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Evaluation of Manufactured Soil Using Dredged Material from Confined Placement Facilities in Mobile, Alabama

Phase 1: Greenhouse Bench-Scale Test

Thomas C. Sturgis, Charles R. Lee, Henry C. Banks, Jr., Kervin Johnson, J. Patrick Langan, Susan I. Rees, and Carl Dyess

June 2002

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Phase 1: Greenhouse Bench-Scale Test

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Preface

This report describes work performed by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. This study was sponsored by the U.S. Army Engineer District, Mobile, Mobile, Alabama, under a civil works reimbursable project. The Project Manager was Mr. J. Patrick Langan, Mobile District.

The study was conducted and the report prepared by Drs. Thomas C. Sturgis and Charles R. Lee, Fate and Effects Branch (FEB), Environmental Processes and Effects Division (EPED), Environmental laboratory (EL), ERDC. Messrs. Henry C. Banks, Jr., and Kervin Johnson, AScI Corporation, provided assistance in preparing and conducting the laboratory/greenhouse screening tests and in the collection of data. Mr. Langan, Dr. Susan I. Rees, and Mr. Carl Dyess provided technical assistance, especially in support of the application of innovative recycled soil manufacturing technology.

The study was conducted under the direct supervision of Dr. Bobby L. Folsom, Jr., Chief, FEB, and under the general supervision of Drs. Richard E. Price, Chief, EPED, and Edwin A. Theriot, Director, EL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

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Executive Summary

The U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, has established Cooperative Research and Development Agreements (CRDAs) to develop technology for the manufacture of topsoil using sediment/soil, organic waste material, and biosolids. The technology would allow the development of fertile topsoil that could be used in a beneficial, productive, and environmentally sound manner. In addition, the manufactured topsoil technology would provide an alternative to conventional disposal (e.g., landfills and confined placement facilities (CPFs)) of the nation's waste/resource materials.

Bench-scale screening tests (seed germination and plant growth) were used in Phase 1 in developing this technology to evaluate the feasibility of using dredged material collected from CPFs in Mobile, AL, to develop a fertile manufactured topsoil product. Bench-scale screening tests included proprietary blends with a range of dredged material content from three CPFs (North Blakeley, South Blakeley, and North Pinto), a range of cellulose content, and N-Viro biosolids.

a. *Seed germination test*. Tomato, marigold, vinca, and ryegrass were tested following modified procedures used by a nationally known bagged soil producing company. Seed germination was highest in the North Blakeley Site 1 blends and least in blends using dredged material from North Pinto CPF as the primary ingredient. The best seed germination was observed in Blends 3, 4, and 5 prepared with North Blakeley Site 1 dredged material, cellulose A, and N-Viro biosolids.

b. *Extended plant growth test using manufactured soil blends*. A 7-week plant growth test was conducted using the same experimental design as for the seed germination study. Visual observations of leaf color, size, and shape and total aboveground biomass were used to evaluate the influence of the different manufactured soil blends on plant growth. Results showed that the highest aboveground biomass was obtained from blends using dredged material from the North Blakeley Site 1 CPF. There was no significant difference in ryegrass biomass among proprietary blends (e.g., Blends 1, 2, 3, and 5) consisting of dredged material from North Blakeley Site 1 (Test 1) CPF. There was no significant difference observed in plant aboveground biomass when unamended proprietary blends (Blends 1, 2, 3, and 5) were compared with proprietary Blends 6 and 10 amended with calcium.

In summary, topsoil can be manufactured from dredged material collected at North Blakeley Site 1 CPF blended with cellulose and N-Viro biosolids. Manufactured soil proprietary Blends 1, 2, 3, and 5 and proprietary Blends 6 and 10 amended with calcium showed the greatest potential for a fertile manufactured topsoil product. Cellulose A, used in this study, will require additional Ca as the amount of cellulose increases in the proprietary blends. Soil products can be manufactured from dredged material from the South Blakeley CPF according to proprietary Blends 4, 8, and 12. North Pinto CPF dredged material was least productive of the dredged material for manufacturing topsoil products.

1 Introduction

Background

Nonpoint and point source soil particles and other materials in runoff find their way to the bottom of waterways. These soil particles become sediment that eventually has to be removed from the waterways to maintain navigation. The U.S. Army Corps of Engineers (USACE) is responsible for maintaining the Nation's navigable waterways and annually dredges approximately 400 million cubic meters of sediment. Finding placement sites for dredged material is becoming difficult, since most confined placement facilities (CPFs) are at full capacity. Likewise, sewage sludge can no longer be disposed of in the ocean; consequently, sewage sludge is piling up on land at many sewage-treatment facilities. Currently, large volumes of sewage sludge are placed in landfills; however, landfills are filling at accelerated rates. To resolve the accumulation and disposal of sewage sludge, the U.S. Environmental Protection Agency (USEPA) issued 40 CFR Part 503 regulations (USEPA 1990, 1993, 1995). The 503 regulations promote the reuse of biosolids derived from sewage sludge and establish maximum limits for metals in soils amended with biosolids derived from sewage sludge for agricultural production. These limits were based on risk-assessment evaluations (USEPA 1989). To address both the excess of dredged material and sewage sludge, the Environmental Laboratory at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, conducted manufactured soil screening tests using its Cooperative Research and Development Agreements (CRDAs) with Paul Adam and N-Viro International, Inc.

The CRDA allowed ERDC to use N-Viro, a patented formulation developed by N-Viro International, as an ingredient of the Recycled Soil Manufacturing Technology (RSMT) (formerly Terraforms) to manufacture topsoil from dredged material. CRDAs that have been established or are pending will enable manufactured soil technology to be developed and demonstrated at USACE confined placement sites. They are listed in the following tabulation:

Cooperating Company	Aspect of Manufactured Soil
BION Technologies, Inc.[1]	Reconditioned biosolids from dairy cow manure
Scott and Sons Company[1]	Bagged soil products and screening procedures
N-Viro International, Inc.	Reconditioned biosolids from sewage sludge
Recycled Soil Manufacturing Technology (RSMT) (formerly Terraforms)	Formulation and blending equipment

[1] Pending.

The recycled soil manufacturing technology is site specific. The optimal blend for a specific dredged material will depend on the physical and chemical characteristics of that dredged material and the locally available cellulose and biosolids. The blend found productive for one site may not be similar to dredged material, cellulose, and biosolids from other sites. Therefore, bench-scale tests and demonstrations (pilot-scale and large-scale) should be conducted on each individual dredged material. Following successful demonstration of the recycled soil manufacturing technology, commercialization of the technology would be developed by the CRDA partners and local interests. Since there are proprietary restrictions placed on describing the specific amount and nature of each ingredient that makes up the manufactured topsoil product, implementation and application of the recycled soil manufacturing technology will require contacting appropriate ERDC Environmental Laboratory scientists and/or obtaining licenses from Mr. Paul Adam, the patent holder. Commercialization of this technology will provide additional placement capacity for future dredged material and will recycle the nation's waste materials in a beneficial, productive, and environmentally sound manner.

Purpose and Scope

The purpose of this report is to present results of screening tests conducted to determine the feasibility of using dredged material from CPFs in Mobile, AL, in the manufacture of topsoil products. The best formulation of dredged material, cellulose, and N-Viro biosolids was determined and recommended for field demonstration or commercialization.

2 Materials and Methods

Collection of Dredged Material

The dredged material used in this study was collected from the North Blakeley, South Blakeley, and North Pinto CPFs in Mobile, AL (Figure 1). Dredged material was collected from four sites within the North Blakeley CPF (Figures 1, 2, and 3). Dredged material from Sites 1 and 2 was collected at the weir and from a pile east of the weir, respectively (Figure 2). Dredged material from Sites 3 and 4 was collected at the spur dike (Figure 3). Three sites were randomly selected for sampling within the South Blakeley CPF (Figures 1, 4, 5, and 6). Dredged material was also collected from three locations near the State Park within the North Pinto CPF (Figures 1 and 7). Dredged material collected from each site within the CPFs was placed into 5-gal buckets and transported to the ERDC, Vicksburg, MS. Upon arrival at ERDC, the dredged material from each site within the placement facility was composited separately and thoroughly mixed using a Lightnin™ mixer model 12. The dredged material was then stored at 4 °C until greenhouse/laboratory testing. Subsamples of dredged material collected at each site within the CPFs were stored at 4 °C for chemical and physical characterization.

Manufactured Soil Screening Tests, Seed Germination and Plant Growth

North Blakeley screening tests

Manufactured topsoil screening tests (seed germination and plant growth) using modified procedures of a national bagged soil product company were used to evaluate the feasibility of manufacturing topsoil from dredged material collected from CPFs in Mobile, AL, that can be used in an environmentally sound manner. These tests included various blends of dredged material, cellulose, and N-Viro biosolids (biosolids derived from reconditioned sewage sludge). A specific blend was prepared by placing the appropriate amounts of cellulose A or B and N-Viro biosolids in a

Twin Shell Dry Blender model LB-10317 (V-mixer) and mixing for 5 min. Dredged material from North Blakeley, South Blakeley, or North Pinto was then added and mixed an additional 5 min. This process was repeated until all blends were prepared.

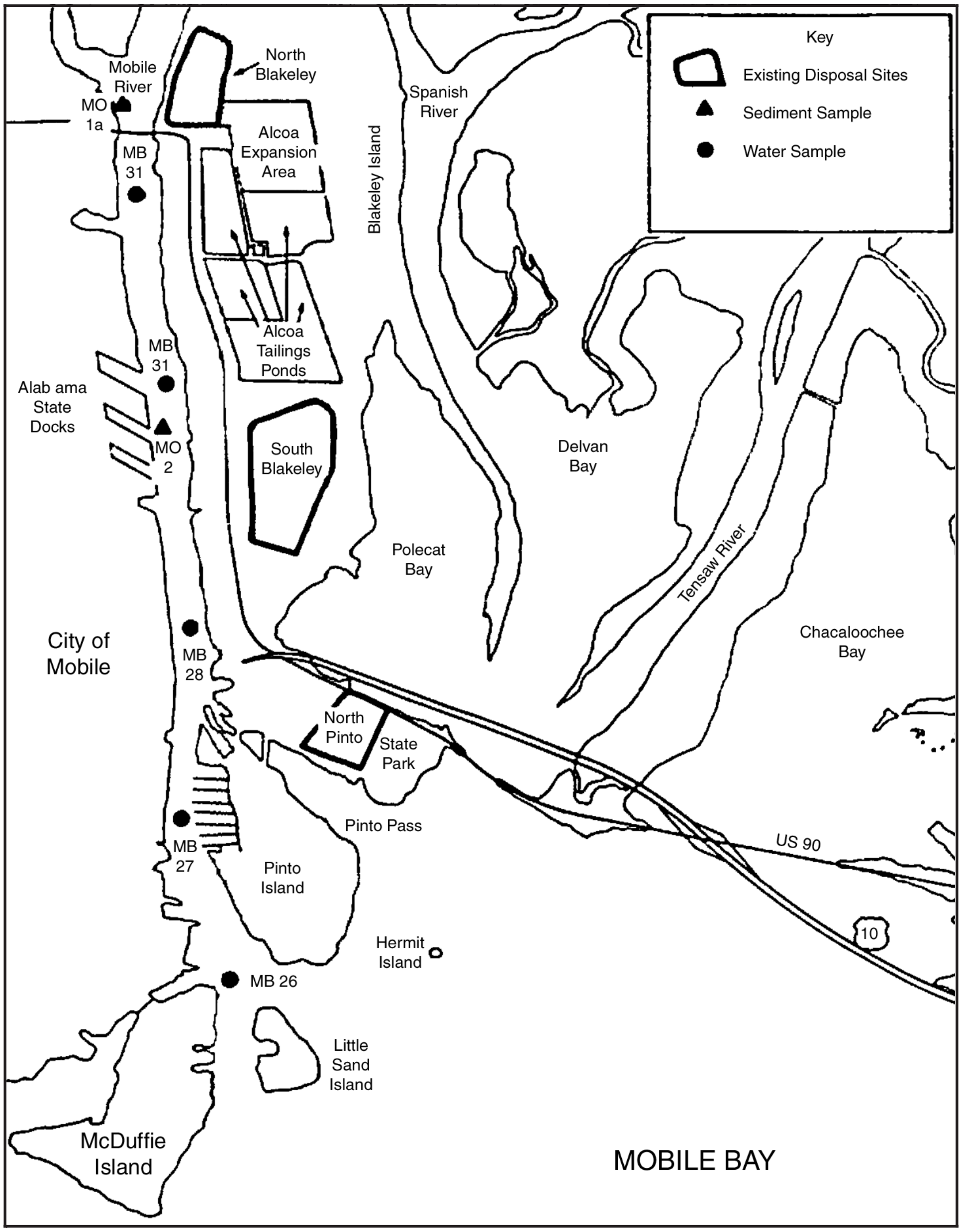

Figure 1. Map showing locations of North Blakeley, South Blakeley, and North Pinto CPFs in Mobile, AL

