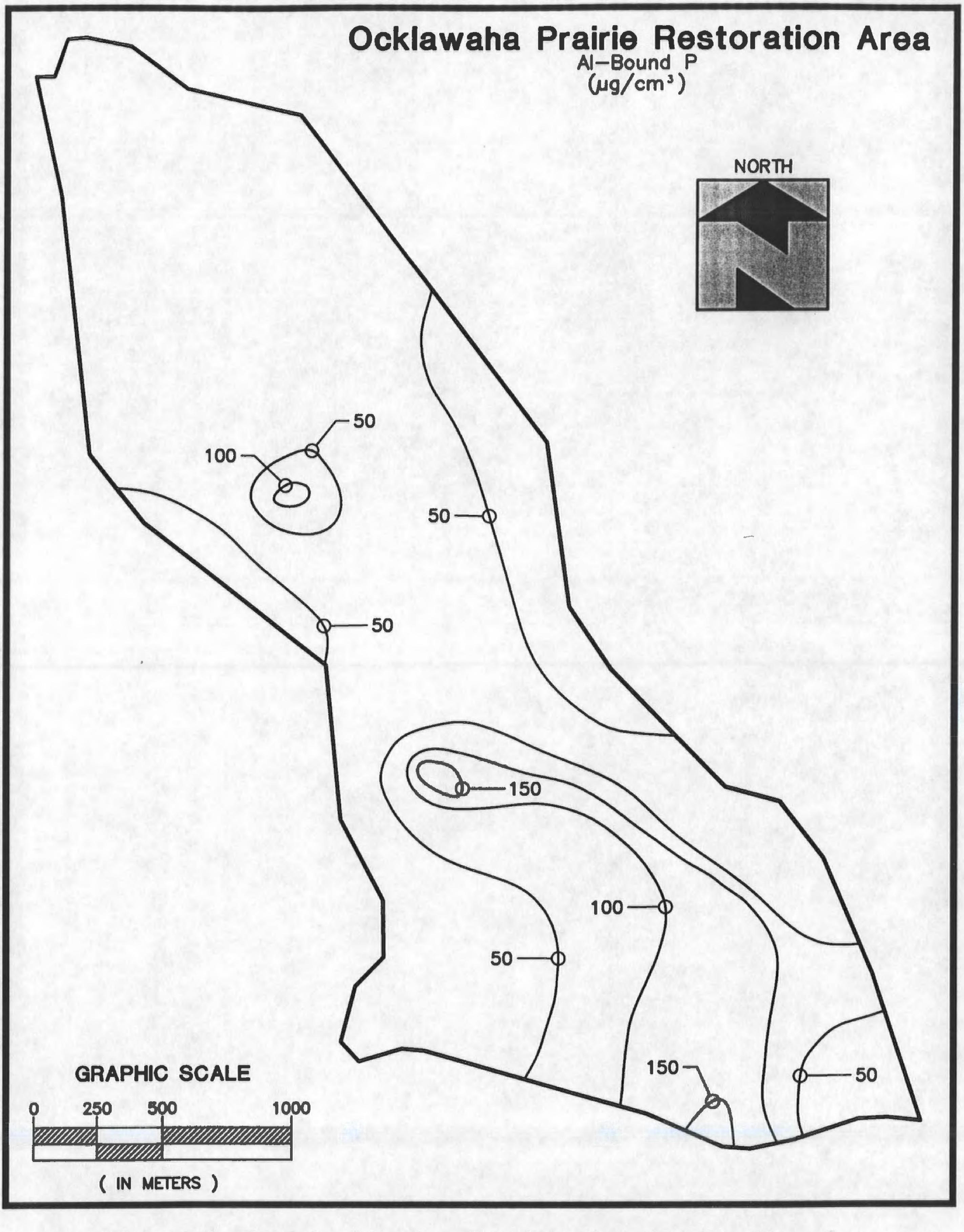

Figure 3-10. Isopleths of Aluminum-Bound Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

information provided in Table 3-4. The percentage of soil available phosphorus is highly variable throughout the Ocklawaha Prairie site, with individual values ranging from approximately 3.5-47.7%. On an overall basis, approximately 10.9% of the total phosphorus in the soils at the Ocklawaha Prairie site is potentially available for release. This value is similar to soils at the Lake Griffin and Sunnyhill sites where approximately 10-13% of the total soil phosphorus is potentially available, but is substantially greater than available phosphorus at the Long Farm site where less than 1% of the total soil phosphorus is potentially available as either saloid-bound or iron-bound phosphorus.

Isopleths of the percentage of available soil phosphorus in the top 10 cm of the Ocklawaha Prairie site are presented in Figure 3-11. Elevated areas of available soil phosphorus are apparent along the northeast and western central portions of the site.

3.4 Mass of Available Sediment Phosphorus

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the Ocklawaha Prairie site were generated by graphically integrating the total available phosphorus isopleths presented in Figure 3-9. Areas contained within each of the isopleth contours were calculated using AutoCAD Release 12.0.

A summary of estimated total available sediment phosphorus at the Ocklawaha Prairie site is given in Table 3-5. On a mass basis, the Ocklawaha Prairie Restoration Site contains approximately 44,728 kg of available soil phosphorus in the top 10 cm of the 2550-acre restoration area. On a molar basis, this equates to approximately 1,442,822 moles of available phosphorus to be inactivated as part of the soil inactivation process. This value is approximately 3.7 times the moles of available phosphorus estimated for the Sunnyhill site (387,904 moles).

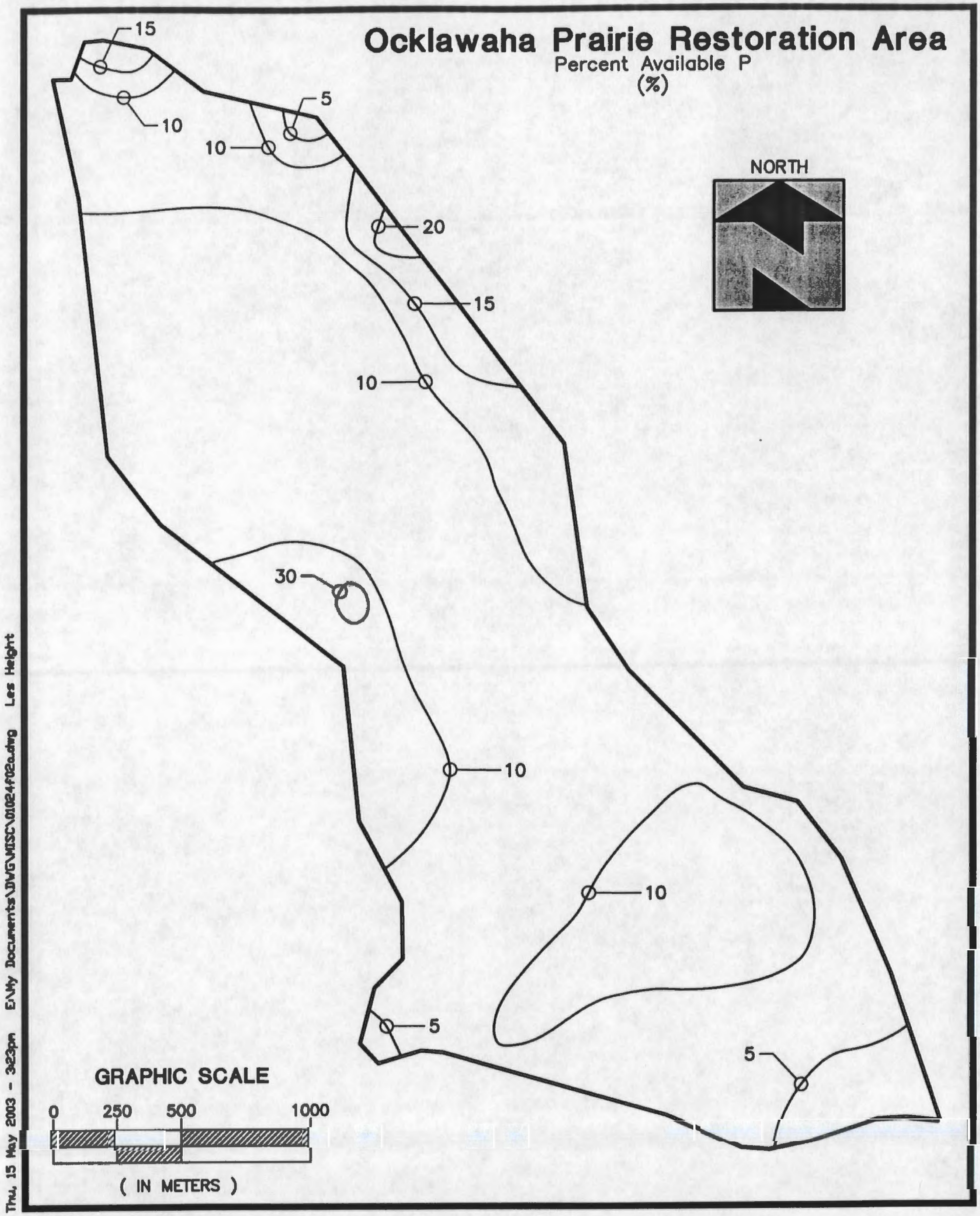

Figure 3-11. Isopleths of Percent Available Phosphorus in the Top 10 cm of Soils at the Ocklawaha Prairie Restoration Site.

TABLE 3-5

ESTIMATES OF AVAILABLE PHOSPHORUS IN THE TOP 10 cm OF SOILS AT THE OCKLAWAHA PRAIRIE RESTORATION SITE

(Based on a 2550-acre site)

CONTOUR ($\mu g/cm^3$)	MEDIAN CONCENTRATION ($\mu g/cm^3$)	CONTOUR AREA (ac)	SOIL DEPTH (cm)	AVAILABLE PHOSPHORUS	
				(kg)	(moles)
< 25	12.5	403.4	10	2,040	65,813
25-50	37.5	1297.2	10	19,686	635,035
50-75	62.5	711.7	10	18,000	580,635
75-100	87.5	125.3	10	4,441	143,242
> 100	112.5	12.4	10	561	18,097
	OVERALL:	2550.0		44,728	1,442,822

3.5 Laboratory Jar Testing

3.5.1 Raw Water Characteristics

Chemical characteristics of the composite raw surface water sample collected during August 2002 at the Ocklawaha Prairie site are summarized in Table 3-6. The composite surface water sample was found to be approximately neutral in pH, with a measured value of 6.97. The measured specific conductivity value of 295 μmho/cm in the composite sample is similar to specific conductivity values measured at the Lake Griffin and Long Farm sites. The sample appears to be moderately well buffered, with a measured alkalinity of 81.6 mg/l. This value is similar to alkalinity values measured at the Lake Griffin site.

Composite surface water collected at the Ocklawaha Prairie site is characterized by only moderately elevated levels of total nitrogen, with a measured concentration of 3093 μg/l. Dissolved organic nitrogen is the dominant nitrogen species present, comprising 72% of the total nitrogen measured at the site. The composite surface water sample is characterized by relatively low levels of inorganic nitrogen, with NH_3 and NO_x together comprising only 15% of the total nitrogen measured. The remaining nitrogen in the composite surface water is particulate in nature.

TABLE 3-6

CHEMICAL CHARACTERISTICS OF RAW COMPOSITE SURFACE WATER COLLECTED AT THE OCKLAWAHA PRAIRIE SITE

PARAMETER	UNITS	RAW WATER CHARACTERISTICS
pH	s.u.	6.67
Specific Conductivity	µmho/cm	295
Alkalinity	mg/l	81.6
NH_3-N	µg/l	414
NO_x-N	µg/l	36
Particulate N	µg/l	416
Diss. Organic N	µg/l	2227
Total N	µg/l	3093
Diss. Ortho-P	µg/l	172
Diss. Organic P	µg/l	85
Particulate P	µg/l	142
Total P	µg/l	399
TSS	mg/l	17.4
Turbidity	NTU	3.2
Chlorophyll-a	mg/m^3	26.7
Color	Pt-Co	141

Composite surface water at the Ocklawaha Prairie site is characterized by moderately elevated levels of total phosphorus. The measured total phosphorus concentration of 399 μg/l is approximately 25% less than the mean total phosphorus concentration of 540 μg/l measured at the Lake Griffin Flow-way site, but represents only 8% of the total phosphorus value measured at the Long Farm site. The dominant phosphorus species is dissolved orthophosphorus which comprises approximately 43% of the total phosphorus measured. The remaining phosphorus is primarily particulate in nature, with only a small amount of dissolved organic phosphorus present.

The composite surface water sample collected from the Ocklawaha Prairie site is characterized by moderate levels of suspended solids and turbidity. Chlorophyll-a within the composite sample appears to be moderately elevated, with a measured value of 26.7 mg/m^3. The composite sample was also found to be highly colored, with a measured color concentration of 141 Pt-Co units.

3.5.2 Jar Test Results

The results of laboratory jar tests using alum on the composite surface water sample collected from the Ocklawaha Prairie site are presented in Table 3-7. Laboratory jar tests were performed using applied alum doses of 5, 7.5, 10, 12.5, 15, and 20 mg Al/liter. These doses were selected to provide information on a wide range of application rates which could be potentially utilized at the site.

Addition of alum at each of the six treatment doses resulted in a reduction in pH within the sample, based upon measurements performed one minute after alum addition. An applied alum dose of 20 mg Al/liter required the addition of lime as a buffering agent since the pH level of the treated sample was depressed to a value less than 5.5 after addition of the alum coagulant. A lime dose of 14.6 mg Ca/liter was required in this sample to achieve the desired pH level of 5.5 after one minute. The pH of each of the treated samples gradually increased over the 24-hour settling period, reaching values ranging from 6.37-7.12 after a 24-hour settling period.

