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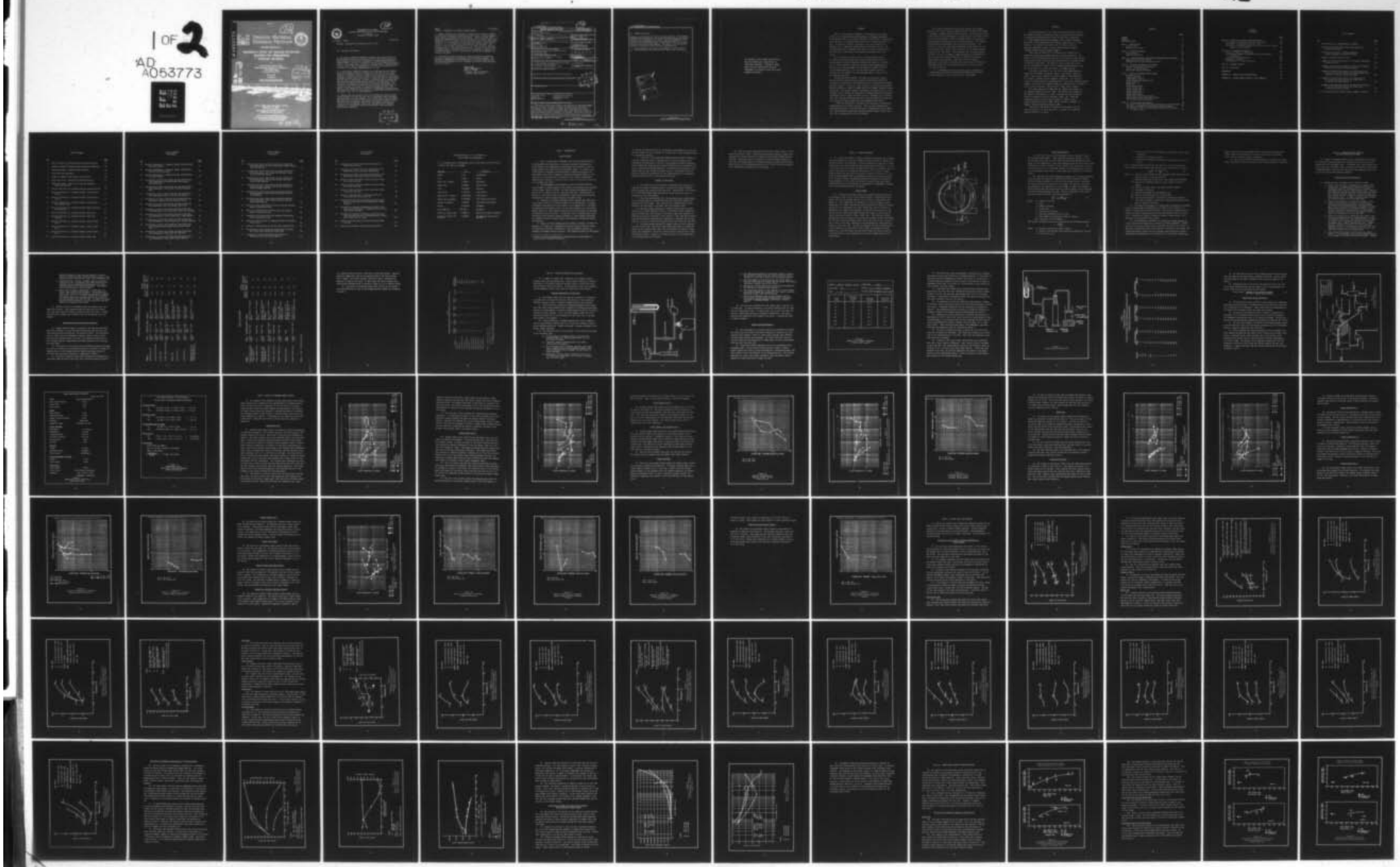

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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-5

FEASIBILITY STUDY OF VACUUM FILTRATION SYSTEMS FOR DEWATERING DREDGED MATERIAL

by

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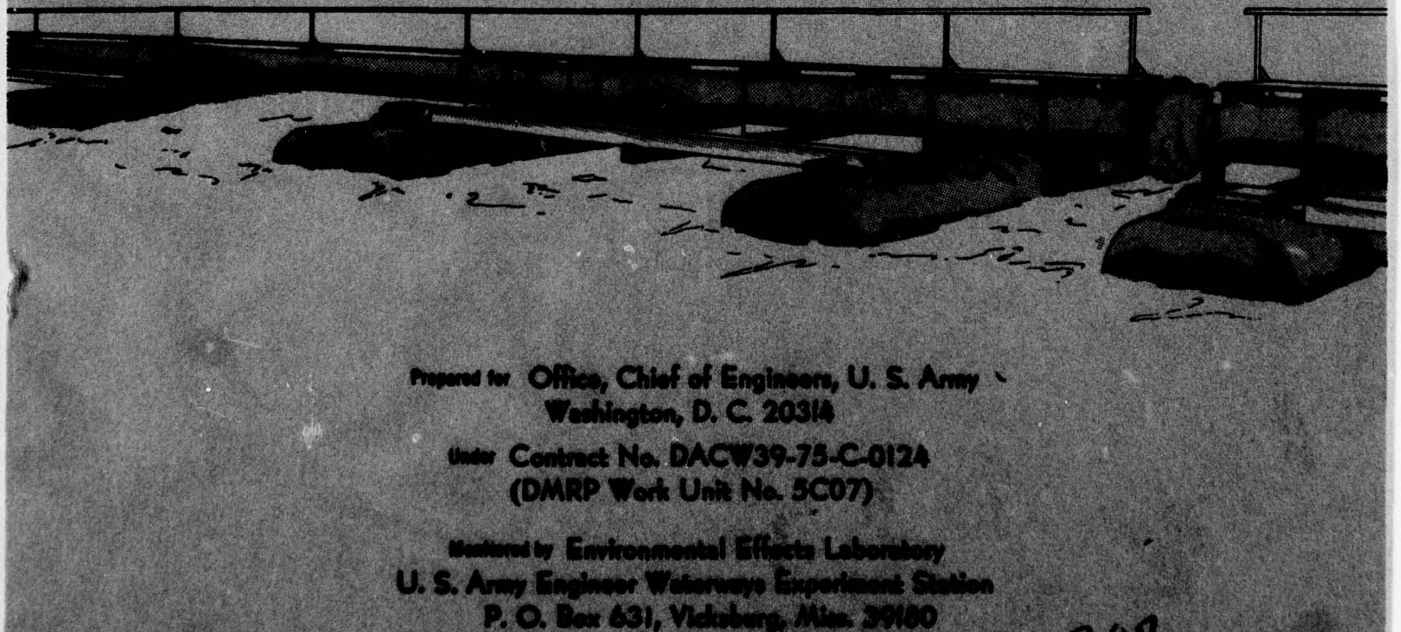
February 1978

Final Report



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UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

31 May 1978

SUBJECT: Transmittal of Technical Report D-78-5

TO: All Report Recipients

1. The report transmitted herewith represents the results of one research effort (work unit) initiated as part of Task 5C (Disposal Area Reuse Research) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 5C is included as part of the Disposal Operations Project of the DMRP, which, among other considerations, includes research into the various ways of improving the efficiency and acceptability of facilities for confining dredged material on land.

2. A particularly attractive concept for mitigating the land requirements for disposal sites is to increase the life expectancy of sites through the periodic removal of dredged material for use or disposal elsewhere. Optimally, the sites could be used indefinitely and be truly permanent disposal facilities; however, continuing needs for the dredged material must be identified. Moreover, procedures must be established for processing and/or rehandling the material, and mechanisms must be identified for marketing the material under known constraints. The laboratory investigation reported herein evaluated the feasibility of vacuum filtration as a means for dewatering dredged material, thus making it more manageable and attractive for subsequent productive use. The contracted effort was accomplished by Ryckman/Edgerley/Tomlinson and Associates, Inc., of St. Louis, Missouri.

3. Samples from five disposal areas representing both saline and nonsaline sediments and from one site (not a containment area) considered representative of in situ sediment to be dredged from a marine environment were used in laboratory and bench-scale vacuum filtration studies. Particle-size distribution, composition, and specific resistance to filtration were determined; filter leaf determinations to simulate operation of a continuous filter and bench-scale vacuum filtration studies were conducted.

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4. Samples collected were diluted to between 8 and 25 percent solids by weight and chemically conditioned for the various testing procedures. Seven chemical coagulants were investigated. Results obtained indicated that dredged material from the different sites could be effectively dewatered to 45 to 60 percent solids (depending on the site) using lime dosages of 7 to 10 percent of the solids in the sample. Filter yields of up to 9 lb of solids/ft^2/hr (43.9 kg/m^2/hr) were observed. The quality of the filtrate was generally in the range of 500 to 1500 mg/ℓ suspended solids. The technical feasibility of using vacuum filtration in dredged material disposal activities was established. However, the economic feasibility is still questionable and must be determined on a case-by-case basis.

5. The results of this study may be used for background information and general guidelines for designing vacuum filtration systems. More specific recommendations on the feasibility of vacuum filtration and more specific guidelines will be contained in the forthcoming synthesis report for Task 5C.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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A laboratory study was performed of the feasibility of dewatering dredged material by vacuum filtration. Characterizations were made for samples from six disposal areas: Penns Neck Spillway, Apalachicola Bay, Mobile Bay, Toledo Harbor, Craney Island, and Browns Lake. Investigations of particle size distribution, specific resistance to filtration, filter leaf studies, and bench-scale vacuum filtration studies were conducted. The samples collected were diluted to between 8 and 25 percent solids by weight and

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chemically conditioned for the various testing procedures. Seven chemical coagulants were investigated. The results attained indicated that dredged material from the different sites could be effectively dewatered to 45 to 60 percent solids (depending on the site) using lime dosages of 7 to 10 percent of the solids in the sample. Filter yields of up to 9.0 lb solids per square foot per hour were observed. The quality of the filtrate was generally in the range of 500 to 1500 mg/ℓ suspended solids.

Field studies of a pilot plant are recommended to further evaluate the operating parameters of vacuum filtration under actual conditions.

SUMMARY

The U. S. Army Corps of Engineers, in carrying out its responsibility for the development and maintenance of navigable waterways in the United States, is presently faced with the problem of transporting and disposing of an estimated 400 million yd^3 of dredged material each year. In addition, suitable containment areas, near enough to the dredging sites to minimize transportation and disposal costs but in locations which have a minimum direct effect on other important water-use activities in the areas, are becoming increasingly scarce and costly.

The possibility of reusing new or existing disposal areas as collection and processing sites, where valuable portions of the dredged material would be separated and made available for productive use, is being studied as a means of minimizing the dredged material disposal area land requirement and recovering all usable fractions of the dredged material. Such a reuse scheme, however, must be operated so as to minimize the environmental impact of the recovery and disposal operation.

Recognizing these problems, the Corps has initiated a comprehensive research program directed towards providing more definitive information concerning the environmental effects of dredging and dredged material disposal. A portion of this program is directed towards determining techniques to reuse or extend the life of dredged material containment areas. One possible method of extending the useable life of a containment area is through the dewatering of dredged material by mechanical techniques, such as vacuum filtration prior to placement in the containment area, thereby eliminating the need to provide additional volume for the retention of water present with the dredged material slurry.

A study was undertaken to determine the feasibility of dewatering dredged material by vacuum filtration. The study plan provided for a wide-range evaluation of vacuum filtration of dredged material by laboratory and bench-scale simulations including Buchner funnel, filter leaf (0.1 ft^2), and bench-scale (3.0 ft^2) studies.

The results obtained from this study indicate that dredged material, with solids contents ranging from 8 to 20 percent by weight, is amenable to dewatering by vacuum filtration. Filter yields as high as 9.0 $lb/ft^2/hr$ were obtainable at a lime dosage of 10 percent of the total dry solids weight. Filtrate suspended solids concentrations produced were consistently as low as 500 to 1000 mg/ℓ. The filtrate would normally be discharged into the receiving waterway. The majority of the sites investigated exhibited large portions of very fine particle sizes (greater than 70 percent of the sample passing through the No. 200 sieve). This indicates that vacuum filtration would be a part of a treatment scheme including fractionalization of the slurry by grit removal techniques or vibratory screening to remove larger particle sizes. This would yield an economic advantage to the system by providing for the recovery of by-products (sand and gravel) and by reducing the volume of the slurry prior to vacuum filtration.

It is recommended that a pilot plant study be conducted at a dredged material disposal site where operating conditions and further evaluation of filter yields can be investigated.

PREFACE

The work described in this report was performed under Contract No. DACW39-75-C-0124, "Feasibility Study of Vacuum Filtration Systems for Dewatering Dredged Material" dated 30 June 1975, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and Ryckman/Edgerley/Tomlinson & Associates, St. Louis, Missouri. The research was sponsored by the Office, Chief of Engineers (DAEN-CWO-M) under the civil works research program, "Dredged Material Research Program (DMRP)."

This study was conducted to investigate the feasibility of mechanically dewatering dredged material by vacuum filtration. The emphasis of the investigation was on the filter yields and the filtrate quality which could be expected upon dewatering with an optimum dosage of chemical conditioners. The impact of such a study lies in the area of increasing the useful life of dredged material disposal sites and the recovery of a useful by-product of dredged material.

Principal investigators for this study from Ryckman/Edgerley/Tomlinson & Associates include Mr. Bruce W. Long and Mr. Dominic J. Grana. Other persons involved in certain phases of this study were Mr. Richard J. Edwards and Mr. Thomas M. Lachajczyk. Mr. Gregory T. Griffin performed laboratory determinations on the various dredged material samples. This study was conducted under the supervision of Dr. James W. Irvin, Project Principal, and Mr. Bruce W. Long, Project Manager.

This study forms part of DMRP Task 5C, Disposal Area Reuse, of the Disposal Operations Project (DOP). The contract was managed by Mr. Norman R. Francingues Jr., Chief, Treatment Processes Research Branch, Environmental Effects Laboratory (EEL), WES. Other EEL personnel involved in this study included Mr. Thomas K. Moore, Disposal Operations Project, DMRP, and Mr. Charles C. Calhoun, Jr., Manager, Disposal Operations Project, DMRP.

Directors of WES during the conduct and preparation of this report were COLS G. H. Hilt, CE, and J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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Conversion Factors, U. S. Customary To Metric Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
square feet	0.092903	square meters
acres	0.4046856	hectares
cubic yards	0.7645549	cubic meters
gallons (U.S. liquid)	0.003785412	cubic meters
cubic feet per minute	0.02831685	cubic meters per minute
gallons per minute	0.003785	cubic meters per minute
pounds	0.4535924	kilograms
tons (2000 lb)	907.1847	kilograms
pounds per square inch	0.6894757	newtons per square centimeter
pounds per square feet per hour	4.882428	kilograms per square meter per hour

PART 1: INTRODUCTION

Scope of Work

1. The U.S. Army Corps of Engineers (CE) has been responsible for the development and maintenance of navigable waterways throughout the United States since Congressional authorization was received in 1824 to remove sandbars and snags from major navigable waters. At present, over 19,000 miles* of waterways and approximately 1,000 harbor projects are maintained by the Corps in support of American waterborne commerce. The importance of these projects is indicated by the volume of waterborne commerce which exceeded 1.5 billion tons in 1970, an 85 percent increase in total tonnage since 1950.[1]

2. The development and maintenance of these waterways generates large volumes of dredged material which require transportation and disposal. At the present level of activity, the Corps dredges approximately 400 million yd^3 of sediment from U.S. waterways each year. Approximately 60 percent of this total volume is discharged to open waters with 25 percent discharged to confined dredged material containment areas.

3. Disposal in confined containment areas requires some 7000 acres of new land per year at an average annual cost of $170 million. Suitable containment areas which are close enough to the dredging sites to minimize transportation and disposal costs, and are also situated so as to minimize adverse effects on other important local water-use activities, are becoming increasingly scarce and costly. In addition, due to continued rapid industrialization and population growth contiguous to some navigable waterways, the dredged material from many harbors and navigation channels has become contaminated.

4. Because of these dredged material disposal problems, the Corps of Engineers is conducting a comprehensive research program directed towards providing more definitive information on the environmental effects of dredging and dredged material disposal. This program includes the development

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* A table of factors converting U.S. customary units of measurement to metric units is presented on page 12.

of disposal alternatives which are technically, environmentally, and economically feasible and will consider the alternative of using dredged material as a manageable resource.

5. A portion of this extensive dredged material research program is directed towards the reuse or extended use of confined disposal areas. Preliminary investigations by the U.S. Army Engineer Waterways Experiment Station (WES) have indicated that vacuum filtration may be potentially useful in concentrating dredged material.[2] Concentration by dewatering techniques would not only extend the useful life of a containment area, but would also improve the properties of the dredged material for subsequent handling and application to some beneficial purpose.

Purpose of the Study

6. The objective of this study was to determine the feasibility of reducing the volume of dredged material contained in confined disposal areas by dewatering through vacuum filtration. Additionally, the feasibility of filtering hopper dredge overflow by vacuum filtration prior to discharge was also investigated.

7. The study plan provided for a broad evaluation of vacuum filtration of dredged material through laboratory and bench-scale simulations consisting of three stages. Each stage was more sophisticated and considered a narrower range of variables than the preceding stage.

8. The first stage consisted of a Buchner funnel study of vacuum filtration of dredged material slurries. The Buchner funnel studies were used to evaluate the effectiveness of different coagulating chemicals in reducing the specific resistance of the slurries. More than 500 individual runs were made using seven different coagulants or combinations of coagulants for a total of 16 different samples during this portion of the study.

9. The second stage consisted of studies using a 0.1-ft^2 effective area test filter leaf. The filter leaf studies were used to confirm the results of the Buchner funnel tests and to determine the effects of drum speed, drum submergence, and filter cloth porosity on vacuum filter yield and filtrate quality. Based on a favorable outcome of the second stage, a third stage study was initiated.

10. The third stage consisted of bench-scale studies using a 3.0-ft^2 rotary vacuum belt filter. The bench-scale studies permitted larger scale evaluation of vacuum filtration as applied to dewatering dredged material slurries. During the study, the effects of those variables observed in the first two stages could be confirmed and scale-up problems and criteria which could not be determined using the 0.1-ft^2 filter leaf were evaluated on a continuously operating piece of equipment.

PART II: VACUUM FILTRATION

11. Vacuum filtration of sludges resulting from primary and secondary sewage treatment and of process industry slurries has been in common use in the United States for many years. Vacuum filtration was selected for these applications over other mechanical dewatering operations because: 1) it is a continuous process with self-cleaning filter media, and therefore does not require down time for cleaning and pretreating; 2) it effects a higher solids capture than many other alternatives, therefore resulting in a filtrate of higher quality than corresponding streams from other operations; 3) it is more efficient in dewatering difficult biological and industrial waste sludges; 4) it is a more cost-effective solution than many other alternatives; and 5) it has proven its performance in thousands of applications across the United States and Europe.

Filter Design

12. A rotary-drum vacuum filter is a cylindrical drum covered with filter media, cloth or wire, on the outside surface. Beneath the filter fabric, the drum is divided radially into a series of compartments (see Figure 1). Each compartment is connected by a series of pipes, called drainlines, to a common rotating valve which controls the amount of vacuum applied to each compartment as it goes through the cycle of filtration, dewatering, air drying, and discharge. During the filtration cycle, the filter drum is continuously passed through the sludge or slurry where it picks up solids by vacuum to form a filter cake. The filtrate is drawn through the cloth by vacuum and the solids are retained on the filter media. As the filter cake thus formed rotates out of the filter trough, vacuum is still drawn on the cake, resulting in the dewatering and subsequent air drying of the filter cake. The cake is separated from the filter media by a doctor knife or, in the case of a belt filter, by passing the filter media over a roll with sharp curvature which causes the cake to drop off. The filter media is then resubmerged in the filter trough and the cycle begins again.

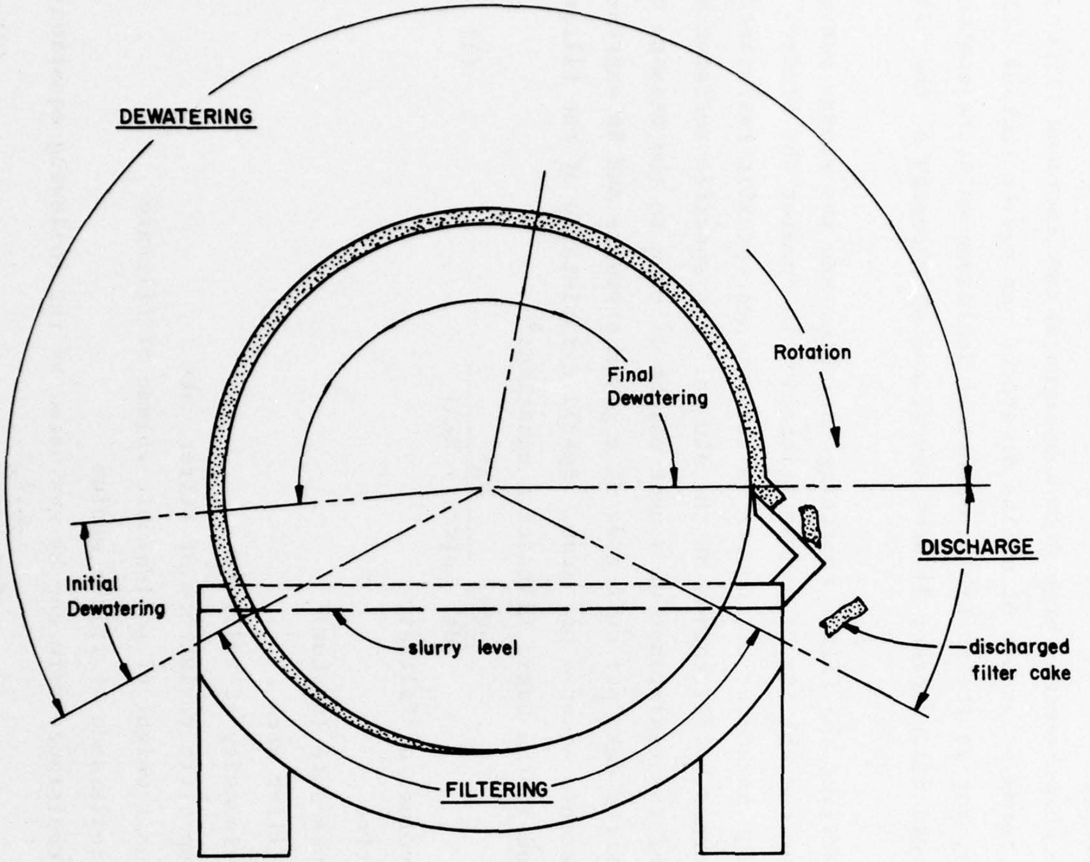


Figure 1

Basic Principle of Continuous
Rotary Vacuum Filtration^3

Operating Variables

13. Numerous filter operating parameters can be changed to affect the filtration performance. These operating variables include: 1) the vacuum drawn during both the cake formation and dewatering phases; 2) the degree of drum submergence - high drum submergences may increase filter yield (expressed in terms of pounds of solids dewatered per square foot of filter area per hour), but at the possible expense of increased moisture content in the discharged filter cake; 3) drum speed; and 4) porosity of the filter medium.

14. Overlying the filter operating variables are the sludge variables which determine the ability of vacuum filtration to dewater the sludge. The basic sludge parameter of concern is the average specific resistance of the cake formed by filtration of the sludge. The specific resistance is a measure of the resistance of a unit weight of cake to the passage of liquid through the cake per unit area at a given pressure and is expressed in terms of seconds squared per gram. Specific resistance of the filter cake is defined in the basic filtration equation:[4]

$$\frac{dV}{dt} = \frac{PA^2}{\mu(rcV + R_mA)} \qquad (1)$$

where: V = volume of filtrate

t = time

P = pressure (vacuum)

A = filter area

μ = viscosity of filtrate

r = specific resistance of filter cake

c = unit weight of solids/unit volume of filtrate

R_m = resistance of filter medium

The specific resistance term can be evaluated by the following equation:

$$r = \frac{2PA^2m}{\mu c} \qquad (2)$$

where: r = specific resistance of cake in sec^2/g

P = pressure drop through filter medium and sludge cake in g/cm^2

A = filter area in cm^2

m = slope of t/V vs. V plot (determined from Buchner funnel study) in sec/mℓ^2

μ = viscosity of filtrate in poise

c = weight of dry sludge cake solids per unit volume of filtrate in g/cc

For a constant pressure filtration, the yield of a rotary vacuum filter can be related to the specific resistance of the filter cake as follows:[5]

$$Y = \left(\frac{2P}{\mu} \cdot \frac{W}{r} \cdot \frac{F_f}{T_R} \right)^{1/2} F_C \qquad (3)$$

where: Y = yield of filter in mass of dry suspended solids formed per unit time per unit of filter medium area

P = pressure difference across filter cake during cake formation

W = mass of dry suspended solids per unit volume of liquid in sludge

F_f = fraction of total filter area used for cake formation

μ = viscosity of filtrate

r = specific resistance of cake measured at P

T_R = time for one revolution of the filter drum

F_C = cake correction factor: the ratio of the mass of liquid in unit mass of sludge to the mass of filtrate obtained when unit mass of sludge is filtered

15. The specific resistance of a sludge cake is therefore a principal factor in determining the amenability, in terms of filter yield, of a sludge to dewatering by vacuum filtration. The specific resistance can be reduced by adding coagulating and flocculating chemicals prior to filtration. A reduction in specific resistance results, theoretically, in an increase in the attainable filter yield.

16. Determining the feasibility of dewatering dredged material by vacuum filtration necessitates an evaluation of many parameters. Coagulation and flocculation studies must be performed to evaluate the effect of different conditioning agents on the specific resistance of the sludge cake. Conditioning agents reduce the forces between slurry particles, thereby permitting the agglomeration of the particles. If the proper conditioning

agent is used at the proper dosage levels, this particle agglomeration should result in larger particle sizes and a more porous, permeable filter cake with reduced specific resistance.