Figure 2. Mobile North Blakeley CPF Sites 1 and 2

Figure 3. Mobile North Blakeley CPF Sites 3 and 4

Figure 4. Mobile South Blakeley CPF Site 1

Figure 5. Mobile South Blakeley CPF Site 2

Figure 6. Mobile South Blakeley CPF Site 3

Figure 7. Mobile North Pinto CPF Sites 1, 2, and 3

Tomato, vinca, marigold, and ryegrass (four annual plant species) were grown from seed in the various blends to evaluate seed germination and plant growth (Table 1). Tomato, marigold, and vinca seed were obtained from Ball Seed Company, Chicago, IL, and ryegrass seeds were purchased from Warrenton Farms and Garden Center, Vicksburg, MS. Tomato, vinca, marigold, and ryegrass are sensitive to salt, metals, and nutrient imbalances and represent a wide spectrum of upland plants.

Table 1
Experimental Design for the Bench-Scale Mobile North Blakeley Sites 1, 2, and 3 Seed Germination and Plant Growth Screening Tests–Test 1

Treatments	
Blend 1	Mobile North Blakeley-Site 1 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 2	Mobile North Blakeley-Site 1 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 3	Mobile North Blakeley-Site 1 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 4	Mobile North Blakeley-Site 1 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 5	Mobile North Blakeley-Site 1 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 6	Mobile North Blakeley-Site 2 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 7	Mobile North Blakeley-Site 2 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 8	Mobile North Blakeley-Site 2 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 9	Mobile North Blakeley-Site 3 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 10	Mobile North Blakeley-Site 3 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 11	Mobile North Blakeley-Site 3 dredged material + cellulose A + N-Viro biosolids (pH - 7)
Blend 12	Mobile North Blakeley-Site 3 dredged material + cellulose A
Blend 13	Mobile North Blakeley-Site 3 dredged material + cellulose A
Blend 14	Mobile North Blakeley-Site 3 dredged material + cellulose A
Blend 15	Mobile North Blakeley-Site 3 dredged material + cellulose A
Blend 16	Fertile reference potting soil
Plant Species	
Lycopersicon esculentum (Tomato - Big Boy)	
Tagetes patula (Marigold)	
Lolium multiflorum Lam (Ryegrass - Gulf Annual)	
Catharanthus roseus (Vinca)	
Experimental Design	
16 treatments x 4 species x 4 replicates randomized block design	
16 x 4 x 4 = 256 pots	

Two hundred and fifty-six 10-cm (4-in.) pots with 10-cm (4-in.) saucers were used in the North Blakeley Screening Test 1 to evaluate seed germination and plant growth. All 10-cm (4-in.) pots were prepared by placing muslin cotton cloth in the bottom of each pot to prevent the loss of soil. Each blend was then added separately to each prepared 10-cm (4-in.) pot, to approximately 1.27 cm (0.5-in.) from the rim. Seeds were added separately to each blend: 10 tomato seeds, 10 marigold seeds, 10 vinca seeds, and 20 ryegrass seeds

All seeded pots were placed in a randomized block design with four blocks on tables in the greenhouse under lights. Lights were arranged in a pattern of alternating high-pressure sodium lamps and high-pressure multi-vapor halide lamps that provided an even photosynthetic active radiation (PAR) distribution pattern of 1200 uEinsteins/m^2/sec and a day length of 16 hr. The temperature in the greenhouse was maintained at 32.2 ± 5 °C during the day and 21.1 ± 5 °C at night. Relative humidity was maintained as close to 100 percent as possible, but never less than 50 percent.

Emerged seedlings were counted after 14 and 21 days to determine mean seed germination percentages. Plants, except for the ryegrass, were thinned to one plant per pot when more than one seed germinated in a pot. The plant seedlings were then allowed to grow and develop an additional 4 weeks to evaluate plant growth and appearance. After 7 weeks, all plants were photographed and harvested from the various blends. The plant was cut just above the soil surface, washed to remove any soil particles, and then blotted to remove excess water. The plant material was then bagged, weighed, dried, and reweighed to determine fresh and dry biomass. Table 1 shows the experimental design used in the North Blakeley Screening Test 1.

A second screening test was conducted using only dredged material from North Blakeley CPF Site 1. Calcium (Ca) was added to preselected blends to evaluate the effectiveness of calcium in reducing the adverse effects of salt on vegetative growth (Table 2). Calcium was added to the various blends as $CaSO_4$. For example, Blends 2-4 consisted of dredged material from North Blakeley Site 1, celloluse A, and N-Viro biosolids, with no calcium amendment, while Blends 5-7 received similar amounts of ingredients but were amended with calcium. Blends 8-10 received similar amounts of ingredients but were amended with twice the amount of calcium that Blends 5-7 received. The greenhouse setup was similar to that in the first North Blakeley screening test. Preparation of blends (using fresh dredged material) and ingredients were also similar to those in the first test. Dredged material from North Blakeley Site 1 was selected because it showed the best potential as a manufactured topsoil product. Ryegrass was the only plant species tested in this study. Ryegrass was selected as the model plant species because of its growth potential as shown in the first study. Table 2 shows the experimental design used in Screening Test 2.

Table 2
Experimental Design for the Bench-Scale Mobile North Blakeley Site 1 Seed Germination and Plant Growth Screening Tests–Test 2

Treatments		
Blend 1	Mobile North Blakeley-Site 1 dredged material	
Blend 2	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + no calcium
Blend 3	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + no calcium
Blend 4	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + no calcium
Blend 5	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + calcium
Blend 6	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + calcium
Blend 7	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + calcium
Blend 8	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + 2x calcium
Blend 9	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + 2x calcium
Blend 10	Mobile North Blakeley-Site 1 dredged material	+ cellulose A + N-Viro biosolids + 2x calcium
Blend 11	Fertile reference potting soil	
Plant Species		
Lolium multiflorum Lam (Ryegrass - Gulf Annual)		
Experimental Design		
11 treatments x 1 species x 4 replicates randomized block design		
11 x 1 x 4 = 44 pots		

A third screening test was conducted using dredged material from all three sites within the North Blakeley CPF. The purpose of this screening test was to evaluate a different type of cellulose (B) than that used in Screening Tests 1 and 2. The greenhouse setup and preparation of blends were similar to those in the first screening test. Table 3 shows the experimental design used in the third test using North Blakeley dredged material and ryegrass as the model plant species.

Table 3
Experimental Design for the Bench-Scale Mobile North Blakeley Sites 1, 2, and 3 Seed Germination and Plant Growth Screening Tests–Test 3

Treatments	
Blend 1	Mobile North Blakeley-Site 1 dredged material
Blend 2	Mobile North Blakeley-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 3	Mobile North Blakeley-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 4	Mobile North Blakeley-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 5	Mobile North Blakeley-Site 2
Blend 6	Mobile North Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 7	Mobile North Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 8	Mobile North Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 9	Mobile North Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 10	Mobile North Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 11	Mobile North Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 12	Mobile North Blakeley-Site 3
Blend 13	Fertile reference potting soil
Plant Species	
Lolium multiflorum Lam (Ryegrass - Gulf Annual)	
Experimental Design	
13 treatments x 1 species x 4 replicates randomized block design 13 x 1 x 4 = 52 pots	

South Blakeley screening tests

Bench-scale screening tests were conducted to ascertain the suitability of manufacturing soil from dredged material collected from the South Blakeley CPF. These tests included various blends of dredged material, cellulose B, and N-Viro biosolids. The greenhouse setup, procedures, and preparation of blends were similar to those in the North Blakeley screening tests. Ryegrass was the only plant species tested in this study. Table 4 shows the experimental design used in the South Blakeley screening tests.

North Pinto screening tests

Bench-scale screening tests were conducted to ascertain the suitability of manufacturing soil from dredged material collected from the North Pinto CPF that can be used in an environmentally sound manner. These tests included various blends of dredged material, cellulose B, and N-Viro as biosolids. The greenhouse setup, procedures, and preparation of blends

Table 4 Experimental Design for the Bench-Scale Mobile South Blakeley Sites 1, 2, and 3 Seed Germination and Plant Growth Screening Tests	
Treatments	
Blend 1	Mobile South Blakeley-Site 1
Blend 2	Mobile South Blakeley-Site 1 dredged material + cellulose B+ N-Viro biosolids
Blend 3	Mobile South Blakeley-Site 1 dredged material + cellulose B+ N-Viro biosolids
Blend 4	Mobile South Blakeley-Site 1 dredged material + cellulose B+ N-Viro biosolids
Blend 5	Mobile South Blakeley-Site 2
Blend 6	Mobile South Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 7	Mobile South Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 8	Mobile South Blakeley-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 9	Mobile South Blakeley-Site 3
Blend 10	Mobile South Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 11	Mobile South Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 12	Mobile South Blakeley-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 13	Fertile reference potting soil
Plant Species	
Lolium multiflorum Lam (Ryegrass - Gulf Annual)	
Experimental Design	
13 treatments x 1 species x 4 replicates randomized block design 13 x 1 x 4 = 52 pots	

were similar to those in the previous screening tests. Ryegrass was the only plant species tested in this study. Table 5 shows the experimental design used in the North Pinto screening tests.

Table 5 Experimental Design for the Bench-Scale Mobile North Pinto Sites 1, 2, and 3 Seed Germination and Plant Growth Screening Tests	
Treatments	
Blend 1	Mobile North Pinto-Site 1
Blend 2	Mobile North Pinto-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 3	Mobile North Pinto-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 4	Mobile North Pinto-Site 1 dredged material + cellulose B + N-Viro biosolids
Blend 5	Mobile North Pinto-Site 2
Blend 6	Mobile North Pinto-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 7	Mobile North Pinto-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 8	Mobile North Pinto-Site 2 dredged material + cellulose B + N-Viro biosolids
Blend 9	Mobile North Pinto-Site 3
Blend 10	Mobile North Pinto-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 11	Mobile North Pinto-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 12	Mobile North Pinto-Site 3 dredged material + cellulose B + N-Viro biosolids
Blend 13	Fertile reference potting soil
Plant Species	
Lolium multiflorum Lam (Ryegrass - Gulf Annual)	
Experimental Design	
13 treatments x 1 species x 4 replicates randomized block design 13 x 1 x 4 = 52 pots	

3 Statistical Analysis

Experimental data were analyzed using analysis of variance (ANOVA) procedures of the Statistical Analysis System (SAS Institute, Inc. 1989). Tests of normality were performed using the Shapiro-Wilk statistic: homogeneity of variance was evaluated using Levene's test. Comparisons of means were performed using Duncan's Multiple Range Test. In this report, statements of statistical significance without specific indication of probability level refer to $P < 0.05$.

4 Results and Discussion

Dredged Material Characterization

The concentrations of the various inorganic and organic chemicals in dredged material collected from all CPFs are shown in Tables 6-9. The USEPA has promoted the reuse of biosolids by promulgating 40 CFR Part 503 regulations. USEPA published 40 CFR Part 503 regulations to indicate the acceptable level of metals in agricultural soils from the application of biosolids derived from sewage sludge. The intent of the 503 regulations is to establish regulatory levels to prevent adverse effects on human health and the environment. Bulk metal concentrations in dredged material from all three CPFs are considerably below those specified in the 40 CFR Part 503 guidelines, and, as a result, metal content should not be of public concern (Table 6).