TABLE 3-7

RESULTS OF LABORATORY JAR TESTS USING ALUM ON THE COMPOSITE SURFACE WATER SAMPLE COLLECTED FROM THE OCKLAWAHA SITE

PARAMETER	UNITS	RAW WATER CHARACTERISTICS	APPLIED ALUM DOSE (mg Al/liter)					
			5.0	7.5	10.0	12.5	15.0	20.0
pH (initial)	s.u.	6.97	6.97	6.97	6.97	6.97	6.97	6.97
pH (after 1 min)	s.u.	6.97	6.45	6.27	6.10	5.86	5.57	5.51
pH (after 1 hr)	s.u.	6.97	6.58	6.40	6.27	6.01	5.69	5.62
pH (after 24 hr)	s.u.	6.97	7.12	7.04	7.05	6.67	6.48	6.37
Spec. Cond.	μmho/cm	295	307	313	322	339	344	396
Alkalinity	mg/l	81.6	60.5	48.4	35.8	13.7	11.1	22.9
NH_3-N	μg/l	414	304	269	340	360	391	419
NO_x-N	μg/l	36	33	32	24	25	24	21
Particulate N	μg/l	416	420	421	381	269	56	91
Diss. Organic N	μg/l	2227	1978	1907	1546	1291	1091	977
Total N	μg/l	3093	2735	2629	2291	1945	1562	1508
Diss. Ortho-P	μg/l	172	16	2	1	< 1	< 1	< 1
Diss. Organic P	μg/l	85	77	54	21	13	10	8
Particulate P	μg/l	142	175	180	108	56	9	5
Total P	μg/l	399	268	236	130	70	20	14
TSS	mg/l	17.4	13.3	30.1	19.3	15.3	8.5	4.0
Turbidity	NTU	3.2	7.2	11.7	8.9	6.0	4.2	1.4
Chlorophyll-a	mg/m^3	26.7	28.9	10.3	7.1	2.8	1.5	1.3
Color	Pt-Co	141	99	60	42	24	13	10
Lime Dose Added	mg Ca/liter	--	0.0	0.0	0.0	0.0	0.0	14.6

The addition of the alum coagulant resulted in a reduction in measured alkalinity values with each of the tested doses. In contrast, conductivity values increased in the treated samples from an initial value of 295 μmho/cm in the raw water to a value of 396 μmho/cm at the maximum tested alum dose of 20 mg/l.

Addition of the alum coagulant had little impact on measured concentrations of NO_x or ammonia within the treated samples. The addition of alum appeared to reduce measured concentrations of particulate nitrogen and dissolved organic nitrogen with lower equilibrium concentrations at increasing alum doses. Overall, total nitrogen concentrations were reduced by the alum addition, with reductions ranging from 12% at the lowest tested alum dose to more than 50% at the highest tested alum dose.

Addition of the alum coagulant appeared to have the most impact on phosphorus species within the composite sample. The addition of alum resulted in a substantial decrease in measured concentrations of dissolved orthophosphorus with increasing alum dose. Reductions in dissolved orthophosphorus concentrations ranged from 91% at the lowest tested alum dose to more than 99% at the highest tested alum dose. However, in contrast, alum addition at the lower tested doses resulted in increases in measured concentrations of particulate phosphorus. This unusual behavior is related to the extremely small floc size which was produced by coagulation at these lower alum doses. This floc was extremely resistant to settling, and much of the phosphorus which was absorbed onto the floc still remained in the water column after the 24-hour settling period. This phenomenon is also evident in measured concentrations of TSS and turbidity which actually increased at lower alum doses, while decreasing at higher alum doses. Alum doses of approximately 10 mg Al/liter or more were required to result in a net reduction in measured concentrations of particulate phosphorus. However, in spite of the unusual settling characteristics observed for the floc at low doses, net reductions in total phosphorus were observed at each of the treatment doses. Phosphorus reductions ranged from approximately 33% at the lowest tested alum dose to more than 96% at the highest tested alum dose.

Alum coagulation of the composite surface water also resulted in substantial reductions in concentrations of chlorophyll-a, with a percentage reduction of more than 95% at the highest dose. Alum coagulation is also affective in reducing color within the composite sample, with color reductions ranging from 30-93%.

In summary alum coagulation of surface water within the Ocklawaha Prairie site will result in substantial reductions in measured concentrations of both total nitrogen and total phosphorus, particularly at treatment doses in excess of 10-12 mg Al/liter. Alum doses in excess of 15 mg/l will require the supplemental addition of lime as a buffering agent to prevent undesirable reductions in pH values within the treated water. At higher treatment doses, equilibrium concentrations of total nitrogen should be approximately 1500 μg/l or less, with total phosphorus concentrations of approximately 20 μg/l or less. The resulting water column should be relatively clear, with reduced levels of TSS, turbidity, and chlorophyll-a.

SECTION 4

AMENDMENT EVALUATION AND APPLICATION PLAN

The results of the analyses presented in the previous sections are used to evaluate aluminum-based and calcium-based amendment requirements for the Ocklawaha Prairie site, review potential application methods and costs, select the optimum amendment for sediment phosphorus inactivation, develop an application plan for the selected amendment, and discuss the anticipated longevity of the recommended amendment application. The specific conclusions reached during these analyses are presented in the following sections.

4.1 Evaluation of Potential Amendments

4.1.1 Aluminum-Based Coagulants

4.1.1.1 Conventional Aluminum-Based Coagulants

Aluminum-based coagulants are available in either liquid or solid form. The most common liquid forms are aluminum sulfate, $Al_2(SO_4)_3 \cdot 14H_2O$, commonly called alum, along with aluminum chloride, $AlCl_3$. Alum is manufactured by dissolving bauxite in sulfuric acid while aluminum chloride is manufactured by dissolving bauxite in hydrochloric acid. Many manufacturing and fabrication processes prefer to use alum rather than aluminum chloride due to concerns over the additional chloride ions added when using aluminum chloride. Preferences for aluminum-based coagulants appear to vary regionally throughout the United States. In southeastern portions of the U.S., alum is clearly the preferred coagulant, with a relatively small market for aluminum chloride. However, in northeastern portions of the U.S., the use of aluminum chloride appears to be somewhat higher, although alum is still the preferred coagulant within the region.

Another factor significantly affecting the selection of a potential aluminum amendment is the type of application and the associated chemical purity required. Due to differences in the purity of the raw materials used in the manufacture of aluminum sulfate and aluminum chloride, commercial grade aluminum chloride is characterized by substantially higher levels of trace metals than are present in alum. As a result, water coagulated with aluminum chloride may also contain higher residual levels of metals than would occur if the same water were coagulated using alum. Although trace metal concentrations may not be a significant concern in many industrial manufacturing processes where aluminum-based coagulants are used, this issue is of great concern when coagulating surface water which must meet regulated water quality criteria at the completion of the coagulation process.

In addition to aluminum sulfate and aluminum chloride, a number of polymeric aluminum compounds have been developed, primarily in response to specific manufacturing or industrial needs. These polymeric aluminum-based coagulants are designed to enhance certain flocculation-based processes, such as colloidal removal. None of these issues appear to be of significant concern at the Ocklawaha Prairie site that would warrant or justify the use of polymerized aluminum compounds over common inorganic salts of aluminum. Polymerized aluminum coagulants are also considerably more expensive than alum and less widely available.

Liquid alum contains approximately 48.5% dry aluminum sulfate. The mixture exhibits a light green to light yellow color with a specific gravity of approximately 1.335 (60°F), a bulk weight of approximately 11.1 pounds/gallon, and contains approximately 4.4% Al by weight. Liquid alum is transported in stainless steel tankers which have a capacity of approximately 4500-5000 gallons each. The liquid alum is unloaded through a reinforced rubber hose using an onboard pump or with air supplied by an onboard compressor.

Aluminum sulfate is also available in both granular and powdered forms which contain approximately 9% Al by weight. Dry granular alum is shipped in either 50-pound bags or in bulk pneumatic transport trucks with a typical capacity of 40,000 pounds. These transport trucks are usually self-unloading using compressed air at 450-650 ft^3/min (cfm) and 15 psi pressure. A large silo or storage tank is necessary to contain the solids pumped from the pneumatic transport. The granular alum is then distributed from the storage tank using gravity, mechanical, or pneumatic systems to reach the point of use. Granular alum has a bulk density of 63-71 lbs/ft^3, while powdered alum has a bulk density of 38-45 lbs/ft^3.

Recently, General Chemical Corp., the leading producer of alum in the U.S., has developed a buffered alum product called Baraclear. Baraclear is a dry mixture of alum and lime which reduces the decrease in pH often observed when using standard alum at high doses or in poorly buffered waters. Baraclear comes in a variety of sizes, ranging from 0.25-inch pellets to 1-inch x 3-inch briquettes.

For over a century, alum was sold primarily in a dry form which was relatively easy to package and economical to ship long distances. However, in the past several decades, there has been a growing demand for alum in liquid form for use in manufacturing and other applications. Both forms perform similar chemical functions when added to water. Some of the advantages responsible for the trend toward increased use of liquid alum are the lower manufacturing costs for liquid alum due to the reduced energy consumption required for manufacture, reduced handling and storage costs for liquid alum compared with the granular form, along with substantial improvements in the efficiency and precision of the distribution process when applying alum in a liquid form compared to a solid form.

Granular alum was used in the first alum lake treatment ever performed, at Lake Langsjon in Sweden (Jernelov, 1971). During this application, as well as subsequent studies, it was discovered that floc formation is somewhat better when liquid alum is used. As a result, Peterson, et al. (1973) mixed granular alum with lake water on board the delivery barge during the surface application to Horseshoe Lake, Wisconsin, which was the first application performed in the United States. Since that time, liquid alum has been used for all subsequent whole-lake applications due to its availability and ease of transfer.

When aluminum is added to water, phosphorus is removed by three primary mechanisms: (1) formation of insoluble $AlPO_4$; (2) sorption on the surface of $Al(OH)_3$ floc; and (3) by entrapment of phosphorus containing particulate matter in the $Al(OH)_3$ floc. The removal or inactivation of phosphorus by formation of either $AlPO_4$ or $Al(OH)_3$ is most effective in the pH range of 5.5-7.5 when maximum floc production occurs and when the solubility of the phosphorus intercepting compounds is minimal. Therefore, the use of alum for soil inactivation of phosphorus release is indicated primarily for soils which are approximately neutral to slightly acidic in nature.

4.1.1.2 Aluminum-Based Sludge Residuals

In addition to using raw alum in granular form, aluminum-based water treatment sludges have also been used for inactivation of sediment phosphorus release as well as in filter media used for treatment of stormwater runoff. Aluminum-based coagulants are commonly used in drinking water treatment facilities for removal of suspended solids and turbidity in the raw water. To enhance the speed of the coagulation process, aluminum is typically added in substantial excess during the coagulation process. As a result, the sludge generated during this process has a significant amount of residual aluminum which can be utilized for additional phosphorus interception or inactivation. One significant advantage of this material is that it is often available free of charge, except for shipping costs.

Harper, et al. (1983) may have been the first to attempt to use waste sludge, formed during the flocculation and clarification process for treatment of drinking water, to intercept and inactivate phosphorus in Lake Eola, in Orlando, Florida. Two different water treatment plant sludges were investigated by Harper, including a calcium carbonate-based water treatment plant sludge obtained from the Clyde Doyle Water Treatment Plant in Cocoa, and an alum-based water treatment plant sludge obtained from a treatment facility on the Hillsborough River in Tampa, FL. A series of in-situ experiments were performed using underwater isolation chambers to evaluate sediment phosphorus release under extended anoxic conditions. The alum sludge residual exhibited significant control over sediment phosphorus release with virtually no phosphorus release observed in the alum sludge treated chamber over the four-month monitoring program. Subsequent laboratory studies indicated that sludge doses of 40-80 grams of dry sludge per square meter of bottom sediment were necessary to inhibit orthophosphorus release. However, the calcium-based residual did not exhibit significant interception of sediment phosphorus, with phosphorus release rates similar to those observed in the control chamber.

Harper also utilized alum residual in an underground filtration system designed to provide filtration for stormwater runoff prior to entering the lake. A 50:50 mixture of sludge and coarse sand was utilized in the filter media which removed approximately 99% of the incoming orthophosphate, 80% of the total phosphorus, and more than 70% of suspended solids and organic nitrogen.

The SJRWMD has also utilized alum residual for inactivation of soil phosphorus release on flow-way areas adjacent to Lake Apopka. The residual sludge was obtained from the City of Melbourne Drinking Water Treatment Plant which uses a combination alum/polymer treatment process for treating water from Lake Washington for potable use. Characteristics of the alum sludge residual obtained from the City of Melbourne Treatment Plant are given in Table 4-1 based upon information provided by SJRWMD. The alum sludge has a residual phosphorus uptake capacity of approximately 60 mg P per g of sludge on a dry weight basis. Based on prior experience with landspreading of this material, SJRWMD recommends a minimum application rate of 6.5 wet tons per acre, based on a 25% solids content, which is considered to be the lowest application rate that can be performed while still providing a good even coverage within the treatment area.

TABLE 4-1

CHARACTERISTICS OF ALUM SLUDGE RESIDUAL OBTAINED FROM THE CITY OF MELBOURNE DRINKING WATER TREATMENT PLANT

(SOURCE: SJRWMD)

PARAMETER	VALUE
P Fixation Capacity	60 mg P/gram dry sludge
Minimum Application Rate	6.5 wet tons/acre (based on 25% solids content)

4.1.2 Calcium-Based Coagulants

4.1.2.1 Comparison of Calcium-Based Coagulants

Unlike alum, calcium-based coagulants are available primarily in solid form as either lime, $Ca(OH)_2$, or limestone, $CaCO_3$. Each of these compounds is produced in both powder and granular form. Lime has the highest percentage of calcium by weight, containing approximately 54% calcium, compared with 40% calcium by weight in limestone. As a result, approximately 35% more mass of calcium carbonate would be required for any given application to equal the mass of calcium produced when using lime.

In addition to the powdered and granular formulations, both lime and limestone are available as a slurry which consists of a suspension of solids in a water base. Due to the limited solubility of both limestone and lime, virtually all of the solids remain in a suspended slurry form. The slurry must be continuously stirred to prevent the solids from rapidly settling onto the bottom of the container. According to the Chemical Lime Corporation, lime can be delivered in 5000-gallon tanker trucks as a pre-mixed slurry containing 40% solids by weight. The slurry is maintained in a suspended form by agitation devices within the tanker.

Calcium forms several insoluble compounds with phosphate, among which hydroxyapatite, $Ca_5(OH)(PO_4)_3$, seems to be the most important. Minimum solubility for this compound occurs in the pH range of approximately 9-11, which suggests that inactivation of soil release of phosphorus using lime is most effective under alkaline soil conditions.