17. The effects of other operating variables including drum submergence, drum speed, filter cake porosity, and vacuum drawn must be assessed.

PART III: DREDGED MATERIAL SAMPLING AND CHARACTERIZATION PROGRAM

18. Samples of dredged material used in the laboratory and bench-scale vacuum filtration studies were collected from 13 sites at six CE dredged material containment areas. Containment areas, and sampling locations within each containment area, were selected to ensure a wide range of dredged material particle-size distribution and composition and to represent both saline and nonsaline sediments.

Sampling Locations and Methods

19. Dredged material containment areas sampled included:

a. Grassy Island and Penn #7 disposal sites, Maumee River, Toledo, Ohio. Dredged material deposited in these two containment areas is representative of a freshwater environment near a heavily industrialized area. Samples were collected from two locations within the Grassy Island site (hereafter called Toledo Site A and Toledo Site B) and from one location in Penn #7 (hereafter called Toledo Land Disposal Site). A sample of hopper dredge overflow was collected onboard the CE Hoffman dredge.

b. Craney Island disposal area, Norfolk, Virginia. This 2500-acre disposal site, located at the confluence of the James River and Chesapeake Bay, receives dredged material from the Norfolk Channel, Chesapeake Bay, James River, and all harbors in the general vicinity. Due to the wide variation in characteristics of the dredged material contained in the site, four sampling locations within the containment area were selected.

c. Penns Neck disposal area, Pennsville, New Jersey. This 397-acre area receives heavily silted material from the Philadelphia Harbor area. This dredged material is high in organics and is considered typical of an estuarine environment and a highly industrialized area. Dredged material is pumped to the west side of the site and discharge flows out a sluice gate on the east side. Two sampling locations, one on the west and one on the east side, were selected in this disposal area.

d. Lower Polecat Bay disposal area, Polecat Bay, Mobile, Alabama. This containment area receives dredged material from a highly industrialized marine environment. Dredged material collected at the site was expected to contain mostly fine-grain sediment with high organic content. One sampling location was selected within this containment area.

e. Apalachicola Bay, Florida. Sediment samples from Apalachicola Bay (not a containment area) were collected by CE personnel and are considered representative of in situ sediment samples from a marine environment. The samples were collected using a Peterson dredge.

f. Browns Lake, Vicksburg, Mississippi. Browns Lake is a 20-acre lake located on WES property. During March and April, 1976, this lake was dredged to increase the average depth from 3 to 9 ft. A total of 235,000 yd^3 of sediment was removed during this dredging operation and placed in two land disposal sites near the lake. A sample of dredged material from the disposal sites was collected by WES personnel for inclusion in this study.

20. Samples collected at dredged material containment areas were taken with a shovel. Where deposited material had dried, the surface crust was broken and moist samples collected beneath the crust. Between 30 and 60 gal of sample were collected from each containment area site sampled.

Dredged Material Characterization Results

21. Dredged material samples collected at the locations discussed above were analyzed to permit characterization based upon particle-size distribution (grain-size analysis) and Atterberg limits. Test procedures used to conduct sieve and hydrometer analyses, specific gravity determinations and Atterberg limits for each of the samples are presented in the CE manual entitled "Engineering and Design Laboratory Soils Testing," EM 1110-2-1906.[6]

22. The results of the particle-size distribution analyses performed for each of the samples are presented graphically in Plates A1 through A16. Characteristics of the dredged material samples determined during the particle-size distribution analyses are summarized in Table 1.

23. The types of material which were collected and investigated in this study range in texture from silty clay to gravelly sand and from 98

Table 1

Characteristics of Dredged Material Samples

Sample	Color	Textural Class	Content	Specific Gravity	Solids Content (%) by Weight	Silt/Clay Content (%)
Apalachicola Bay	Grayish black	Silty clay	Small amount of organic matter	2.75	29	98
Toledo Land Disposal	Grayish brown	Silty clay loam	Small amount of organic matter	2.74	40	98
Browns Lake	Grayish brown	Loam or sandy loam	Small amount of organic matter	2.67	47	98
Toledo Hopper Overflow	Light brown	Silty clay or silty clay loam	Very small amount organic matter and sand	2.85	3	97
Mobile Bay	Black	Silty clay loam	Small amount of organic matter and sand	2.65	44	96
Toledo Site A	Grayish black	Silty loam or silty clay loam	Leaves and other organic matter	2.69	46	95
Toledo Site B	Grayish brown	Silty loam or silty clay loam	Leaves and other organic matter	2.68	46	95
Ninety percent S/C* 50% Toledo Site A + 50% Penns Spillway	Grayish black	Silty loam	Small amount of organic matter	2.66	50	90

Table 1 (Concluded)

Sample	Color	Textural Class	Content	Specific Gravity	Solids Content (%) by Weight	Silt/Clay Content (%)
Seventy-five percent S/C* - 50% Mobile + 50% Craney 2	Grayish black	Silty loam	Small amount of organic matter	2.74	53	73
Craney Island Site 2	Gray	Sandy loam	Small amount of organic matter	2.53	62	62
Sixty percent S/C* 50% Penns Spillway + 50% Craney 1	Grayish black	Sandy loam	Large amount of organic matter, some shell fragments	2.60	59	58
Penns Neck Spillway	Grayish black	Loam or sandy loam	Small amount of organic matter	2.61	53	55
Craney Island Site 4	Black	Loamy sand	Shell fragments, decaying organic matter	2.49	56	30
Craney Island Site 1	Grayish black	Loamy sand	Shells up to 8cm diameter, large amount organic matter	2.48	65	20
Penns Neck Inlet	Light brown	Sand	Gravel up to 12 cm diameter, small amount of organic matter	2.71	95	12
Craney Island Site 3	Grayish black	Gravelly sand	Gravel up to 8 cm diameter, organic matter	2.84	78	2

Notes: *S/C: Silt/Clay Content.

to 2 percent finer than the No. 200 sieve in silt/clay content. Specific gravities ranged from 2.84 for the gravelly sand in the Craney Island Site 1 sample. The solids contents reported in Table 1 represent the material as taken in the field. In most cases the solids contents were diluted with deionized water to achieve a range of 15 to 25 percent solids.

24. The results of Atterberg limits tests as well as the Unified Soil Classification for each of the dredged material samples are presented in Table 2.

Table 2

Results of Atterberg Limits Tests and Unified Soil Classification Data

Site	Silt/Clay Content*	Clay Content**	Liquid Limit	Plastic Limit	Plasticity Index	Activity	Unified Soil Classification***
Apalachicola	98	41	153	79	74	1.8	OH-MH
Mobile Bay	96	35	82	47	35	1.0	OH-MH
Toledo Hopper Overflow	97	100	70	43	27	0.68	OH-MH
Toledo Site B	95	23	74	41	33	1.4	OH-MH
Toledo Land Disposal	98	26	80	47	33	1.3	OH-MH
Toledo Site A	95	8	61	35	26	3.3	OH-MH
Craney Island Site 2	62	8	33	--	--	--	SM-SC
Penns Neck Spillway	55	12	52	35	17	1.4	OH-MH
Craney Island Site 4	30	10	53	29	24	2.4	SC
Craney Island Site 1	20	5	54	27	27	5.4	SC
Penns Neck Inlet	12	1	--	--	--	--	SP
Craney Island Site 3	2	1	--	--	--	--	SM-SC

Notes: *Percent finer than 0.74 mm

**Percent finer than 0.002 mm

***a. OH-MH is a dual classification; oven-dry shrinkage limits not determined.
b. SM-SC material too sandy to determine Atterberg limits.

PART IV: TESTING PROCEDURES AND APPARATUS

25. A number of studies were conducted on the samples from the disposal areas and Apalachicola Bay. These studies consisted of specific resistance to filtration (using the Buchner funnel), filter leaf tests, and bench-scale vacuum filtration. An explanation of the test procedures and the apparatus used in each study are presented in this section.

Specific Resistance to Filtration

26. The Buchner funnel test for specific resistance to filtration was conducted to evaluate the relative efficiencies of seven different chemical coagulants used to condition dredged disposal site material.

27. These tests were conducted on duplicate samples from 13 field sites and three blended samples which consisted of variously proportioned mixtures of field samples to simulate dredged material with 60, 75, and 90 percent silt/clay contents. Also, two field samples, Penns Neck Inlet and Craney Island Site 3, were eliminated at this point due to the high sand content of the samples.

28. Various dilutions of dredged material were used to simulate solids concentrations, ranging from 12 to 25 percent by weight, found in actual dredging operations. Figure 2 presents a schematic diagram of the Buchner funnel apparatus.

29. The procedures used in this portion of the study are described in the following steps:

- a. A stock sample of dredged material is diluted with deionized water to a solids concentration of 15 to 20 percent by weight.
- b. Individual samples containing 100 g dry solids content each are weighed.
- c. For those runs using a chemical coagulant, the coagulating chemical in the proper dosage is added to the slurry containing 100 g of sample, and the slurry is mixed thoroughly.
- d. Whatman No. 1 filter paper is placed in the 11.0 cm I.D. funnel and wetted with 3 ml of water to properly seat the filter paper.

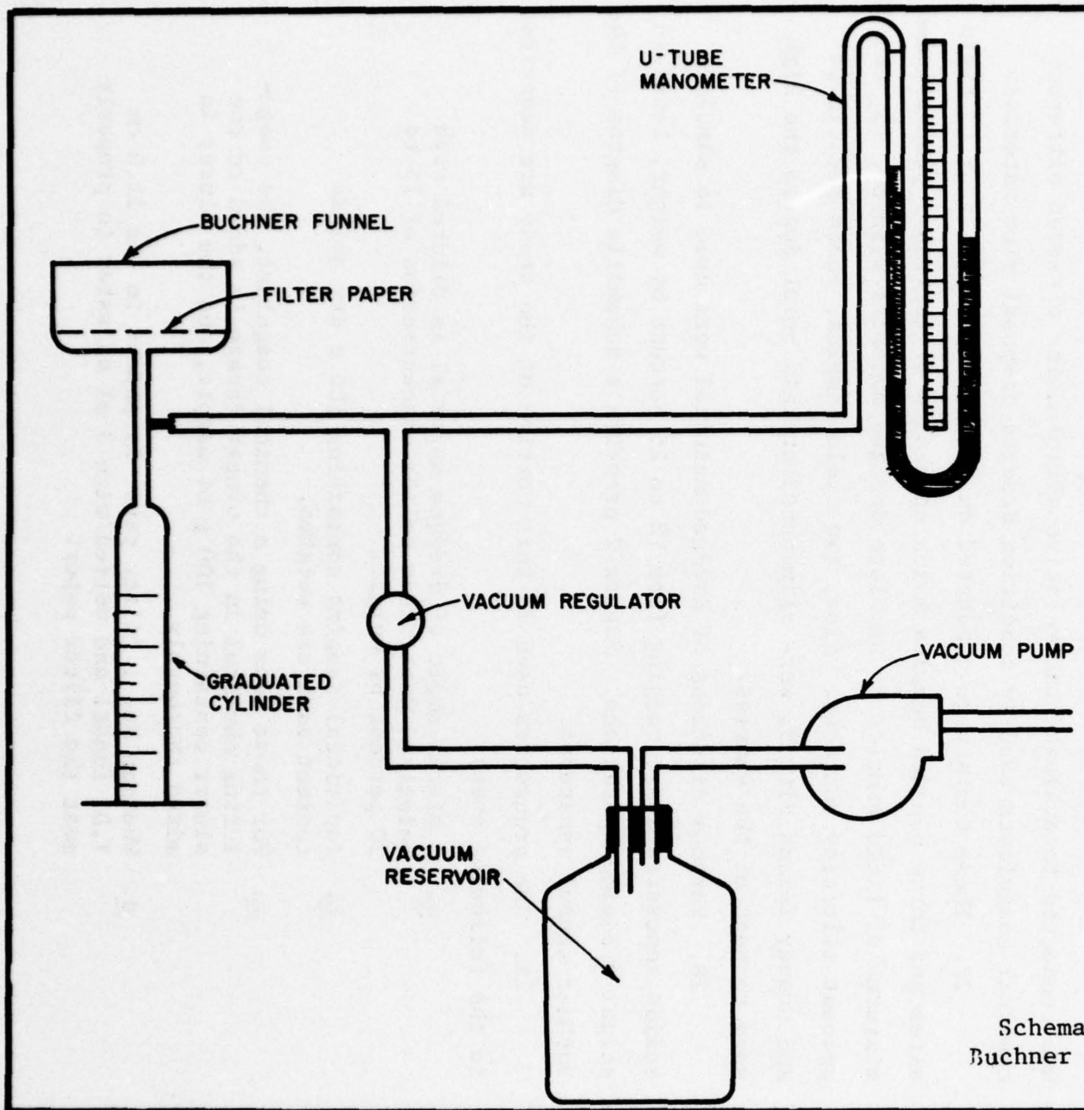


Figure 2
Schematic Diagram of
Buchner Funnel Laboratory
Apparatus

e. The vacuum pump attached to the Buchner funnel is started and allowed to operate with the filter valved-off until a vacuum of 40 cm of Hg is built up in the vacuum reservoir.

f. The mixed sample is then poured onto the filter paper so that the entire paper is covered and the vacuum valve opened, resulting in vacuum drawn on the filter.

g. Readings of filtrate volume and vacuum (from the manometer) are recorded at specified time intervals.

h. The vacuum pump remains on and readings of filtrate volume and vacuum continue for a period of 4 to 5 min or until the manometer reading falls-off drastically.

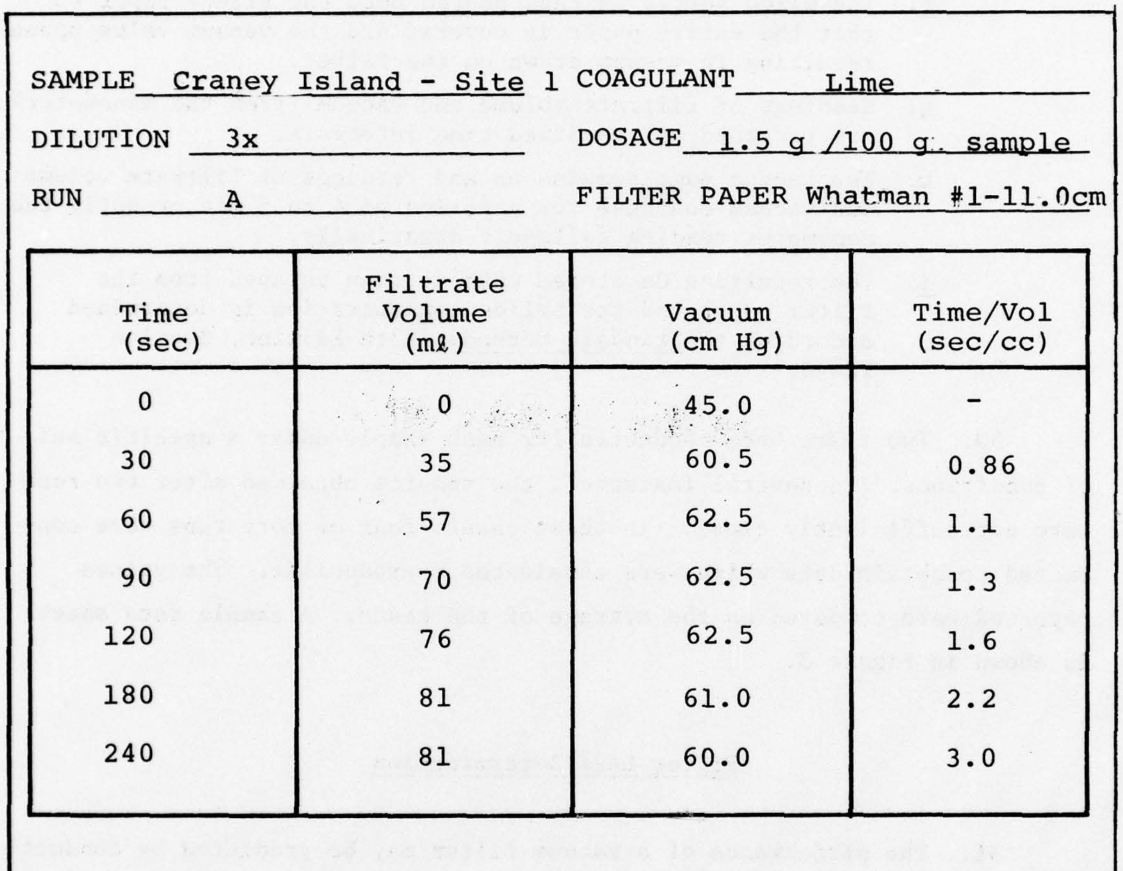
i. The resulting dewatered cake is then scraped from the filter paper and the solids concentration is determined according to Standard Methods, 13th Edition, Section 224-G.[7]

30. Two tests were conducted for each sample under a specific set of conditions. In several instances, the results obtained after two runs were not sufficiently close. In these cases, four or more runs were conducted to obtain data which were considered reproducible. The values reported were computed as the average of the tests. A sample data sheet is shown in Figure 3.

Filter Leaf Determination

31. The performance of a vacuum filter may be predicted by conducting filter leaf tests which effectively simulate the operation of a continuous filter through a series of timed steps involving cake formation and subsequent draining and discharge. The filter leaf test offers an accurate comparative determination of filter media as well as established yield and unit operation data.

32. Filter leaf studies generally serve as the preliminary work preceding bench- or pilot-scale vacuum filtration studies. Buchner funnel studies were used to provide information on conditioning agents and their effects on the filterability of the dredged material. This section describes the filter leaf studies conducted, using the Buchner funnel results as a base from which to begin the study.



SAMPLE Craney Island - Site 1 COAGULANT Lime

DILUTION 3x DOSAGE 1.5 g /100 g. sample

RUN A FILTER PAPER Whatman #1-11.0cm

Time (sec)	Filtrate Volume (mℓ)	Vacuum (cm Hg)	Time/Vol (sec/cc)
0	0	45.0	-
30	35	60.5	0.86
60	57	62.5	1.1
90	70	62.5	1.3
120	76	62.5	1.6
180	81	61.0	2.2
240	81	60.0	3.0

Figure 3
Sample Data Sheet, Buchner Funnel Test Data[8]

33. The filter leaf study was designed to determine the following information about vacuum filtration of dredged material: 1) the effect of drum speed and drum submergence on filter cake yield; 2) the effect of varying conditioner dosage on filtrate quality, particularly in terms of suspended solids; and 3) the effect of cloth porosity on cake yield, filtrate quality, and cake release.

34. Lime (with and without ferric chloride) and a cationic polyelectrolyte, Hercofloc 844, were determined from previous Buchner funnel studies to be the most suitable conditioning agents for use in vacuum filtration. These agents consistently reduce the specific resistance of the cake to between 5 and 10 x 10^7 sec^2/g.

35. To determine the effect of differing cloth porosity, a number of different filter cloths were used as the filter medium during the filter leaf tests. A schematic diagram of the test apparatus is presented in Figure 4. This apparatus was used according to procedures outlined in a document provided by the Komline-Sanderson Engineering Corporation.[3]

36. Simulation of actual vacuum filter operation was achieved by immersing the 0.1-ft^2 filter leaf in the slurry for a given amount of time (corresponding to the filtering time) and then removing the leaf from the slurry and allowing the vacuum to dewater the cake (again, for a fixed time period). Data correlating drum speed, drum submergence, and these filtering and dewatering times are presented in Table 3.

37. To obtain a single data point, a series of five filter leaf tests were conducted and averaged. This effort was necessary to be confident of the reproducibility of the data. More than 700 individual filter leaf tests were conducted.

38. A slurry of the proper solids concentration was conditioned with one of three chemical coagulants: lime, lime with ferric chloride, or Hercofloc 844. The vacuum pump was turned on and allowed to build up a vacuum of 35 to 40 cm of Hg in the vacuum reservoir. Vacuum was then applied to the leaf, and the leaf immediately was placed in the mixed slurry for the predetermined amount of time (see Table 3), then removed and inverted for the allowed drying time.

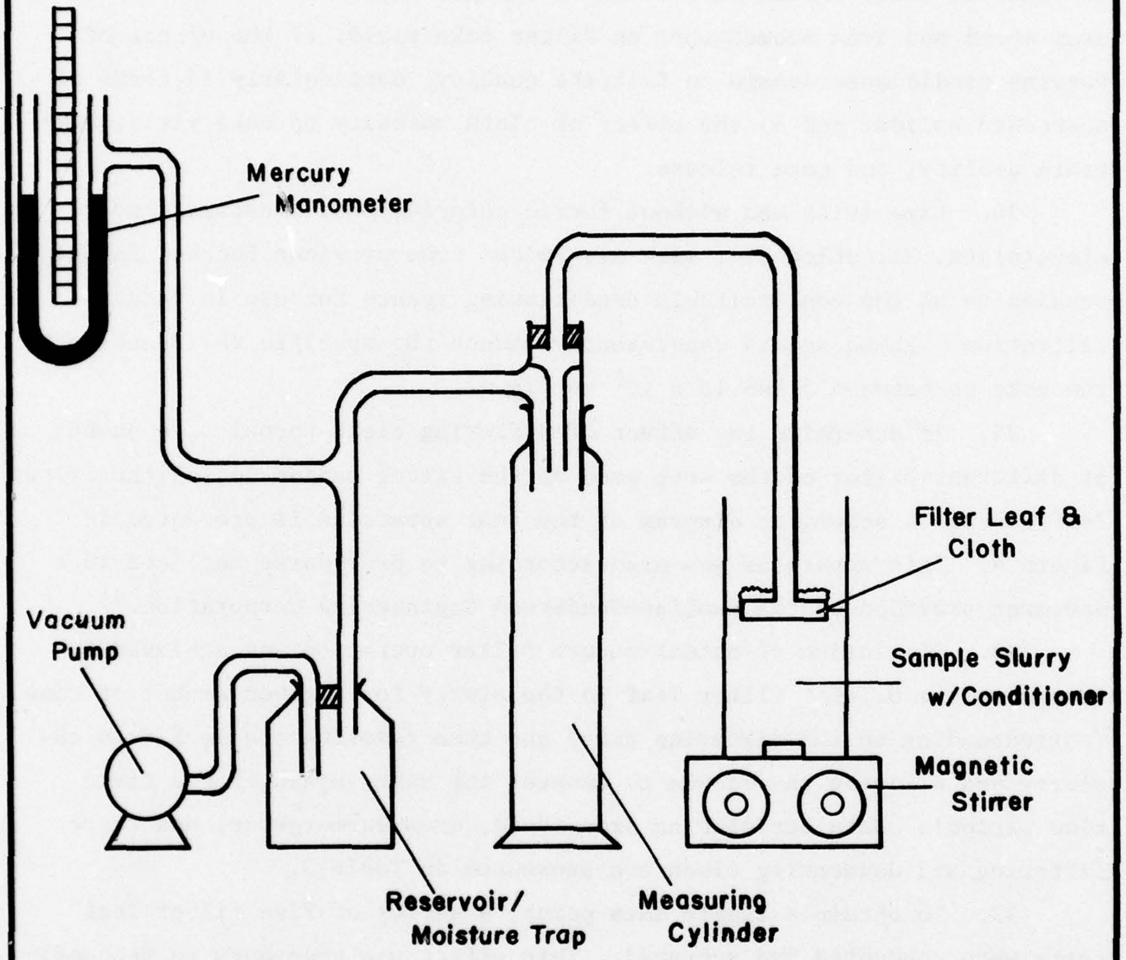


Figure 4
Filter Leaf Test Apparatus[8]

Table 3

Filtration Cycle Chart

Scraper Discharge, Roller Discharge, and Precoat Filters[3]

(Theoretical Time in Seconds)

	25% submergence		37-1/2% Submergence		60% Submergence	
Min/rev	Filter	Dewater	Filter	Dewater	Filter	Dewater
1/3	5	13	8	10	12	6
1/2	7	20	11	16	18	9
2/3	10	26	15	21	24	12
1	15	39	23	32	36	18
1-1/2	22	59	34	47	54	27
2	30	78	45	63	72	36
3	45	117	67	95	108	54
4	50	156	90	126	144	72
5	75	195	113	158	180	90
6	90	234	135	189	216	108
7	105	273	158	221	252	126
8	120	312	180	252	288	144
10	150	390	225	315	360	180
12	180	468	270	378	432	216
14	210	546	315	441	504	252

39. The cake from the entire filter medium surface was then scraped from the cloth and a solids content assessment conducted. Percent solids were determined on the basis of weight of dry solids per weight of wet solids.

40. Knowing the area of the filter leaf media (0.1 ft^2), the time of filtering and dewatering, and the weight of dry solids obtained, the filter yield could be calculated from the formula

$$\text{Filter yield} = \frac{\text{(weight of dry solids in pounds}}{(0.1\ \text{ft}^2)\ \ \text{(cycle time in hours)}} \qquad (5)$$

Bench-Scale Vacuum Filtration

41. The bench-scale vacuum filtration study consisted of conducting continuous vacuum filtration of dredged material slurries from seven sites for a specified set of conditions. These conditions were predetermined by the results of the Buchner funnel and filter leaf studies.

42. The bench-scale apparatus, shown in Figure 5, consisted of a continuous 3.0 ft^2 flexibelt vacuum filter with a helix/roll discharge. The components outlined were part of the system as shipped. The unit was supplied by Komline-Sanderson Engineering Corporation, Peapack, New Jersey.[3]

43. The study was designed to establish relationships between filter yield and filtrate quality and operational parameters such as filter media porosity, chemical coagulation, and drum speed.

44. Several samples were taken during each of the 33 separate runs. These samples included six cake solids, three filtrate total solids, three filtrate suspended solids, three influent slurry total solids, three influent slurry solids, and two total solids on the slurry remaining in the filter trough. The results of this sampling schedule gave the data necessary to arrive at filter yield and filtrate quality for each test condition. A sample data sheet and the ensuing calculations are presented in Figures 6 and 7.