Table 6
Metal Analysis of Dredged Material Collected from CPFs in Mobile, Alabama

	Confined Placement Facilities			
Analytes	**North Blakeley mg/kg**	**South Blakeley mg/kg**	**North Pinto mg/kg**	**EPA 503 Guidance mg/kg**
Ag	<0.522	<0.482	<0.52	
As	8.76	6.51	7.95	41.0
Be	0.737	0.63	0.76	
Cd	0.416	0.34	0.32	39.0
Cr	39.30	31.15	32.20	
Cu	15.80	14.35	22.10	1500.0
Ni	18.30	15.80	16.50	420.0
Pb	22.40	17.30	15.60	300.0
Sb	<1.04	<1.97	<1.04	
Se	<1.30	<1.21	<1.30	
Tl	<1.30	<1.21	<1.30	
Zn	113.00	86.45	94.20	2800.0

Table 7
Dioxin Analysis of Dredged Material from CPFs in Mobile, Alabama

Analytes	Confined Placement Facilities		
	North Blakeley pptr	South Blakeley pptr	North Pinto pptr
2,3,7,8-TCDD	1.90	1.20	0.35[1]
1,2,3,7,8-PeCDD	1.50[1]	1.00	0.48
1,2,3,4,7,8-HxCDD	3.00	2.90	0.99
1,2,3,6,7,8-HxCDD	11.70	9.60	3.50
1,2,3,7,8,9-HxCDD	16.20	24.90	7.30
1,2,3,4,6,7,8-HpCDD	386.00	345.00	150.00
1,2,3,4,6,7,8,9-OCDD	ND	ND	5320.00
2,3,7,8-TCDF	12.50	6.70	2.60
1,2,3,7,8-PeCDF	0.62[1]	0.73	ND
2,3,4,7,8-PeCDF	1.00	1.20	ND
1,2,3,4,7,8-HxCDF	7.00	5.90[1]	2.70
1,2,3,6,7,8-HxCDF	2.00	1.70	0.53
2,3,4,6,7,8-HxCDF	2.90	2.50	1.40
1,2,3,7,8,9-HxCDF	0.50[1]	ND	ND
1,2,3,4,6,7,8-HpCDF	36.30	27.20	8.20
1,2,3,4,7,8,9-HpCDF	3.00	2.30	0.84
1,2,3,4,6,7,8,9-OCDF	128.00	86.70	43.30
Total TCDD	37.10	22.20	12.00
Total PeCDD	43.70	29.90	9.50
Total HxCDD	383.00	454.00	124.00
Total HpCDD	1210.00	1190.00	502.00
Total TCDF	35.10	20.10	5.10
Total PeCDF	18.30	18.90	7.80
Total HxCDF	65.10	34.30	15.10
Total HpCDF	127.00	92.90	32.60

Note: ND = not detected.
[1] Estimated maximum possible concentration (EMPC).

Table 8
Dioxin TEQ Values for Dredged Material from CPFs in Mobile, Alabama

Analytes	Confined Placement Facilities		
	North Blakeley pptr	South Blakeley pptr	North Pinto pptr
2,3,7,8-TCDD	1.90	1.20	0.35
1,2,3,7,8-PeCDD	0.75	0.50	0.24
1,2,3,4,7,8-HxCDD	0.30	0.29	0.099
1,2,3,6,7,8-HxCDD	1.17	0.96	0.35
1,2,3,7,8,9-HxCDD	1.62	2.49	0.73
1,2,3,4,6,7,8-HpCDD	3.86	3.45	1.50
1,2,3,4,6,7,8,9-OCDD	ND	ND	5.32
2,3,7,8-TCDF	1.25	0.67	0.26
1,2,3,7,8-PeCDF	0.31	0.037	ND
2,3,4,7,8-PeCDF	0.50	0.60	ND
1,2,3,4,7,8-HxCDF	0.70	0.59	0.27
1,2,3,6,7,8-HxCDF	0.20	0.17	0.053
2,3,4,6,7,8-HxCDF	0.29	0.25	0.14
1,2,3,7,8,9-HxCDF	0.050	ND	ND
1,2,3,4,6,7,8-HpCDF	0.36	0.27	0.82
1,2,3,4,7,8,9-HpCDF	0.30	0.023	0.008
1,2,3,4,6,7,8,9-OCDF	0.128	0.086	0.043
Total TEQ	13.688	**11.586**	**9.45** **7.5**[1]

Note: ND = not detected.
[1] Average TEQ value for natural soils in North America (USEPA 1995).

Table 9
PAH Analysis of Dredged Material from CPFs in Mobile, Alabama

Analytes	Confined Placement Facilities		
	North Blakeley μg/kg	South Blakeley μg/kg	North Pinto μg/kg
Phenol			
bis(2-Chloroethyl)ether			
2-Chlorophenol			
1,3-Dichlorobenzene			
1,4-Dichlorobenzene			
1,2-Dichlorobenzene			
2,2'-oxybis(1-Chloropropane)			
Benzyl alcohol			
2-Methylphenol			
3/4-Methylphenol			
N-Nitroso-di-n-propylamine			
Hexachloroethane			
Nitrobenzene			
Isophorone			
2-Nitrophenol			
2,4-Dimethylphenol			
bis(2-Chloroethoxy)methane			
Benzoic acid			
2,4-Dichlorophenol			
1,2,4-Trichlorobenzene			
Naphthalene		16.10J	
4-Chloroaniline			
Hexachlorobutadiene			
4-Chloro-3-methylphenol			
2-Methylnaphthalene	5.36J	6.15J	
Hexachlorocyclopentadiene			
2,4,6-Trichlorophenol			
2,4,5-Trichlorophenol			
2-Chloronaphthalene			
2-Nitroaniline			
Dimethylphthalene			
2,6-Dinitrotoluene			
2,4-Dinitrotoluene			
Acenaphthylene	8.90J	7.01J	12.18J
3-Nitroaniline			
Acenaphthene		7.33J	

(Continued)

Note: Blank spaces = not detected.
J = estimated below quantitation limit.

Table 9 (Concluded)

Analytes	Confined Placement Facilities		
	North Blakeley µg/kg	South Blakeley µg/kg	North Pinto µg/kg
2,4-Dinitrophenol			
4-Nitrophenol			
Dibenzofuran		13.88J	15.83J
Diethylphthalate	13.13BJ	9.75BJ	
4-Chlorophenyl-phenylether			
Fluorene	6.72J	7.24J	15.36J
4-Nitroaniline			
4,6-Dinitro-2-methylphenol			
N-Nitrosodiphenylamine			
4-Bromophenyl-phenylether			
Hexachlorobenzene			
Pentachlorophenol			
Phenanthrene	24.29J	73.76J	45.19J
Anthracene	11.97J	18.82J	34.68J
Di-n-butylphthalate	142.14BJ	105.32BJ	110.81BJ
Fluoranthene	61.66J		130.15J
Pyrene	49.19J	68.97J	180.83J
Butylbenzylphthalate	24.05J		
3,3'-Dichlorobenzidine			
bis(2-Ethylhexyl)phthalate	129.42BJ	113.29BJ	109.67BJ
Benzo(a)anthracene	19.02J	44.35J	77.05J
Chrysene	15.78J	44.66J	91.13J
Di-n-octylphthalate			
Benzo(b)fluoranthene		49.23J	149.35J
Benzo(k)fluoranthene		21.95J	42.04J
Benzo(e)pyrene	19.95J	29.78J	69.90J
Benzo(a)pyrene	19.71J	30.84J	87.78J
Perylene	537.40	289.86J	314.10J
Indeno(1,2,3-cd)pyrene			
Dibenz(a,h)anthracene			
Benzo(g,h,i)perylene			31.16J

Note: All values were below detection limits, except those given, and these were J values.
J = estimated below quantitation limit
B = present in blank.
Blank spaces = not detected.

Dioxin was detected in dredged material from all three CPFs at extremely low levels (parts per trillion (pptr)). Calculated total dioxin equivalent (TEQ) values for dredged material from North Blakeley and South Blakeley CPFs are slightly higher than the average concentration of 7.5 pptr that is normally found in soils (Tables 7 and 8) (USEPA 1995). Blending dredged material with organic materials will reduce the level of dioxin to below that observed in normal soils. For example, the projected TEQ value for Blend 4 containing dredged material from North Blakeley CPF, cellulose A, and N-Viro biosolids would be 6.8 pptr, which is below that normally found in soils. The addition of organic matter to the proprietary blends will also result in adsorption and immobilization of most contaminants (Hamaker and Thompson 1972; Karickhoff, Brown, and Scott 1979). An evaluation of PAH analysis revealed low concentrations or values below detection limits (Table 9). The ultimate decision on the use of manufactured topsoil will depend on the final level of contamination, the potential for contaminant migration and release, and land use objective. Particle size distribution appears to be similar among the dredged material collected from the three CPFs (Table 10).

Table 10
Physical Characterization of Dredged Material from CPFs in Mobile, Alabama

Particle Size	Confined Placement Facilities		
	North Blakeley percent	South Blakeley percent	North Pinto percent
Sand	39.37	30.06	38.70
Silt	28.50	34.56	32.62
Clay	32.13	35.38	28.68

Seed Germination Tests

North Blakeley screening tests

Results of the seed germination tests are shown in Tables 11, 12, 13, and 14. An evaluation of the ANOVA showed that seed germination in the North Blakeley Site 1 blends was influenced by treatment ($P = 0.0001$) and species ($P = 0.0001$). Seed germination in Blend 16 (reference soil) was generally significantly higher than seed germination in all blends made of dredged material from the North Blakeley CPF (Tables 11, 12, 13, and 14). Further evaluation of the data revealed that percent seed germination was highest in blends using dredged material from North Blakeley Site 1 and least in blends consisting of dredged material from North Blakeley Site 3 ($P < 0.05$) (Tables 11, 12, 13, and 14).

Table 11
Seed Germination Values from Mobile North Blakeley Site 1 Test 1

	Tomato, percent ± standard error		Marigold, percent ± standard error	
Blend	**14 Days**	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	85.0 ± 6.5a	85.0 ± 6.5a	97.5 ± 2.5a	97.5 ± 2.5a
5	82.5 ± 4.8a	82.5 ± 4.8a	78.5 ± 6.3b	87.5 ± 6.3b
4	67.5 ± 10.3c	77.5 ± 10.3b	77.5 ± 4.8b	72.5 ± 7.5b
3	47.5 ± 14.9d	52.5 ± 13.8d	75.0 ± 8.7b	60.0 ± 9.1c
2	75.0 ± 2.9b	77.5 ± 4.8b	45.0 ± 9.6d	40.0 ± 10.8d
1	62.5 ± 6.3c	67.5 ± 10.3c	57.5 ± 8.5c	52.5 ± 7.5c
	Ryegrass, percent ± standard error		**Vinca, percent ± standard error**	
Blend	**14 Days**	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	95.0 ± 3.5a	98.8 ± 1.3a	62.5 ± 5.3a	72.5 ± 7.5a
5	88.8 ± 3.1a	92.5 ± 1.4a	22.5 ± 8.6d	22.5 ± 8.6d
4	77.5 ± 3.2b	91.3 ± 1.3a	42.5 ± 6.3b	37.5 ±4.8c
3	86.3 ± 6.3a	93.8 ± 2.4a	62.5 ± 7.5a	60.0 ±9.1b
2	75.0 ± 2.0b	86.3 ± 4.3a	32.5 ± 13.8c	32.5 ±14.4c
1	66.3 ± 8.0c	67.5 ± 7.5b	0.0 ± 0.0e	0.0 ± 0.0e

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 12
Seed Germination Values from Mobile North Blakeley Site 2 Test 1