4.2 Factors Affecting Amendment Selection

Selection of the appropriate soil amendment for inactivation of phosphorus release is based upon two primary factors, including soil pH and application conditions. Soil pH conditions affect chemical composition of the soil amendment (i.e., aluminum- or calcium-based), whereas application conditions affect the form of the amendment (soil, liquid, etc.). Aspects of these issues with respect to the Ocklawaha Prairie site are addressed in the following sections.

4.2.1 Soil pH Conditions

The first factor affecting selection of a soil amendment is the ambient pH of the soils to be inactivated. Soils which have ambient pH values in the range of 5.5-7.5 would be most effectively inactivated using aluminum-based compounds, since aluminum-phosphorus associations exhibit minimum solubilities in this pH range. As seen in Table 3-2, measured pH values in the soil samples collected from the Ocklawaha Prairie Restoration site fall primarily within the pH range of 6.9-7.8.

Use of calcium-based coagulants for phosphorus interception is favored primarily in highly alkaline soil conditions, with pH values in excess of approximately 8.5-9. This pH range is substantially higher than the range of soil pH values measured at the Ocklawaha Prairie Restoration site. As a result, the use of an aluminum-based inactivant appears to be most appropriate for reducing soil phosphorus release at the Ocklawaha Prairie site.

4.2.2 Application Conditions

The second factor affecting the selection of the appropriate chemical inactivant is the environment under which the application is conducted, primarily the presence or absence of water in the treatment area. A topographic map of the Ocklawaha Prairie Restoration site is given in Figure 4-1. The majority of the site appears to have elevations primarily between 36 and 40 ft (NGVD). A summary of bathymetric data for the Ocklawaha Prairie site is given in Table 4-2 based upon information provided by SJRWMD.

Variations in recorded water elevations at the Ocklawaha Prairie site from 1995-2002 are presented in Figure 4-2, also based upon information provided by SJRWMD. During the period of record summarized in Figure 4-2, water elevations at the Ocklawaha Prairie Restoration site have ranged from approximately 37-40 ft (NGVD), with an overall mean of 39 ft. At an elevation of 39 ft, approximately 72% of the overall site will be inundated with water, although only 173 acres, approximately 7% of the site, would have a water depth greater than 3 ft which is required for a boat-based alum application. Even if the water level were raised to 40 ft (NGVD), only 447 acres, or approximately 18% of the site, would have a water depth sufficient for a boat-based application.

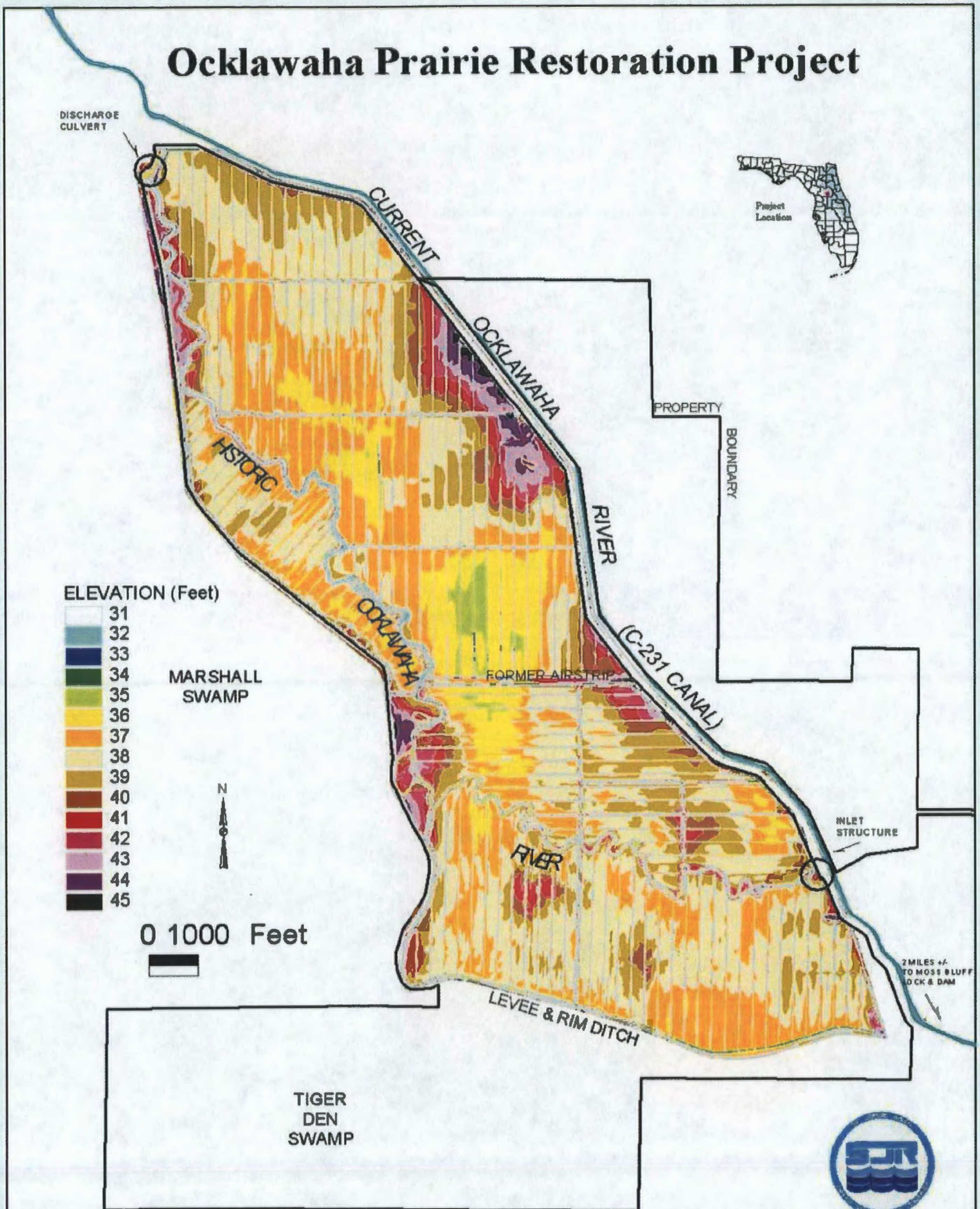

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Figure 4-1. Topographic Map of the Ocklawaha Prairie Restoration Site.

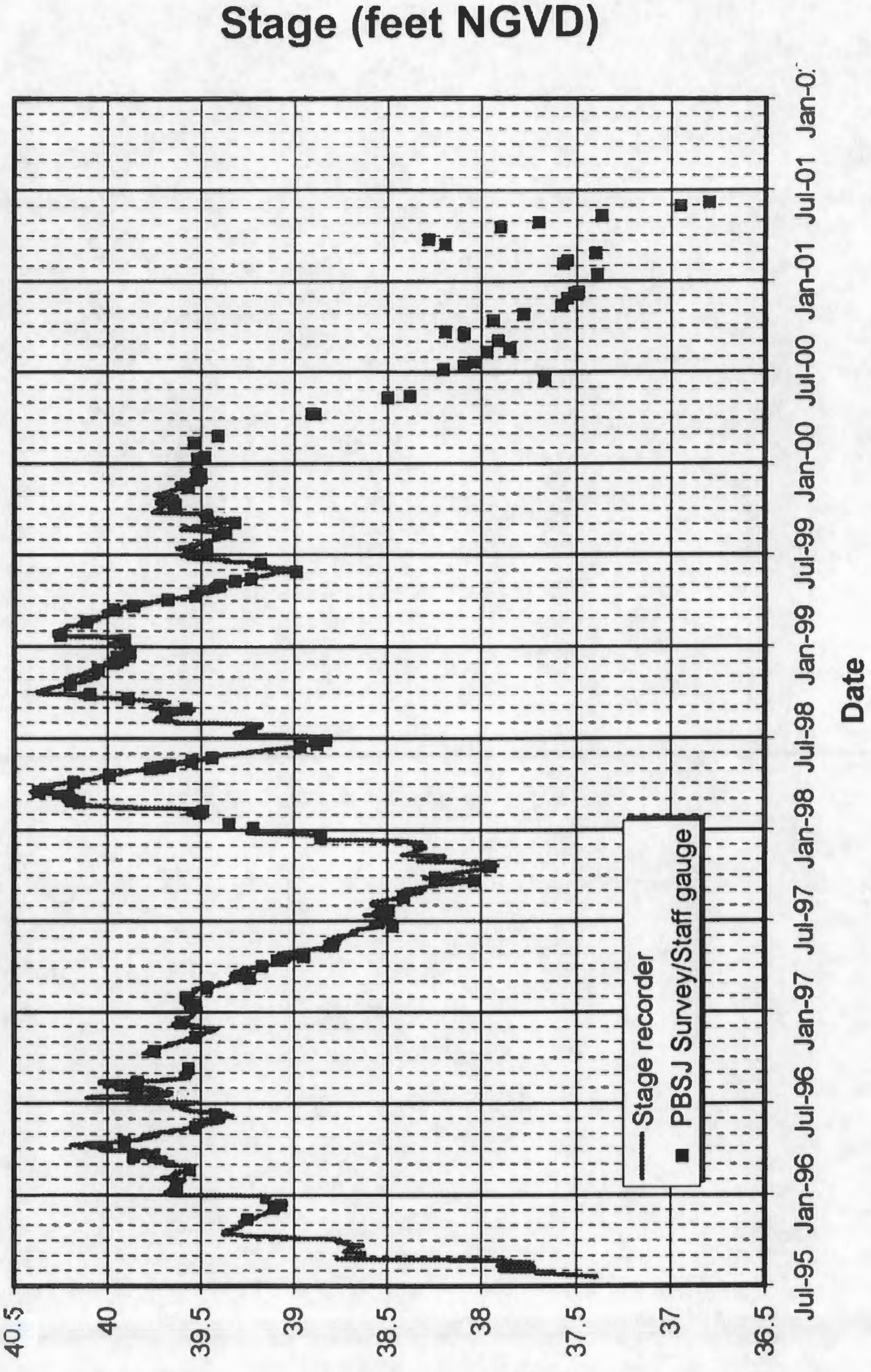

Figure 4-2. Recorded water level elevation at the Ocklawaha Prairie Restoration Site from 1995 - 2002 (Source: SJRWMD).

TABLE 4-2

BATHYMETRIC DATA FOR THE OCKLAWAHA PRAIRIE RESTORATION SITE

(Source: SJRWMD)

WATER ELEVATION (ft)	TOTAL AREA (acres)	WATER VOLUME (ac-ft)	FRACTION OF SITE INUNDATED	MEAN DEPTH (ft)	AREA >3 ft DEEP (acres)
33	15	8	0.01	<0.1	0
34	21	26	0.01	<0.1	0
35	56	64	0.02	<0.1	0
36	173	179	0.07	<0.1	15
37	447	489	0.18	0.2	21
38	1066	1245	0.42	0.5	56
39	1826	2691	0.72	1.1	173
40	2177	4693	0.85	1.8	447
41	2347	6955	0.92	2.7	1066
42	2436	9346	0.96	3.7	1826
43	2500	11,814	0.98	4.6	2177
44	2550	14,339	1.00	5.6	2347
45	2550	16,889	1.00	6.6	2436

Water-based application of alum could still be performed using airboats or a Marsh Master type vehicle, although this type of application would be substantially more time consuming due to the limited quantity of alum which can be transported using these vehicles and the large number of repeat trips which would be necessary to complete the application. In addition, application of liquid alum to an extremely shallow water column may create an acidic environment which may be detrimental to the existing vegetation and may actually increase the release of phosphorus from the restoration site soils.

Another factor which may affect the application process at the Ocklawaha Prairie site is the presence of dense vegetation in portions of the site. Much of the perimeter of the site and portions of the southern quadrant are vegetated with either wetland or transitional species, ranging from cattails and marsh species to shrub and hardwood hammocks. A map of existing vegetation at the Ocklawaha Prairie site is given in Figure 4-3. Even if the site were to be flooded with a sufficient depth of water to allow boating access, the existing vegetation would limit areas of the site which could be treated, particularly in the perimeter and southern areas. Based on discussions with SJRWMD personnel, it appears that only about 250 acres of contiguous open water is present at the site.

4.3 Comparison of Potential Alum Application Methodologies

As discussed in Section 4.2.1, due to the approximately neutral soil characteristics at the Ocklawaha Prairie site, the use of an alum-based inactivant appears to be most appropriate for reducing soil phosphorus release at this site. Aluminum-based inactivants can be applied as liquid alum, in a dry granular or pelletized form, or as alum residual. A comparison of potential alum application methodologies at the Ocklawaha Prairie Restoration Site is given in Table 4-3. A discussion of the potential for application of each of the three amendment types is given in the following sections.