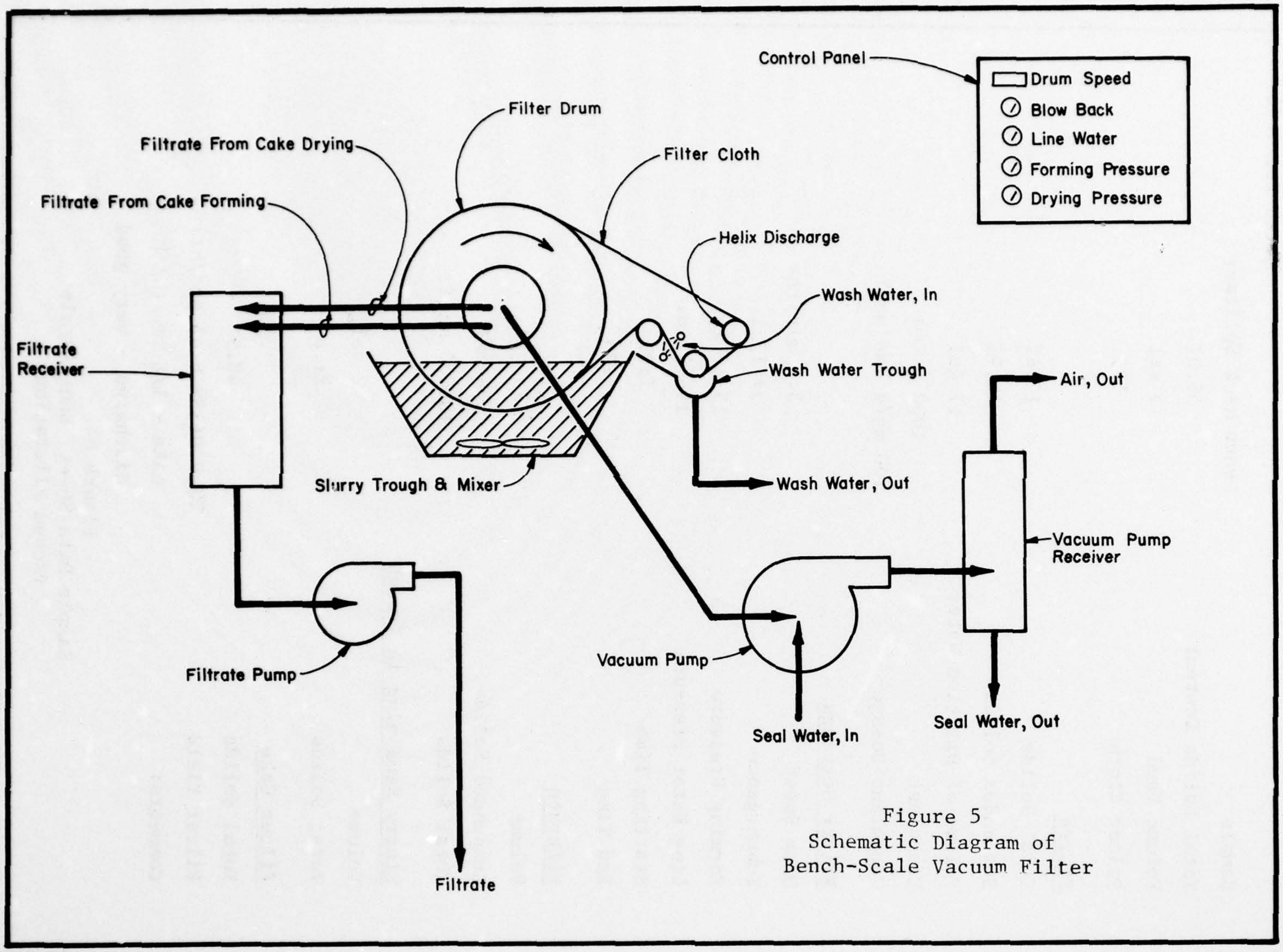


Figure 5
Schematic Diagram of
Bench-Scale Vacuum Filter

BENCH-SCALE VACUUM FILTRATION

March 26, 1976

Sample	Penns Neck Spillway
Total Solids Content	56.0%
Volume Used	5 gal
Filter Cloth	525
Slurry	
Total Solids	17.4%
Suspended Solids	11.9%
Volume of Dilution Water	17 gal
Coagulant	1000 g CaO
Coagulant Dosage	100 mg/g (94 act)
Filter Settings	
Drum Speed	3.4 min/rev
Submergence	37-1/2%
Forming Pressure	15-17 in.
Line Water Pressure	15-17 in.
Starting Time	1:30
End Time	2:30
Filtrate	
Volume	15 gal
Suspended Solids	500 mg/ℓ
Total Solids	10,000 mg/ℓ
Slurry Remaining in Trough	
Volume	2 gal
Total Solids	21.6%
Filter Cake	
Total Solids	48.9%
Filter Yield	TS 9.0(TSS 6.45 psf/hr)
Comments:	cake - 1/8 in. thick discharge - very good

Figure 6
Sample Data Sheet, Bench-Scale
Vacuum Filtration

Penns Neck Spillway - Lime (100 mg/g)

Filter Yield & Coagulant Dosage Calculations

Influent Solids

TS 174 g/ℓ x 22 gal x 3.785 x 1/454 = 31.9 lb
TSS 119 g/ℓ x 22 gal x 3.785 x 1/454 = 21.8 lb

Filtrate Solids

TS 10.0 g/ℓ x 15 x 3.785 x 1/454 = 1.3 lb
TSS 0.5 g/ℓ x 15 x 3.785 x 1/454 = 0.06 lb

Solids Remaining in Trough

TS 216 g/ℓ x 2 x 3.785 x 1/454 = 3.6 lb
TSS (0.68) 216 g/ℓ x 2 x 3.785 x 1/454 = 2.4 lb

Filter Yield

TS {31.9 - 1.3 - 3.6} / {1.0 x 3} = 9.0 psf/hr
TSS {21.8 - 0.06 - 2.4} / {1.0 x 3} = 6.45 psf/hr

Lime Dosage

56.0% solids in sample
560 x 5 x 3.785 = 10,600 g dry solids
1000 g lime added

$$\frac{1{,}000{,}000 \text{ mg}}{10{,}600} = 94 \text{ mg/g dry solids}$$

Figure 7
Sample Data Sheet,
Lime Filter Yield and Coagulant
Dosage Calculations

PART V: RESULTS OF BUCHNER FUNNEL STUDIES

45. The purpose of the extensive testing scheme used in the Buchner funnel studies was to demonstrate the dewaterability of dredged material with a vacuum filter and to determine the type and dosage of chemical coagulant which would effectively enhance the dewatering of the material. As results were obtained and analyzed, a decision was made to concentrate the remaining Buchner funnel studies on lime and polymer 844 as the principal coagulants of interest. A discussion of the results by site is presented below. Supportive data from the funnel tests are presented in Appendix B.

Apalachicola Bay

46. Buchner funnel study results for Apalachicola Bay are presented in Table B1 and Figure 8. The material from this site was diluted to 16.9 percent solids for all tests. Three sets of data plots are presented in Figure 8. The first involves lime, ferric chloride (FeCl), and alum coagulants. These three coagulant studies generally produced the same shape plot on the plot of specific resistance versus coagulant dosage. However, under identical conditions, the addition of lime alone consistently produced a cake which dewatered more rapidly to the cracking point (breakpoint time), with an average cake solids of 40 percent, and with specific resistance reaching a low of 1.1×10^8 sec^2/g at 100 mg/g. The runs with both ferric chloride and alum produced cake solids contents of 43 and 41 percent, respectively, but in each case cake cracking took a longer period of time with higher specific resistances. The cracking point represents the point at which such a volume of water has been removed from the filter cake that the cake shrinks, and particles shift and realign themselves. The vacuum drawn on the filter cake drops sharply at the cracking point due to the passage of air directly through the filtering medium.

47. The second set of plots involves two runs with ferric chloride plus lime. For each of these runs, lime dosage was held constant at 24 and 44 mg/g of dry solids, respectively, while the ferric chloride concentrations were varied. These runs show that the combination of a small

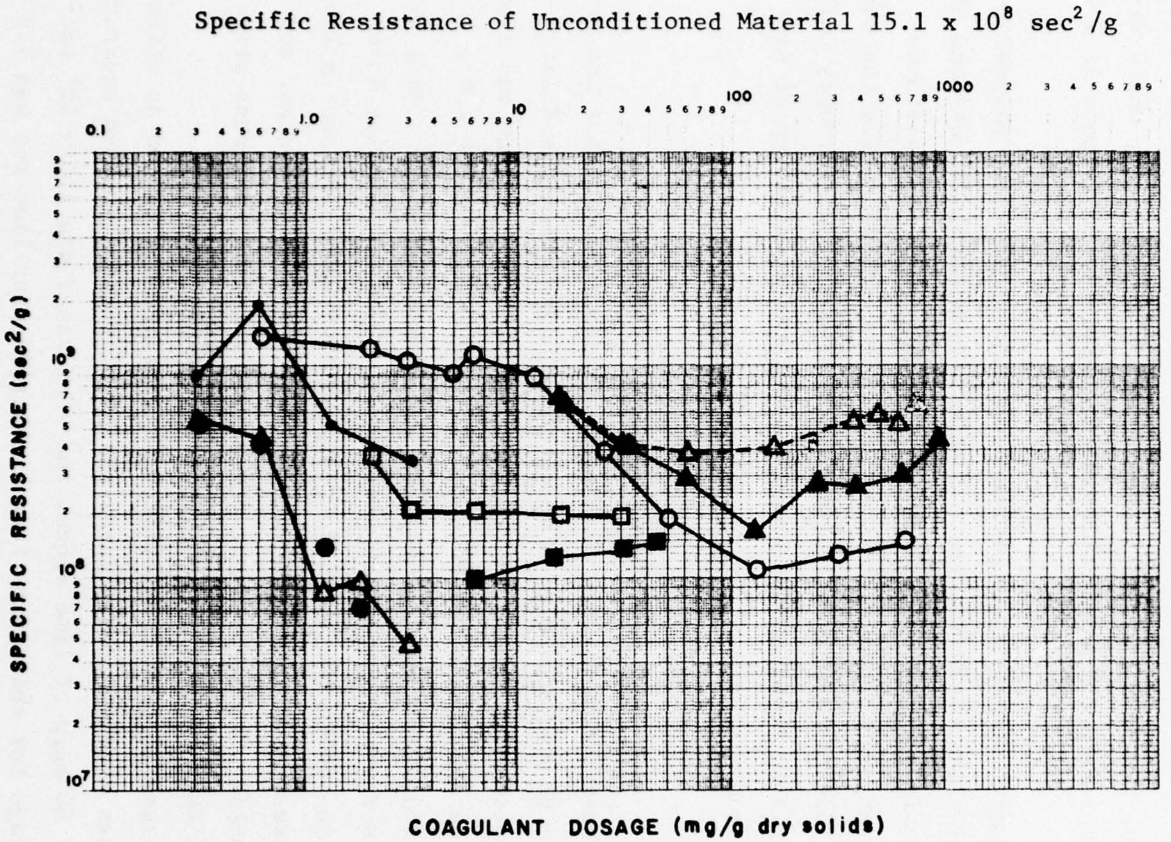


Figure 8
Specific Resistance vs. Coagulant Dosage, Apalachicola Bay

dosage of ferric chloride plus a small dosage of lime produce a lower specific resistance and the same cake solids content than either coagulant when used alone. For example, when lime is used alone at a dosage of 24 mg/g dry solids, the specific resistance is 4.0 x 10^8 sec^2/gm; while with the addition of 3 mg/g of ferric chloride the specific resistance is 2.0 x 10^8 sec^2/g.

48. The next set of plots presents data obtained using polymeric coagulants. As illustrated in Figure 8, the cationic polymer 844 and the moderately anionic polymer 1036 give very similar specific resistance results. However, 844 produced cake at 40 percent solids, while the cake solids of the 1036 run averaged 33 percent. Polymer 1054, strongly anionic, was not effective in reducing the specific resistance, although it did produce a good quality cake at 41 percent solids.

Toledo Harbor Site A

49. Buchner funnel study results for Toledo Harbor Site A are presented in Table B2 and Figure 9. The material from Site A was diluted to 22.4 percent solids. As shown in Figure 9, the ferric chloride and alum runs reduced the specific resistance to very low levels, about 6.0 x 10^7 sec^2/g at dosages of 9 mg/g. Increasing the dosage above the 9 mg/g level was found to increase the specific resistance. Much higher lime doses were required to reduce the specific resistance to 6.0 x 10^7 sec^2/g level. However, the use of lime produces cake solids averaging 55 percent and rapid cake cracking, while both the ferric chloride and alum runs produced cake solids of 48 percent at much longer breakpoint times.

50. The use of ferric chloride plus lime again produced an effect which gave lower specific resistances than either chemical used separately. At a dosage of 50 mg/g of lime alone, the resistance was 1.0 x 10^8 sec^2/g, while the average for the entire ferric chloride plus lime run was 7.0 x 10^7 sec^2/g with comparable solids content of 53 percent and shorter breakpoint times.

51. The use of the cationic polymer 844 exhibited much better results than either of the anionic polymers 1036 or 1054 with respect to

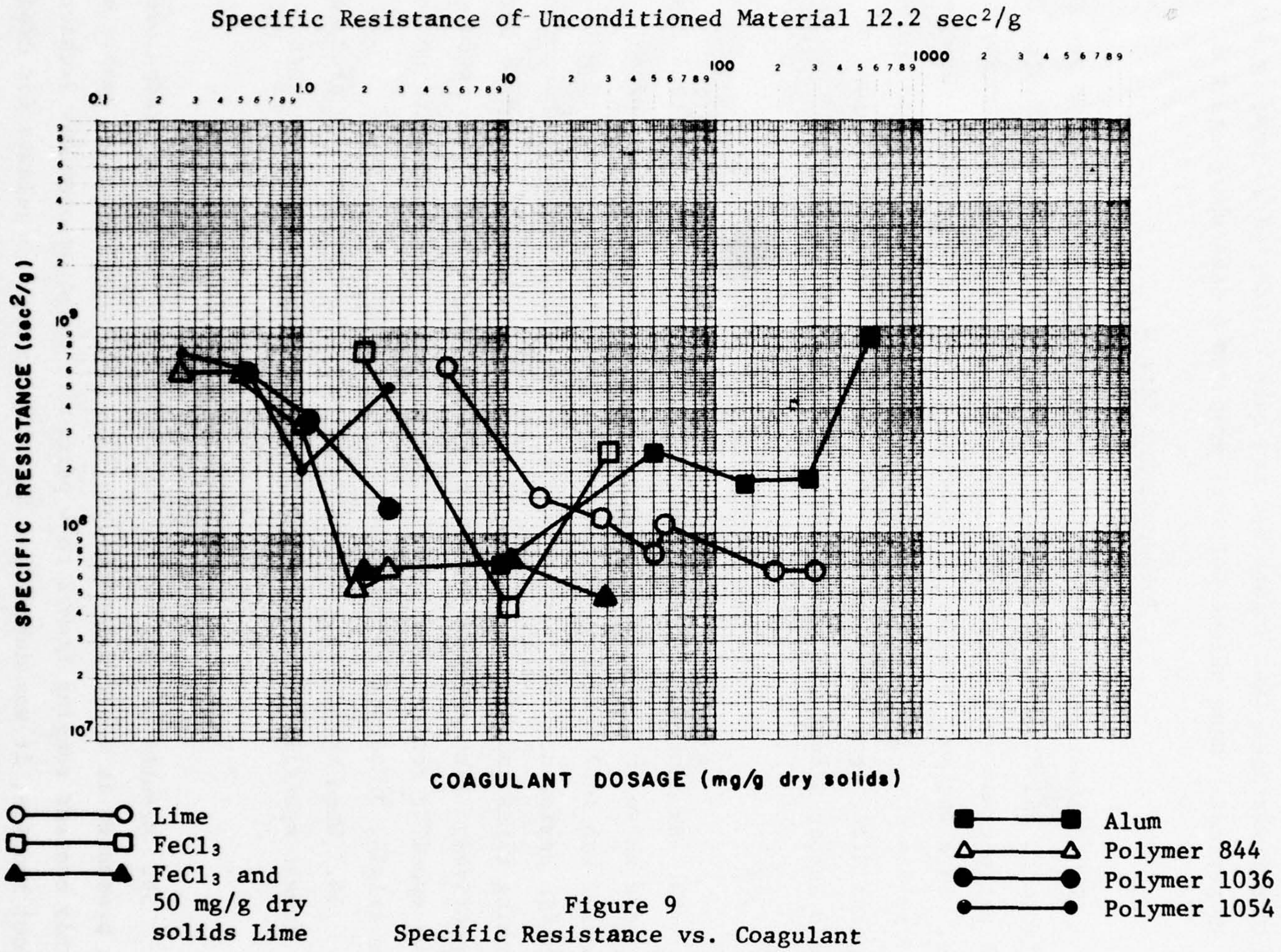


Figure 9
Specific Resistance vs. Coagulant Dosage, Toledo Harbor Site A

specific resistance (see Figure 9), and cake solids, 48 percent versus 38 and 40 percent. None of the polymers produced a cake which cracked.

Toledo Harbor Site B

52. Buchner funnel study results for Toledo Harbor Site B are shown in Table B3 and Figure 10. The solids content of Site B was diluted to 17.8 percent and only two coagulants, lime and alum, were tested for this site. This was done because the results of the Buchner funnel runs, as well as the soil classification of the materials from Site B and the Land Disposal Site, were very similar. For these reasons further study of Toledo Harbor Site B was eliminated.

Toledo Harbor Land Disposal Site

53. Buchner funnel study results for the Toledo Harbor Land Disposal Site are shown in Table B4 and Figure 11. The solids content of this material was 16.7 percent. As shown in Figure 11, lime produced a lower specific resistance than either ferric chloride or alum with shorter cake cracking times and higher cake solids, 53 percent versus 37 and 48 percent, respectively. The addition of ferric chloride plus lime again produced lower specific resistances, with comparable cake solids contents to the lime trials, 52 versus 53 percent.

54. When the three polymers were used, the cationic 844 produced the lowest specific resistance and the highest cake solids contents.

Hopper Overflow

55. Results of the Buchner funnel studies for hopper dredge overflow are presented in Table B5 and Figure 12. The hopper overflow sample had a solids content ranging from 2 to 4 percent. Based on previous Buchner funnel studies, it was determined that the optimum coagulants for dredged material dewatering consist of lime or Hercofloc cationic polymer 844. Therefore, coagulants were limited to these two materials for the subject tests.

Specific Resistnace of Unconditioned Material 12.2 x 10^8 sec^2/g

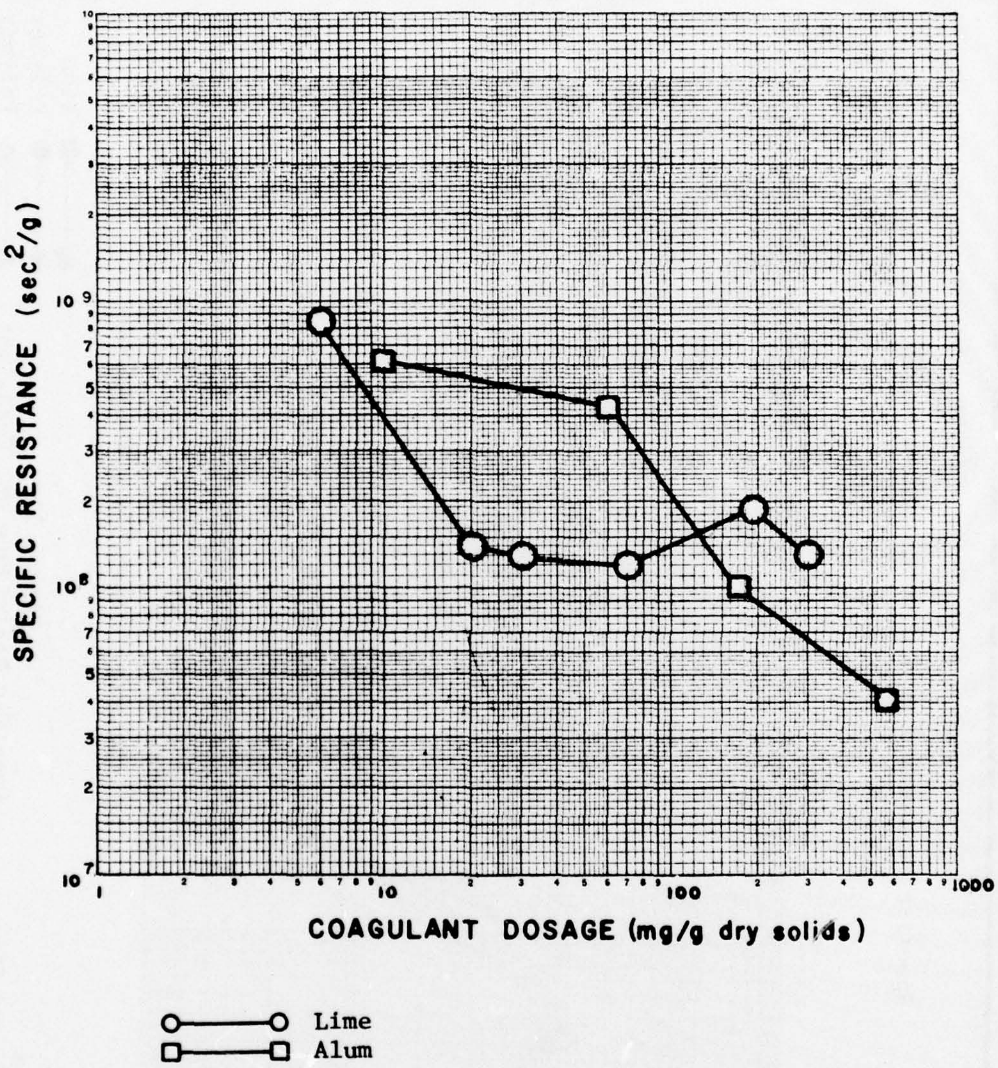


Figure 10
Specific Resistance vs.
Coagulant Dosage, Toledo
Harbor Site B

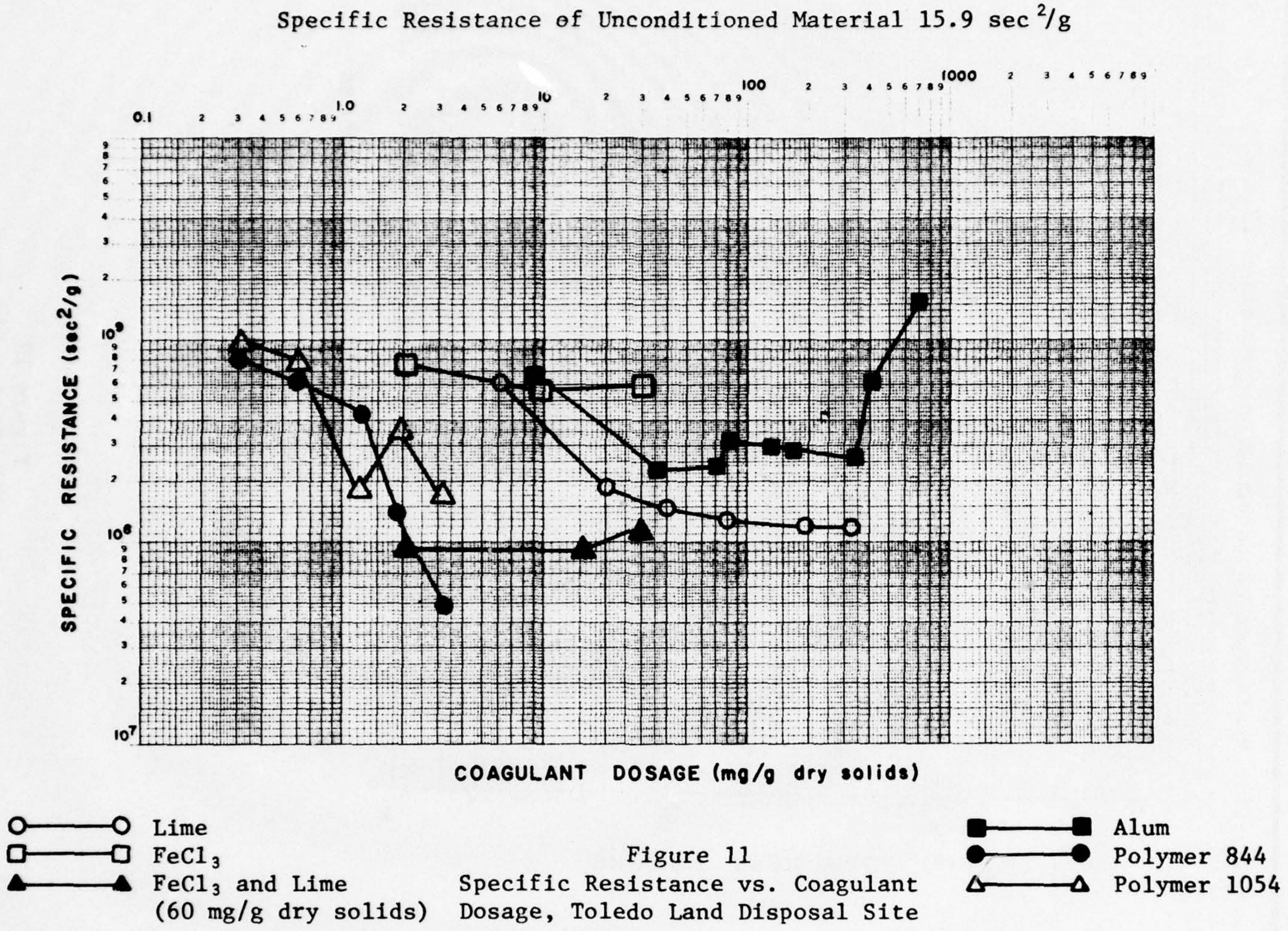


Figure 11
Specific Resistance vs. Coagulant
Dosage, Toledo Land Disposal Site

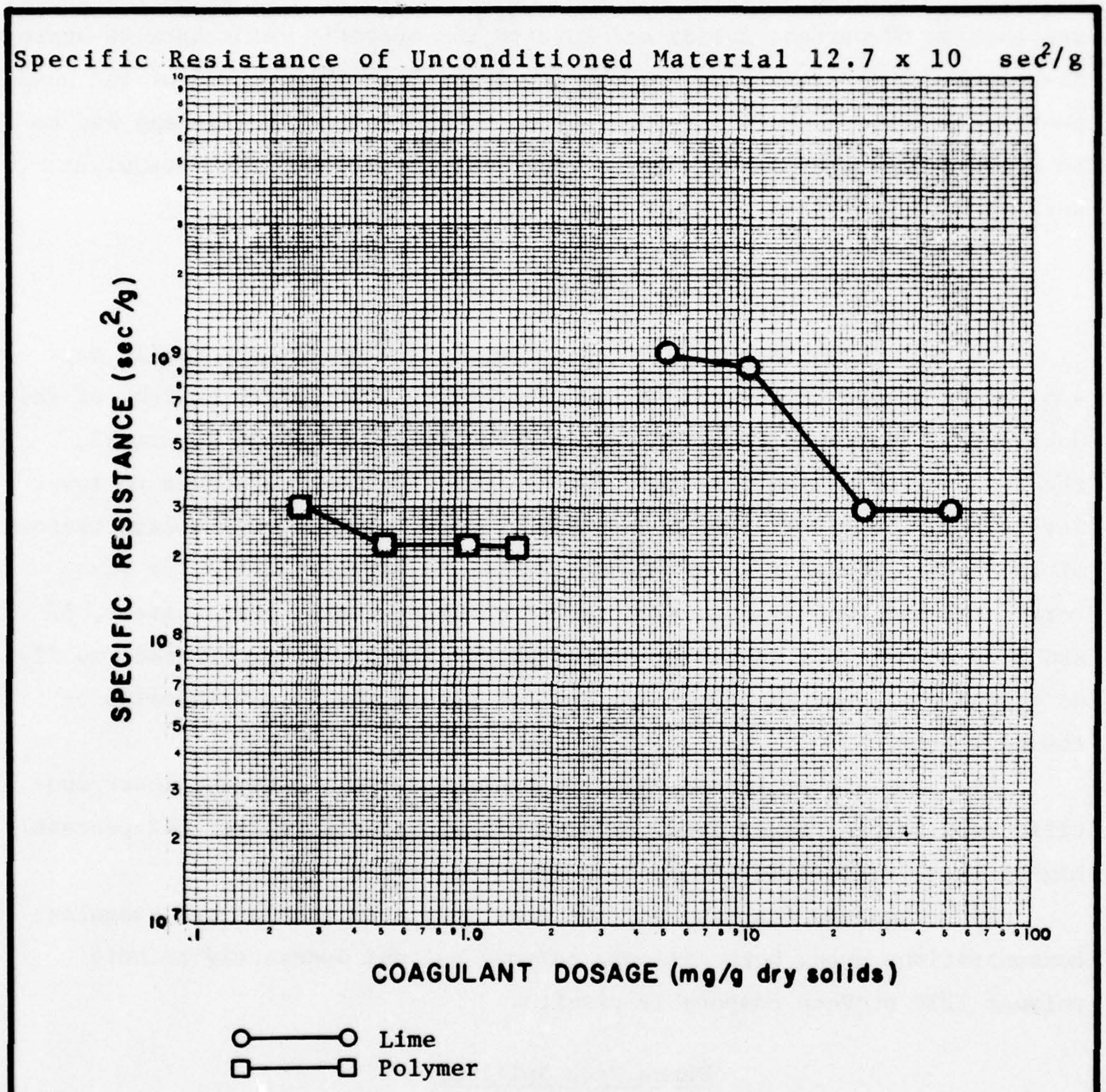


Figure 12
Specific Resistnace vs.
Coagulant Dosage, Hopper
Overflow, Toledo Harbor