	Tomato, percent ± standard error		Marigold, percent ± standard error	
Blend	**14 Days**	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	85.0 ± 6.5a	85.0 ± 6.5a	97.5 ± 2.5a	97.5 ± 2.5a
8	72.5 ± 4.8b	80.0 ± 8.2a	57.5 ± 9.5c	45.0 ± 11.9b
7	35.0 ± 9.8c	57.5 ± 11.1b	77.5 ± 8.6b	50.0 ± 10.8b
6	0.0 ± 0.0d	20.0 ± 5.8c	47.5 ± 16.3c	37.5 ±12.5c
	Ryegrass, percent ± standard error		**Vinca, percent ± standard error**	
Blend	**14 Days**	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	95.0 ± 3.5a	98.8 ± 1.3a	62.5 ± 10.3a	72.5 ± 7.5a
8	77.5 ± 5.2b	77.5 ± 5.2b	32.5 ± 12.5b	20.0 ± 7.1b
7	76.3 ± 3.8b	75.0 ± 3.6b	5.0 ± 2.8c	12.5 ± 6.3b
6	21.3 ± 8.3c	21.3 ± 8.3c	2.5 ± 2.5c	0.0 ± 0.0c

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 13
Seed Germination Values from Mobile North Blakeley Site 3 Test 1, With N-Viro

Blend	Tomato, percent ± standard error		Marigold, percent ± standard error	
	14 Days	21 Days	14 Days	21 Days
16 (reference soil)	85.0 ± 6.5a	85.0 ± 6.5a	97.5 ± 2.5a	97.5 ± 2.5a
11	67.5 ± 9.5b	80.0 ± 10.0a	72.5 ± 9.5b	60.0 ± 12.2b
10	0.0 ± 0.0c	2.5 ± 2.5c	2.5 ± 8.6c	2.5 ± 2.5c
9	2.5 ± 2.5c	15.0 ± 15.0b	0.0 ± 0.0c	0.0 ±0.0c
Blend	**Ryegrass, percent ± standard error**		**Vinca, percent ± standard error**	
	14 Days	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	95.0 ± 3.5a	98.8 ± 1.3a	62.5 ±10.3a	72.5 ±7.5a
11	41.5 ± 9.7b	43.8 ± 9.7b	0.0 ± 0.0b	0.0 ±0.0b
10	1.3 ± 1.3c	5.0 ± 3.5c	0.0 ± 0.0b	0.0 ±0.0b
9	0.0 ± 0.0c	1.3 ± 1.3c	0.0 ± 0.0b	0.0 ±0.0b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 14
Seed Germination Values from Mobile North Blakeley Site 3 Test 1, Without N-Viro

Blend	Tomato, percent ± standard error		Marigold, percent ± standard error	
	14 Days	21 Days	14 Days	21 Days
16 (reference soil)	85.0 ± 6.5a	85.0 ± 6.5a	97.5 ± 2.5a	97.5 ± 2.5a
15	30.0 ±14.7b	35.0 ± 12.6b	47.5 ± 14.0b	60.0 ± 12.0b
14	7.5 ± 4.8c	27.5 ± 16.0b	0.0 ± 0.0d	2.5 ± 2.5d
13	0.0 ± 0.0c	7.5 ± 13.8c	10.0 ± 7.1c	0.0 ±0.0d
12	7.5 ± 4.8c	7.5 ± 4.8c	0.0 ± 0.0d	17.5 ± 0.0c
Blend	**Ryegrass, percent ± standard error**		**Vinca, percent ± standard error**	
	14 Days	**21 Days**	**14 Days**	**21 Days**
16 (reference soil)	95.0 ± 3.5a	98.8 ± 1.3a	62.5 ± 0.0a	72.5 ± 7.5a
15	28.8 ± 9.7b	47.5 ± 3.2b	5.0 ± 0.0b	7.5 ± 7.5b
14	35.0 ± 12.6b	40.0 ± 15.0b	0.0 ± 0.0b	0.0 ± 0.0b
13	1.3 ± 1.3c	5.0 ± 2.9c	0.0 ± 0.0b	0.0 ± 0.0b
12	1.3 ± 1.3c	7.5 ± 3.2c	0.0 ± 0.0b	0.0 ± 0.0b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Percent seed germination in Blends 3, 4, and 5 containing dredged material from North Blakeley CPF Site 1 was approximately the same but was significantly higher than in Blends 1 and 2 ($P < 0.05$) (Table 11). Similar seed germination results were observed in blends using dredged material from North Blakeley Sites 2 and 3 (Tables 12, 13, and 14). For example, lowest seed germination was observed in blends with the highest percentage of dredged material (Tables 12, 13, and 14). Blends 8 and 11 using dredged material from North Blakeley Sites 2 and 3, respectively, showed the highest percent seed germination, but these values were significantly lower than seed germination values from Blend 16 (fertile reference soil) (Tables 12 and 13).

The ANOVA also showed some time-species and treatment-species interaction effects ($P=0.0001$). Tomato seed germination in Blend 5 using North Blakeley Site 1 dredged material was not significantly different from that in Blend 16 (fertile reference soil) ($P < 0.05$), but tomato seed germination in Blends 1, 2, 3, and 4 was significantly lower at days 14 and 21. However, ryegrass seed germination in Blends 1, 2, 3, 4, and 5 was significantly lower than in Blend 16 at day 14 ($P < 0.05$). At day 21, there was no significant difference in ryegrass seed germination among Blends 3, 4, 5, and 16 ($P < 0.05$).

The movement of water from dredged material to seeds and uptake are the essential steps toward seed germination. Therefore, the differences observed in seed germination among the different North Blakeley blends and sites are most likely due to factors that affect the rate and extent of water movement from the manufactured soil to the seeds. For example, North Blakeley blends with higher amounts of dredged material showed significantly lower seed germination (Tables 11, 12, 13, and 14; Figure 8). This may be ascribed to the higher soil compaction or bulk density of the dredged material. Dredged material with a high bulk density/soil consolidation/compaction will decrease the capillary and vapor movement of water near the seed, which will result in the physical restriction of the swelling seed and decreased imbibition and, subsequently, impede seed germination (Hagon and Chan 1977).

Ryegrass seed germination was significantly higher in all blends when compared with the other plant species ($P < 0.05$). Seed germination was in the order of: ryegrass > tomato > marigold > vinca. This may suggest that ryegrass seed may be more efficient in taking up water. In addition, it may also show that ryegrass seed may be able to complete germination at lower water contents than tomato, marigold, and vinca seeds (Raven and Eichorn 1986). Comparisons of North Blakeley Site 3 blends with and without N-Viro biosolids showed that the addition of N-Viro biosolids did not enhance seed germination ($P > 0.05$) (Tables 13 and 14). This was not surprising since seed germination is dependent on water imbibition and the rate of water movement from soil to seeds and not on nutrient content of the blend.

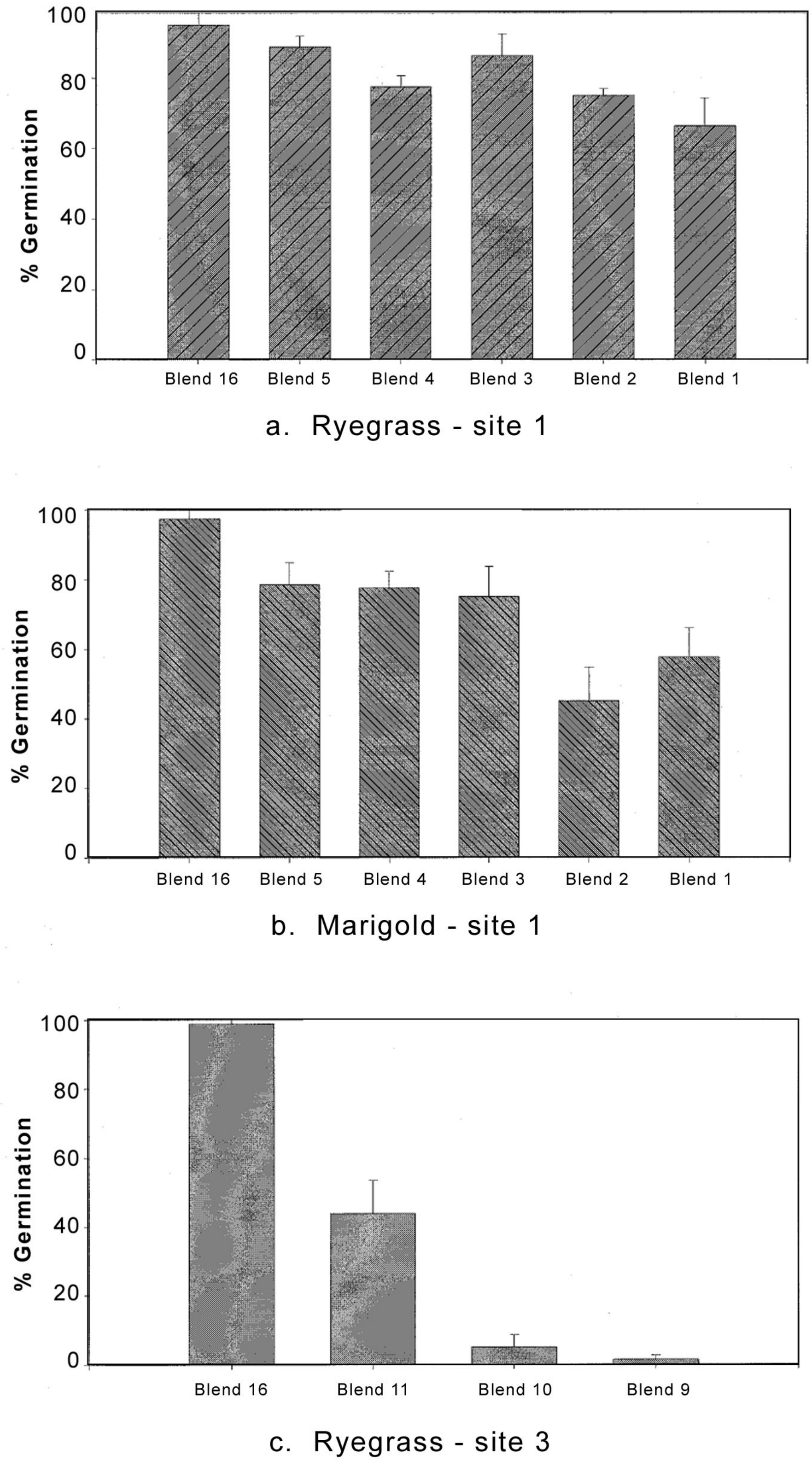

Figure 8. Seed germination results from blends prepared with dredged material from Mobile North Blakeley Sites 1 and 3

Seed germination values from blends prepared with dredged material from North Blakeley Site 1 CPF are presented in Tables 15, 16, and 17. An evaluation of the ANOVA showed that seed germination was influenced by treatment ($P = 0.0001$) and time ($P = 0.0004$). Percent seed germination was extremely low (<40 percent), or no seeds germinated, in blends containing dredged material from North Blakeley CPF Site 1, cellulose A, and N-Viro biosolids amended with calcium (Tables 15, 16, and 17). However, seed germination data at day 21 did occasionally show a significant increase ($P < 0.05$). Generally, percent seed germination was significantly lower than in Blend 11 (fertile reference soil) (Tables 15, 16 and 17).