4.3.1 Liquid Alum

Liquid alum can be applied to the Ocklawaha Prairie Restoration Site using conventional boats and barges, for areas with water depths greater than approximately 2.5-3 ft, or by using airboats or Marsh Master-type equipment in shallow water areas which cannot be accessed by standard boats or barges. However, a minimum water depth of approximately 1-2 ft would still be required when using airboats with large onboard tanks or a Marsh Master-type vehicle which is used to pull a floating barge with an onboard tank. Application of liquid alum over the entire site would require a combination of the two methodologies, with conventional boats and barges

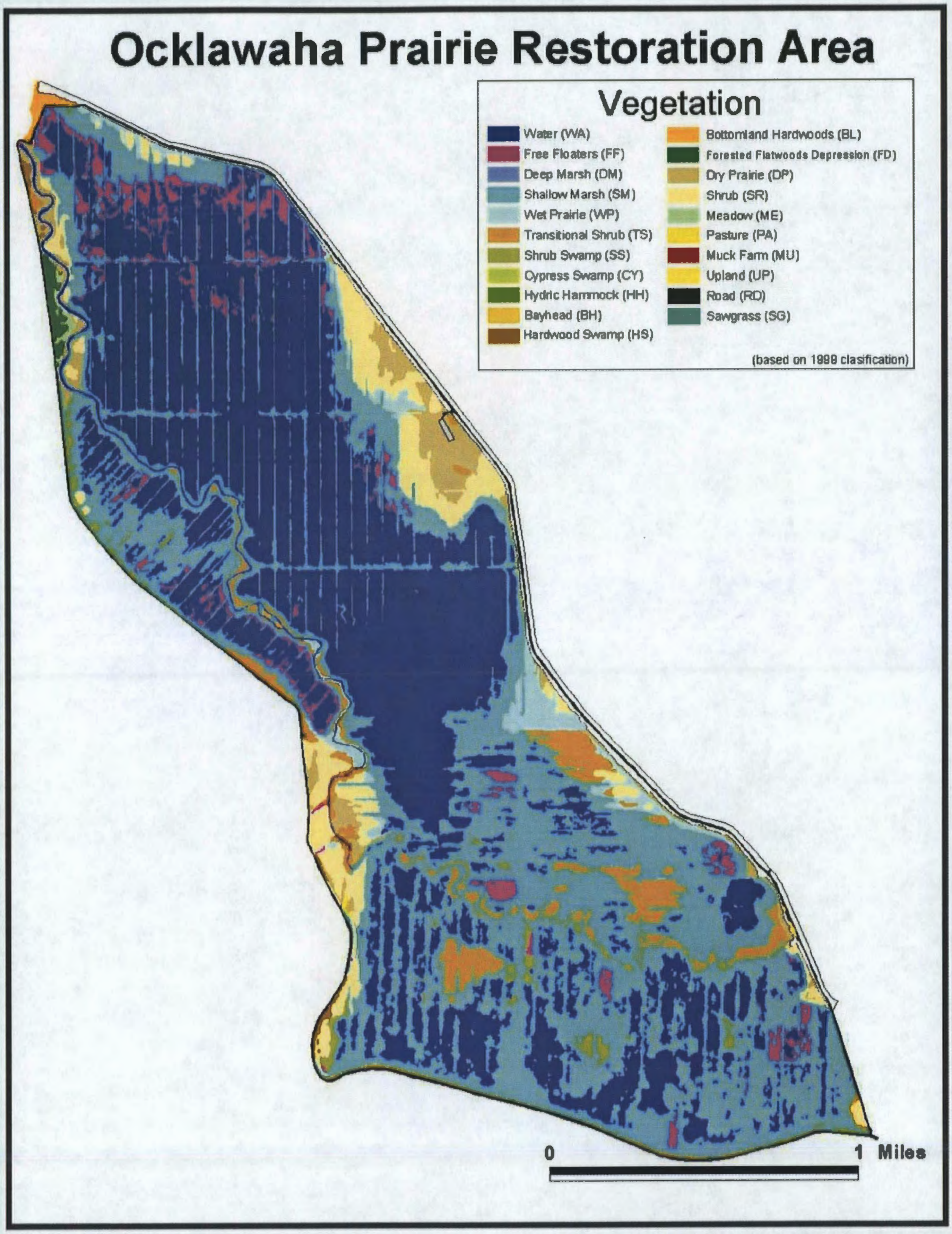

Figure 4-3. Existing Vegetation at the Ocklawaha Prairie Restoration Site (Source: SJRWMD).

TABLE 4-3

COMPARISON OF POTENTIAL ALUM APPLICATION METHODOLOGIES AT THE OCKLAWAHA PRAIRIE RESTORATION SITE

AMENDMENT TYPE	TYPE OF APPLICATION	COMMENTS
1. Liquid Alum	a. Deep water (≥2.5-3 ft)	1. Performed using conventional boats or barges 2. Requires flooding of site to elevation 42.0 ft 3. Could access approximately 80% of site 4. Proven technology 5. Relatively accurate application 6. Substantial land clearing required for boat access
	b. Shallow water (< 2.5 ft)	1. Performed using airboats or Marsh Masters 2. Time-consuming operation 3. No land clearing required 4. May cause water column or soil acidification 5. Likely damage to vegetation from application equipment and alum contact 6. Relatively accurate application
2. Dry Alum	a. Land-based	1. Requires relatively dry site 2. Performed using standard agricultural equipment 3. Time-consuming operation due to size of site and limited carrying capacity of equipment 4. Would need partially flooded conditions after application to create and distribute floc 5. May cause soil and water column acidification if buffered alum is not used; increases product costs 6. Relatively accurate application 7. No research to demonstrate that dry alum will form a uniform floc blanket after dissolving 8. May require mowing or clearing in some areas prior to application
	b. Aerial	1. Performed using aircraft 2. Relatively expensive application costs; labor-intensive to load product into aircraft 3. Would need partially flooded conditions after application to create and distribute floc 4. May cause soil and water column acidification if buffered alum is not used; increases product costs 5. Questionable accuracy of application 6. Standard alum would have considerable dust issues; may require special formulation; increased product costs 7. Aerial application of alum has never been done before 8. No research to demonstrate that dry alum will form a uniform floc blanket after dissolving
3. Alum Residual	a. Land-based	1. Requires relatively dry site 2. Performed using standard agricultural equipment 3. May require mowing or clearing in some areas prior to application 4. Time-consuming and expensive application process 5. Residual obtained free of charge 6. Would need partially flooded conditions after application to create and distribute floc 7. Would not cause soil or water column acidification 8. Relatively accurate application

used in deeper open areas and airboats or Marsh Master-type equipment used in the shallow areas. This combined methodology may eliminate some of the need for land clearing or mowing activities since the conventional boat could be used in the open deeper areas, and the airboats or Marsh Masters could be used in the shallow and heavily vegetated areas. However, it is unlikely that airboats or Marsh Master-type vehicles could navigate all areas of the site due to the density of vegetation, necessitating land clearing activities in many areas. The combined treatment methodology would result in a relatively accurate application process by simply using buoys or other navigational aids. However, this type of application would be relatively time consuming, particularly in areas where airboats or Marsh Masters would be used. There may also be damage to vegetation from the application equipment as well as from alum contact with existing vegetation.

However, the use of airboats or Marsh Master-type equipment to access shallow areas at the site will not be desirable due to the substantial potential for water column acidification resulting from applying the required alum dose to a shallow water column area. Equilibrium pH levels in shallow areas treated with alum may be reduced to values less than 4.0 which would threaten vegetation, benthic species, and larger aquatic organisms. This type of application may actually increase soil phosphorus release as a result of the acidic conditions. As a result, a minimum water level of approximately 3 ft should be maintained in areas where liquid alum is applied to the site.

4.3.2 Dry Alum

4.3.2.1 Land-Based Application

Granular or pelletized dry alum could be applied to the Ocklawaha Prairie Restoration Site using either land-based or aerial applications. Application of dry alum in a land-based process could be performed using standard agricultural equipment. This application would require a relatively dry site and would be a time consuming operation due to the size of the site and the limited carrying capacity of standard farm equipment. After the application is complete, the area would need to be flooded to create and distribute the alum floc necessary for inactivation of the soils. This type of process may require mowing or clearing in many areas prior to the application to allow for access and proper operation of the agricultural spreading equipment. Care would also need to be taken when reflooding the site to provide sufficient water so that water column acidification did not occur as a result of dissolution of the dry alum. However, no prior research has been performed to document the required application rate of dry alum to achieve soil inactivation as well as to demonstrate that dry alum would form a uniform floc blanket after dissolving during the reflooding process.

4.3.2.2 Aerial Application

Aerial application of dry alum would be performed using standard aircraft. This type of application would be relatively expensive due to rental costs for the aircraft, as well as the labor-intensive nature of loading the product into the aircraft for each application trip. The accuracy of this type of application would be somewhat questionable due to the likely possibility of uneven coverages during the aerial application process. The site would need to be flooded after the application has been performed to create and distribute the floc which may cause water column acidification if insufficient water is applied. The application of standard granular alum would have considerable dust consequences and may require a special formulation to minimize dust which would increase raw product costs. An aerial application of alum has never been attempted before, and no previous information exists to document the accuracy or effectiveness of this type of application.

4.3.3 Alum Residual

Application of alum residual to the Ocklawaha Prairie Restoration Site would require relatively dry conditions at the time of application to support the agricultural equipment used for the application process. Mowing or clearing would be needed in many areas prior to the application to allow proper access and operation of the application equipment. This type of application would be very time consuming and expensive due to the relatively small amount of residual which could be transported at any one time. However, one advantage of this process is that the residual could be obtained free-of-charge, with costs incurred only for transporting the material from the selected water treatment plant to the application site. Partially flooded conditions would be needed after the application to create and distribute the floc. The application of alum residual would not cause soil or water column acidification as can be expected when applying raw alum products, since much of the acidity formed during the floc formation process will have been previously neutralized. This type of application can also be relatively accurate when properly conducted.

4.4 Evaluation of Application Options

Based upon the analyses presented in the previous sections, it appears that alum can be feasibly applied to the Ocklawaha Prairie Restoration Site in either a liquid or residual form. The lack of previous research and experience with application of granular or powdered alum for soil inactivation eliminates these materials from further consideration.

Feasibility evaluations and cost estimates were prepared for three separate alum treatment options at the Ocklawaha Prairie Restoration Site. The first of these options includes a water-based application of liquid alum using a combination of conventional boats/barges and Marsh Master/airboats. Separate cost estimates and feasibility evaluations are conducted for water surface elevations at 40.0, 41.0 ft, and 42.0 ft (NGVD), as well as with and without existing vegetation. The second treatment option evaluated includes treatment of areas immediately adjacent to the main creek. This application would be performed using alum residual under post-construction conditions at the Restoration Site. The third option involves construction of an outflow treatment system which would provide alum treatment for all discharges of water leaving the restoration area as a result of flow through the restored channel. Rather than provide inactivation within the soil itself, this treatment system is designed to remove phosphorus which has been released into the water column during migration through the site until such time as phosphorus release is no longer significant within the site. Specific details of each of these evaluated options are given in the following sections.

4.4.1 Water-Based Application of Liquid Alum

This treatment option involves removal of existing vegetation followed by a boating-based application to as much of the site as could be accessed at water depths of 3 ft or more. Vegetation removal can be achieved by one of two primary methods. First, the site could be dried as much as possible, and the existing vegetation burned to achieve a cleared site. Assuming that site draining and burning activities are performed by SJRWMD personnel, this land clearing method would not result in any additional contractor-related expenses to the District. After the vegetation has been removed, District personnel could then redirect the revegetation process to eliminate unwanted exotics and maximize establishment of desirable vegetation within the site.

The second method of removing vegetation at the site involves mowing and/or cutting of existing vegetation using land-based agricultural equipment. Under this scenario, the vegetation would be cut as close to the ground as possible so as not to interfere with the evenness of the application process. This technique would not destroy the existing vegetation which would recover relatively quickly to a community structure similar to what existed prior to the vegetation removal process. The recommended clearing activities will require the site to be in a relatively dry condition at the time of the clearing operation. As a result, clearing activities are best conducted under dry season conditions to optimize accessibility of the land clearing equipment.

Separate feasibility evaluations were conducted for water surface elevations at 40.0 ft, 41.0 ft, and 42.0 ft (NGVD) within the restoration area. Assuming that a minimum water depth of 3 ft is required for a traditional boating/barge application process, the evaluated water surface elevations of 40.0 ft, 41.0 ft, and 42.0 ft (NGVD) will allow boating access to areas of the site with elevations of 37.0 ft or less, 38.0 ft or less, and 39.0 ft or less, respectively.

Land areas included in each of these three separate scenarios were evaluated by ERD based upon the topographic map of the Ocklawaha Prairie Restoration Site provided in Figure 4-1. Separate exhibits were generated by ERD for areas of the restoration site which would have a water depth of 3 ft or more at elevations 37, 38, and 39, reflecting areas of the site which could be reached using a standard boat/barge-based application. Based upon these analyses, approximately 447 acres (18% of the total site) could be accessed with a boat/barge-type application at a water surface elevation of 40.0 ft. At a water surface elevation of 41.0 ft, approximately 1066 acres (42% of the total site) could be accessed with a boat/barge-based application. If water levels were increased to 42.0 ft, approximately 1826 acres (72% of the total site) could be reached using a boat/barge-based application. At a water surface elevation of 42.0 ft, the portions of the site which could not be reached with the boat-based application are areas with more upland characteristics which are infrequently inundated with water and contribute relatively insignificant phosphorus release on an annual basis.

Based on information provided by SJRWMD, the normal water level at the Ocklawaha Prairie site is 37-40 ft, suggesting that water levels would need to be raised from 2-5 ft to perform a boating-based application, depending on the starting water elevation. A summary of estimated inflow requirements to increase water levels at the Ocklawaha Prairie site to elevation 40.0, 41.0, and 42.0 ft is given in Table 4-4 based on beginning water elevations ranging from 37-41 ft. The additional water volumes required could be obtained by gravity flow, assuming that the C-231 Canal is at a higher stage, or by pumping, if necessary.

Estimates of areas within the Ocklawaha Prairie Restoration Site with water depths in excess of 3 ft at water surface elevations of 40.0, 41.0, and 42.0 ft (NGVD) are indicated on Figures 4-4, 4-5, and 4-6, respectively. Isopleths of available phosphorus in the top 10 cm of soils at the restoration site are also included, based upon the information contained in Figure 3-9, to assist in estimation of inactivation requirements for each of the three areas.