56. As shown in Table B5, both lime and polymer 844 yielded a cake approaching 60 percent solids and lowered the specific resistance to approximately 3 x 10^8 sec^2/g. Due to the low initial solids content of the hopper overflow sample, however, the cake produced was extremely thin and had to be scraped from the filter paper. Cake drying times for each coagulant were low, ranging from 45 to 58 sec.

Mobile Bay

57. The results of the Buchner funnel studies for the Mobile Bay sample are presented in Table B6 and Figure 13. The solids content of the Mobile Bay sample was diluted to 17.6 percent. As shown in Figure 13, the use of lime as the coagulant reduced the specific resistance to lower levels than did either ferric chloride or alum. The average solids content of the cake produced from the lime runs was 45 percent, while for the ferric chloride and alum runs the solids contents were, respectively, 37 and 41 percent. Unlike the lime runs where cake cracking occurred rapidly, no evidence of cake cracking occurred for either the ferric chloride or the alum runs.

58. The use of ferric chloride plus lime again produced lower specific resistances, lower cake cracking times, and cake solids (44 percent) higher than ferric chloride or lime used separately.

59. The data from the polymer runs indicated that at the coagulant concentrations used, both cationic polymer 844 and moderately anionic polymer 1036 produce comparable results.

Penns Neck Spillway

60. The results of the Buchner funnel study for Penns Neck Spillway are presented in Table B7 and Figure 14. This sample was diluted to a solids content of 24.5 percent. Data indicate that lower specific resistances and higher cake solids were produced when ferric chloride was used instead of lime. However, cake cracking time was longer for ferric chloride. The use of ferric chloride plus lime again produced better results than either chemical used separately.

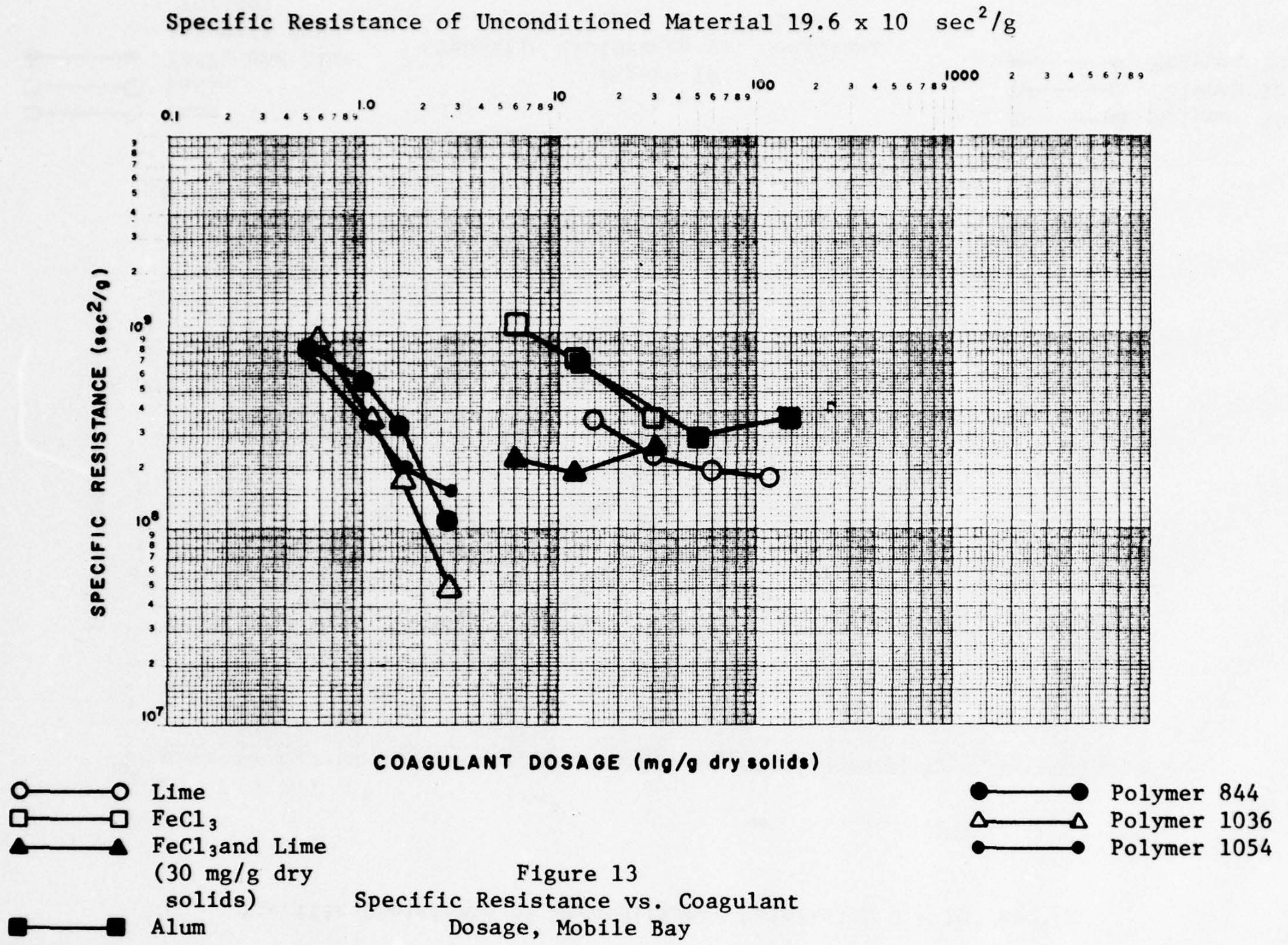


Figure 13
Specific Resistance vs. Coagulant
Dosage, Mobile Bay

Specific Resistance of Unconditioned Material 8.0 x 10^8 sec^2/g

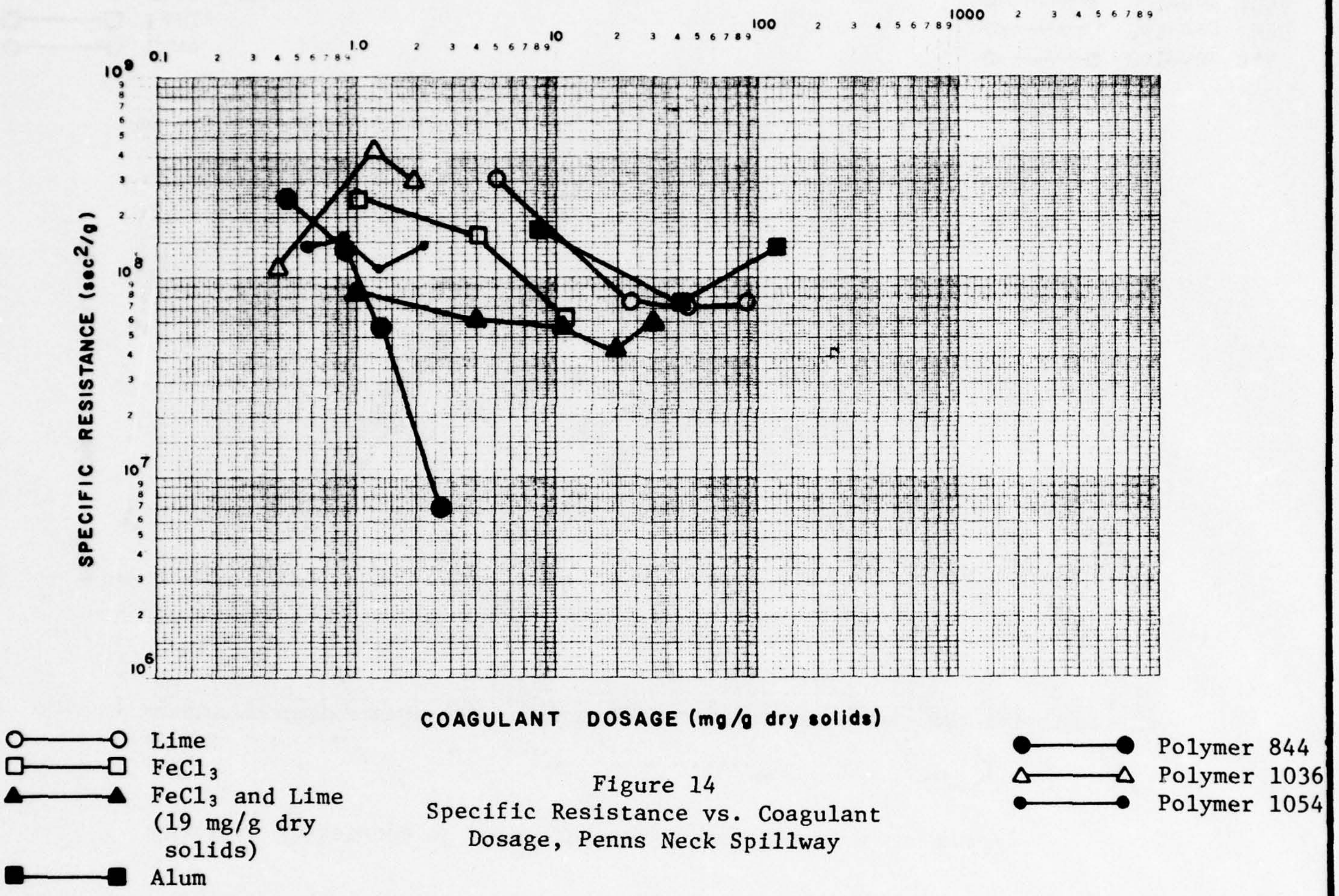


Figure 14
Specific Resistance vs. Coagulant Dosage, Penns Neck Spillway

61. Cationic polymer 844 consistently produced better specific resistance results than did either of the anionic polymers. Polymer 844 produced cake solids of 55 percent versus 37 and 36 percent for polymers 1036 and 1054.

Craney Island Site 1

62. The results from the Craney Island Site 1 Buchner funnel studies are shown in Table B8 and Figure 15. The material used had a solids content of 20.5 percent. The use of lime and lime with ferric chloride results in specific resistances of approximately 1.0×10^8 sec^2/g with cake solids of 48 and 55 percent, respectively. Cake cracking for each run occurred in approximately 80 to 90 sec.

63. Ferric chloride, alum, and the two anionic polymers did not produce results comparable to those observed with lime, lime with ferric chloride, or the cationic polymer 844.

Craney Island Site 2

64. The results from the Craney Island Site 2 Buchner funnel studies are shown in Table B9 and Figure 16. The material used had a solids content of 21.6 percent. Addition of lime produced a cake of 67 percent solids with cake cracking beginning within 30 sec. Specific resistance reached a low level of 4.0×10^7 sec^2/g at a dosage of 20 mg/g. The use of the polymer 844 produced a cake of 63 percent solids with cracking occurring within 30 sec. Specific resistance reached 1.2×10^7 sec^2/g at a dosage of 3.5 mg/g.

Craney Island Site 3

65. The only Buchner funnel tests run on Craney Island Site 3 were on unconditioned samples at different dilutions. No coagulants were used. Because of the high sand content, the samples tended to dewater rapidly to very high cake solids. Therefore, no further investigation of coagulants was pursued.

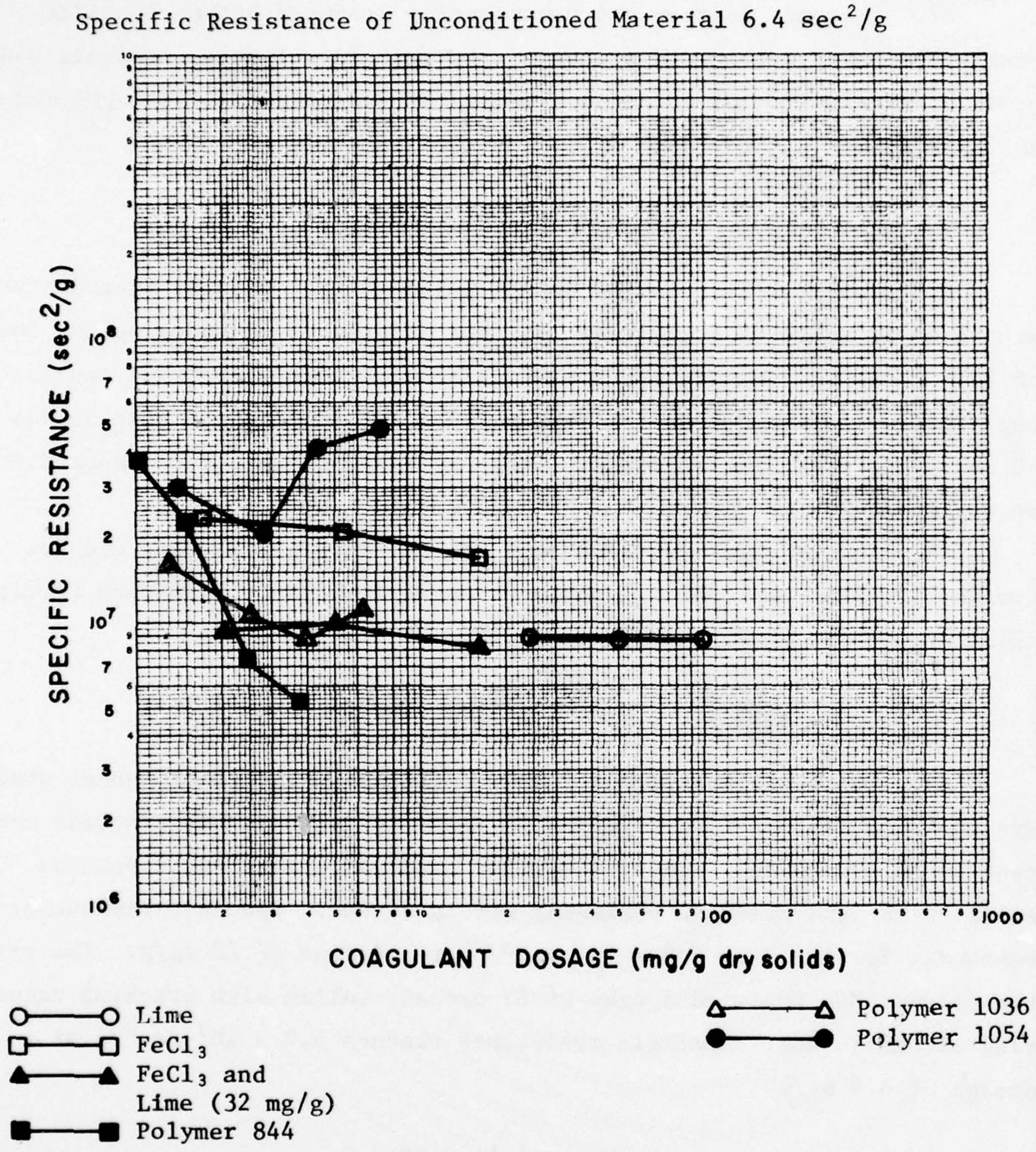
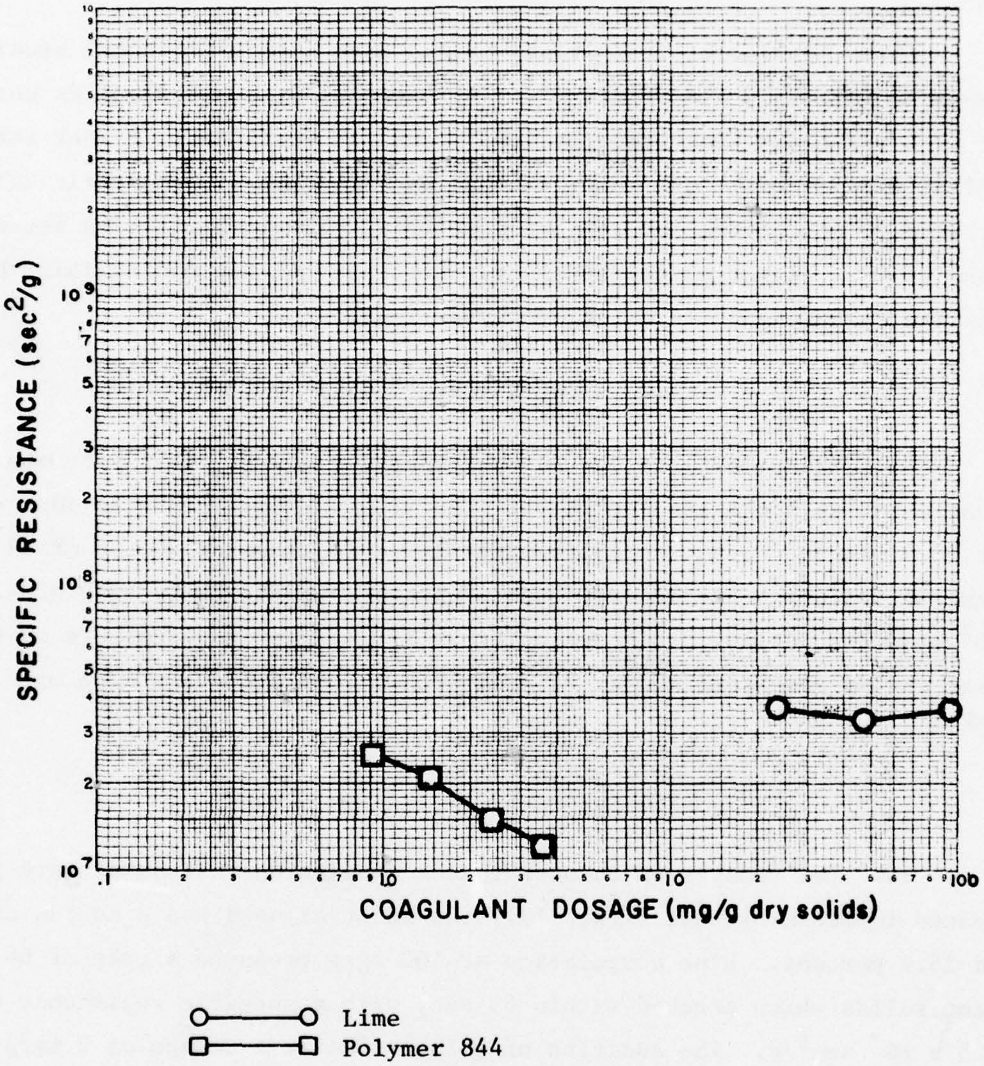


Figure 15
Specific Resistance vs. Coagulant
Dosage, Craney Island Site 1



Specific Resistance of Unconditioned Material 4.9 x 10^8 sec^2/g

Figure 16
Specific Resistance vs. Coagulant
Dosage, Craney Island Site 2

Craney Island Site 4

66. The results from Craney Island Site 4 Buchner funnel studies are shown in Table B10 and Figure 17. The material used had a solids content of 12.4 percent. Lime produces lower specific resistance, higher cake solids (53 percent), and lower breakpoint time than either ferric chloride or alum. The combination of ferric chloride plus lime exhibits better results than either coagulant alone. Cationic polymer 844 exhibits better results than moderately anionic polymer 1036.

Browns Lake Sample

67. The results of the Buchner funnel study for this site are presented in Table B11 and Figure 18. The material used had a solids content of 20.5 percent. Lime coagulation at 100 mg/g produced a cake of 62 percent solids which cracked at 40 sec, with a specific resistance of 4.0×10^7 sec^2/g. Polymer 844 coagulation at 3.0 mg/g produced a cake of 63 percent solids which cracked at 75 sec, with a specific resistance of 4.6×10^7 sec^2/g.

Ninety Percent Silt/Clay Content

68. The results of Buchner funnel studies on this sample are presented in Table B12 and Figure 19. The material used had a solids content of 25.7 percent. Lime coagulation at 100 mg/g produced a cake of 56 percent solids which cracked within 65 sec, with a specific resistance of 6.5×10^7 sec^2/g. The addition of polymer 844 at a dosage of 2 mg/g produced a cake of 50 percent solids with a specific resistance of 4.3×10^7 sec^2/g. No cake cracking was observed at the 2 mg/g dosage.