Table 15
Seed Germination Values from Mobile North Blakeley Site 1 Test 2, No Calcium

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
11 (reference soil)	90.0 ± 6.12a	98.75 ± 1.25a
4	0.00b	0.00c
3	0.00b	0.00c
2	8.75 ± 4.27b	21.25 ± 7.20b
1	1.25 ± 1.25b	5.00 ± 3.54c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 16
Seed Germination Values from Mobile North Blakeley Site 1 Test 2, Plus Calcium

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
11 (reference soil)	90.0 ± 6.12a	98.75 ± 6.5a
7	0.00c	0.00c
6	17.5 ± 7.22b	25.0 ± 16.0b
5	2.50 ± 1.44c	2.50 ± 1.44c
1	1.25 ± 1.25c	1.25 ± 1.25c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 17
Seed Germination Values from Mobile North Blakeley Site 1 Test 2, Plus 2x Calcium in Blends 5, 6, and 7

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
11 (reference soil)	90.0 ± 6.12a	98.75 ± 1.25a
10	10.0 ± 4.1b	38.75 ± 4.73b
9	8.75 ± 3.75bc	17.5 ± 4.79c
8	1.25 ± 1.25c	1.25 ± 1.25d
1	1.25 ± 1.25c	5.00 ± 3.54d

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Percent seed germination from blends consisting of dredged material from North Blakeley Sites 1, 2, and 3 plus cellulose B and N-Viro biosolids as ingredients is shown in Tables 18, 19, and 20. Percent seed germination from North Blakeley Sites 1, 2, and 3 was extremely low (<40 percent). Seed germination in Blend 3, made of dredged material from North Blakeley Site 1, and in Blends 7 and 8, containing dredged material from North Blakeley Site 2, was not significantly different but was significantly lower than in Blend 13 (fertile reference soil) ($P < 0.05$). Percent seed germination was least in blends containing dredged material from North Blakeley Site 3.

Table 18
Seed Germination Values from Mobile North Blakeley Site 1 Test 3

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	90.0 ± 6.12a	98.75 ± 1.25a
4	6.25 ± 3.75c	15.0 ± 7.4c
3	28.75 ± 3.75b	38.75 ± 7.74b
2	0.0 ± 1.25c	6.25 ± 3.75c
1	1.25 ± 1.25c	5.0 ± 3.54c

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 19
Seed Germination Values from Mobile North Blakeley Site 2 Test 3

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	90.0 ± 6.12a	98.8 ± 1.25a
8	25.0 ± 10.8b	30.0 ± 12.8b
7	22.5 ± 7.22b	25.0 ± 7.1b
6	2.5 ± 1.44c	5.0 ± 2.04c
1	1.25 ± 1.25c	2.5 ± 1.44c

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 20
Seed Germination Values from Mobile North Blakeley Site 3 Test 3

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	90.0 ± 6.12a	98.75 ± 1.25a
12	2.5 ± 1.44b	5.0 ± 2.89b
11	2.5 ± 2.5b	5.0 ± 5.0b
10	0.0 ± 0.0b	0.0 ± 0.0b
9	3.8 ± 3.8b	5.0 ± 5.0b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

South Blakeley screening tests

Percent seed germination for blends made of dredged material from South Blakeley Sites 1, 2, and 3 plus cellulose B and N-Viro biosolids as ingredients is shown in Tables 21, 22, and 23. Seed germination in all blends containing dredged material from South Blakeley Sites 1, 2, and 3 was less than 25 percent. Seed germination was higher in blends made of dredged material from South Blakeley Site 3 compared with blends made of dredged material from South Blakeley Sites 1 and 2. However, seed germination in all blends containing dredged material from South Blakeley remained significantly lower than in Blend 13 (fertile reference soil). The general trend in seed germination appears to indicate that as dredged material is increased in the blends, seed germination decreases (Tables 21, 22, and 23).

Table 21
Seed Germination Values from Mobile South Blakeley Site 1 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5 ± 4.79a	100.0 ± 0.0a
4	10.0 ± 5.0b	8.8 ± 5.9b
3	0.0 ± 0.0c	1.3 ± 1.3b
2	0.0 ± 0.0c	0.0 ± 0.0b
1	0.0 ± 0.0c	1.3 ± 1.3b

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 22
Seed Germination Values from Mobile South Blakeley Site 2 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5 ± 4.79a	100.0 ± 0.0a
8	13.75 ± 5.91b	16.25 ± 4.73b
7	0.0 ± 0.0c	2.5 ± 1.44c
6	0.0 ± 0.0c	0.0 ± 0.0c
5	0.0 ± 0.0c	0.0 ± 0.0c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 23
Seed Germination Values from Mobile South Blakeley Site 3 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5 ± 4.8a	100.0 ± 0.0a
12	31.3 ± 4.3b	30.0 ± 5.4b
11	23.8 ± 4.8b	23.8 ± 4.3b
10	2.5 ± 2.5c	2.5 ± 2.5c
9	7.5 ± 7.5c	6.5 ± 6.3c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

North Pinto screening tests

Seed germination for blends prepared with dredged material from North Pinto Sites 1, 2, and 3 is shown in Tables 24, 25, and 26. Seed germination was extremely low (<20 percent) in all blends with North Pinto dredged material as the primary ingredient. Seed germination in Blend 13 (fertile reference soil) was significantly higher than seed germination in all manufactured topsoil blends containing North Pinto dredged material, cellulose B, and N-Viro biosolids (Tables 24, 25, and 26). Seeds only germinated in Blends 4, 8, and 12, which had the lowest amount of dredged material (Tables 24, 25, and 26).

Table 24
Seed Germination Values from Mobile North Pinto Site 1 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5±4.7a	100.0 ± 0.0a
4	13.8±1.4b	17.5 ± 7.2b
3	0.0 ± 0.0c	0.0 ± 0.0c
2	0.0 ± 0.0c	0.0 ± 0.0c
1	0.0 ± 0.0c	0.0 ± 0.0c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 25
Seed Germination Values from Mobile North Pinto Site 2 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5 ± 4.7a	100.0 ± 0.0a
8	7.5 ± 4.3b	13.8 ± 6.8b
7	0.0 ± 0.0b	0.0 ± 0.0c
6	0.0 ± 0.0b	0.0 ± 0.0c
5	0.0 ± 0.0b	0.0 ± 0.0c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 26
Seed Germination Values from Mobile North Pinto Site 3 Test

	Ryegrass, percent ± standard error	
Blend	**14 Days**	**21 Days**
13 (reference soil)	92.5 ± 4.7a	100.0 ± 0.0a
12	13.75 ± 1.4b	17.5 ± 7.2b
11	0.0 ± 0.0c	0.0 ± 0.0c
10	0.0 ± 0.0c	0.0 ± 0.0c
9	0.0 ± 0.0c	0.0 ± 0.0c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Plant Growth Tests

North Blakeley Screening Test 1

Figure 9 shows an overall view of the greenhouse growth test at 7 weeks. An evaluation of the ANOVA showed that treatment ($P = 0.0001$) and species ($P = 0.0001$) influenced aboveground biomass. There was also a treatment-species interaction effect on aboveground biomass ($P = 0.0001$). Plant aboveground biomass harvested from Blend 16 (fertile reference soil) was significantly higher than aboveground biomass harvested from blends containing dredged material from North Blakeley Sites 1, 2, and 3 ($P < 0.05$) (Tables 27, 28, 29, and 30). However, significantly higher plant biomass yields were obtained from blends made of dredged material from North Blakeley Site 1 than from blends made with dredged material from either North Blakeley Sites 2 or 3 (Figure 10). Figure 10 shows an example of ryegrass biomass harvested from Blends 3, 8, and 11 made of dredged material collected from North Blakeley Sites 1, 2, and 3, respectively. Ryegrass biomass from Blend 3, made of dredged material from Site 1, was significantly higher than ryegrass biomass harvested from Blends 8 and 11 from Sites 2 and 3, respectively. Duncan's comparison of means revealed no significant differences in ryegrass biomass yield among Blends 2, 3, and 5 made of dredged material from North Blakeley Site 1 ($P > 0.05$) (Table 27; Figures 11 and 12). Blends 7 and 8 containing dredged material from North Blakeley Site 2 were also similar in ryegrass biomass production (Table 28; Figures 13 and 14).

Figure 9. An overall view of the greenhouse plant growth test

Table 27
Aboveground Plant Biomass Harvested from North Blakeley Site 1 Plant Growth Test 1

	Tomato		Marigold	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	6.108	0.663a	9.29	1.15a
5	0.553	0.068b	0.00	0.00c
4	0.505	0.017b	0.43	0.03c
3	0.523	0.054b	0.58	0.04c
2	0.000	0.000b	0.00	0.00c
1	0.485	0.082b	0.56	0.14b
	Ryegrass		**Vinca**	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	11.14	1.84a	1.06	0.176a
5	5.66	0.89b	0.05	0.015b
4	3.77	0.45d	0.03	0.010b
3	4.58	0.77b	0.00	0.000b
2	5.18	0.80b	0.00	0.000b
1	4.21	0.66c	0.00	0.000b

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 28
Aboveground Plant Biomass Harvested from North Blakeley Site 2 Plant Growth Test 1

	Tomato		Marigold	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	6.11	0.66a	9.29	1.15a
8	0.18	0.03b	0.00	0.00b
7	0.38	0.05b	0.00	0.00b
6	0.51	0.08b	1.58	0.19b
	Ryegrass		**Vinca**	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	11.14	1.84a	1.06	0.18a
8	3.01	0.39b	0.00	0.00a
7	2.90	0.43b	0.00	0.00a
6	1.64	0.26b	0.00	0.00a

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 29
Aboveground Plant Biomass Harvested from North Blakeley Site 3 Plant Growth Test 1

	Tomato		Marigold	
Blend	Fresh Weight, g	Dry Weight, g	Fresh Weight, g	Dry Weight, g
16 (reference soil)	6.11	0.663a	9.29	1.15a
11	0.09	0.024b	0.00	0.00b
10	0.04	0.007b	0.00	0.00b
9	0.05	0.018b	0.00	0.00b
	Ryegrass		**Vinca**	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	11.14	1.84a	1.06	0.18a
11	1.03	0.16b	0.00	0.00b
10	0.04	0.03c	0.00	0.00b
9	0.16	0.05c	0.00	0.00b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 30
Aboveground Plant Biomass Harvested from North Blakeley Site 3 Plant Growth Test 1, Without N-Viro[1]

	Tomato		Marigold	
Blend	Fresh Weight, g	Dry Weight, g	Fresh Weight, g	Dry Weight, g
16 (reference soil)	6.11	0.663a	9.29	1.152a
15	0.12	0.027b	0.00	0.00b
14	0.03	0.008c	0.00	0.00b
13	0.12	0.022b	0.00	0.00b
12	0.39	0.031b	0.00	0.00b
	Ryegrass		**Vinca**	
Blend	**Fresh Weight, g**	**Dry Weight, g**	**Fresh Weight, g**	**Dry Weight, g**
16 (reference soil)	11.14	1.837a	1.06	0.18a
15	0.888	0.106b	0.00	0.00b
14	1.275	0.204b	0.00	0.00b
13	0.405	0.085b	0.00	0.00b
12	0.335	0.084b	0.00	0.00b

Notes: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).
[1] Only cellulose, no N-Viro biosolids, added to dredged material collected from North Blakeley Site 3

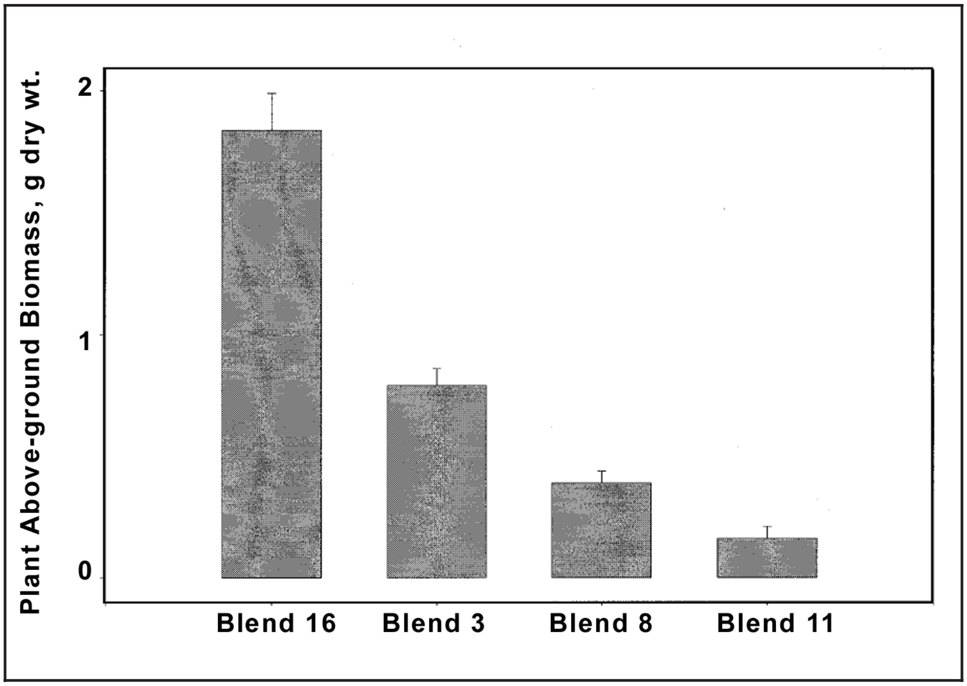

Figure 10. Ryegrass biomass harvested from Blends (l to r) 3, 8, and 11 prepared with dredged material from Mobile North Blakeley Sites 1, 2, and 3, respectively, at 7 weeks