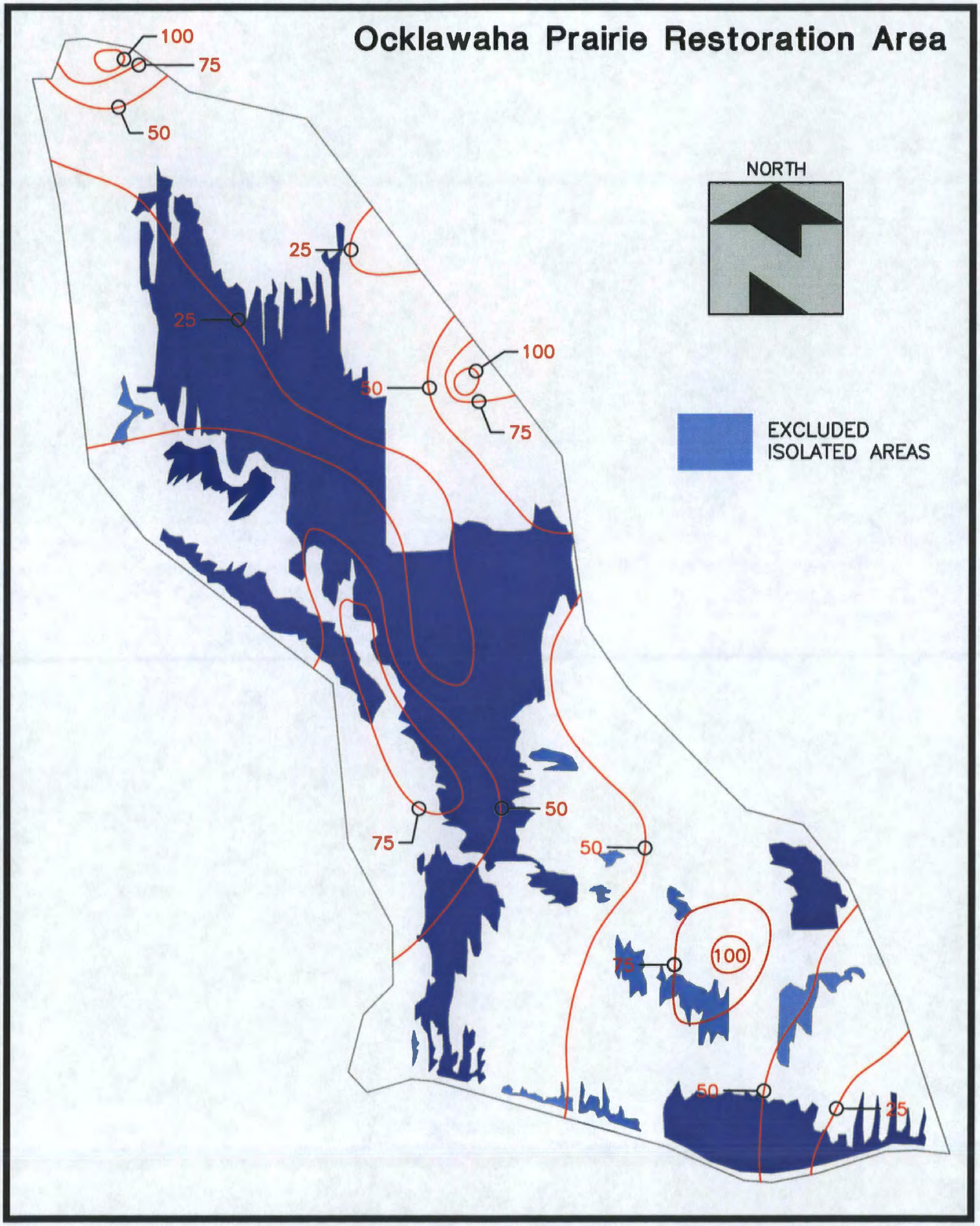

Figure 4-4. Areas of the Ocklawaha Prairie Restoration Site with water depths of 3 ft. or more at a water stage of 40.0 ft. (NGVD). Isopleth lines represent available phosphorus in the top 10 cm of soils

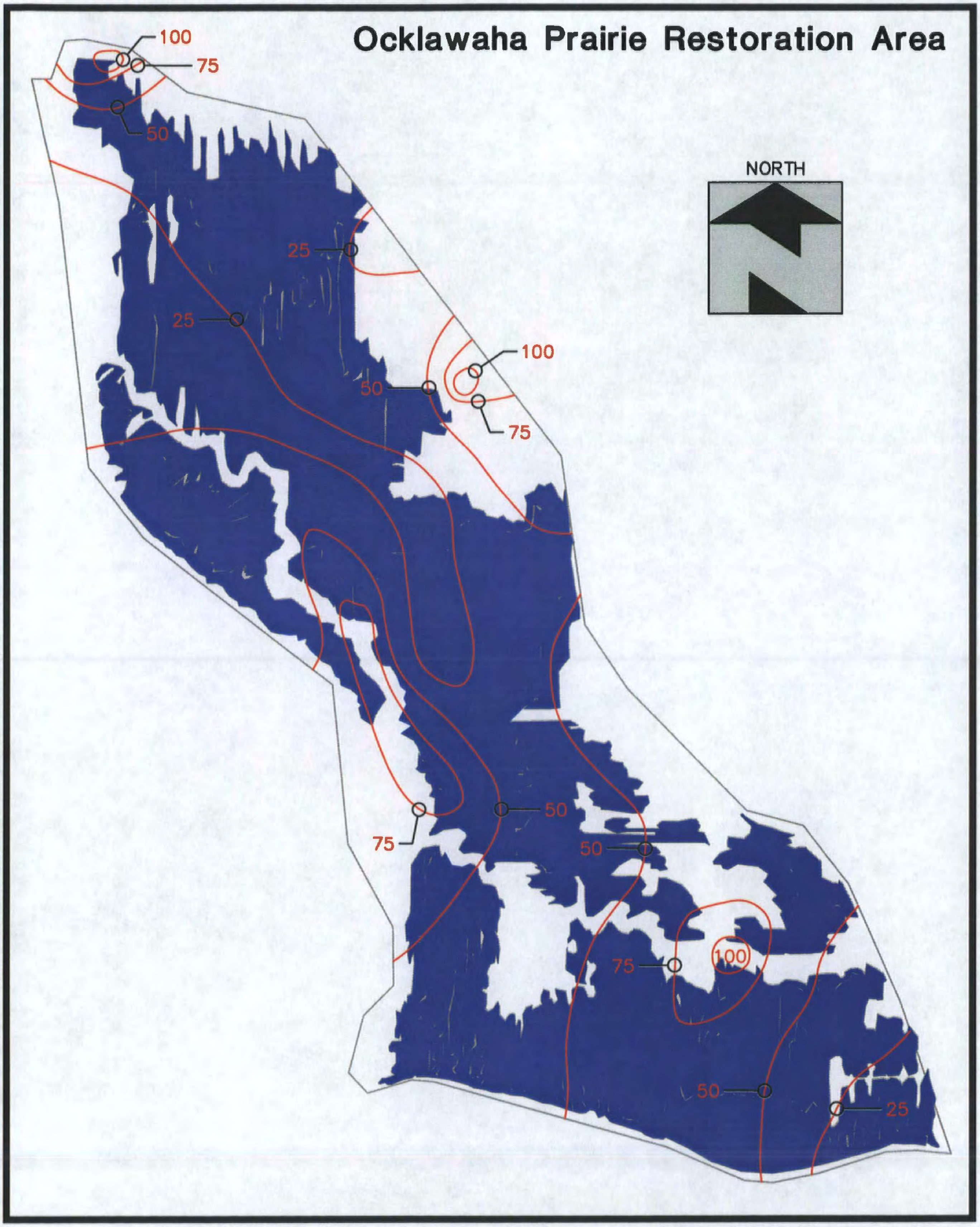

Figure 4-5. Areas of the Ocklawaha Prairie Restoration Site with water depths of 3 ft. or more at a water stage of 41.0 ft. (NGVD). Isopleth lines represent available phosphorus in the top 10 cm of soils

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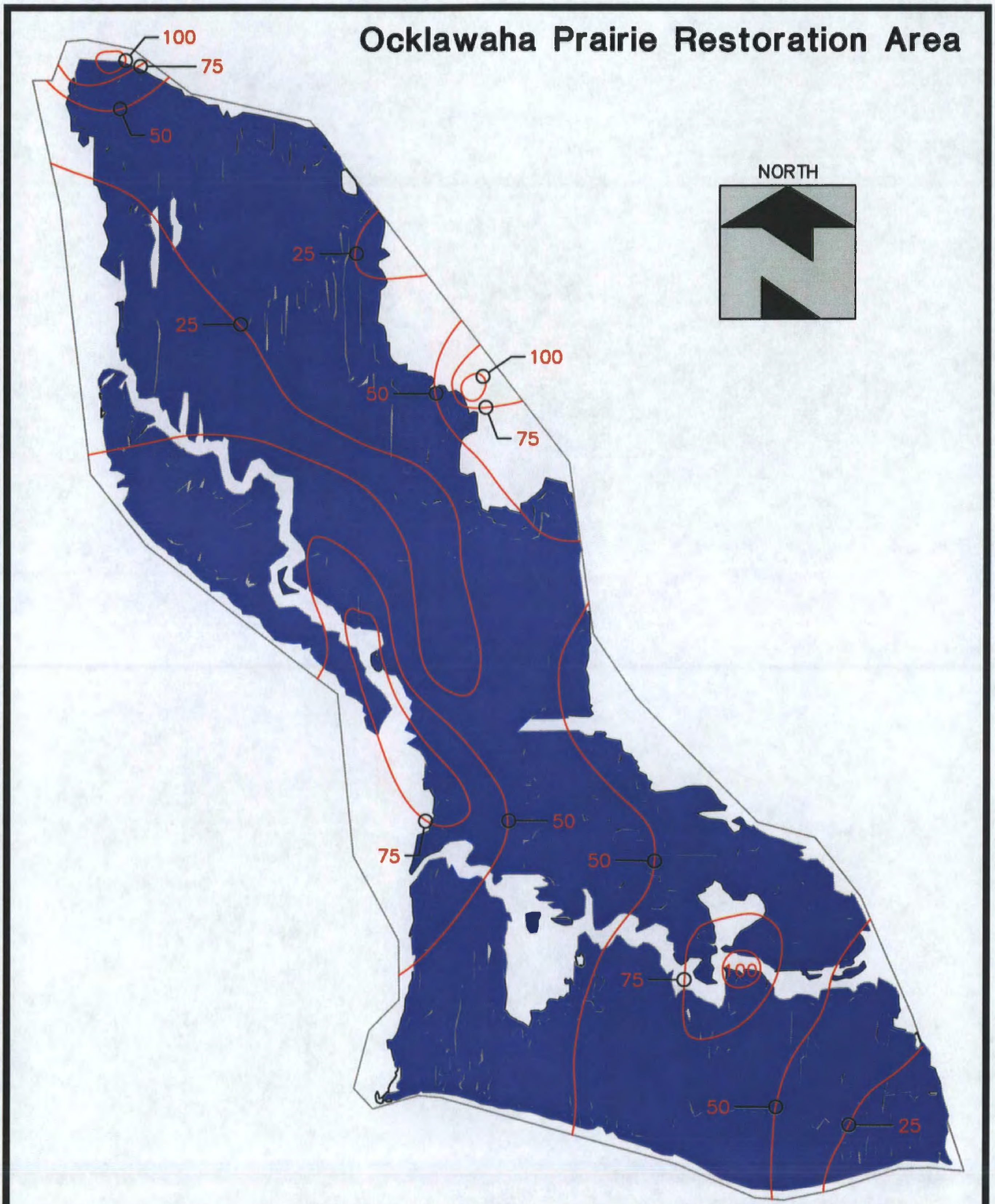

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Figure 4-6. Areas of the Ocklawaha Prairie Restoration Site with water depths of 3 ft. or more at a water stage of 42.0 ft. (NGVD). Isopleth lines represent available phosphorus in the top 10 cm of soils

TABLE 4-4

ESTIMATED INFLOW REQUIREMENTS TO INCREASE WATER LEVELS AT THE OCKLAWAHA PRAIRIE SITE

BEGINNING WATER ELEVATION (ft, NGVD)	STORED WATER VOLUME (ac-ft)	ADDITIONAL VOLUME TO REACH ELEVATION 40 (ac-ft)	ADDITIONAL VOLUME TO REACH ELEVATION 41 (ac-ft)	ADDITIONAL VOLUME TO REACH ELEVATION 42 (ac-ft)
37	489	4204	6466	8857
38	1245	3448	5710	8101
39	2691	2002	4264	6655
40	4693	0	2262	4653
41	6955	--	0	2391

As seen in Figure 4-4, at a water surface elevation of 40.0 ft (NGVD), some of the areas with water depths sufficient for a boat-based application process are isolated and may not be accessible with this application technique. These areas are shaded in light blue on Figure 4-4. At surface water elevations of 41.0 and 42.0 ft, it is assumed that all shaded areas within the restoration site could be accessed using a boating-based application.

Estimates of soil available phosphorus and corresponding inactivation requirements were calculated for the shaded areas in Figures 4-4, 4-5, and 4-6 by integrating the available phosphorus isopleths for the shaded areas on each of the three figures. A summary of the results of this analysis is given in Table 4-5. At a water surface elevation of 40.0 ft, the soils in areas which could be reached with a boating-based application contain approximately 6736 kg of available phosphorus. At a water stage of 41.0 ft, the treatable soil contains approximately 17,542 kg of available phosphorus. When the water stage is increased to 42.0 ft, the available soil phosphorus increases to 30,974 kg.

TABLE 4-5

ESTIMATES OF SOIL AVAILABLE PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR WATER-BASED SURFACE ELEVATIONS OF 40.0, 41.0, AND 42.0 ft (NGVD)

Water Stage: 40.0 ft (NGVD)

CONTOUR INTERVAL	INTERVAL MID-POINT (μg/cm)³	AREA (ac)	AVAILABLE P (kg)		INACTIVANT REQUIREMENT	
			kg	Moles	moles Al[1]	alum (gallons)
<25	12.5	105.4	533	17,194	85,970	10,468
25-50	37.5	250.4	3,800	122,581	612,905	74,632
50-75	62.5	82.5	2,087	67,323	336,615	40,989
75-100	87.5	8.7	316	10,194	50,970	6,207
>100	112.5	0.00	0	0	0	0
Total:		447	6,736	217,292	1,086,460	132,296

1. Based on an Al:P molar ratio of 5:1

Water Stage: 41.0 ft (NGVD)

CONTOUR INTERVAL	INTERVAL MID-POINT (μg/cm)³	AREA (ac)	AVAILABLE P (kg)		INACTIVANT REQUIREMENT	
			kg	moles	moles Al[1]	alum (gallons)
<25	12.5	176.8	894	28,839	144,195	17,558
25-50	37.5	606.9	9,211	297,129	1,485,645	180,904
50-75	62.5	253.4	6,409	206,742	1,033,710	125,873
75-100	87.5	28.3	1,002	32,323	161,615	19,679
>100	112.5	0.6	26	839	4,195	511
Total:		1,066	17,542	565,872	2,829,360	344,525

1. Based on an Al:P molar ratio of 5:1

TABLE 4-5 – CONTINUED

Water Stage: 42.0 ft (NGVD)

CONTOUR INTERVAL	INTERVAL MID-POINT (µg/cm)^3	AREA (ac)	AVAILABLE P (kg)		INACTIVANT REQUIREMENT	
			kg	moles	moles Al[1]	alum (gallons)
< 25	12.5	291.1	1,472	47,484	237,420	28,910
25-50	37.5	1002.6	15,214	490,774	2,453,870	298,802
50-75	62.5	462.0	11,685	376,935	1,884,675	229,493
75-100	87.5	57.8	2,048	66,065	330,325	40,223
> 100	112.5	12.5	555	17,903	89,515	10,900
Total:		**1,826**	**30,974**	**999,161**	**4,995,805**	**608,328**

1. Based on an Al:P molar ratio of 5:1

Estimated inactivation requirements are also included in Table 4-5 for each of the three surface water elevation options. Inactivation requirements are calculated based upon a molar Al:P ratio of 5:1, as utilized by ERD in previous inactivation evaluations. Alum requirements for sediment inactivation range from 132,296 gallons at a water elevation of 40.0 ft, to 608,328 gallons at a water surface elevation of 42.0 ft.