Seventy-Five Percent Silt/Clay Content

69. The results of Buchner funnel studies on this sample are presented in Table B13 and Figure 20. The material used had a solids content of 24.2 percent. Lime coagulation at a dosage of 100 mg/g produced a cake of 52 percent solids which cracked within 75 sec, with a specific resistance of 4.3×10^7 sec^2/g. Polymer 844 coagulation produced a cake of

Specific Resistance of Unconditioned Material 4.7 x 10^8 sec^2/g

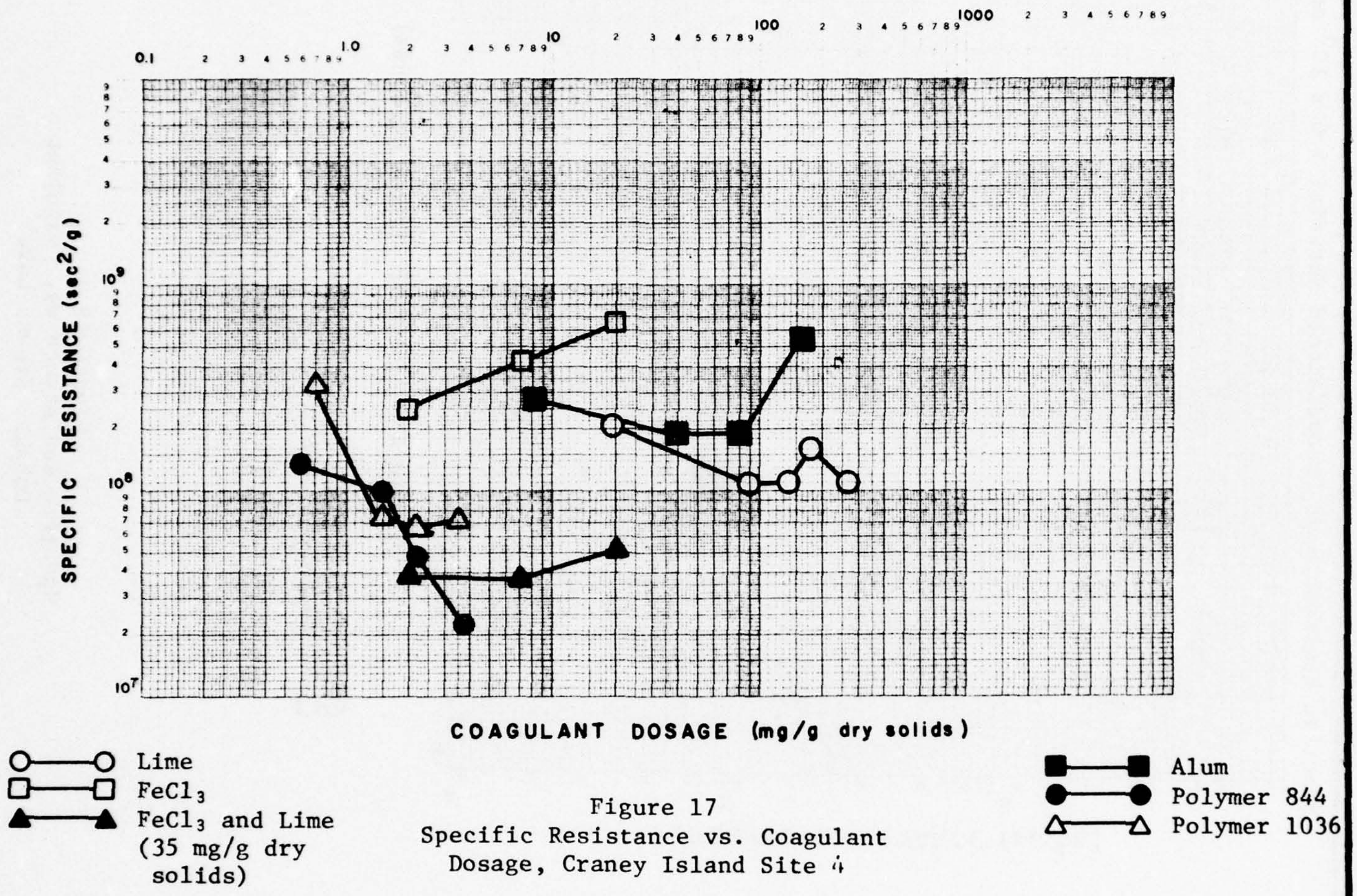
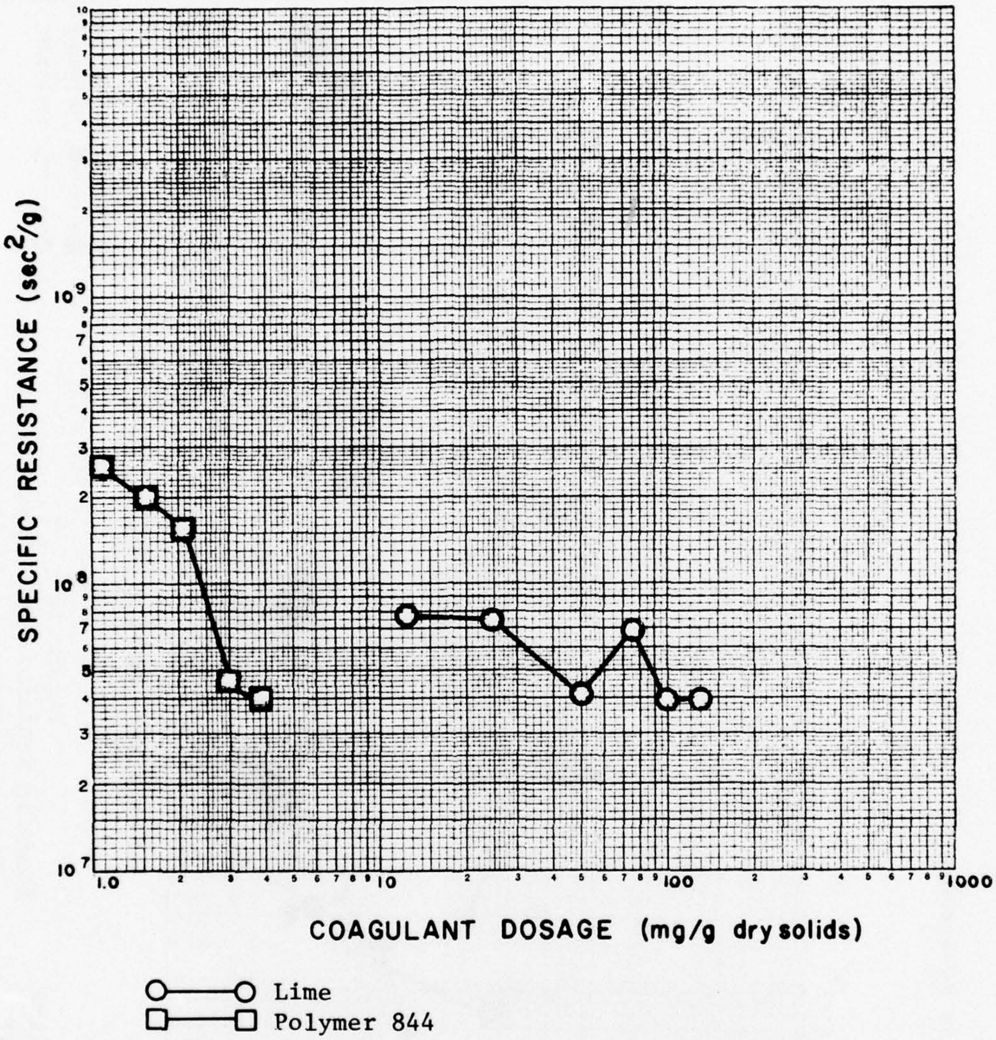
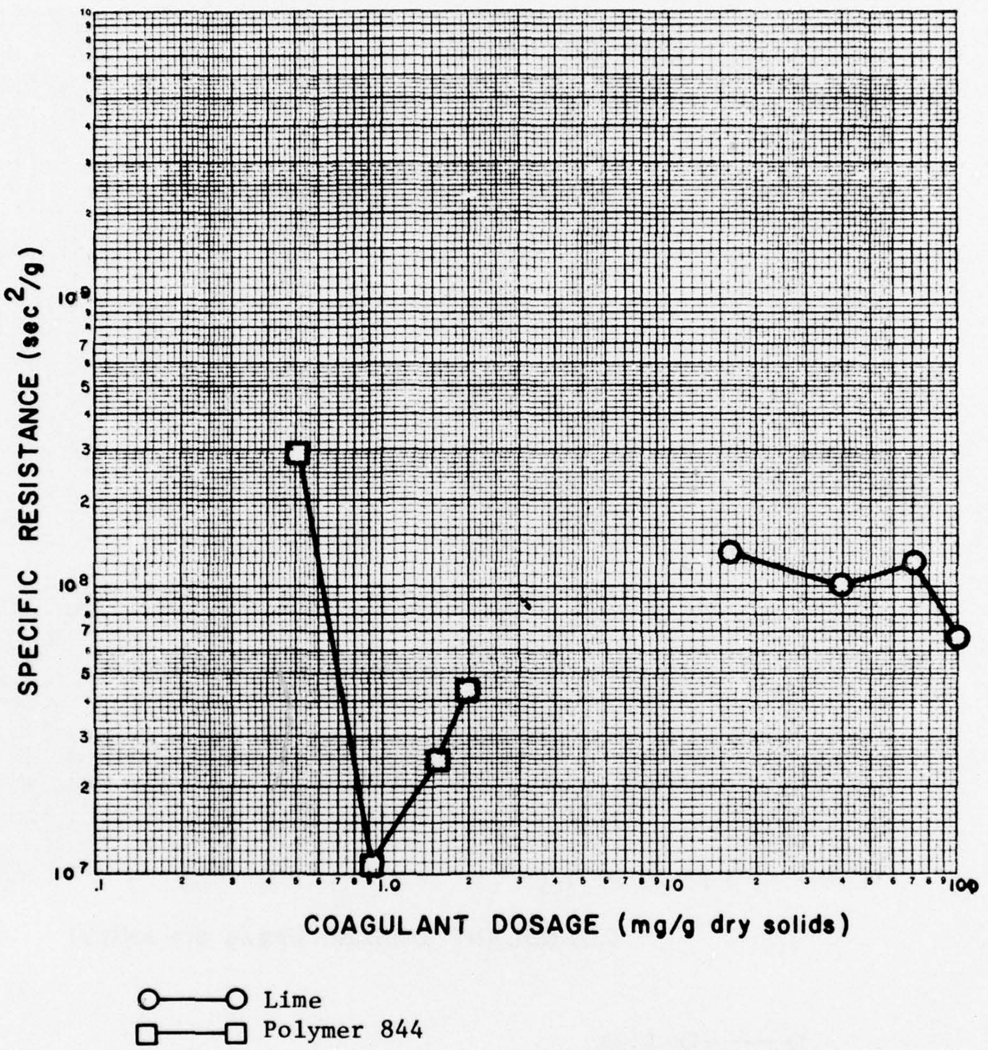


Figure 17
Specific Resistance vs. Coagulant Dosage, Craney Island Site 4



Specific Resistance of Unconditioned Material 5.6 x 10^8 sec^2/g

Figure 18
Specific Resistance vs. Coagulant
Dosage, Browns Lake



Specific Resistance of Unconditioned Material 9.6 x 10^8 sec^2/g

Figure 19
Specific Resistance vs. Coagulant
Dosage, Ninety Percent Silt/Clay
Content

Specific Resistance of Unconditioned Material 5.2 x 10^8 sec^2/g

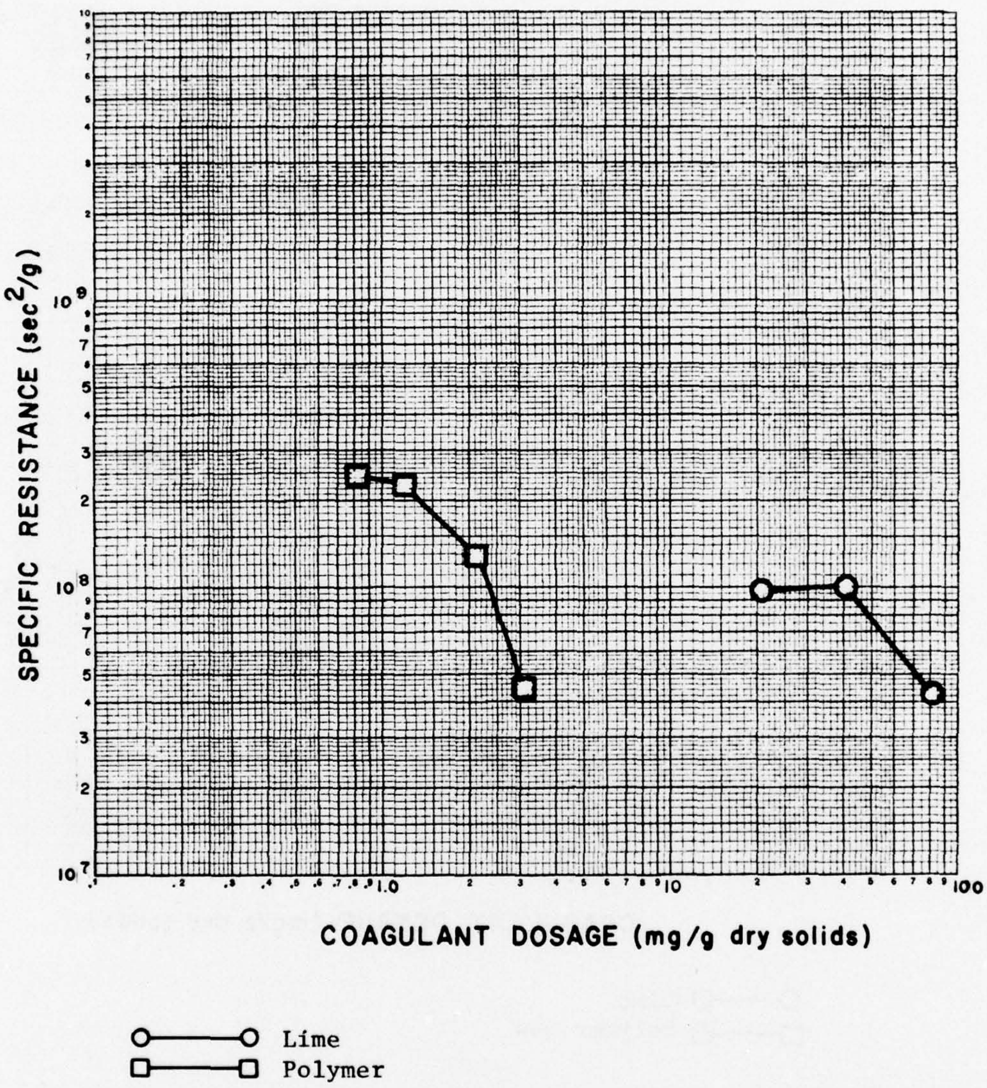


Figure 20
Specific Resistance vs. Coagulant
Dosage, Seventy-Five Percent
Silt/Clay Content

50 percent solids, with a specific resistance of 4.6 x 10^7 sec^2/g at a dosage of 3 mg/g. When polymer was used, however, no cake cracking occurred.

Sixty Percent Silt/Clay Content

70. The results of the Buchner funnel studies on this sample are presented in Table B14 and Figure 21. The material used had a solids content of 17.7 percent. Lime coagulation at 100 mg/g produced a cake with 55 percent solids, which cracked at 72 sec with a specific resistance of 7.0 x 10^7 sec^2/g. Polymer 844 coagulation at 2.8 mg/g produced a cake of 60 percent solids which cracked at 92 sec with a specific resistance of 6.2 x 10^7 sec^2/g.

Specific Resistance of Unconditioned Material 5.0 sec^2/g

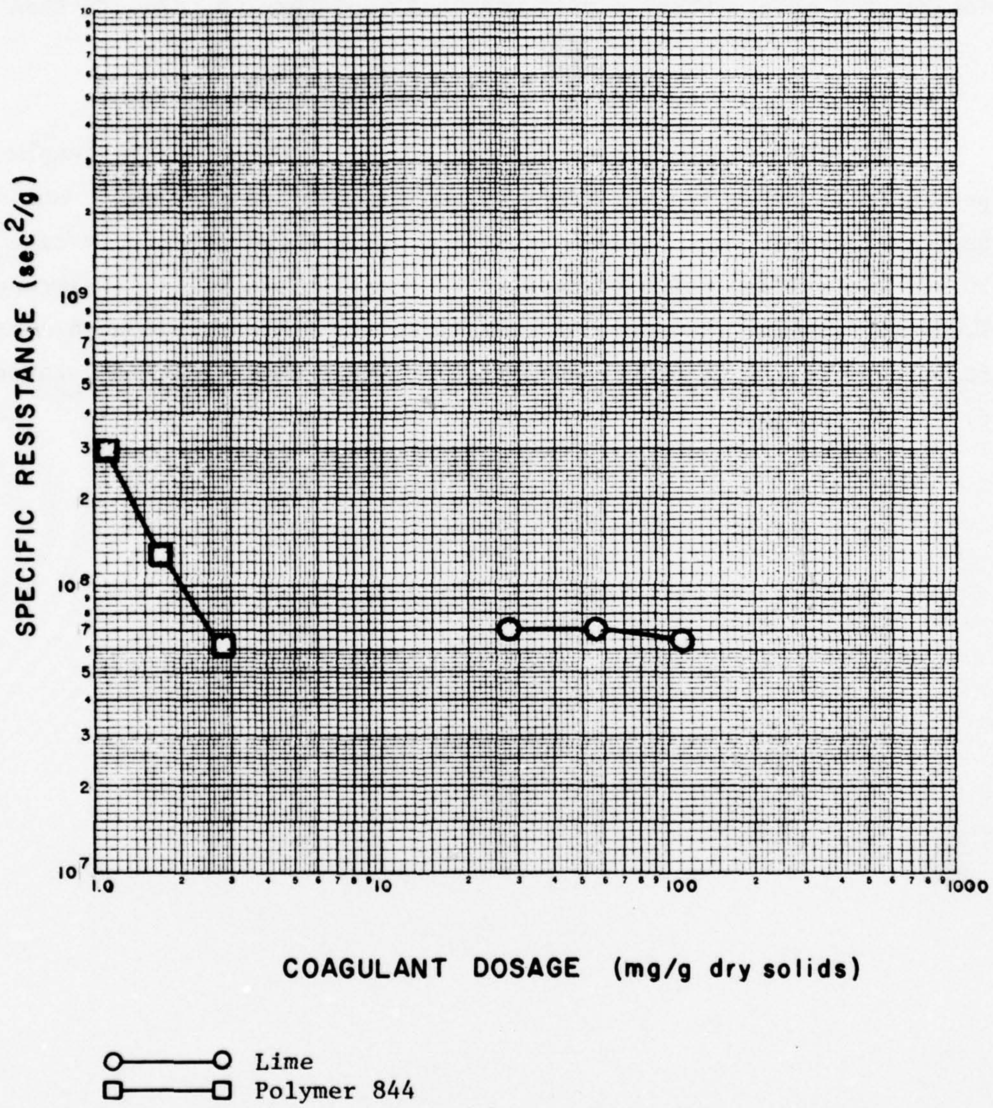


Figure 21
Specific Resistance vs. Coagulant
Dosage, Sixty Percent Silt/Clay
Content

PART VI: FILTER LEAF STUDY RESULTS

71. Filter leaf studies were conducted to expand the results of the Buchner funnel studies and to estimate the filter yields expected when a vacuum filter is used to dewater dredged material. Several parameters influence the effectiveness of vacuum filtration: drum submergence, rotational speed, and the type of filter cloth used. These parameters are discussed below.

The Effect of Drum Speed and Drum Submergence on Filter Yields

72. For all three drum submergences (25 percent, 37-1/2 percent, and 60 percent) at a given drum speed (usually 1 min/rev), the filter cake was weighed and the yield determined in units of pounds/ft^2/hour (on a dry basis). This procedure satisfied the requirements necessary to complete the first objective of this work.

73. The chemical coagulants and the dosages used were derived from the Buchner funnel work and, in particular, the plots of specific resistance versus chemical dosage (expressed as milligram of conditioner per gram of dry solids in the slurry).

74. As shown in the figures presented in this section, increasing the drum submergence increases the yield of cake on the filter. The increased submergence means a lower dewatering time is available (see Table 3) and a higher cake moisture content is expected. This expectation has been verified and the trends presented in the figures.

75. A drum speed of 1 min/rev was used throughout the tests, except in some specific studies performed on samples from Apalachicola Bay, Craney Island Site 1, Browns Lake, and the tailormade samples. One min/rev was used because of the high yields obtained. It was felt that 0.5 min/rev was an impractical speed for scale-up purposes.

Apalachicola Bay

76. The correlations between drum speed and filter yield showed that increased drum speed increased cake yield as illustrated in Figure 22. However, filter cake solids content decreased with increased drum speed.

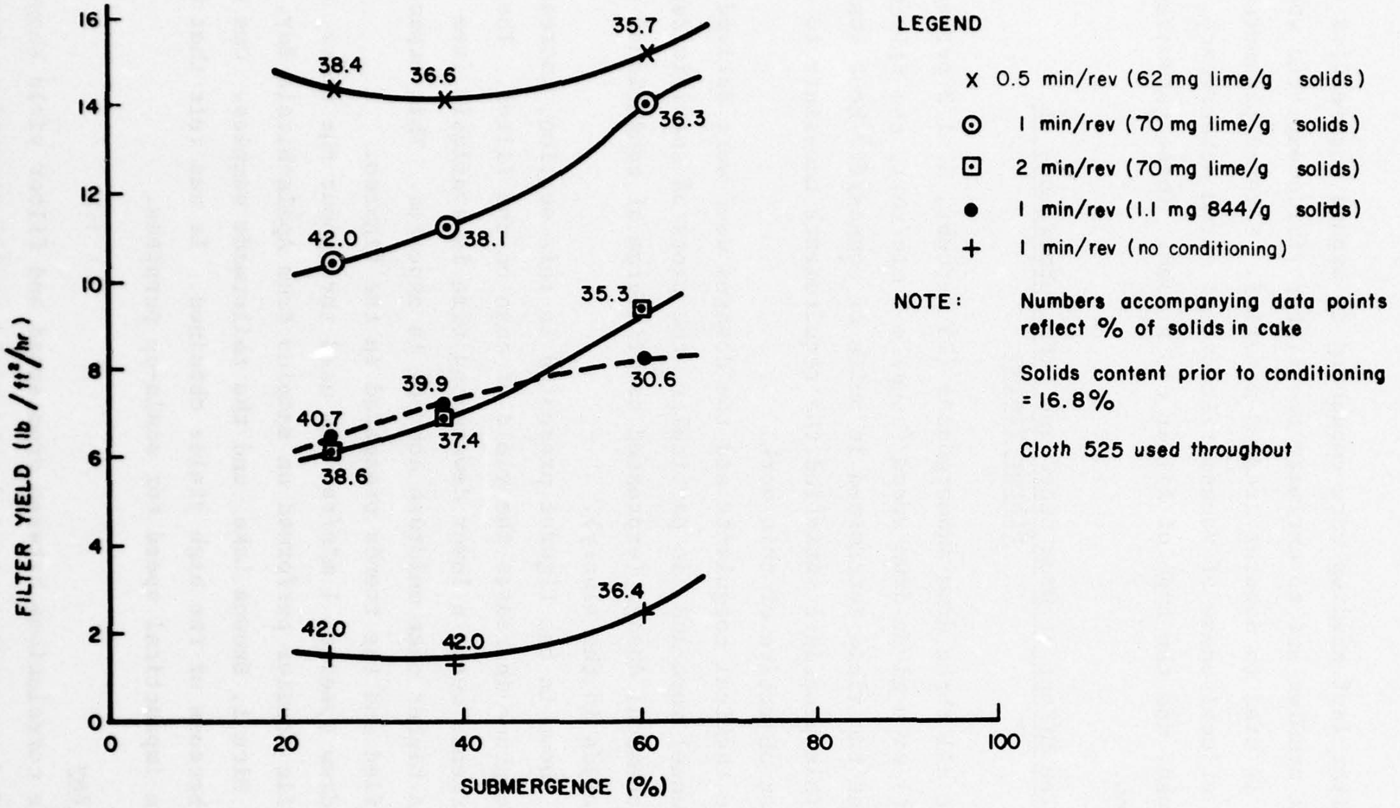


Figure 22
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence
With and Without Conditioning,
Apalachicola Bay

77. Of the three conditioners used (lime, lime with ferric chloride, and polyelectrolyte Hercofloc 844), lime and lime with ferric chloride appeared to be most effective, producing cake yields as high as 14 $lb/ft^2/hr$. The polyelectrolyte used did not produce as high a cake yield (only 8 $lb/ft^2/hr$) as was obtained with lime and ferric chloride, and lime alone. The cake solids levels were generally poorer for the polyelectrolyte than for the other conditioning agents (≈30 percent versus ≈35 percent).

78. Results from vacuum filtration of an unconditioned sample are shown in Figure 22. The attempts yielded predictably low filter yield (less than 2.5 $lb/ft^2/hr$) even though the solids content of the cake ranged from 36 to 42 percent.

Toledo Harbor

79. As with the Apalachicola Bay sample, the highest filter yields for the Toledo Harbor samples were obtained when conditioning was employed at higher drum submergences as shown in Figures 23 through 25. When using lime conditioning, yields of 22 and 11 $lb/ft^2/hr$ were obtained from Site A and the land disposal area, respectively. In addition, the cake solids obtained were consistently above 43 percent solids.

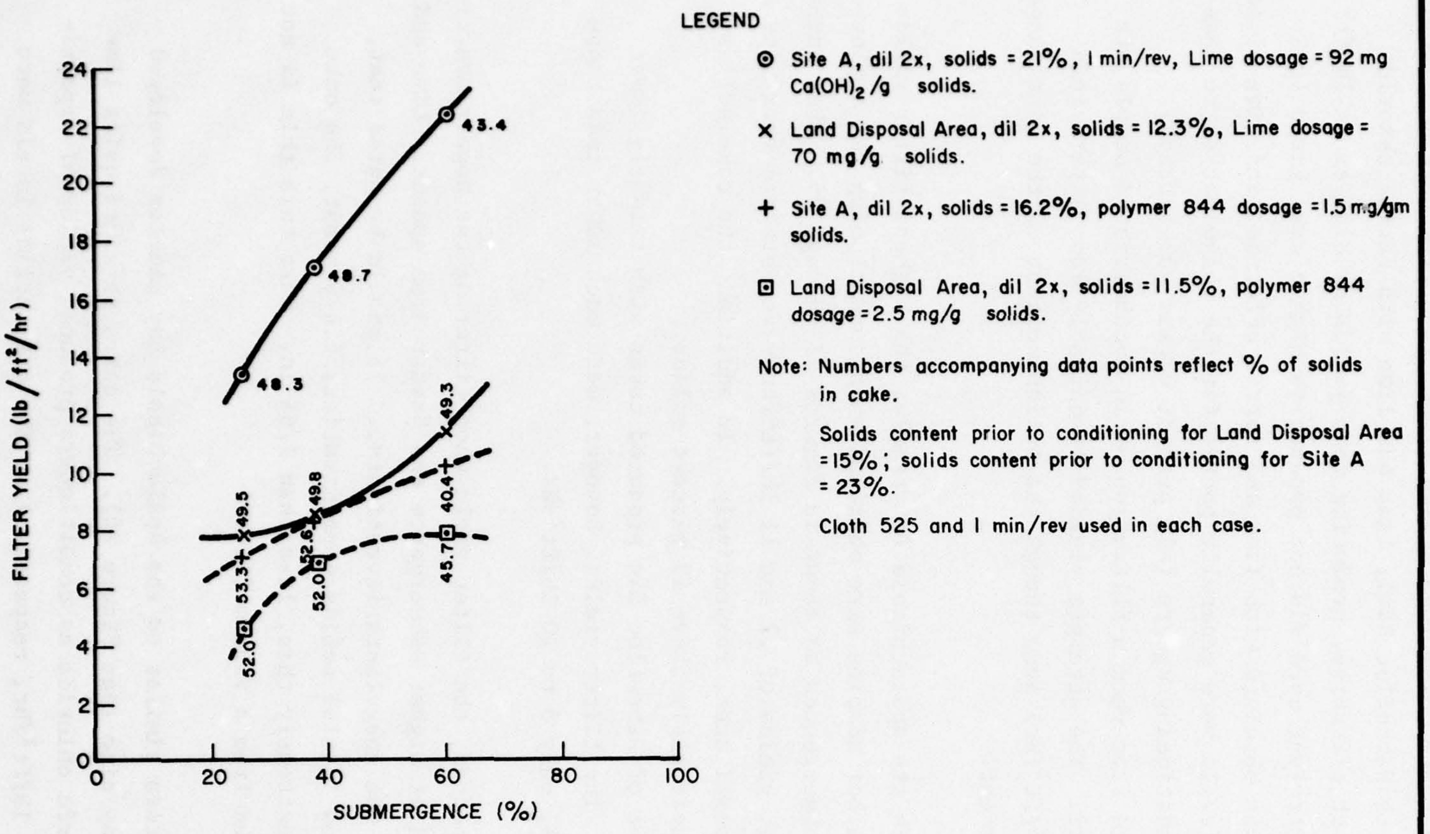
80. The use of Hercofloc 844 produced cakes with slightly lower solids contents. The filter yields, however, were much lower than those obtained for lime, only 8 to 10 $lb/ft^2/hr$.