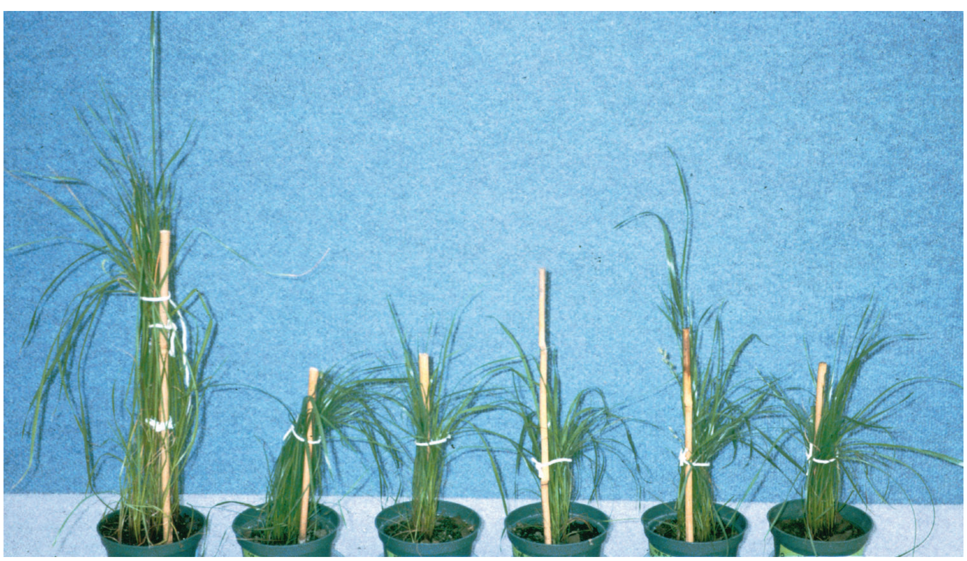

Figure 11. Ryegrass plants growing in blends prepared with dredged material from Mobile North Blakeley Site 1, at 7 weeks (l to r, Blends 16, 5, 4, 3, 2, and 1)

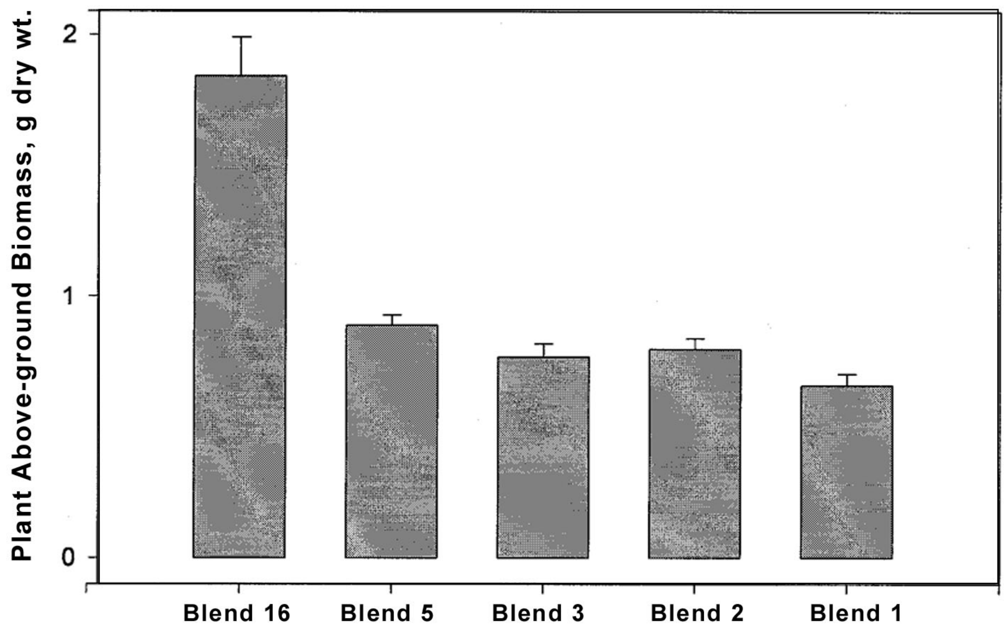

Figure 12. Ryegrass biomass harvested from blends prepared with dredged material from Mobile North Blakeley Site 1

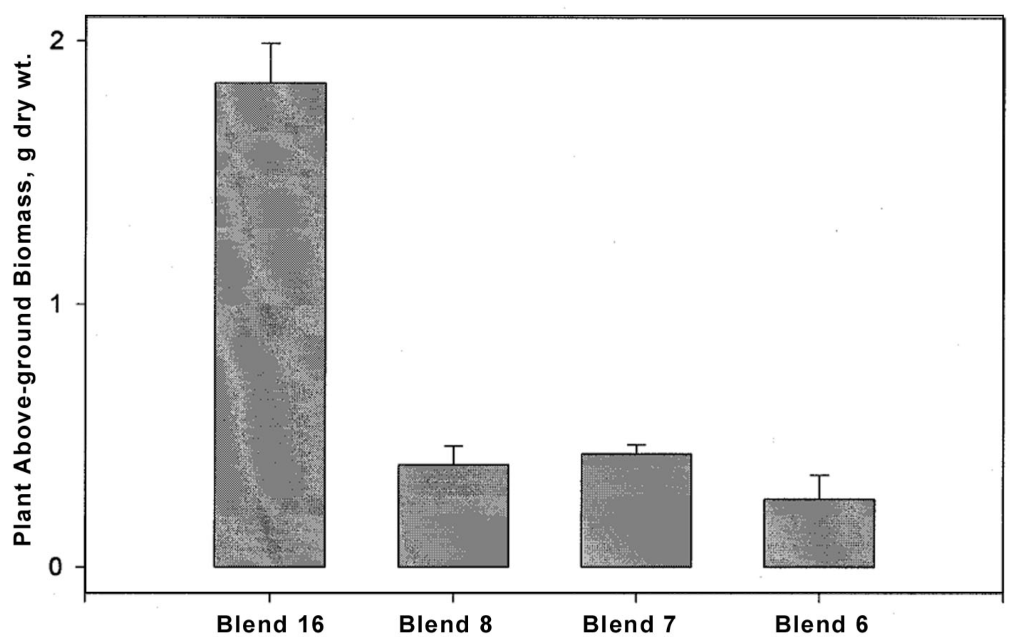

Figure 13. Ryegrass biomass harvested from blends prepared with dredged material from Mobile North Blakeley Site 2

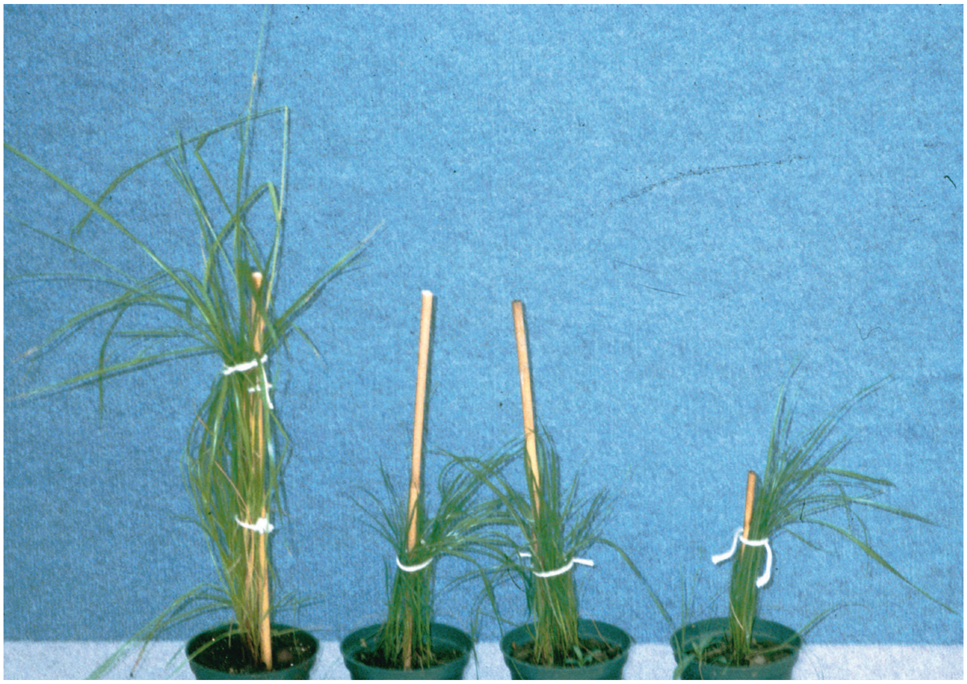

Figure 14. Ryegrass plants growing in blends prepared with dredged material from Mobile North Blakeley Site 2, at 7 weeks (l to r, Blends 16, 8, 7, and 6)

A comparison of aboveground biomass harvested from blends containing dredged material from North Blakeley Site 3 with and without N-Viro biosolids showed no significant difference in plant biomass yield (Figure 15; Tables 29 and 30). This suggests that the additional N-Viro biosolids did not supply sufficient nutrients to enhance plant growth or that the cellulose A,

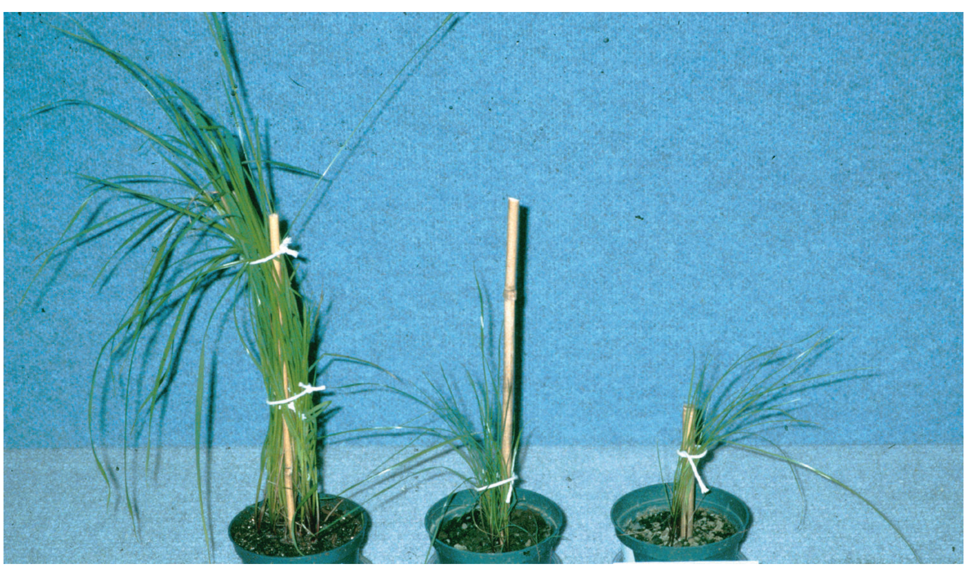

Figure 15. Ryegrass plants growing in blends prepared with dredged material from North Blakeley Site 3, at 7 weeks (l to r, Blends 16 and 11 (with N-Viro biosolids) and 15 (without N-Viro biosolids))

which was high in Na, masked the effect of the N-Viro biosolids. The addition of Miracle Gro™ (13N-13P-13K) to the blends appeared to have corrected many of the symptoms by increasing the blends' fertility.