A summary of estimated average water column alum doses for the three evaluated water surface elevation options is given in Table 4-6. Estimated average water column alum doses are approximately 5.1 mg Al/liter at a water surface elevation of 40.0 ft, 8.9 mg Al/liter at a water surface elevation of 41.0 ft, and 11.7 mg Al/liter at a water surface elevation of 42.0 ft. These estimated average water column doses are near the middle of the range of applied alum doses tested during the laboratory jar testing procedures summarized in Table 3-7. Based upon the information provided in Table 3-7, each of the three alum doses indicated in Table 4-6 could be applied to water within the Ocklawaha Prairie Restoration Site without the need for supplemental buffering agents to maintain a minimum water column pH value of approximately 5.5-6.0 during the application process. As a result, no buffering agents are included in the cost evaluations for these options summarized in a subsequent section.

TABLE 4-6

ESTIMATED AVERAGE WATER COLUMN ALUM DOSES FOR THE EVALUATED WATER SURFACE ELEVATION OPTIONS

WATER ELEVATION (ft, NGVD)	WATER VOLUME (ac-ft)	ALUM REQUIREMENT (gallons)	AVERAGE WATER COLUMN DOSE (mg/l as Al)
40.0	4,693	132,296	5.1
41.0	6,955	344,525	8.9
42.0	9,346	608,328	11.7

An additional evaluation was conducted to evaluate the feasibility of performing sediment inactivation to areas of the Ocklawaha Prairie Restoration Site which have open water characteristics under existing conditions. This application option would not involve vegetation removal and would include only those areas which consist of open water. Estimates of the extent of open water at the Ocklawaha Prairie Restoration Site were obtained from Figure 4-3. For purposes of this evaluation, open water areas are considered to be only the central open water area indicated on Figure 4-3. Although narrow strips of open water may exist in some of the old farm fields in northern portions of the site, the perimeters of these areas are heavily vegetated, and it is unlikely that these areas can be accessed using a boating-based application. Even if these areas could be accessed, much of the alum would need to be sprayed over the existing vegetation which would result in vegetation damage and an untested success rate for inactivating sediments under heavily vegetated conditions. As a result, treatment areas included under this treatment option are limited to the central open water areas only.

An estimate of areas of the Ocklawaha Prairie Restoration Site with existing open water conditions is given in Figure 4-7. Isopleth lines representing available phosphorus in the top 10 cm of the soils are also included for evaluation purposes. Estimates of soil available phosphorus and inactivation requirements for existing open water areas are provided in Table 4-7. Open

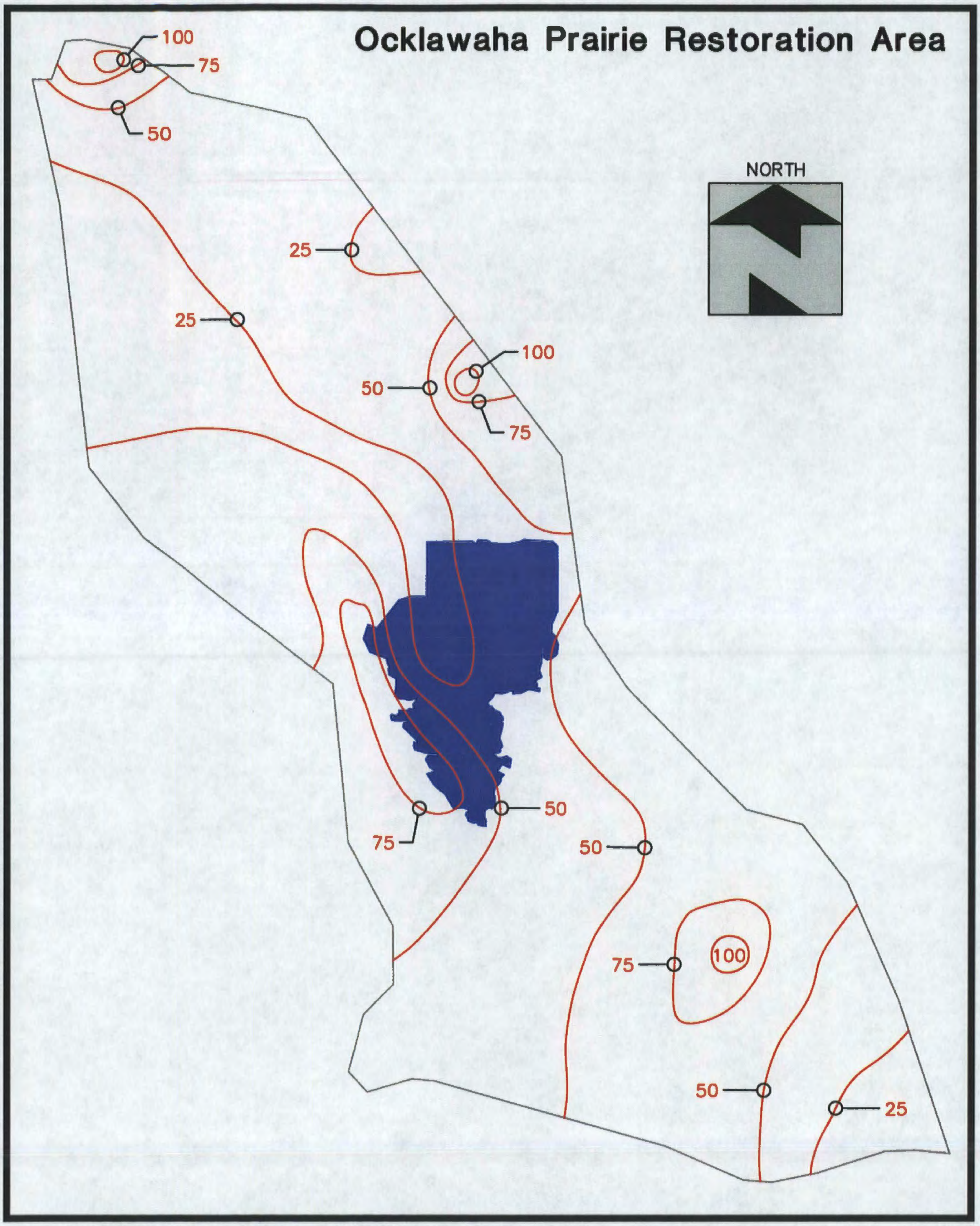

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Figure 4-7. Areas of the Ocklawaha Prairie Restoration Site with existing open water conditions. Isopleth lines represent available phosphorus in the top 10 cm of soils water areas of the site are assumed to cover approximately 192 acres or approximately 8% of the total site. However, the areas included on Figure 4-7 represent a large portion of the potentially treatable areas, based upon a water surface elevation of 40.0 ft, as summarized on Figure 4-4.

As seen in Table 4-7, open areas of the Ocklawaha Prairie Restoration Site contain approximately 3077 kg of available phosphorus. Inactivation of this phosphorus in the top 10 cm of the soil will require approximately 60,453 gallons of alum.

TABLE 4-7

ESTIMATES OF SOIL AVAILABLE PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR EXISTING OPEN WATER AREAS OF THE OCKLAWAHA PRAIRIE RESTORATION SITE

CONTOUR INTERVAL	INTERVAL MID-POINT P ($\mu g/cm^3$)	AREA (ac)	AVAILABLE P		INACTIVANT REQUIREMENTS	
			Kg	moles	moles Al[1]	Alum (gallons)
< 25	12.5	37.33	189	6,097	30,485	3,712
25-50	37.5	112.79	1,712	55,226	276,130	33,624
50-75	62.5	31.02	785	25,323	126,615	15,418
75-100	87.5	11.08	392	12,645	63,225	7,699
> 100	112.5	0.00	0	0	0	0
TOTAL:		**192**	**3,077**	**99,291**	**496,455**	**60,453**

1. Based on a molar Al:P ratio of 5:1

4.4.2 Treatment of Areas Immediately Adjacent to the Historical Riverbed

A second treatment option was evaluated based upon application of soil amendment in areas immediately adjacent to the historic riverbed. For this scenario, it is assumed that application of a soil amendment would occur after construction has been completed for the proposed channel modifications which are part of the on-going restoration effort by the Army Corps of Engineers. Since the channel would probably be in a dewatered condition at the completion of the construction activities, it is assumed that alum residual would be used as the soil amendment since it can be applied to soils without concern over soil acidification that would occur if liquid alum were used.

This option assumes that alum residual would be applied to an area extending approximately 200 ft on each side of the historic channel. These areas are currently heavily vegetated. Portions of the existing vegetation will need to be removed to accomplish the proposed restoration modifications. For purposes of this option, it is assumed that approximately 50% of the areas to be treated will be cleared as part of the construction processes, with the remaining 50% containing vegetation that would need to be mowed or cleared.

An estimate of the length of the historic riverbed contained within the Ocklawaha Prairie Restoration Site was generated by ERD based upon aerial photography provided by SJRWMD. Based upon this analysis, it is assumed that the riverbed is approximately 31,421 ft (5.95 miles) in length. Assuming an application area of 200 ft on each side of the creek, the total area to be treated with residual is approximately 12,568,400 ft^2 or 288.5 acres.

Based on prior experience, SJRWMD has indicated that the minimum application rate required for even distribution of the residual material is approximately 6.5 wet tons/acre. This application rate is substantially greater than the required application rates based upon the available phosphorus within the sediments. Therefore, a uniform application rate of 6.5 wet tons/ acre will be assumed for treatment of areas adjacent to the riverbed. Although this value exceeds the required residual application rate, the excess residual will result in a longer-lasting and more effective treatment for this option.

A summary of residual requirements for soil inactivation along the historic riverbed channel is given in Table 4-8. Residual requirements are calculated based upon a treated area of 288.5 acres and a minimum application rate of 6.5 wet tons/acre, as recommended by SJRWMD. Application of residual to areas adjacent to the riverbed channel will require approximately 1875 tons of wet residual, based upon a 25% solids content, or approximately 1543 yd^3 of material based upon an assumed density of 90 lbs/ft^3. Assuming a standard 18 yd^3 dump truck, delivery of the residual to the Ocklawaha site will require approximately 85.75 standard truck loads of material.

TABLE 4-8

SUMMARY OF RESIDUAL REQUIREMENTS FOR SOIL INACTIVATION ALONG THE RIVERBED CHANNEL

AREA TREATED (acres)	RESIDUAL APPLICATION RATE (wet tons/acre)	TOTAL RESIDUAL		STANDARD TRUCK LOADS[2]
		(wet tons)	$(yd^3)^1$	
288.5	6.5	1875	1543	85.75

1. Based on an assumed density of 90 lb/ft^3
2. Based on a standard 18 yd^3 truck

4.4.3 Construct Outflow Treatment System

The options evaluated in the two previous sections are based upon reduction or elimination of soil phosphorus release to minimize increases in phosphorus concentrations in water which flows through the Ocklawaha Prairie Restoration Site. However, an outflow treatment option was also evaluated which does not attempt to reduce the rate of phosphorus release. This option assumes that phosphorus released from the on-site soils will continue to occur for a period of time until the available phosphorus within the soils has been exhausted. To prevent transport of elevated phosphorus concentrations to downstream areas, this option assumes that a chemical treatment system will be constructed near the point of discharge from the property, located on the northwest corner of the restoration site (Figure 4-1), prior to discharge of the water back into the C-231 Canal. The treatment system would utilize liquid alum for phosphorus removal and interception upstream of the point of discharge.

Previous studies performed by ERD have indicated that alum is extremely affective in reducing phosphorus concentrations in agricultural waters containing elevated phosphorus levels. This treatment option assumes that a chemical injection will be constructed within the channel upstream of the final point of discharge from the site. The water will then be diverted into a settling basin for floc collection or simply allowed to settle over existing submerged portions of the site. Phosphorus removals in the range of 80-90% can be anticipated as a result of this process.

A number of assumptions involving water flow rates, annual treatment volumes, and chemical doses were necessary to perform an evaluation of the outflow treatment option. A summary of assumptions used in this evaluation is given in Table 4-9. This evaluation assumes that water flow rates discharging through the restoration site will range from 10-100 cfs, with an annual average flow rate of approximately 25 cfs. The chemical treatment system will be designed to treat all water discharging through the channel up to a maximum of 100 cfs. Annual O&M costs are calculated based upon an assumed annual average water flow rate of 25 cfs and an annual treated water volume of 18,099 ac-ft. It is also assumed that an alum dose of 7.5 mg Al/liter will be required for phosphorus removal, with an additional polymer dose of 1 mg/l to assist in floc settling.

A conceptual schematic of the outfall treatment system is given in Figure 4-8. The physical configuration of the outfall treatment system will be similar to systems previously utilized in the farming areas along the north shore of Lake Apopka. Alum would be injected into the flow on a flow-weighted basis, with supplemental agitation performed by aeration or mechanical mixers. The precipitate generated during the treatment process will be allowed to settle in a constructed settling pond or dispersed throughout existing flooded areas of the site.

Alum treatment of the estimated annual water volume of 18,099 ac-ft/yr will require approximately 814,455 gallons of alum each year. An additional 40,723 gallons of polymer will also be required. The system will generate an anticipated floc volume of approximately 54.3 ac-ft/yr. As indicated previously, this floc volume can be collected in a dedicated settling pond or dispersed throughout existing flooded areas. If the anticipated annual floc volume were to be distributed over a flooded area of approximately 250 acres, the resulting accumulation of alum floc would be approximately 2.5 inches/yr over the 250-acre area. This floc would be beneficial in reducing or eliminating phosphorus release from soils in areas where floc is deposited.