Hopper Overflow

81. As expected, the filter yield when filtering the hopper overflow sample increased at higher submergence and faster drum speeds. Lime and polymer 844 were the coagulants investigated. It should be noted that, because of the low initial solids concentration, 4.4 percent, the cake that formed was extremely thin, less than 1/64 in. Cake this thin is not readily discharged from a vacuum filter.

Mobile Bay

82. A pattern similar to the Apalachicola Bay samples developed for the Mobile Bay site (see Figure 26). The cakes obtained using lime and lime and ferric chloride as conditioners produced yields of approximately 16 and 21 $lb/ft^2/hr$, respectively. The cake solids levels were approximately 37 percent. The use of Hercofloc 844, however, resulted in cakes with only 31 percent solids and yields of around 8 $lb/ft^2/hr$.



Note: Numbers accompanying data points reflect % of solids in cake.

Solids content prior to conditioning for Land Disposal Area = 15%; solids content prior to conditioning for Site A = 23%.

Cloth 525 and 1 min/rev used in each case.

Figure 23
Correlation of Filter Leaf Yields and Cake Solids With Drum Submergence, Toledo Site A and Land Disposal Area

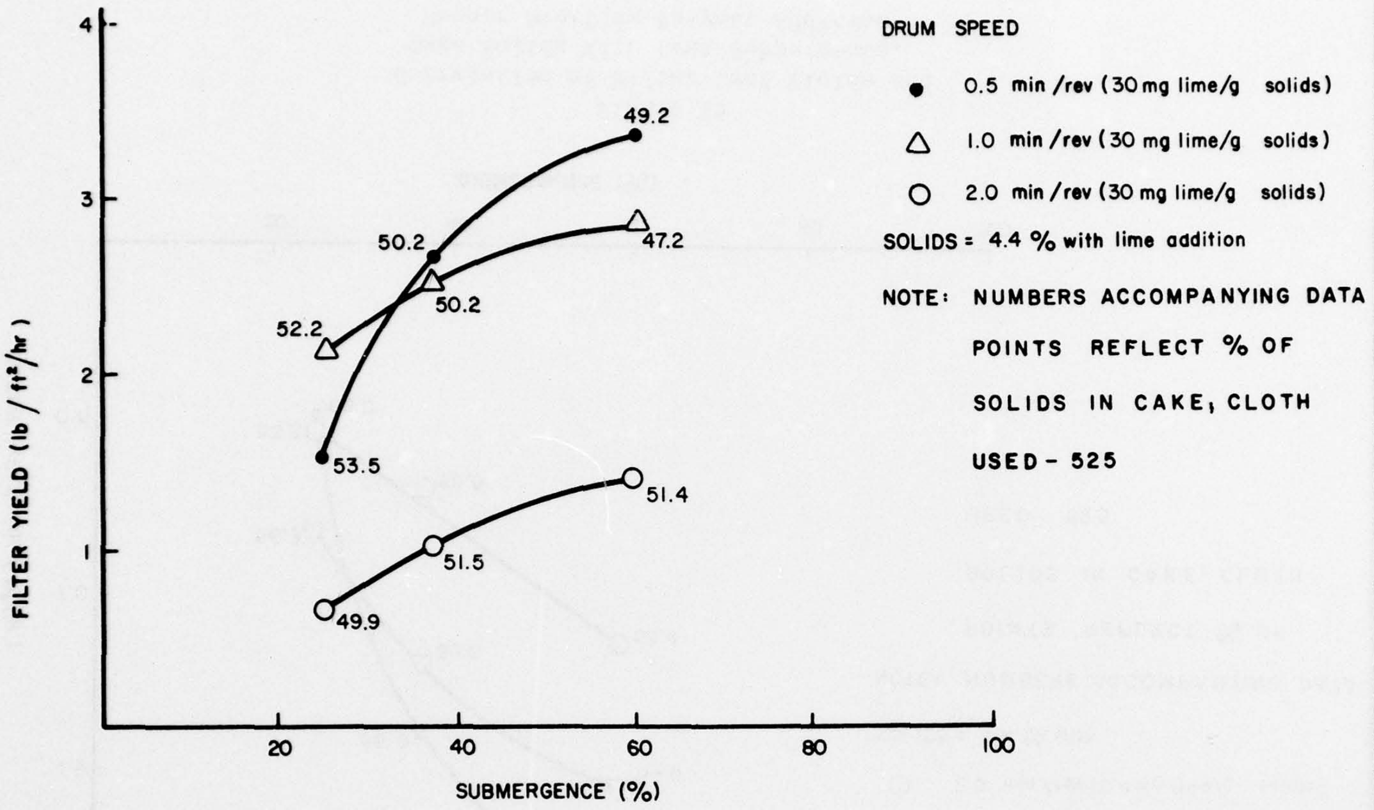


Figure 24
Correlation of Filter Leaf Yields
and Cake Solids With Drum Submergence,
Hopper Overflow Lime Addition

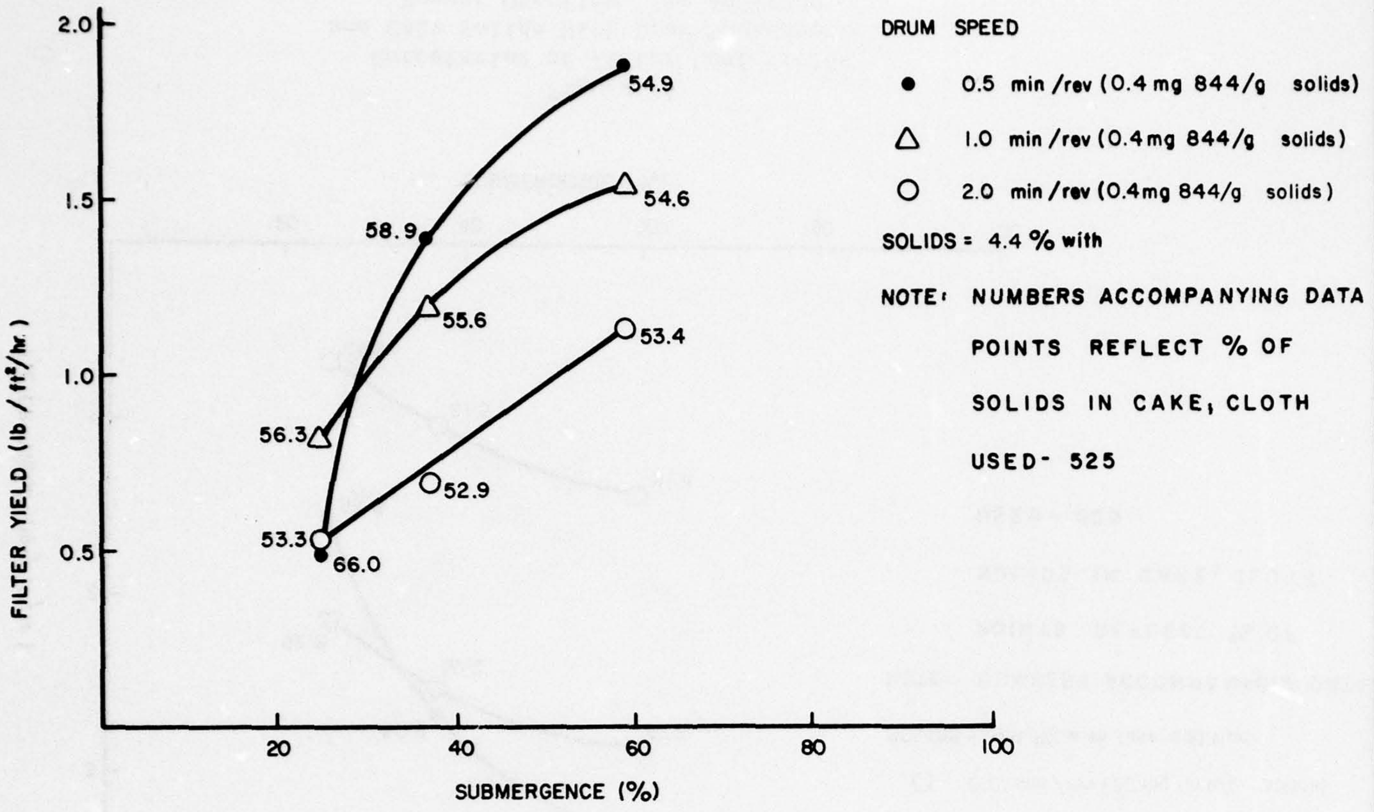


Figure 25
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Hopper Overflow Polymer Addition

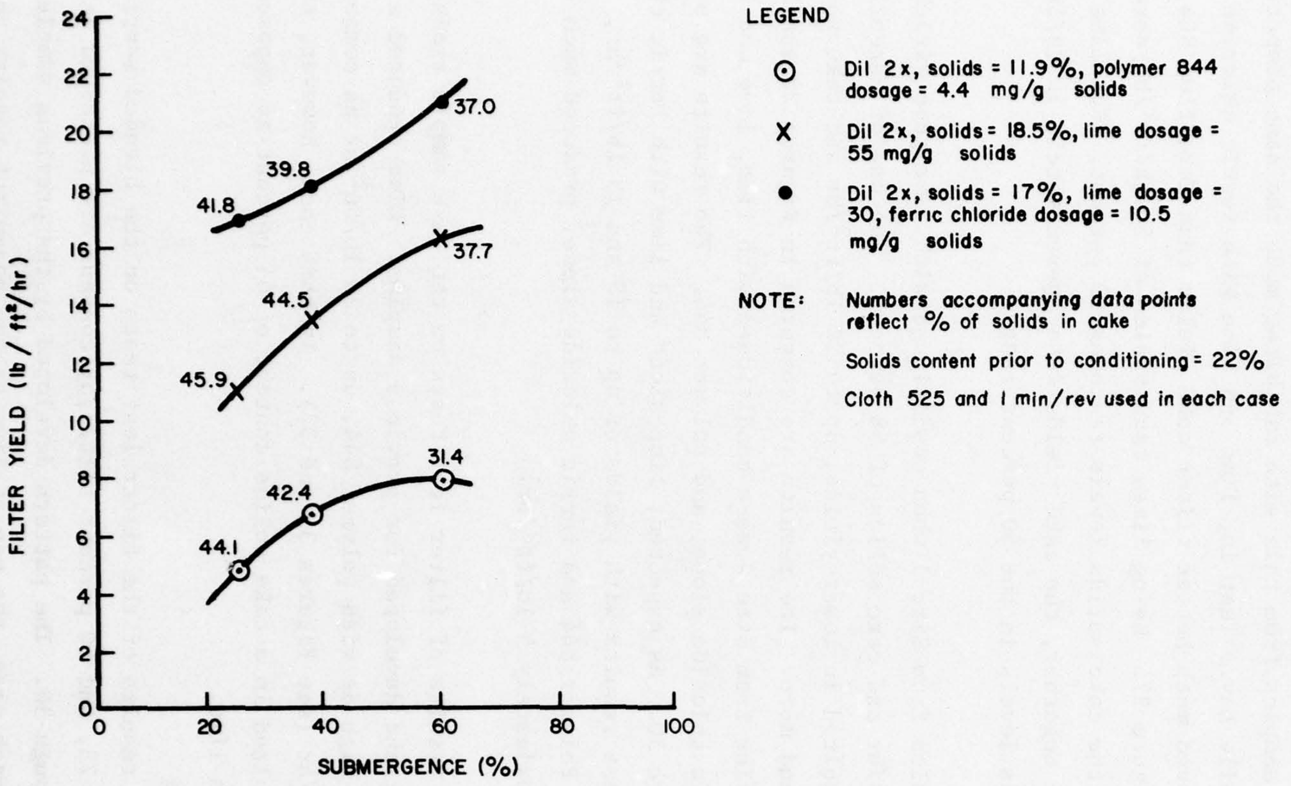


Figure 26
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence
and Conditioning, Mobile Bay

Penns Neck

83. The samples from this site exhibited much the same properties as those of Mobile Bay. That is, lime and lime with ferric chloride conditioning produced much better filter cake yields than Hercofloc 844, as presented in Figure 27. Using lime, cake yields of 50 $lb/ft^2/hr$ were obtained, with the cake solids levels reaching 50 percent. For lime and ferric chloride together, the cake yields were approximately 32 $lb/ft^2/hr$ with cake solids levels in the 50 percent range.

Craney Island

84. Samples from Site 1 when conditioned with lime gave yields of up to 42 $lb/ft^2/hr$ and cake solids of 58 percent. The use of Hercofloc polymer 844 resulted in lower yields, up to 22 $lb/ft^2/hr$ and cake solids of 50 percent and more. The results are compared in Figures 28 and 29.

85. Samples from Site 4 were conditioned with lime, lime and ferric chloride, ferric chloride alone, and polymer 844. The results are presented in Figure 30. As expected, lime alone and lime with ferric chloride produced the best results with yields of up to 15 and 13 $lb/ft^2/hr$, respectively. Polymer 844 and ferric chloride alone, produced much lower yields of approximately 5 $lb/ft^2/hr$.

Browns Lake

86. The results of filter leaf tests on the lake sample again appear to follow the trend developed for previous samples. Lime produced a filter yield twice as high as with polymer 844, up to 20 $lb/ft^2/hr$ as compared with 11 $lb/ft^2/hr$ (see Figures 31 and 32). In this case, however, the use of polymer resulted in a cake solids content of 64 percent as opposed to 60 percent with lime.

Blended Samples

87. The results of the filter leaf tests on the blended samples containing 90, 75, and 60 percent silt/clay content are presented in Figures 33 through 38. The pattern developed by the previous samples was repeated. In each case, the use of lime as the coagulant results in filter yields which were approximately twice those obtained using the polymer Hercofloc 844. Solids contents using either coagulant for the same sample were generally higher with lime than with the polymer.

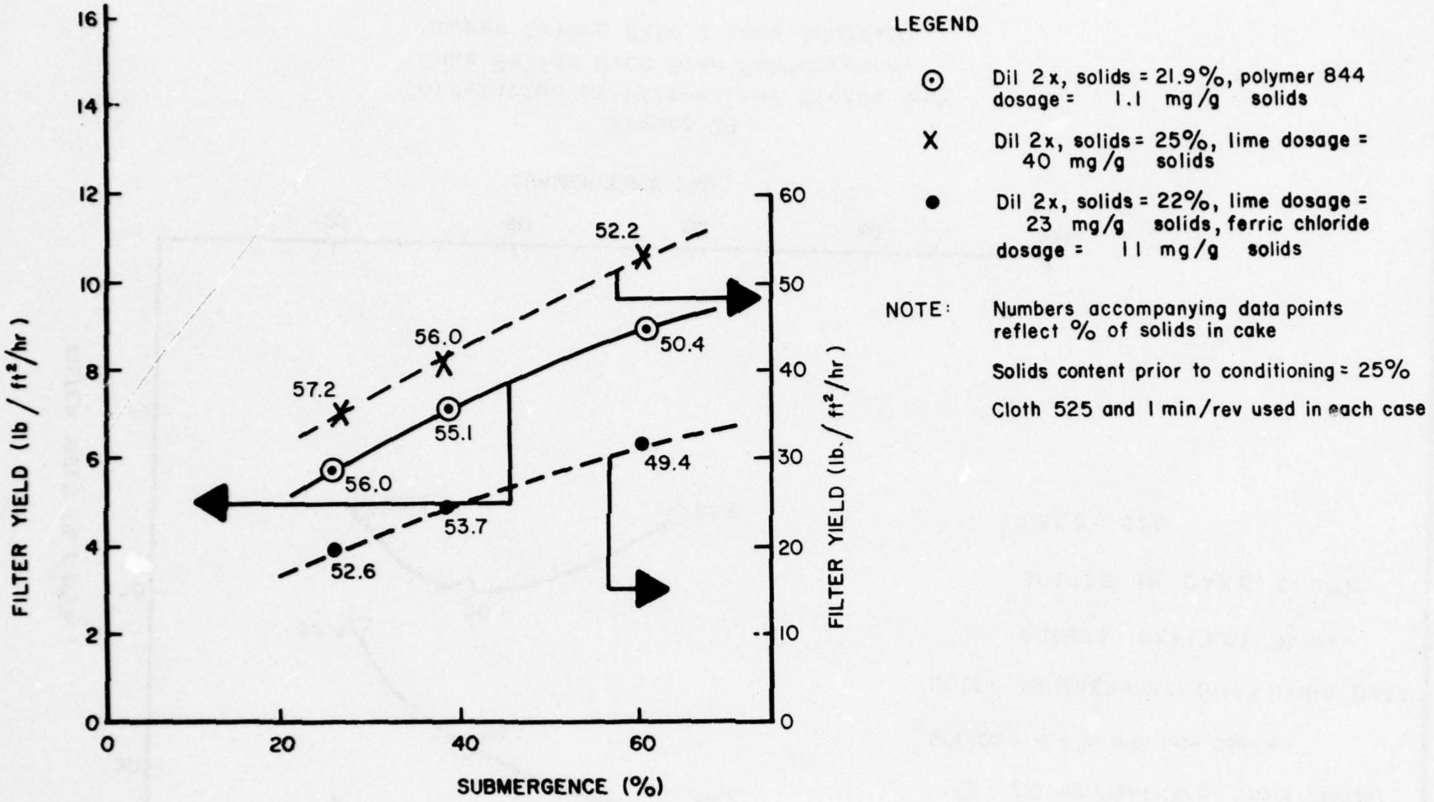


Figure 27
Correlation of Filter Leaf Yields
and Cake Solids With Drum
Submergence and Conditioning,
Penns Neck Spillway

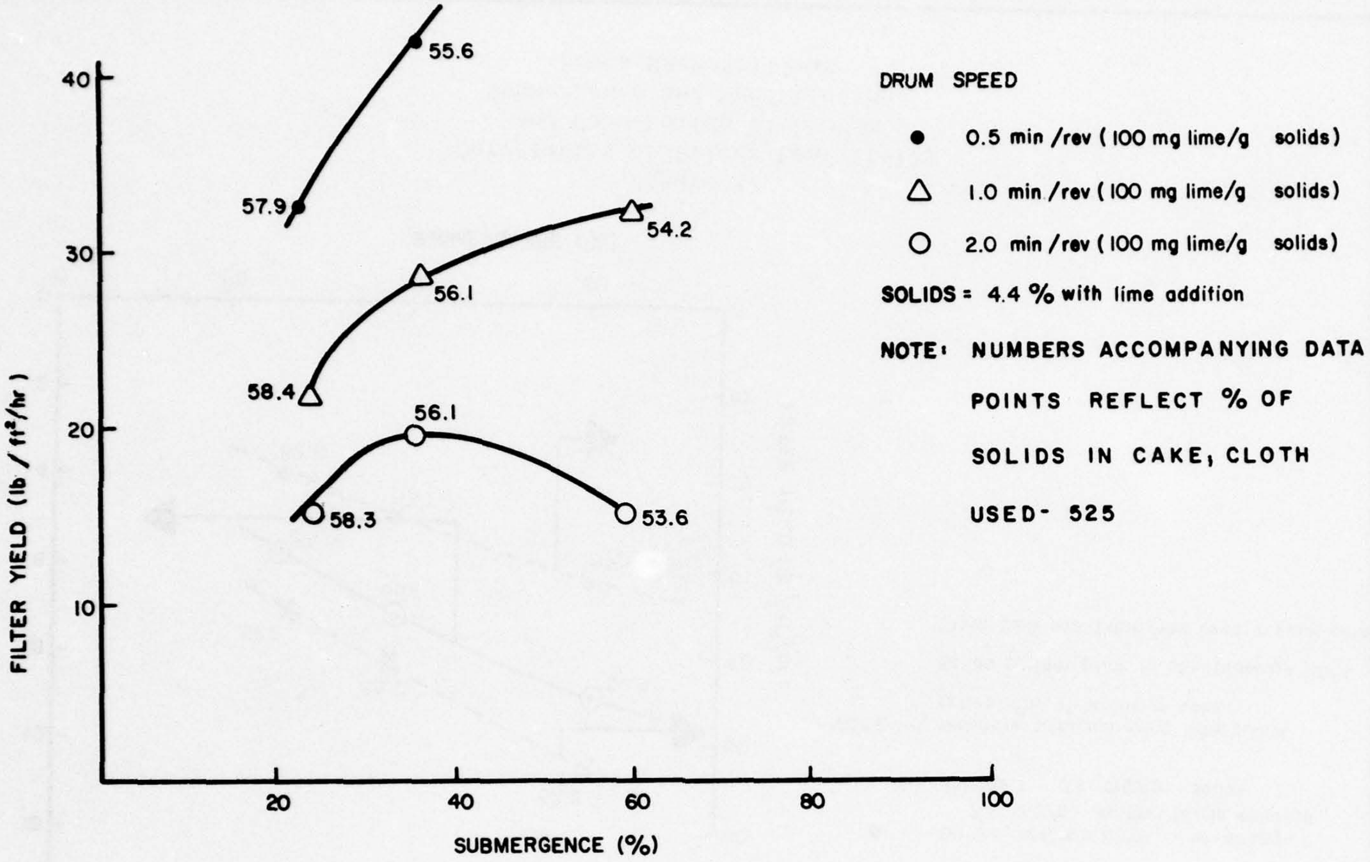


Figure 28
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Craney Island Site 1 Lime Addition

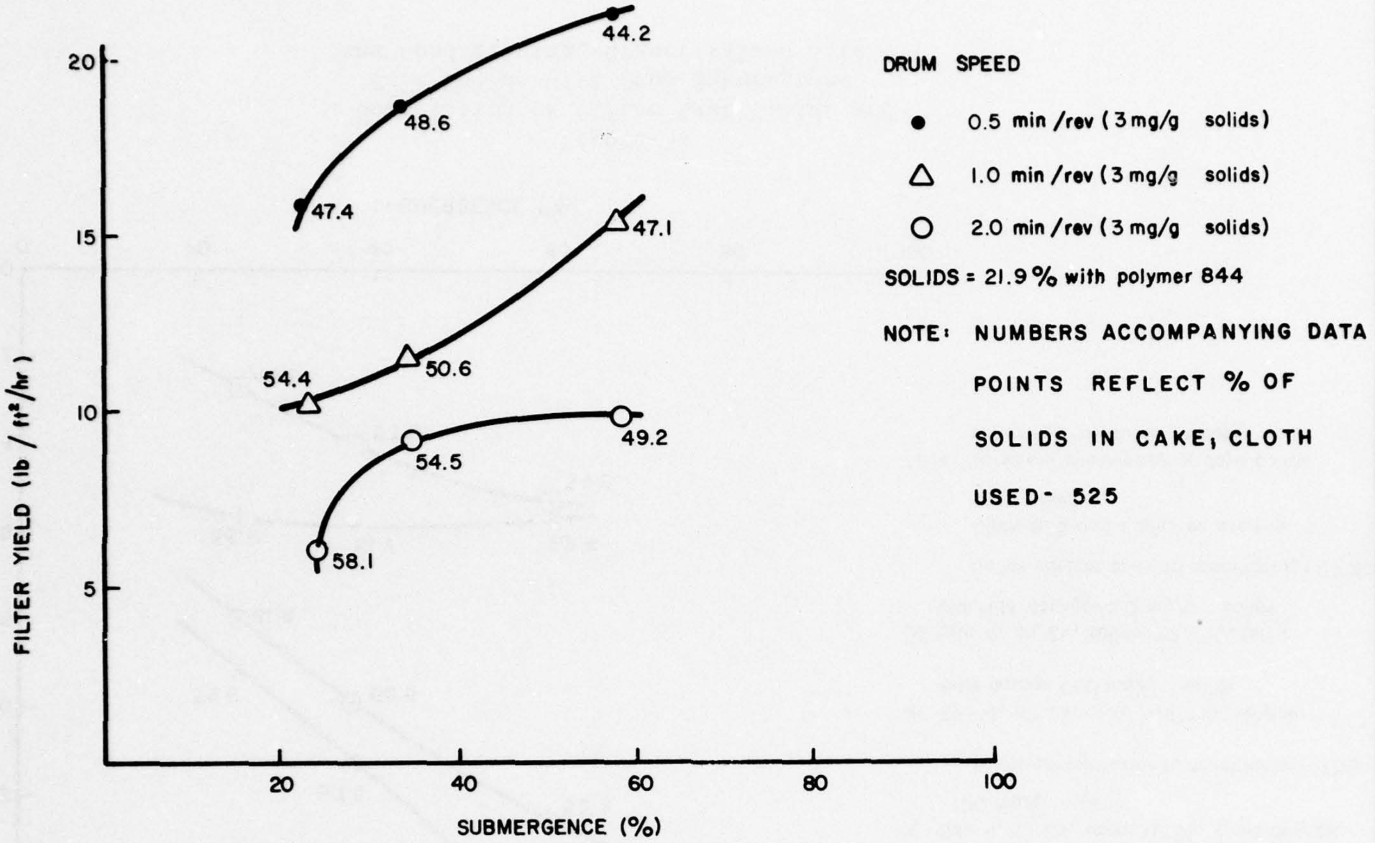


Figure 29
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Craney Island Site 1 Polymer Addition