The addition of cellulose A as an ingredient may have elevated the level of exchangeable Na in the blends. Elevated levels of exchangeable Na in the soil can affect plant productivity by causing poor soil aeration and low water availability to plant roots (Lee et al. 1985). In addition, elevated levels of Na may also block the absorption of water and essential nutrients, which will lead to nutrient deficiency and poor growth.

Visual observations of leaf color, size, and shape and total aboveground biomass were used to evaluate the influence of the different North Blakeley manufactured soil blends on plant growth. Visual observations, during the first 3 weeks revealed differences in leaf color, size, and shape between plants growing in the various manufactured soil blends and plants growing in the fertile reference soil. All plant species grew less vigorously in the manufactured soil blends than in the reference soil. For example, tomato plants developed a purple coloring on the leaf petioles and veins caused by anthocyanin formation. This response to phosphorus deficiency was also observed on the stems. There were also necrotic areas on the leaves and petioles, which is also a phosphorus deficiency symptom. Ryegrass did not show anthocyanin and chlorotic conditions, but there was a general overall appearance of stunted growth, but not as prevalent as in the tomato, vinca, and marigold plants. This suggests that ryegrass may be less sensitive to nutrient deficiency than tomato, vinca, and marigold. During week 4, Miracle Gro™ was added daily for one week to all of the North Blakeley blends to increase their fertility. At the end of 7 weeks, the addition of nutrients to the blends appeared to have eliminated many of the symptoms ascribed to nutrient deficiency.

North Blakeley Screening Test 2

Data from blends comprised of dredged material from North Blakeley Site 1 indicated that only treatment influenced aboveground biomass ($P = 0.0001$). Plant aboveground biomass harvested from Blend 11 (fertile reference soil) was significantly higher than aboveground biomass harvested from blends made of North Blakeley Site 1 dredged material, cellulose, and N-Viro biosolids and amended with calcium (Tables 31, 32, and 33). Duncan's comparison of means revealed no differences in plant aboveground biomass between Blends 6 and 10 consisting of dredged material from North Blakeley Site 1 and amended with calcium at rates of 5 and 10 tons/acre, respectively (Tables 31, 32, and 33; Figures 16, 17, and 18). Aboveground biomass obtained from Blends 6 and 10 was significantly higher than that from Blends 2 and 9, with no calcium and calcium applied at a rate of 10 tons/acre, respectively (Tables 31, 32, and 33; Figures 16, 17, and 18). The results indicate the need for increasing Ca with increasing cellulose in the blend (Tables 31, 32, and 33).

Table 31
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 1 Test 2, No Calcium

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
11 (reference soil)	9.46	2.31a
4	0.003	0.003c
3	0.00	0.00c
2	4.24	0.63b
1	0.26	0.09c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 32
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 1 Test 2, Plus Calcium

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
11 (reference soil)	9.46	2,31a
7	0.00	0.00c
6	5.70	0.89b
5	0.24	0.05c
1	0.26	0.09c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 33
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 1 Test 2, Plus 2x Calcium in Blends 5, 6, and 7

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
11 (reference soil)	9.46	2.31a
10	7.22	1.24b
9	3.69	0.63c
8	0.00	0.00d
1	0.26	0.09d

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Visual observations of leaf color, size, and shape and aboveground biomass were used to evaluate the productivity of the various manufactured topsoil blends. Visual observations during the first 3 weeks revealed that all seeds in the various blends germinated slower and generally grew less vigorously in the manufactured topsoil blends than plants in the reference soil. After week 4, leaf color, size, and shape revealed similarities between ryegrass plants growing in Blends 6 and 10 and ryegrass plants growing in Blend 11. At the end of 7 weeks, plants growing in Blends 2 and 9 looked healthy and were similar in appearance to plants growing in Blends 6, 10, and 11 (Tables 31, 32, and 33).

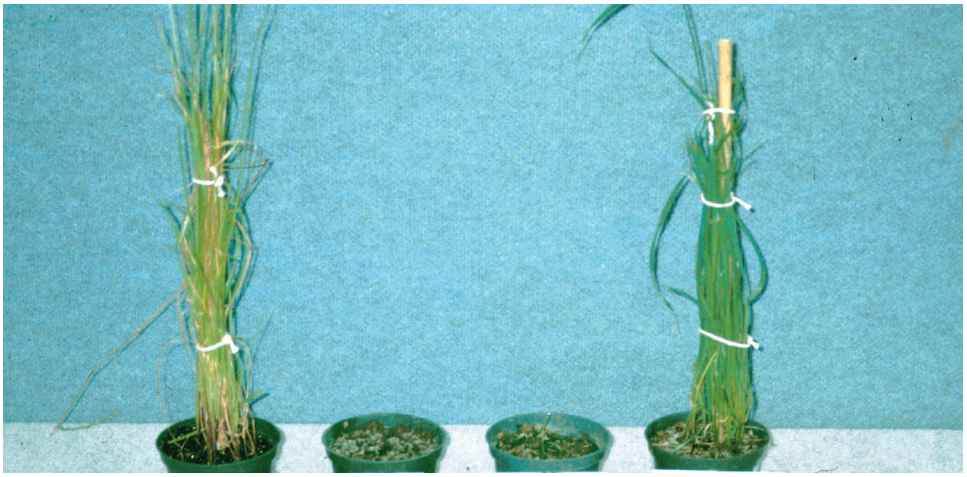

Figure 16. Ryegrass plants growing in Blends 11, 4, 7, and 10 prepared with dredged material from North Blakeley Site 1 and amended with calcium, at 7 weeks (l to r, Blends 11, 4, 7, and 10)

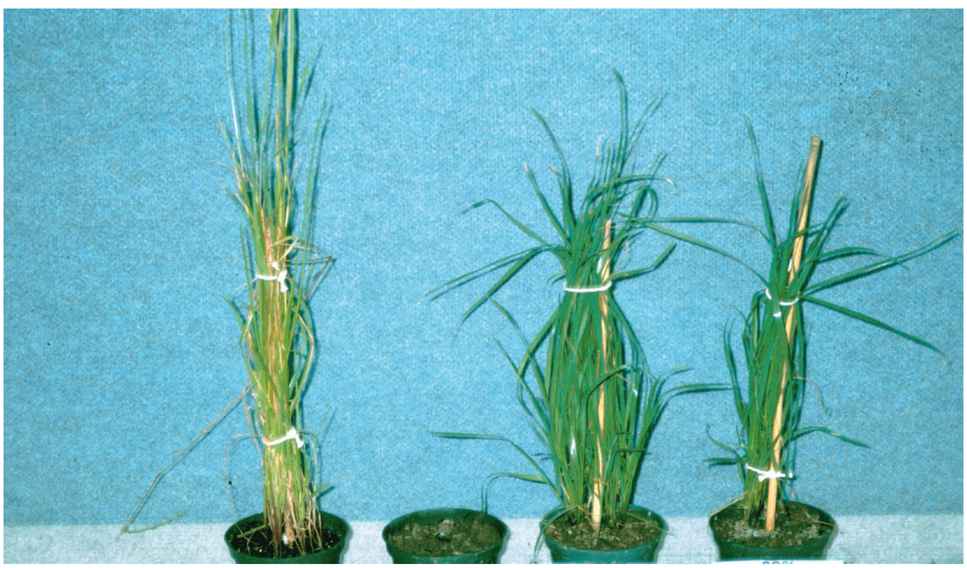

Figure 17. Ryegrass plants growing in Blends 11, 3, 6, and 9 prepared with dredged material from North Blakeley Site 1 and amended with calcium, at 7 weeks (l to r, Blends 11, 3, 6, and 9)

Figure 18. Ryegrass plants growing in Blends 11, 2, 5, and 8 prepared with dredged material from North Blakeley Site 1 and amended with calcium, at 7 weeks (l to r, Blends 11, 2, 5, and 8)

North Blakeley Screening Test 3

Aboveground biomass yields from North Blakeley Screening Test 3 are shown in Tables 34, 35, and 36. Poor plant growth occurred in blends made of dredged material from North Blakeley Sites 1, 2, and 3. However, highest aboveground biomass yields were obtained from Blend 8 (Table 33). Aboveground biomass from North Blakeley Sites 1, 2, and 3, dredged material blends with cellulose and N-Viro biosolids as ingredients, was significantly less than aboveground biomass obtained from Blend 13 (fertile reference soil) (Figures 19, 20, and 21).

Table 34
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 1 Test 3

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	9.46	2.31a
4	0.00	0.00b
3	0.40	0.11b
2	0.00	0.00b
1	0.26	0.09b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 35
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 2 Test 3

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	9.46	2.31a
8	1.10	0.27b
7	0.24	0.05c
7	0.00	0.00c
5	0.00	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Table 36
Aboveground Plant Biomass Harvested from Mobile North Blakeley Site 3 Test 3

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	9.46	2.31a
12	0.15	0.03b
11	0.24	0.01b
10	0.00	0.00b
9	0.20	0.003b

Note: Different letters indicate that values among blends and within species are significantly different at P < 0.05 (Duncan's multiple range test).

Figure 19. Ryegrass plants growing in blends prepared with dredged material from North Blakeley Site 1 Test 3, at 7 weeks (l to r, Blends 13, 4, 3, 2, and 1)

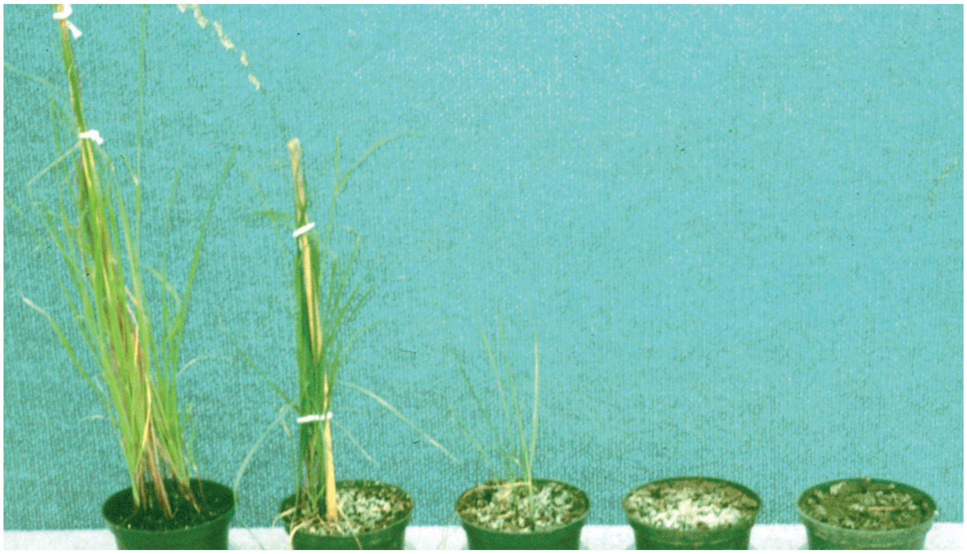

Figure 20. Ryegrass plants growing in blends prepared with dredged material from North Blakeley Site 2 Test 3, at 7 weeks (l to r, Blends 13, 8, 7, 6, and 5)

Figure 21. Ryegrass plants growing in blends prepared with dredged material from North Blakeley Site 3 Test 3, at 7 weeks (l to r, Blends 13, 12, 11, 10, and 9)

The poor growth observed in the blends may be ascribed to the addition of cellulose B as an ingredient, which may have elevated the level of carbon in the blends. Elevated levels of carbon in the blends could have changed the optimal carbon (C) to nitrogen (N) ratio (4:1). If the C:N ratio is high in the blends, microorganisms (bacteria) will use up the available nitrogen before it becomes bioavailable to plants, resulting in nitrogen deficiency and poor plant growth.

Visual observation revealed that ryegrass plants that grew in the various blends did not look as healthy as plants growing in Blend 13. Generally, ryegrass growing in the manufactured topsoil blends showed nutrient deficiency symptoms (e.g., stunted growth, chlorosis). Additional nitrogen fertilizer should correct these symptoms.