TABLE 4-9

ASSUMPTIONS USED FOR EVALUATION OF THE OUTFLOW TREATMENT OPTION

1. Range of water flow rates to be treated = 10-100 cfs

2. Average annual water flow rate = 25 cfs

3. System will be designed to treat a peak water flow rate of 100 cfs

4. Annual O&M costs will be based on the average annual water flow rate = 25 cfs

5. Annual water volume to be treated:

$$\frac{25\ ft^3}{\text{sec}} \ x\ \frac{365\ days}{year} \ x\ \frac{86{,}400\ \text{sec}}{day} \ x\ \frac{ac - ft}{43{,}560\ ft^3} = 18{,}099\ ac - ft/yr$$

6. Using an assumed alum dose of 7.5 mg/l and polymer dose of 1 mg/l:

   a. Annual alum requirement is approximately:

$$\frac{18{,}099\ ac - ft}{year} \ x\ \frac{45\ gallons\ alum}{ac - ft} = 814{,}455\ gallons/year$$

   b. Annual polymer requirement is approximately:

$$\frac{18{,}099\ ac - ft}{year} \ x\ \frac{2.25\ gallons\ polymer}{ac - ft} = 40{,}723\ gallons/year$$

   c. Annual wet floc volume is approximately:

$$0.003\ x\ \frac{18{,}099\ ac - ft}{year} = 54.3\ ac - ft/yr$$

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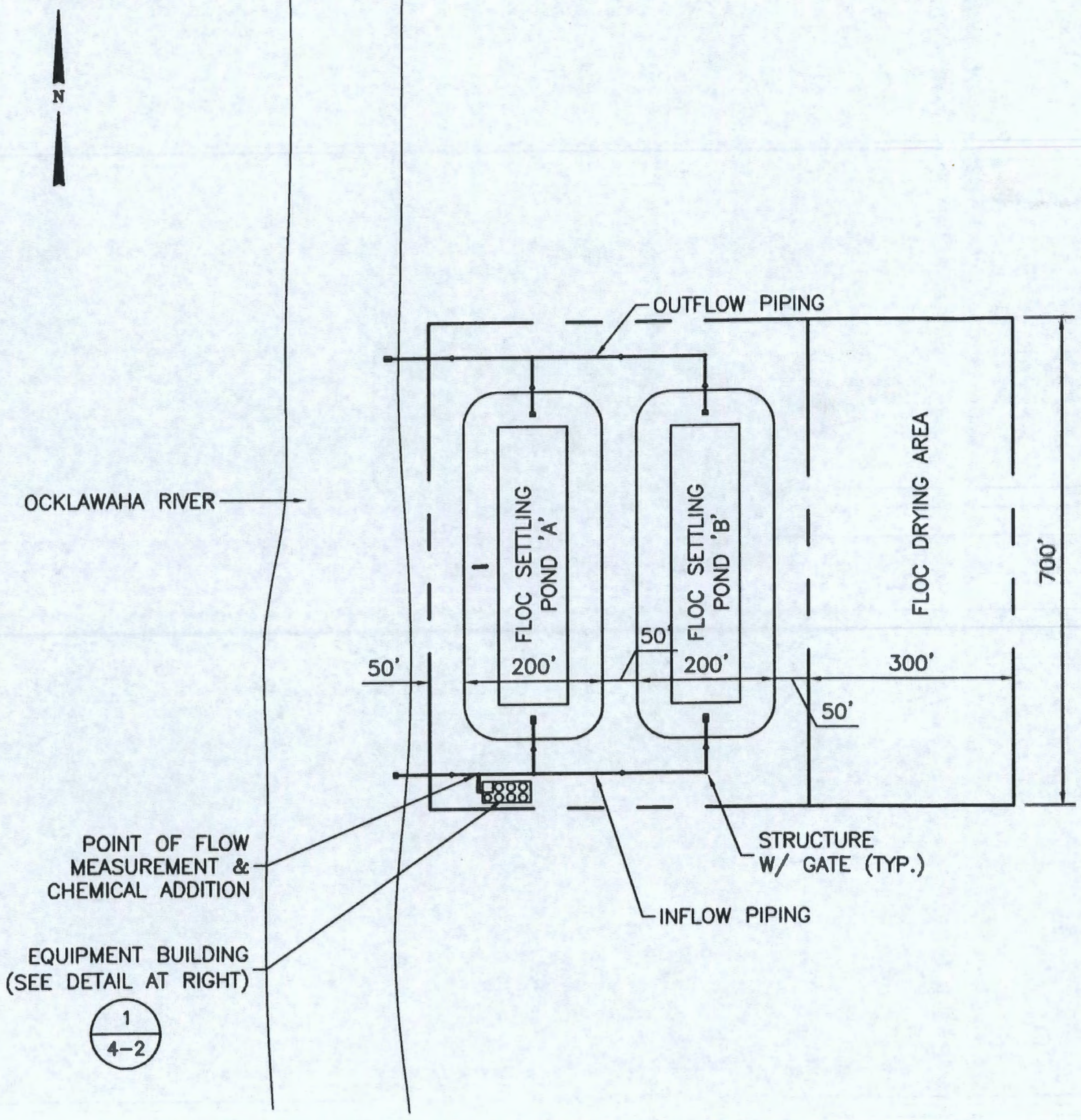

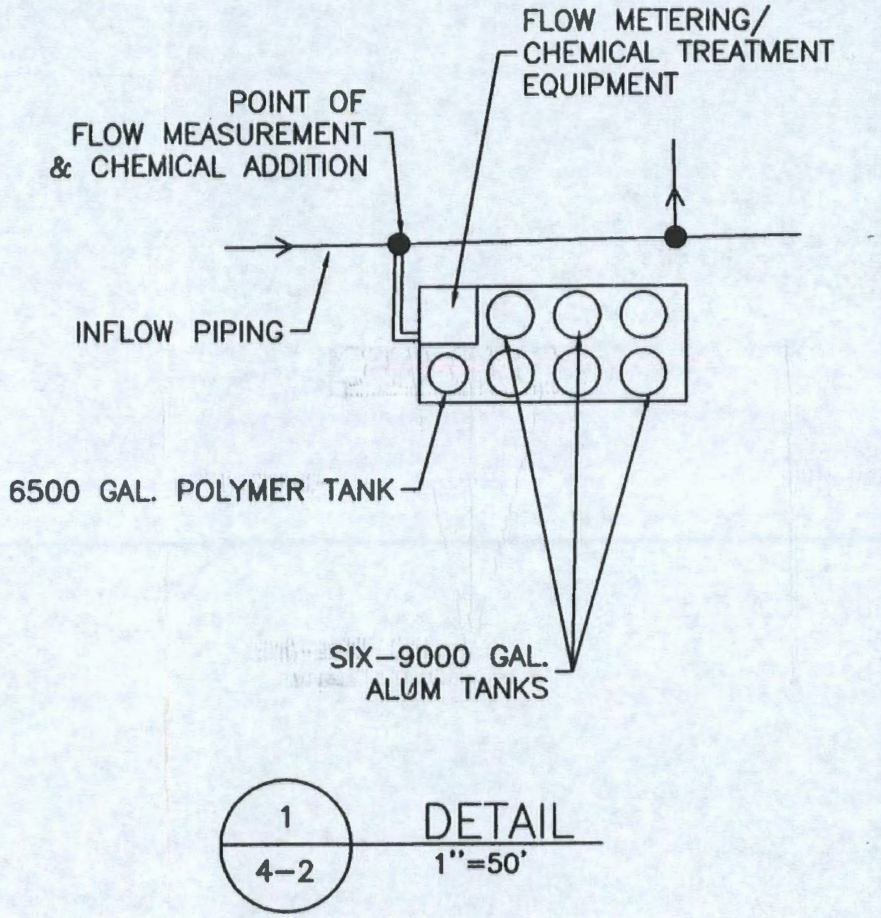

DETAIL
1"=50'

EQUIPMENT BUILDING

OCKLAWAHA PRAIRIE RESTORATION PROJECT
OUTFALL TREATMENT SYSTEM

CONCEPTUAL PLAN

PROJECT NO.	01-024
FIGURE NO.	4-8
SCALE:	1"=200'
DATE:	APR. 2003

4.5 Cost Estimates

Application costs were estimated for each of the three evaluated treatment options at the Ocklawaha Prairie Restoration Site. First, application costs are estimated for a water-based application of liquid alum based upon the three evaluated water stage elevations at the time of application. Vegetation removal is included both by burning as well as traditional land clearing activities. Second, application costs are estimated for treatment of areas immediately adjacent to the historical creek using an alum residual product obtained from the City of Melbourne Water Treatment Plant. The final option evaluated includes construction of an outflow treatment system to remove released phosphorus from water flowing through the site immediately prior to discharge from the restoration area. Cost estimates for each of these options are summarized in the following sections.

4.5.1 Water-Based Application of Liquid Alum

Estimated amendment application costs were calculated for water-based applications of alum using the four treatment options outlined in Section 4.3.1, including water surface elevations of 40.0, 41.0, and 42.0 ft (NGVD), along with application of alum to open water areas only. Estimates of application costs are based upon the calculated alum requirements for the options listed in Tables 4-5 and 4-7.

A summary of estimated application costs for the evaluated treatment options is given in Table 4-10. Estimated quantities of alum required for inactivation are based upon values presented in Tables 4-5 and 4-7. Planning and mobilization costs are estimated to be approximately $5000 for each of the treatment options based on water surface elevations of 40.0, 41.0, and 42.0 ft, with a planning and mobilization of $2500 for application to open water areas only. Estimates of man-hour requirements for each of the evaluated options are also provided in Table 4-10 based upon experience with similar previous applications by ERD. Man-hour requirements are calculated based upon the number of tanker loads, assuming 4500 gallons/tanker load, required for each application. It is assumed that a 2-man crew can apply two tankers of alum in a 10-hour working day. A labor rate of $100/hour is assumed which includes labor costs, expenses, equipment rental, insurance, mileage, and application equipment fees.

TABLE 4-10

ESTIMATED APPLICATION COSTS FOR THE WATER-BASED TREATMENT OPTIONS WITH VEGETATION CLEARING BY BURNING[1]

TREATMENT OPTION	AREA TREATED (acres)	ALUM		APPLICATION EXPENSES				TOTAL COST ($)
		QUANTITY (gallons)	COST[2] ($)	PLANNING/ MOBILIZATION ($)	LABOR			
					MAN-HOURS	LABOR COST ($)	TOTAL LABOR ($)	
Water Surface at El. 40.0 ft	447	132,296	85,990	5,000	300	$100/hr[3]	30,000	120,990
Water Surface at El. 41.0 ft	1,066	344,525	223,940	5,000	780	$100/hr[3]	78,000	306,940
Water Surface at El. 42.0 ft	1,826	608,328	395,415	5,000	1360	$100/hr[3]	136,000	536,415
Open Water Areas Only	192	60,453	39,295	2,500	168	$100/hr[3]	16,800	58,595

1. Vegetation burning and water level regulation will be performed by SJRWMD
2. Based on a cost of $0.65/gallon which includes raw material, shipping, and on-site charges
3. Includes raw labor, insurance, expenses, application equipment, mileage, and rentals

A summary of total estimated application costs for the evaluated options is given in the final column of Table 4-10. The estimated application costs summarized in this table assume that vegetation clearing will occur by burning, with both burning and water level regulation performed by SJRWMD at no additional cost to the project. Estimated total application costs range from approximately $58,595 for treatment of the open water areas only to $538,415 for application of alum to approximately 1826 acres or 72% of the total site.

Estimated application costs for the water-based treatment with vegetation clearing by mowing are summarized in Table 4-11 for the four treatment options evaluated previously. Application costs for the alum are obtained from information provided in Table 4-10, with additional expenses for land clearing activities. For the treatment options involving water surface elevations at 40.0, 41.0, and 42.0 ft, it is assumed that the total area included in each of these options will need to be cleared to at least some degree. However, since these areas also include partial areas of open water, the estimated land clearing costs for these areas may be slightly lower than the values presented in Table 4-11. Application of alum to the open water areas only involves no land clearing activities, and the estimated total cost for this option is the same as the value presented in Table 4-10.

TABLE 4-11

ESTIMATED APPLICATION COSTS FOR THE WATER-BASED TREATMENT WITH VEGETATION CLEARING BY MOWING[1]

TREATMENT OPTION	CLEARED AREA (acres)	LAND CLEARING		ALUM APPLICATION COSTS[3] ($)	TOTAL OPTION COST ($)
		UNIT COST ($/ac)	TOTAL COST ($)		
Water Surface at El. 40.0 ft	556	150	83,400	120,990	204,390
Water Surface at El. 41.0 ft	1,471	150	220,650	306,940	527,590
Water Surface at El. 42.0 ft	1,744	150	261,600	536,415	798,015
Open Water Areas Only	0	150	0[3]	58,595	58,595

1. Assumes that water level regulation will be performed by SJRWMD
2. Includes raw labor, insurance, expenses, application equipment, mileage, and rentals
3. All areas are open water - no land clearing involved

Land clearing costs, which include mowing and/or cutting activities, are estimated to be $150/acre, based upon discussions with District personnel regarding previous clearing activities on District projects. The cleared area for each option in Table 4-11 is equal to the total area to be treated minus the estimated open water area of 192 acres.

Estimated application costs for the water-based treatment with vegetation removal by mowing activities are summarized in the final column of Table 4-11 for each of the evaluated options. Cost estimates presented in this table assume that water level regulation will be performed by SJRWMD at no additional cost. Estimated overall treatment costs range from $58,595 for treatment of open water areas only, to $798,015 for treatment of areas accessible at a water elevation of 42.0 ft.

4.5.2 Application of Alum Residual to Areas Adjacent to Historic Riverbed

A summary of estimated costs for application of alum residual to areas adjacent to the historic riverbed is given in Table 4-12. This cost estimate assumes that approximately 288 acres will be treated with alum residual and that approximately 50% of this area will require land clearing prior to the application process. The application will require approximately 1875 wet tons of alum residual, as estimated in Table 4-8, to treat the entire 288-acre area. The application costs also assume that the residual can be obtained from the City of Melbourne Water Treatment Plant at no cost for the raw material.