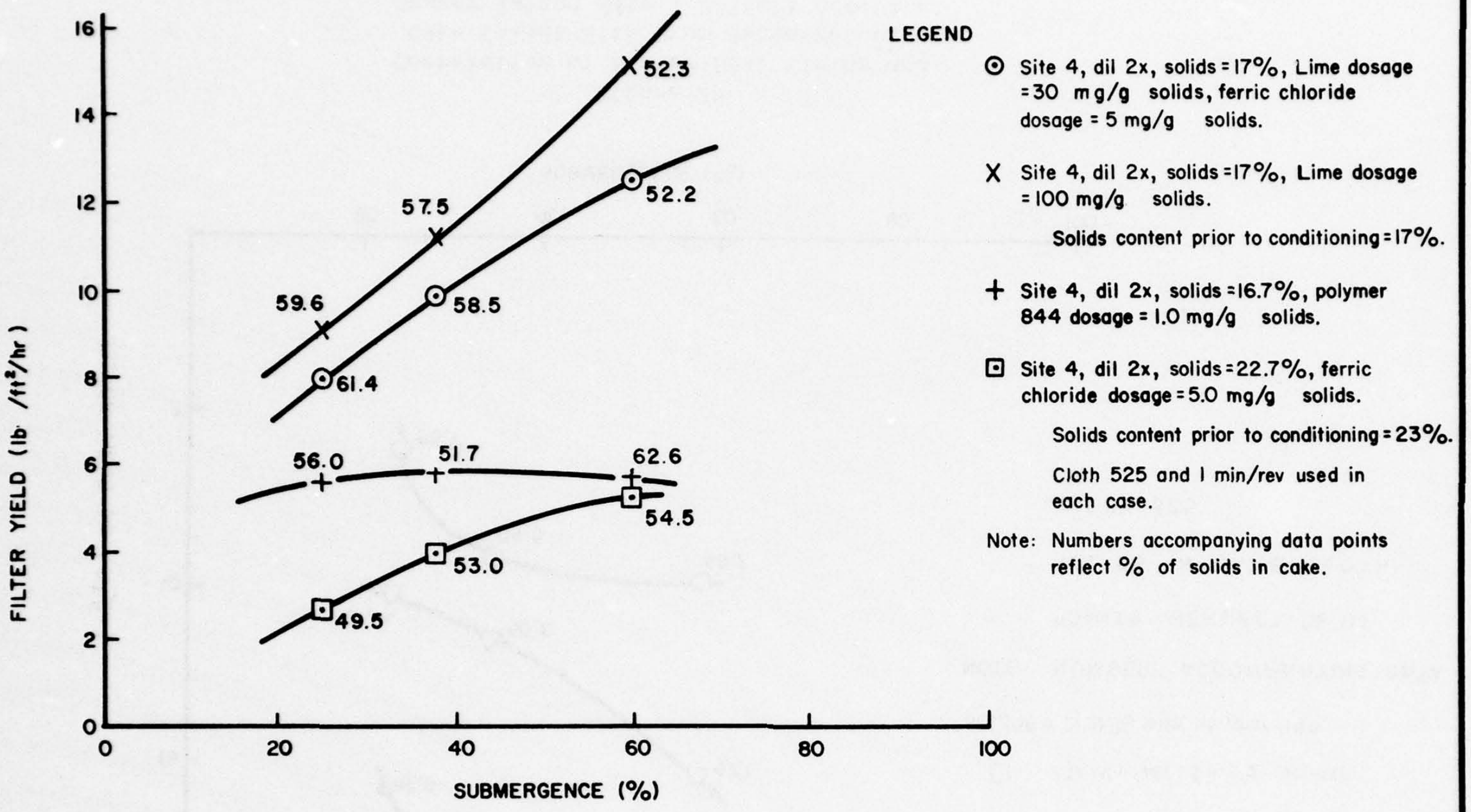


Figure 30
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence
and Conditioning, Craney Island Site 4

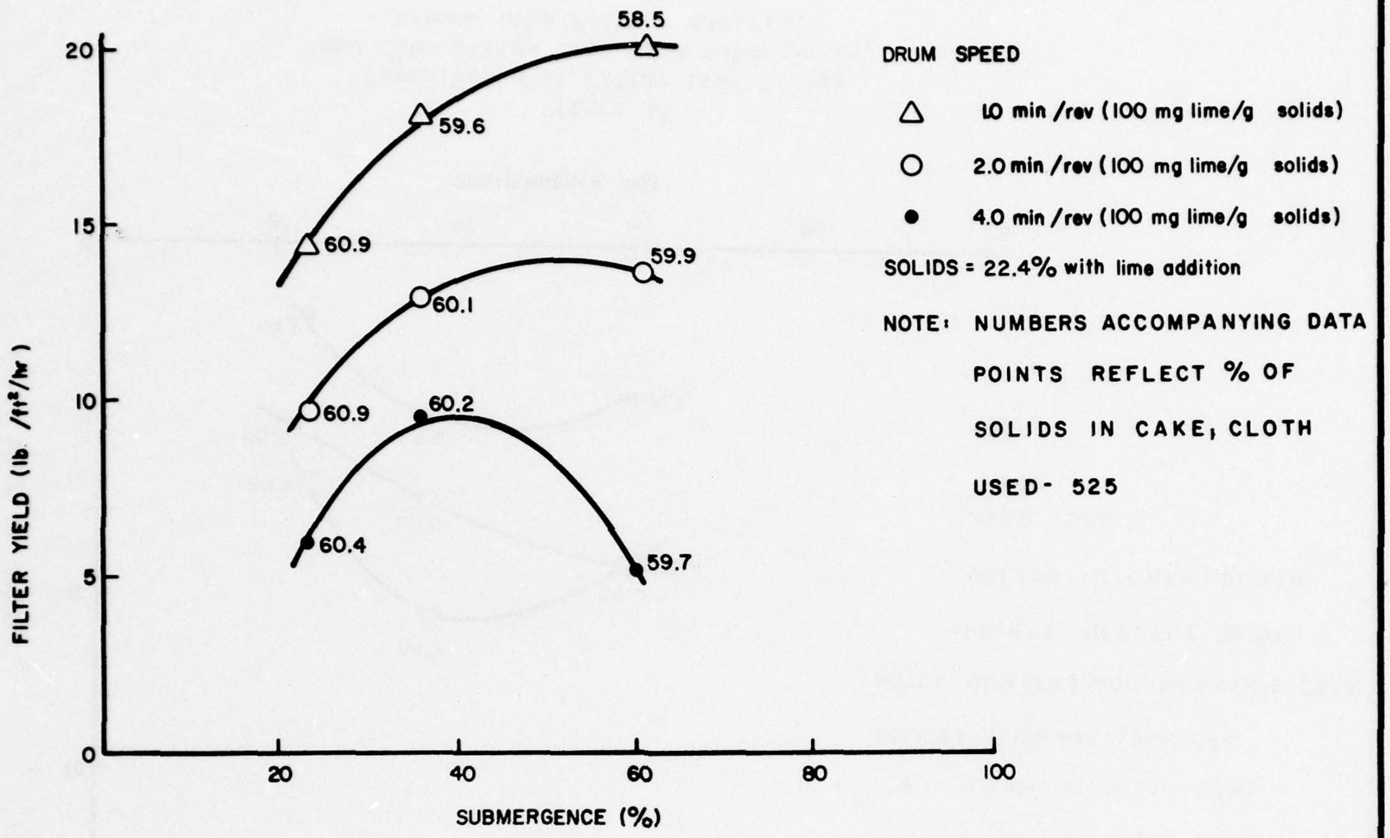


Figure 31
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Browns Lake Lime Addition

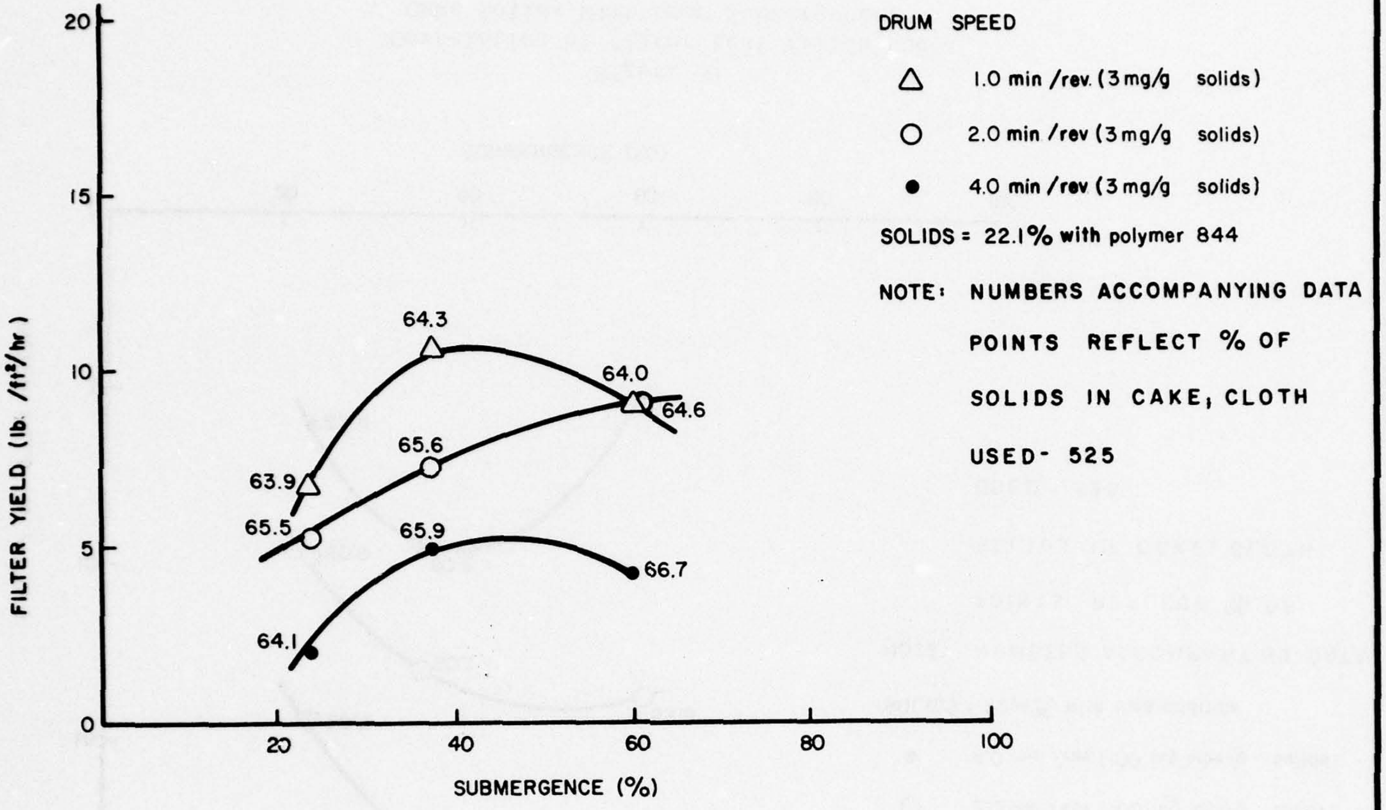


Figure 32
Correlation of Filter Leaf Yields
and Cake Solids With Drum Submergence,
Browns Lake Polymer Addition

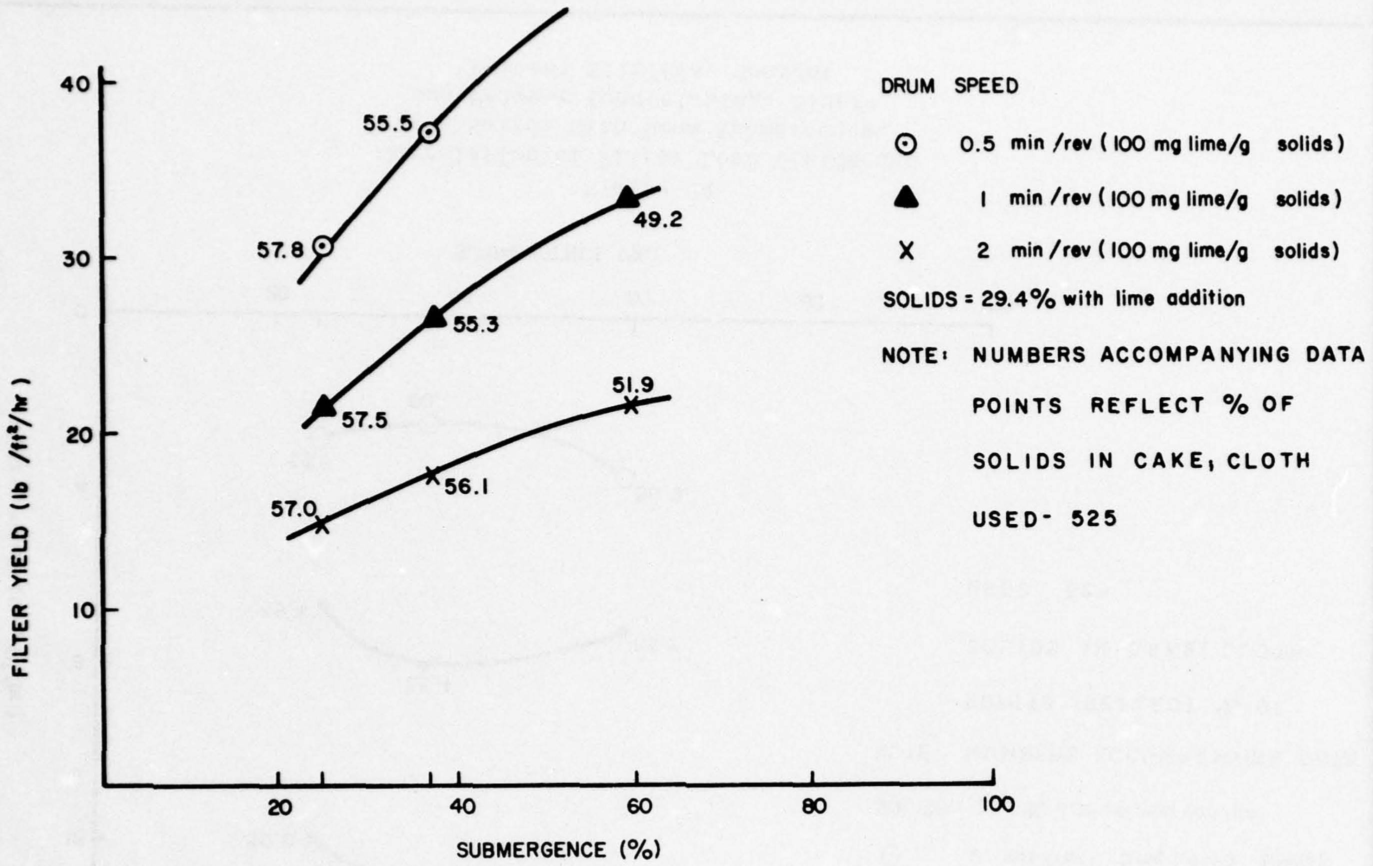


Figure 33
Correlation of Filter Leaf Yields and Cake Solids With Drum Submergence, and Lime Conditioning, Ninety Percent Silt/Clay Content

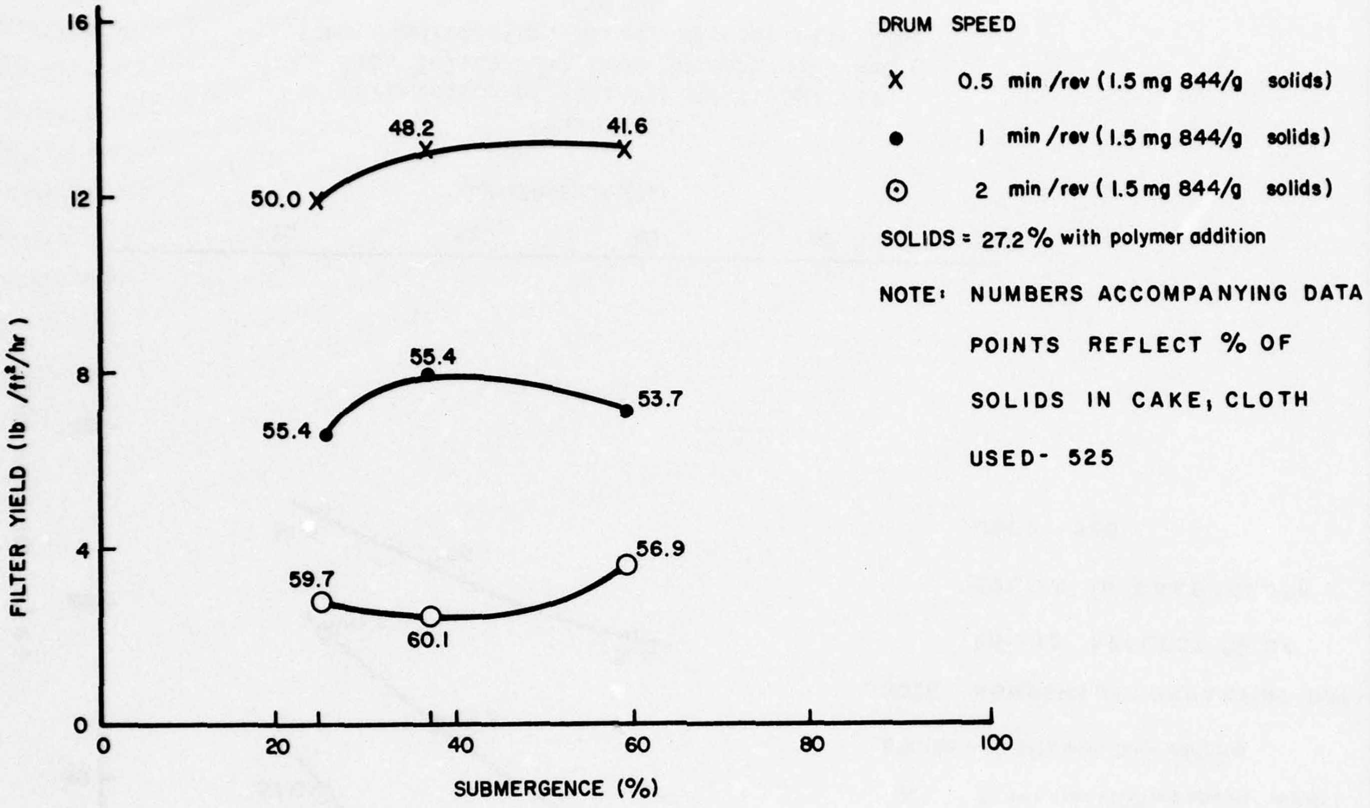


Figure 34
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
and Polymer Conditioning, Ninety
Percent Silt/Clay Content

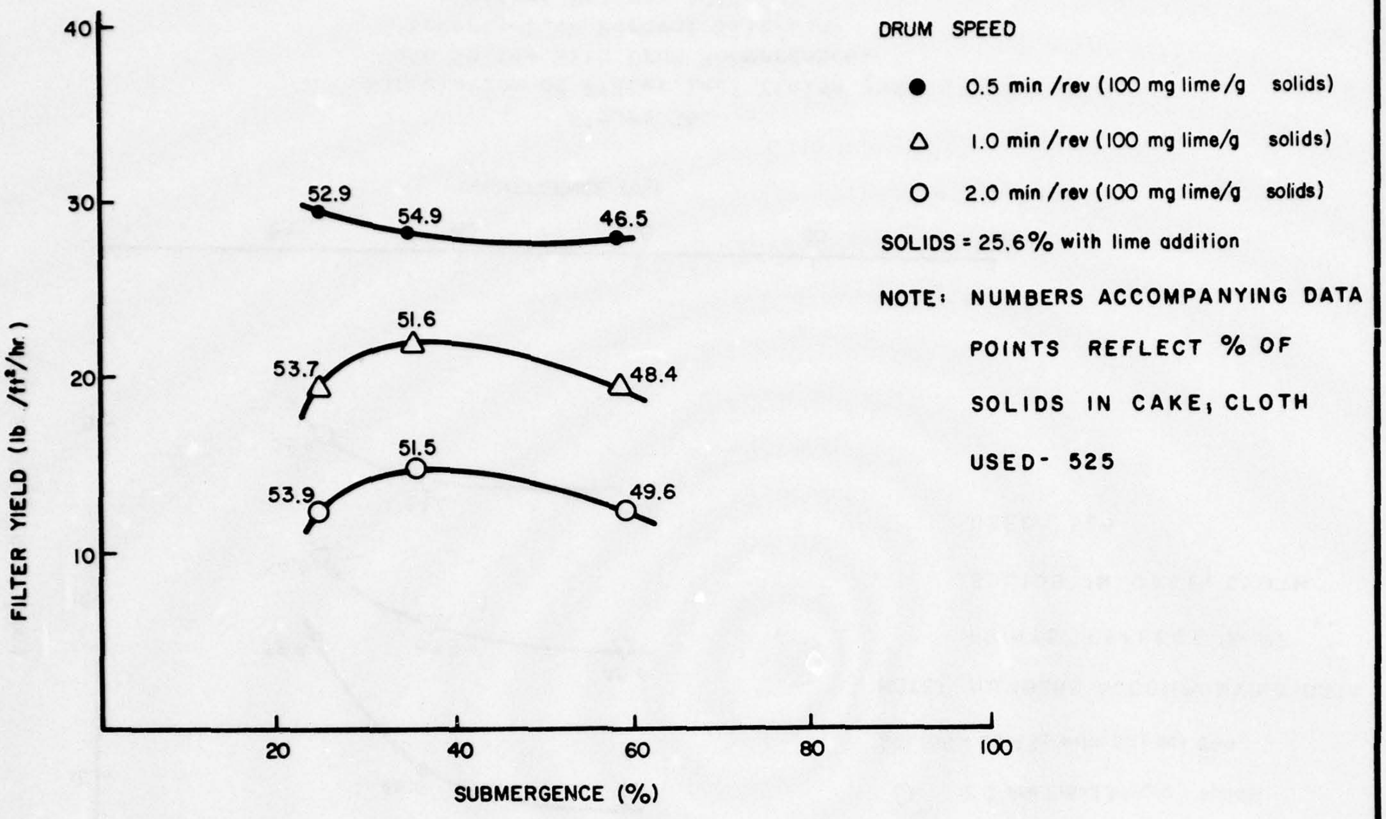


Figure 35
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Seventy-Five Percent Silt/Clay Content
Lime Addition

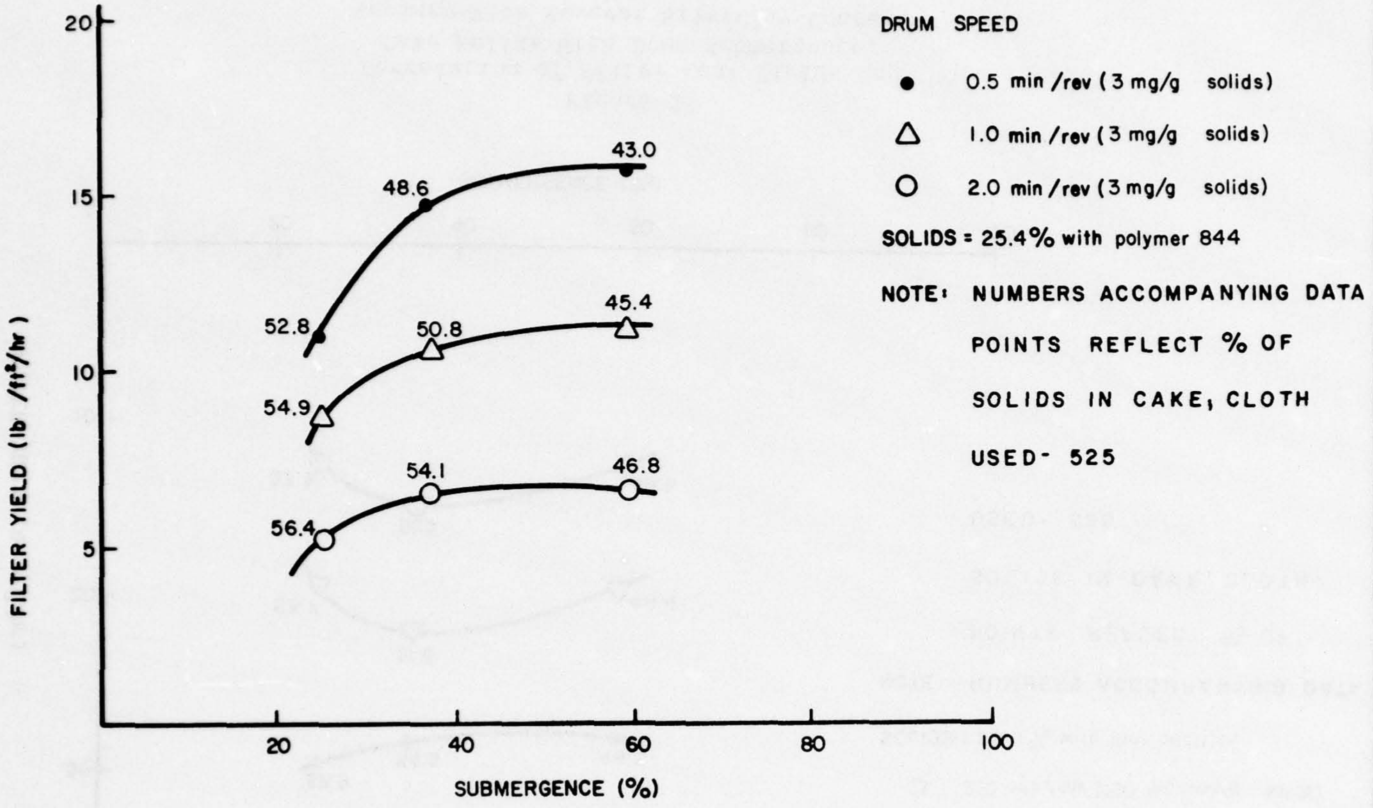


Figure 36
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Seventy-Five Percent Silt/Clay
Content Polymer Addition