South Blakeley screening tests

Data on ryegrass aboveground biomass harvested from the various blends comprised of South Blakeley Sites 1, 2, and 3 dredged material, cellulose B, and N-Viro biosolids are presented in Tables 37, 38, and 39, respectively. Ryegrass grew only in blends that had the lowest amount of dredged material from each site (e.g., Blends 4, 8, and 12). Although there was some growth, ryegrass growth was extremely poor in all blends (Figure 22). Ryegrass aboveground biomass from Blend 13 (fertile reference soil) was significantly higher than ryegrass biomass from the various blends with dredged material from South Blakeley Sites 1, 2, and 3, cellulose B, and N-Viro biosolids as ingredients.

Ryegrass plants growing in the various blends showed stunted growth and nutrient deficiency symptoms. Ryegrass leaves were not as green in color nor as broad as leaves of plants growing in Blend 13. Ryegrass plants did not look as healthy as plants growing in the fertile reference soil. These test results indicate that South Blakeley dredged material can be used as a manufactured topsoil product if the dredged material is limited to the amount indicated in Blends 4, 8, and 12.

Table 37
Aboveground Plant Biomass Harvested from Mobile South Blakeley Site 1 Test

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	12.82a	2.96a
4	0.76b	0.20b
3	0.00c	0.00c
2	0.00c	0.00c
1	0.00c	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 38
Aboveground Plant Biomass Harvested from Mobile South Blakeley Site 2 Test

Blend	Ryegrass	
	Fresh Weight, g	**Dry Weight, g**
13 (reference soil)	12.82a	2.96a
8	1.10b	0.26b
7	0.00c	0.00c
6	0.00c	0.00c
5	0.00c	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 39
Aboveground Plant Biomass Harvested from Mobile South Blakeley Site 3 Test

Blend	Ryegrass	
	Fresh Weight, g	**Dry Weight, g**
13 (reference soil)	12.82a	2.96a
12	0.36b	0.11b
11	0.37b	0.13b
10	0.00c	0.00c
9	0.00c	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

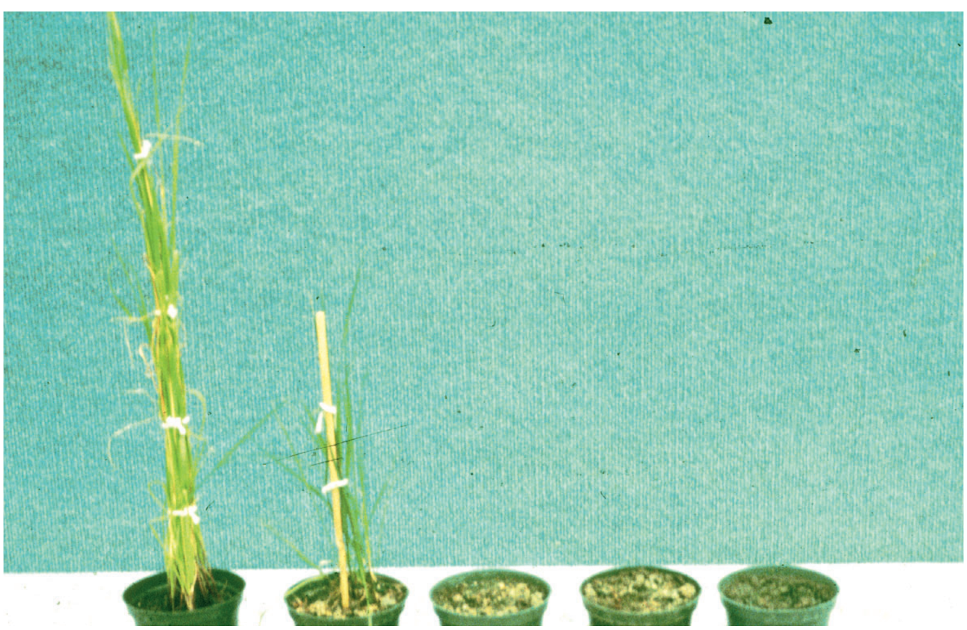

Figure 22. Ryegrass plants growing in blends prepared with dredged material from South Blakeley Site 1, at 7 weeks (l to r, Blends 13, 4, 3, 2, and 1)

North Pinto screening tests

Ryegrass aboveground biomass data from North Pinto Sites 1, 2, and 3 screening tests are presented in Tables 40, 41, and 42, respectively. Although there was some growth observed in the North Pinto blends, plant growth was extremely poor (Figure 23). Ryegrass aboveground biomass from the Blend 13 (fertile reference soil) was significantly higher than ryegrass biomass from the various blends made of dredged material from Mobile North Pinto Sites 1, 2, and 3.

Ryegrass plants growing in the various blends showed stunted growth and nutrient deficiency symptoms. Ryegrass leaves were not as green in color nor as broad as leaves of plants growing in Blend 13. Overall, ryegrass plants did not look as healthy as plants growing in the fertile reference soil. The results from screening tests indicated that productivity from blends made of dredged material from Mobile North Pinto CPF was very low, therefore, dredged material from North Pinto CPF probably should not be used as an ingredient in manufacturing a topsoil product. In order, to use dredged material from North Pinto CPF, further testing is needed to determine what additional amendments would improve the fertility of the dredged material.

Table 40
Aboveground Plant Biomass Harvested from Mobile North Pinto Site 1 Test

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	11.32a	2.23a
4	0.58b	0.17b
3	0.00c	0.00c
2	0.00c	0.00c
1	0.00c	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 41
Aboveground Plant Biomass Harvested from Mobile North Pinto Site 2 Test

	Ryegrass	
Blend	**Fresh Weight, g**	**Dry Weight, g**
13 (reference soil)	11.32a	2.23a
8	0.02b	0.01b
7	0.00b	0.00b
6	0.00b	0.00b
5	0.00b	0.00b

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

Table 42
Aboveground Plant Biomass Harvested from Mobile North Pinto Site 3 Test

Blend	Ryegrass	
	Fresh Weight, g	**Dry Weight, g**
13 (reference soil)	11.32a	2.23a
12	0.001c	0.0003c
11	0.02c	0.020b
10	0.00c	0.00c
9	0.00c	0.00c

Note: Different letters indicate that values among blends and within species are significantly different at $P < 0.05$ (Duncan's multiple range test).

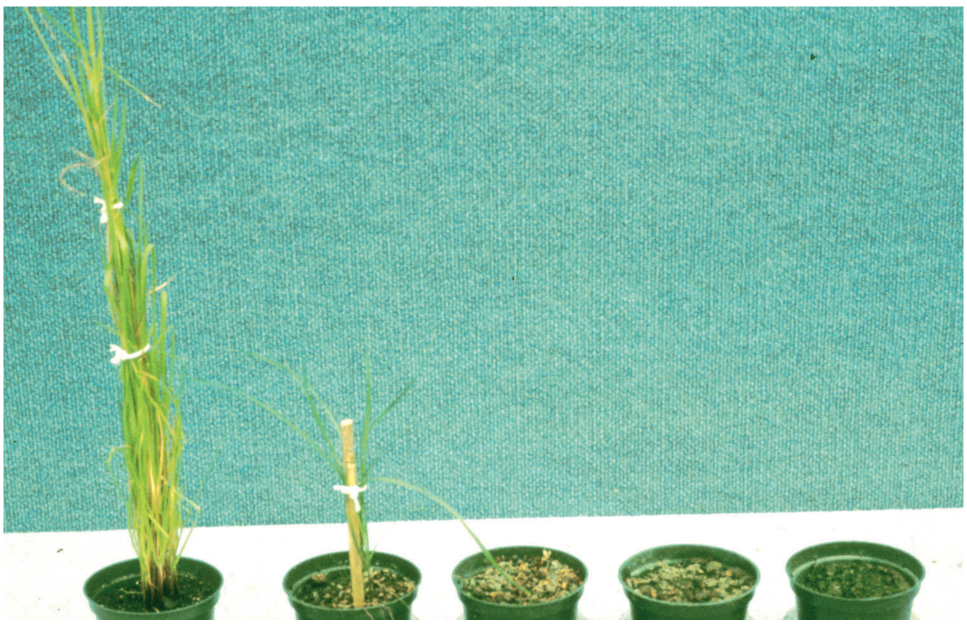

Figure 23. Ryegrass plants growing in blends prepared with dredged material from North Pinto Site 1, at 7 weeks (l to r, Blends 13, 4, 3, 2, and 1)

5 Conclusions and Recommendations

Conclusions

Results from Phase 1 bench-scale screening tests conducted at ERDC, Vicksburg, MS, showed that proprietary blends containing dredged material from North Blakeley Site 1 produced better plant growth than proprietary blends using dredged material from North Pinto and South Blakeley CPFs. There was no significant difference in aboveground biomass among unamended proprietary Blends 1, 2, 3, and 5 containing dredged material from North Blakeley Site 1. Plant growth was improved when Ca was added to blends with higher amounts of cellulose. Although plant growth was improved, there was no significant difference among unamended Blends 1, 2, 3, and 5 when compared with Blends 6 and 10 using North Blakeley Site 1 dredged material amended with calcium.

Salinity levels increased as the amount of cellulose A increased in the blends. The mean salinity levels of blends from North Blakeley Site 1 ranged from 2 to 7 parts per thousand (ppt); blends from North Blakeley Site 2 ranged from 2 to 9 ppt; and salinity level for blends from North Blakeley Site 3 ranged from 2 to 12 ppt. Salinity probably did not suppress plant growth, but lack of growth may be attributed to pH and nutrient deficiency in the dredged material.

Manufacturing topsoil products using dredged material from North Blakeley CPF looks very promising. However, if locally available cellulose A is used as an ingredient, additional Ca should be added as the amount of cellulose increases in the manufactured topsoil product. There may be a potential for manufacturing soil products from South Blakeley CPF if the amount of dredged material used is similar to proprietary Blends 4, 8, and 12. The dredged material from North Pinto CPF shows limited potential for manufacturing soil. Weeds were observed growing in the various manufactured topsoil blends. Therefore, weed control will be required so that desirable grasses and plants can become established.

Recommendations

It is recommended that proprietary Blends 1, 2, 3, or 5 containing dredged material from Mobile North Blakeley Site 1 be demonstrated in Phase 2. Phase 2, should be a pilot-scale field study using proprietary blends identified in Phase 1 (bench-scale screening tests). If sufficient information is obtained from Phase 1 tests, a commercialization plan may be developed, especially for uncontaminated materials, and additional phases may not be needed. Phase 3, a larger-scale demonstration may be needed to provide information on the economics of the manufactured topsoil technology including cost of material, transport, and equipment before full-scale application of this technology or commercialization of the recycled soil manufacturing technology. Superfund, mining, and landfill sites or a commercialization plan should be considered for a Phase 2 demonstration of Blends 1, 2, 3, or 5.

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14. ABSTRACT

Recycling of waste materials within the environment must be a serious national goal in order for the United States to manage its resources wisely. The U.S. Army Engineer Research and Development Center, Vicksburg, MS, has established Cooperative Research and Development Agreements to develop technology for the manufacture of topsoil using contaminated and uncontaminated sediment/dredged material, cellulose waste materials, and biosolids. The recycled soil manufacturing technology (RSMT) allowed the development of fertile topsoil that could be used in a beneficial, productive, and environmentally sound manner. In addition, the RSMT will provide an alternative to conventional disposal of the nation's waste/resource materials (e.g., in landfills or confined disposal facilities). Bench-scale screening tests (seed germination and plant growth) were used to evaluated the feasibility of using dredged material from Mobile, AL, confined disposal facilities (CDFs) to develop a fertile manufactured topsoil. Bench-scale screening tests included proprietary blends with a range of dredged material content from three CDFs (North Blakeley, South Blakeley, and North Pinto), a range of cellulose content, and animal derived biosolids.

15. SUBJECT TERMS

	Confined disposal facilities	Plant growth	Seed germination
Biosolids	Dredged material	Recycled soil manufacturing technology	
Cellulose	Manufactured topsoil	Screening tests	

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