The estimated costs summarized in Table 4-12 assume that land clearing activities will occur on approximately 144 acres or 50% of the total area to be treated. Land clearing costs, which include mowing and/or cutting activities, are estimated to be $150/acre, based upon discussions with District personnel regarding previous clearing activities on District projects.

Application of residual, which includes loading of residual into trucks at the City of Melbourne Water Treatment Plant, hauling the material to the Ocklawaha Prairie Restoration Site, unloading the residual, screening of the residual, and land-based spreading activities, is assumed to be $300/acre. This cost is based upon similar projects performed by the District at Duda Farms and at the Lake Apopka Marsh Flow-way. Allowances for mobilization, demobilization, and planning are also included in Table 4-12 as a lump sum fee.

The sub-total of the work items listed in Table 4-12 is approximately $118,150. With an additional 20% contingency, the overall estimated cost for application of alum residual to areas adjacent to the historic riverbed is approximately $141,780.

TABLE 4-12

ESTIMATED COSTS FOR APPLICATION OF ALUM RESIDUAL TO AREAS ADJACENT TO HISTORIC RIVERBED

ITEM	UNITS	QUANTITY	UNIT COST ($)	TOTAL ESTIMATED CHEMICAL COST ($)
Mobilization, Planning, Insurance	--	lump sum	--	10,000.00
Alum Residual	wet tons	1875[2]	0.00[4]	0.00
Land Clearing	Acre	144[3]	150/acre	21,600.00
Residual Application[1]	Acre	288.5	300/acre	86,550.00
			Sub-Total:	$ 118,150.00
			20% Contingency:	23,630.00
			TOTAL:	**$ 141,780.00**

1. Includes loading of residual into trucks, hauling to Ocklawaha Prairie site, unloading, residual screening, and land-based spreading

2. Based on a solids content of 25% in the residual material

3. Assumed to be 50% of the total treated area of 288 acres

4. Assumes that the residual can be obtained from the City of Melbourne Water Treatment Plant at no charge

4.5.3 Construction of Outfall Treatment System

An opinion of probable construction cost for the Ocklawaha Prairie alum outfall treatment system is given in Table 4-13. Cost estimates included in this table are based upon previous similar projects performed by ERD. Construction costs are included for clearing and grubbing, earthwork for construction of the required settling pond, erosion and turbidity control measures, system components, alum storage tanks, pumps and controls, flow meters, piping, electrical, structural services, and surveying and engineering costs.

The estimated construction cost for the outfall treatment system, including a dedicated settling pond, is approximately $1,555,125. However, if the settling pond were to be eliminated and floc allowed to settle in open areas of the Ocklawaha Prairie, the estimated system

TABLE 4-13

OPINION OF PROBABLE CONSTRUCTION COST FOR THE OCKLAWAHA PRAIRIE ALUM OUTFALL TREATMENT SYSTEM

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
1.	Clearing and Grubbing	AC	15	5,000.00	$ 75,000.00
2.	Earthwork	CY	150,000	4.00	600,000.00
3.	Floating Turbidity Barrier	LF	200	15.00	3,000.00
4.	Staked Silt Fence	LF	3,500	6.00	21,000.00
5.	Sodding	SY	25,000	2.25	56,250.00
6.	Seed and Mulch	SY	25,000	1.00	25,000.00
7.	60-inch HDPE	LF	1,400	90.00	126,000.00
8.	Intake Structure	EA	1	20,000.00	20,000.00
9.	60-inch HDPE MES	EA	4	2,500.00	10,000.00
10.	HDPE Manhole Flow Control Gate	EA	4	10,000.00	40,000.00
11.	Alum Equipment/Tank Enclosure	LS	--	--	75,000.00
12.	6500-gallon HDPE Tank	EA	1	5,000.00	5,000.00
13.	9000-gallon HDPE Tank	EA	6	7,500.00	45,000.00
14.	Alum Pump, Polymer Pump, and Controls	LS	--	--	100,000.00
15.	Water Flow Meter	LS	--	--	50,000.00
16.	Alum and Polymer Flow Meters	LS	--	--	20,000.00
17.	Piping	LS	--	--	50,000.00
18.	Concrete Rubble Riprap	LS	--	--	25,000.00
19.	Fence	LF	3,500	5.00	17,500.00
20.	Electrical	LS	--	--	50,000.00
21.	Mobilization/Bonds/Insurance	LS	--	--	141,375.00
				Sub-Total:	**$ 1,555,125.00**
				Surveying & Engineering:	155,513.00
				SUB-TOTAL:	**$ 1,710,638.00**
				20% Contingency:	342,128.00
				TOTAL:	**$ 2,052,766.00**

construction costs would be reduced to approximately $955,125. Survey and engineering costs are estimated at $155,513. With a 20% contingency, the estimated construction cost for the system is approximately $2,052,766. If the settling pond were to be removed, the estimated construction cost would be approximately $1.4 million.

A summary of estimated O&M costs for the Ocklawaha Prairie alum outfall treatment system is given in Table 4-14. Chemical costs are estimated to be approximately $684,144 per year, with additional costs for labor, power, and renewal and replacement. On an annual basis, the estimated O&M cost for the system would be approximately $698,144.

TABLE 4-14

SUMMARY OF ESTIMATED ANNUAL O&M COSTS FOR THE OCKLAWAHA PRAIRIE ALUM OUTFALL TREATMENT SYSTEM

LABOR COST[1] ($)	CHEMICAL COST[2] ($)	POWER COST ($)	RENEWAL AND REPLACEMENT COST[3] ($)	TOTAL COST ($)
22,800	684,144	3,000	11,000	$ 698,144

1. Based on an hourly rate = $15/hour
2. Based on an alum cost = $0.60/gallon and a polymer cost of $4/gallon
3. Based on a 20-year useful life

4.6 Longevity of Treatment

The treatment options provided in the previous sections utilize both liquid alum and alum residual as soil amendments for reducing phosphorus release from the Ocklawaha Prairie soils. A discussion of the anticipated longevity of each of these treatment options is given in the following sections.

4.6.1 Alum Floc

After initial application, the liquid alum will form a visible floc layer on the surface of the soils within the treated area. This floc layer will continue to consolidate for approximately 30 days, reaching maximum consolidation at that time. Due to the unconsolidated nature of the sediments in much of the area, it is anticipated that a large portion of the floc will migrate into the existing sediments/soils rather than accumulate on the surface as a distinct layer. This process is actually beneficial since it allows the floc to sorb soluble phosphorus during migration through the surficial sediments/soils. The floc remaining on the surface provides a chemical barrier for adsorption of phosphorus which may be released from underlying soils.

Based on previous experiences by ERD, as well as research by others, it appears that a properly applied chemical treatment will be successful in inactivation of the available phosphorus within the treated areas. However, several factors can serve to reduce the effectiveness and longevity of this treatment process. First, wind action may cause the floc to become prematurely mixed into deeper sediments, reducing the opportunity for maximum phosphorus adsorption. Significant wind resuspension has been implicated in several alum applications in shallow lakes which exhibited reduced longevity.

In the absence of wind resuspension, alum inactivation of lake sediments has resulted in long-term benefits ranging from three to more than 10 years. However, in shallow lakes exhibiting substantial resuspension, the effect of the coagulant can be reduced to a period of one year or less. Minimization of wind-induced resuspension is critical to the ultimate success of the amendment application.

If the total vegetative removal option is selected, one potential solution to minimize wind resuspension is to allow the vegetative communities to resprout following the initial removal process, before the treatment is performed. In a water column depth of 3 ft or more, small shoots as tall as 1-2 ft would not significantly interfere with boat maneuverability and would minimize sediment resuspension by wind activity.

Another factor which can affect the perceived longevity and success of the application process is recycling of nutrients by macrophytes from the sediments into the water column. This recycling will bypass the inactivation chemicals since phosphorus will cross the sediment/water interface through the vegetation rather than through the inactivant floc layer. Although this will not affect the inactivation of phosphorus within the sediments, this process may result in increases in dissolved phosphorus concentrations which are unrelated to sediment/water column processes.

Another potential factor which can affect the longevity and success of the application process is interception of the amendment floc by the existing vegetative litter layer on the bottom. This initial interception may prevent the amendment from actually reaching the sediments and performing the intended inactivation process. Although the impact of this is impossible to predict, there is no question that this application method will result in a reduction in the overall efficiency of the treatment process.

A final factor affecting the longevity of the treatment is significant upward of groundwater seepage into the treatment cells during normal operation. This seepage would almost certainly contain elevated phosphorus levels. The calculated amendment requirements for the treatments are designed to inactivate the surficial sediments only and do not include additional amounts for interception of high phosphorus groundwater inflow. Therefore, significant groundwater inflow could rapidly exhaust all available aluminum in the sediments, substantially impacting the success of this application.

4.6.2 Alum Residual

After initial application, the applied residual will mix in with the existing soils and provide continuous uptake for phosphorus release from the soils under flooded conditions. It is likely that the residual application at the Ocklawaha site will be extremely effective in inhibiting phosphorus release from the on-site soils for a considerable period of time. Several factors influence the effectiveness and longevity of this treatment process. First, wind action, which can reduce the longevity of alum treatment in shallow lakes, will not be an issue with the residual. Since floc formation has already occurred in the residual, the fragile unconsolidated floc which is formed initially following application of liquid alum, will not be generated, which will substantially lessen the ability of wind action to cause floc migration.

Another factor which will impact the longevity of the treatment is the substantial excess phosphorus uptake capacity inherent in the selected residual application rate. The recommended residual application rate of 6.5 wet tons/acre is approximately 10-30 times greater than the required residual application rate, based upon the available exchange capacity for phosphorus within the residual. This excess capacity for uptake of phosphorus will substantially increase the longevity of the residual application.

SECTION 5

SUMMARY

Work efforts were performed to evaluate methods of reducing soil phosphorus release on the restoration sites associated with the Ocklawaha Prairie Restoration Site. Previous research performed by the District has indicated that the organic soils at similar sites exhibit a strong potential for long-term release of sediment phosphorus resulting from extended prior use of the restoration site for muck farming operations. The primary objective of this study is to evaluate the use of chemical amendments to inactivate soil phosphorus and improve the net phosphorus retention of the area prior to proposed restoration activities.

Field and laboratory investigations were performed by ERD to assist in evaluating proposed amendments and determining phosphorus soil inactivation requirements. Sediment monitoring was performed by ERD during October 2001 and March 2002 to provide characterization data for soils at the Ocklawaha Prairie site. A total of 30 soil monitoring sites was established within the 2550-acre site. Each of the collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. In addition, a fractionation procedure for inorganic soil phosphorus was also conducted (Chang and Jackson) which allows the speciation of sediment phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound, and aluminum-bound phosphorus.

Potentially available phosphorus in the soils of the restoration area is calculated as the sum of the soluble inorganic phosphorus and easily exchangeable phosphorus fractions, plus iron-bound phosphorus which can become solubilized under reduced conditions. The results of the oil speciation experiments are used to generate isopleths of total available soil phosphorus for the restoration area.

Based upon soil core samples collected by ERD, it appears that soils within the flow-way area exhibit neutral to slightly acidic conditions, favoring the use of aluminum-based amendments. Therefore, both raw alum and alum residual appear to be capable of precipitating and inactivating phosphorus in sediments and soils at the site.

Due to the water-based environment at the site, the application of liquid alum in a boating-based application is an attractive inactivation technique for the Ocklawaha Restoration Site. However, the vast majority of the Ocklawaha Restoration site is heavily vegetated, and substantial clearing activities will be required prior to any water-based application technique.

Detailed evaluations were performed for a variety of treatment options, including water-based applications of liquid alum, treatment of areas immediately adjacent to the historical creek bed, and construction of an outflow alum treatment system. Estimated application costs for a water-based treatment of liquid alum to the restoration area are calculated based upon assumed water surface elevations at the time of the application in the areas which can be reached using the boat-based application methodology. If vegetation clearing were achieved by burning and water level regulation performed by the District, the estimated application cost at a water surface elevation of 40.0 ft would be $120,990 and would provide treatment for approximately 447 acres. At a water surface elevation of 41.0 ft, approximately 1066 acres could be treated at a total cost of $306,940. If the water surface elevation were increased to 42.0 ft, approximately 1826 acres of the restoration site would be reached, with a treatment cost of $536,415. If only the open water areas in the restoration site are treated, approximately 192 acres could be reached at a cost of $58,595.

If land clearing is achieved by mowing activities, application costs for the water-based treatments will increase for each of the evaluated treatment options, with the exception of the open water option. At a water surface elevation of 40.0 ft, the total treatment cost increases to $204,390 At a water surface elevation of 41.0 ft, the estimated treatment cost is $527,590, with an estimated cost of $798,015 at a water elevation of 42.0 ft.

Application of alum residual was also evaluated for areas immediately adjacent to the historic riverbed. For purposes of this evaluation, it is assumed that 200 ft on either side of the historic riverbed would be treated and that approximately 50% of the treated area would require land clearing activities. The estimated cost for this treatment is $141,780 which includes a 20% contingency. This cost estimate assumes that the alum residual is obtained at no charge and has characteristics similar to alum residual used by the District in previous projects.

An opinion of probable construction cost was also developed for construction of an alum outfall treatment system for discharges from the Ocklawaha Prairie site. This option assumes that sediment inactivation would not be performed and that phosphorus removal would occur prior to discharge of water from the Ocklawaha Prairie site. The estimated construction cost for this alternative is $2,052,766 which includes approximately $600,000 for construction of an on-site settling pond. If a settling pond is not desired, and the floc is allowed to settle in open areas of the prairie site, the construction site for the system could be reduced to approximately $1,400,000. The estimated annual O&M cost for this option is $698,144.

Selection of the appropriate treatment option is dependent upon long-term goals and financial limitations of the District. Since the final restoration plan for this area has not been developed at this time, the aspects of this plan will also need to be considered in deciding what areas will be likely targets for sediment release of phosphorus. Each of the evaluated treatment options appears to be adequate to inactivate sediment phosphorus release within the areas treated with each option.

SECTION 6

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