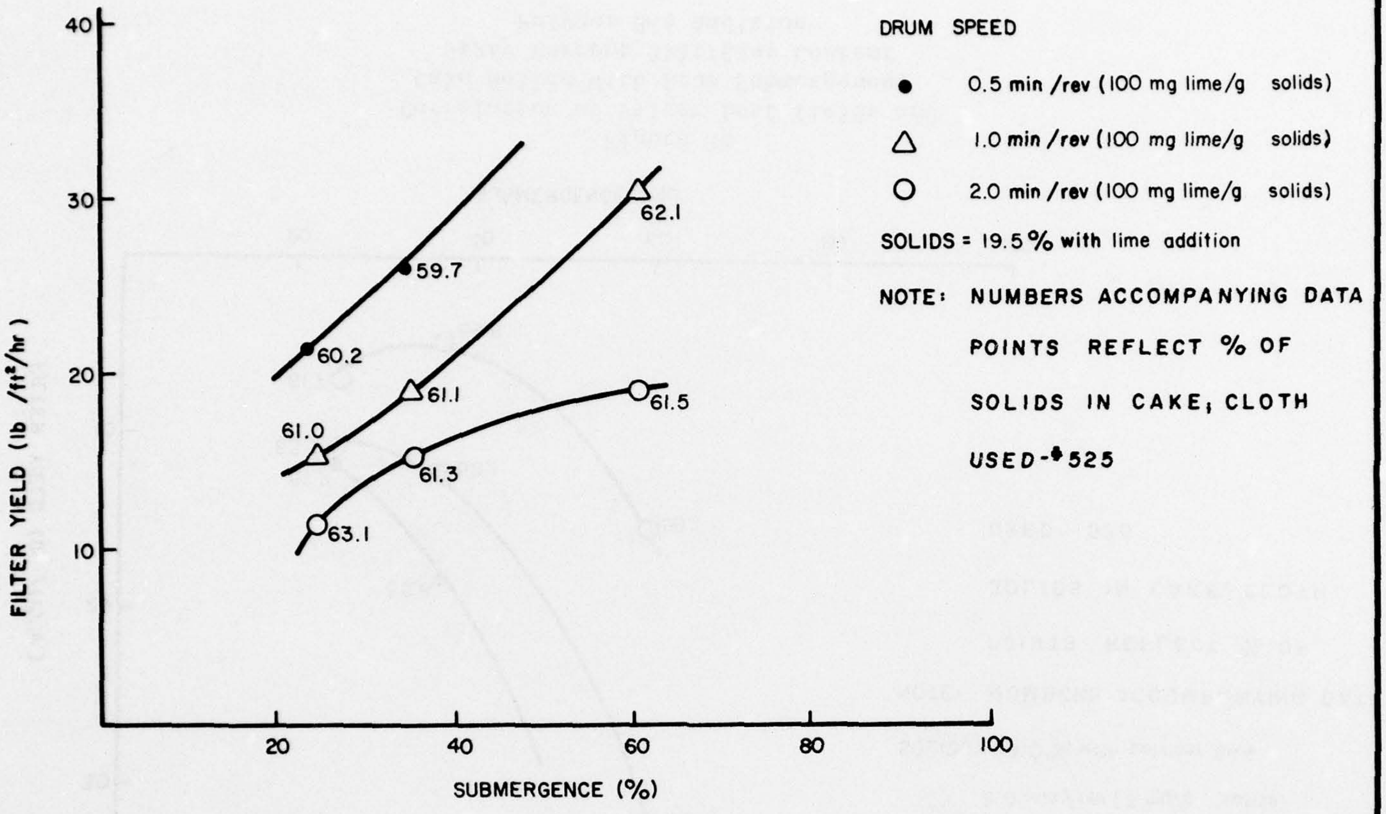


Figure 37
Correlation of Filter Leaf Yields and Cake Solids With Drum Submergence, Sixty Percent Silt/Clay Content Lime Addition

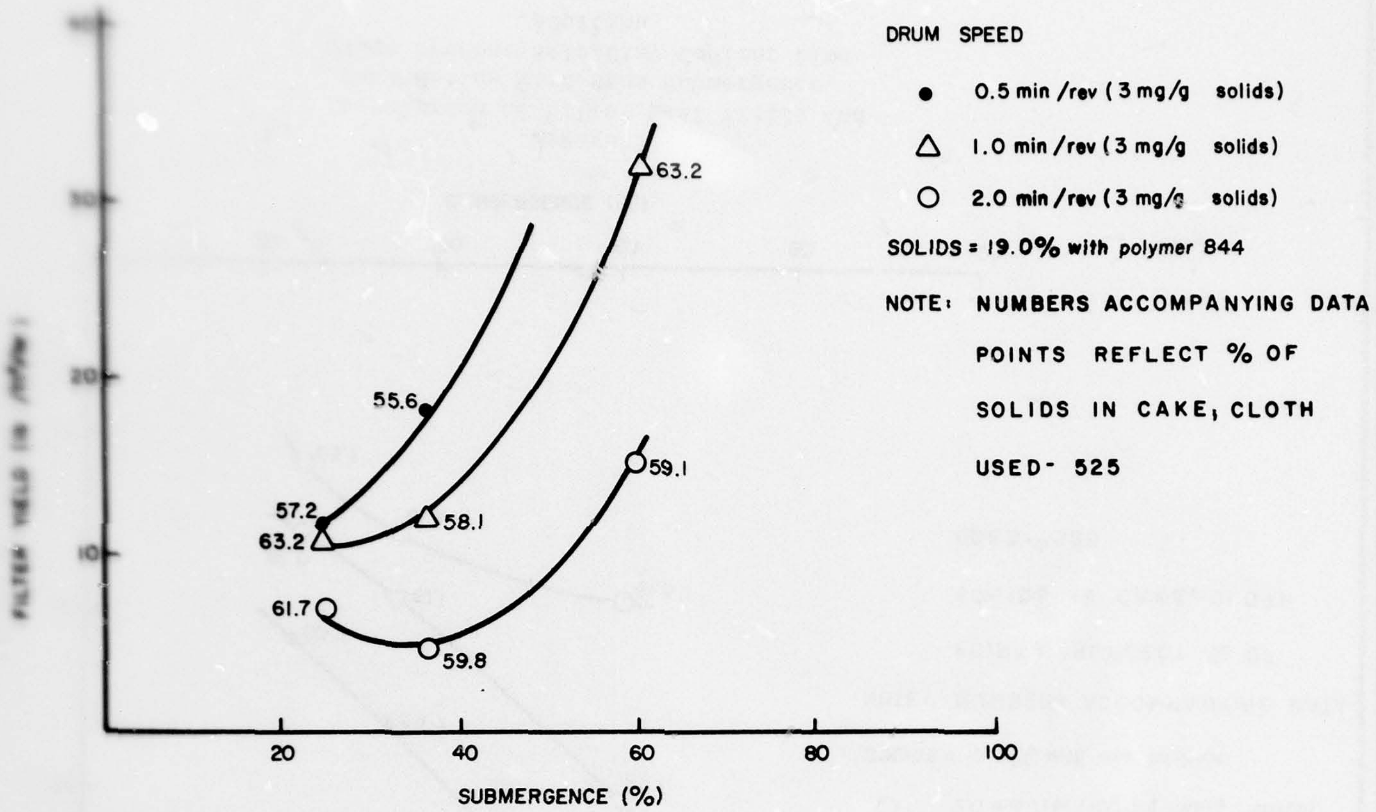


Figure 38
Correlation of Filter Leaf Yields and
Cake Solids With Drum Submergence,
Sixty Percent Silt/Clay Content
Polymer 844 Addition

The Effect of Chemical Conditioning on Filtrate Quality

88. Filtrate quality is an important consideration in designing a vacuum filtration system for dewatering dredged material. The vacuum filter not only must achieve high solids yields, but must also produce a high-quality filtrate. This filtrate must be acceptable for discharge to a receiving body of water; that is, the harbor or waterway where the dredging operation is being conducted. Thus, for this series of experiments, filtrate quality, cake yield, conditioner type, and dosage were compared.

89. For these tests, the drum speed and submergence were fixed and only chemical dosage varied. In each case, a drum speed of 1 min/rev and a submergence of 60 percent were employed. Only Apalachicola Bay samples were investigated because previous studies showed that results obtained from Apalachicola Bay were typical of results obtained with the other sites. Summaries of the results obtained are presented in Figures 39 and 40.

90. In lime conditioning, total filtrate solids become important as well as suspended solids because filtrates resulting from lime conditioned slurries contain a sizeable quantity of lime (in dissolved form). Therefore, correlations have been made between applied lime dosage and the total and dissolved solids in the resultant filtrate. This correlation appears in Figure 41. The results used to make the correlation of filtrate quality with dosage of chemical conditioner are presented in Figures 39 and 40. Although this work was conducted only on samples from Apalachicola Bay, it reveals some significant trends which could be expected in samples from the remaining sites.

91. Generally, the suspended solids level in the filtrate decreases with increased conditioner dosages. Hercofloc 844 conditioning (see Figure 40) appears capable of reducing the suspended solids in the filtrate to 50 mg/ℓ or less at dosages of 3.5 mg/g of sample solids. The filter yield, however, is not increased significantly for polymer dosages above 3 mg/g of solids.

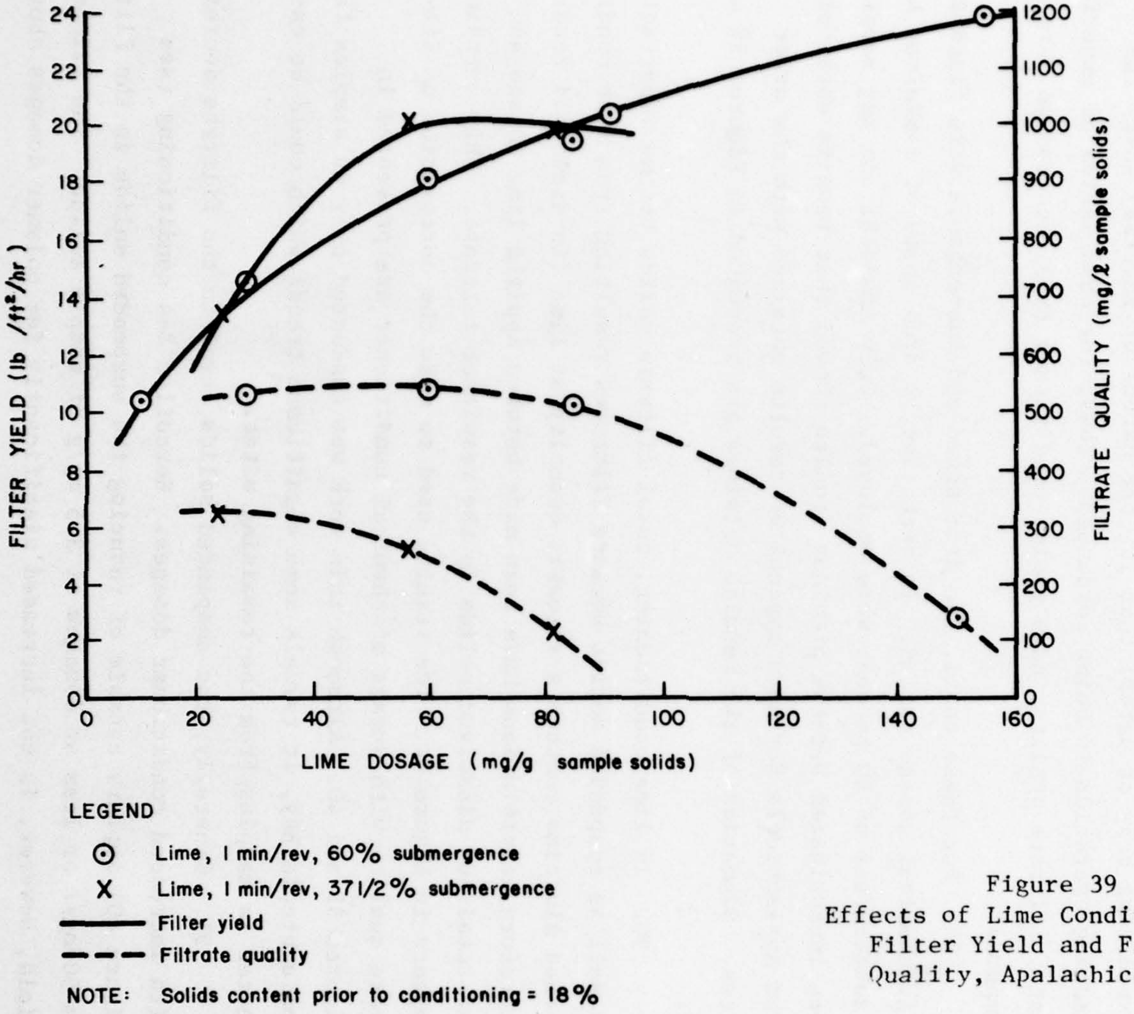


Figure 39
Effects of Lime Conditioning on
Filter Yield and Filtrate
Quality, Apalachicola Bay

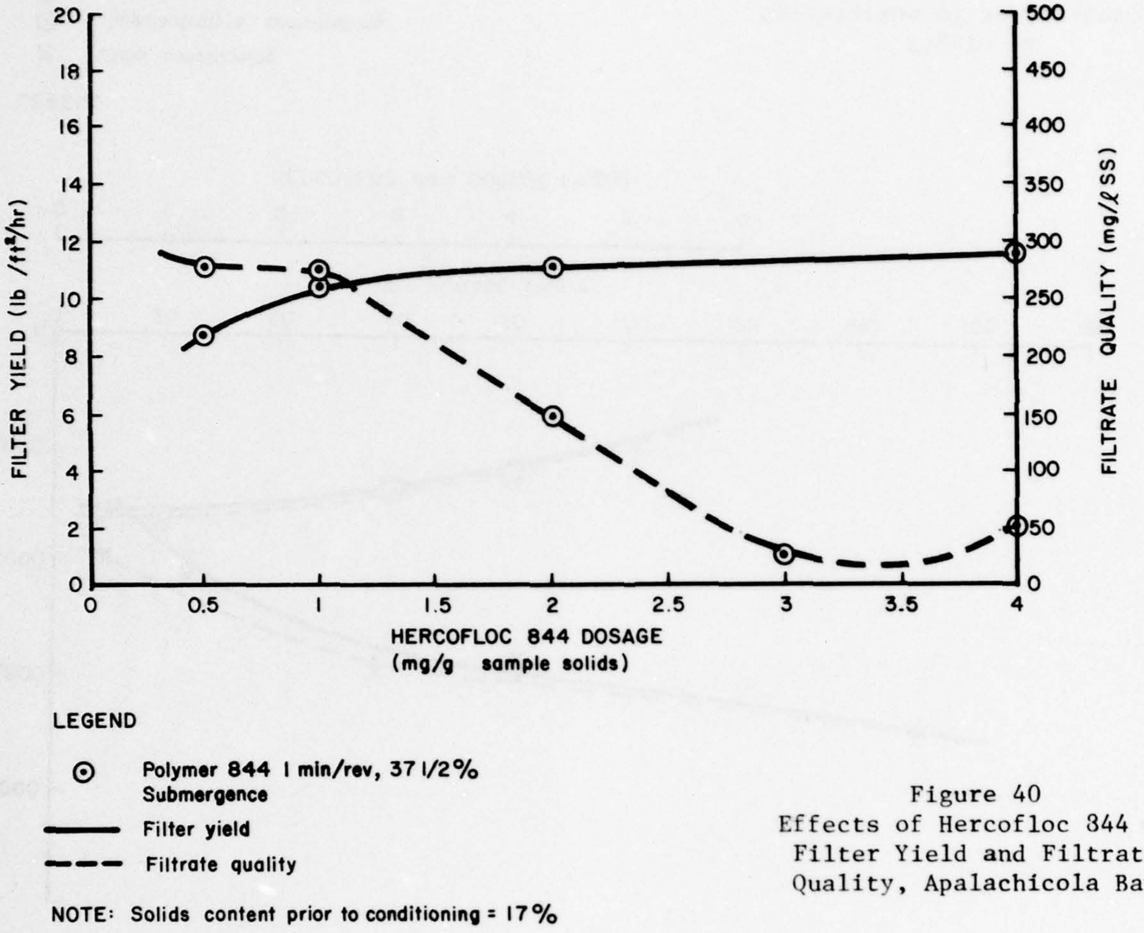


Figure 40
Effects of Hercofloc 844 on
Filter Yield and Filtrate
Quality, Apalachicola Bay

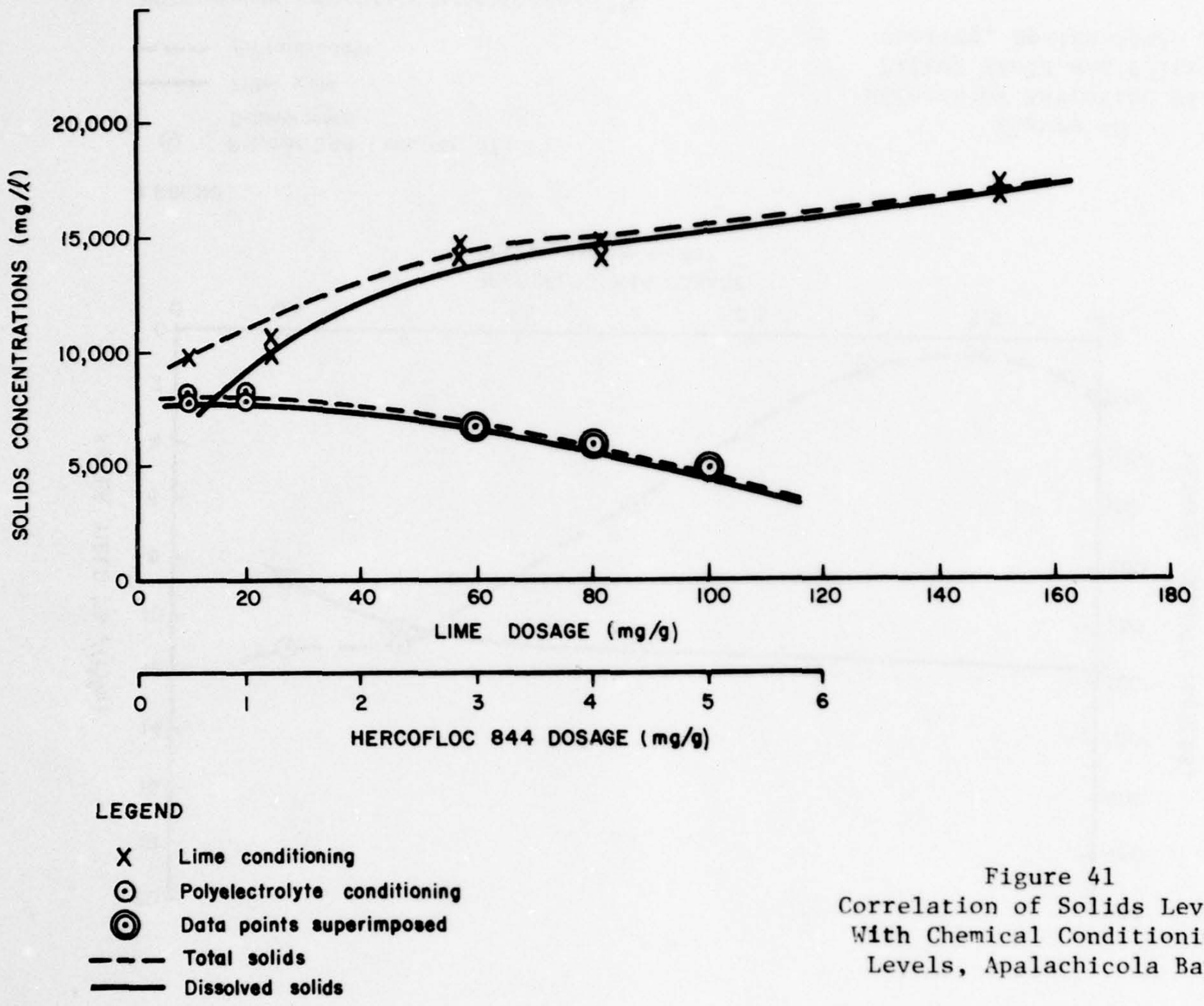


Figure 41
Correlation of Solids Levels
With Chemical Conditioning
Levels, Apalachicola Bay

92. Similar trends are observed for cases where lime was used as a conditioning agent. For lime dosages of greater than 100 mg/g of sample solids, the filtrate suspended solids appear to decrease dramatically at 60-percent submergence. At 37.5-percent submergence the decrease in suspended solids appears to begin at slightly lower dosages of lime (i.e., ≃70 mg lime per gram of sample solids). In both cases, the filter cake yield is not increased significantly by increasing the lime conditioning above 70 mg/g of sample solids.

93. The correlation presented in Figure 41 shows that as the lime dosage increases, the amount of dissolved material in the filtrate increases. This factor obviously mitigates against the generous use of lime to increase cake yields. However, use of lime dosages between 60 and 80 mg/g dredged solids appears realistic. On the other hand, Hercofloc 844 reduces the total solids in the effluent as its dosage increases. Note also that the suspended solids levels will decrease dramatically with an increase in the polymer dosage.

Correlation of Cake Yield and Filtrate Quality with Porosity of Filter Cloth

94. The purpose of this portion of the laboratory testing program was to determine the effects of using different filter cloths on cake yield and filtrate quality. The cloths available have been classified primarily according to their porosity, expressed as standard cubic feet per minute (scfm) that may be passed through the cloth under isobaric conditions.

95. Based on the results of particle-size distribution analyses for all of the dredged material samples, it appears that Toledo Site A has a large portion of small particles (effective size <0.04 mm). Therefore, Toledo Site A was used for this series of tests.

96. Effluent suspended solids plotted as a function of cloth porosity are depicted in Figure 42. A plot of filter yield versus cloth porosity is shown in Figure 43. All data in Figures 42 and 43 are based upon the use of lime as the conditioner. The dosage is indicated in each figure. Doses ranged from 34 to 80 mg lime per gram of solids.

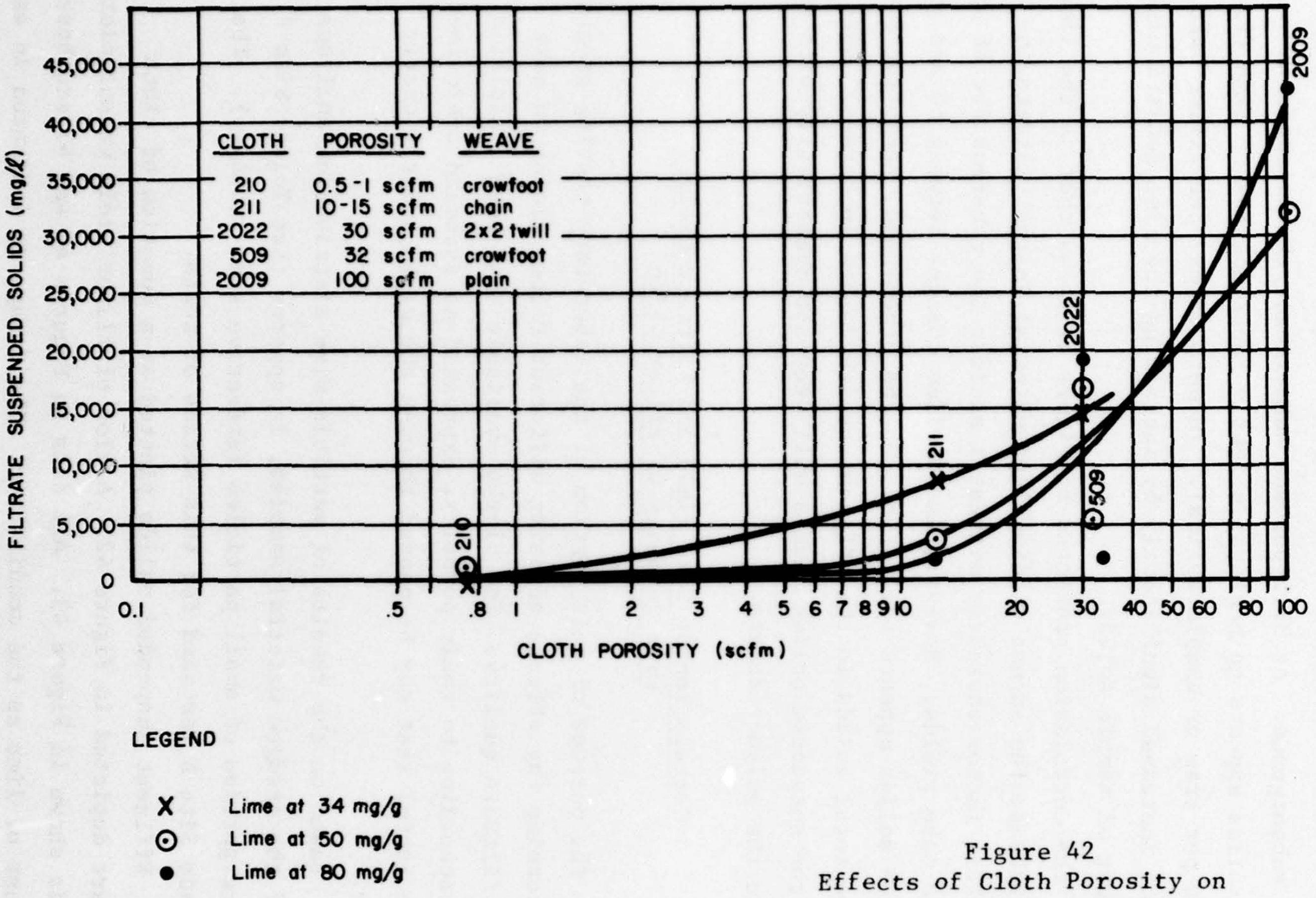


Figure 42
Effects of Cloth Porosity on
Suspended Solids in Filtrate,
Toledo Site A

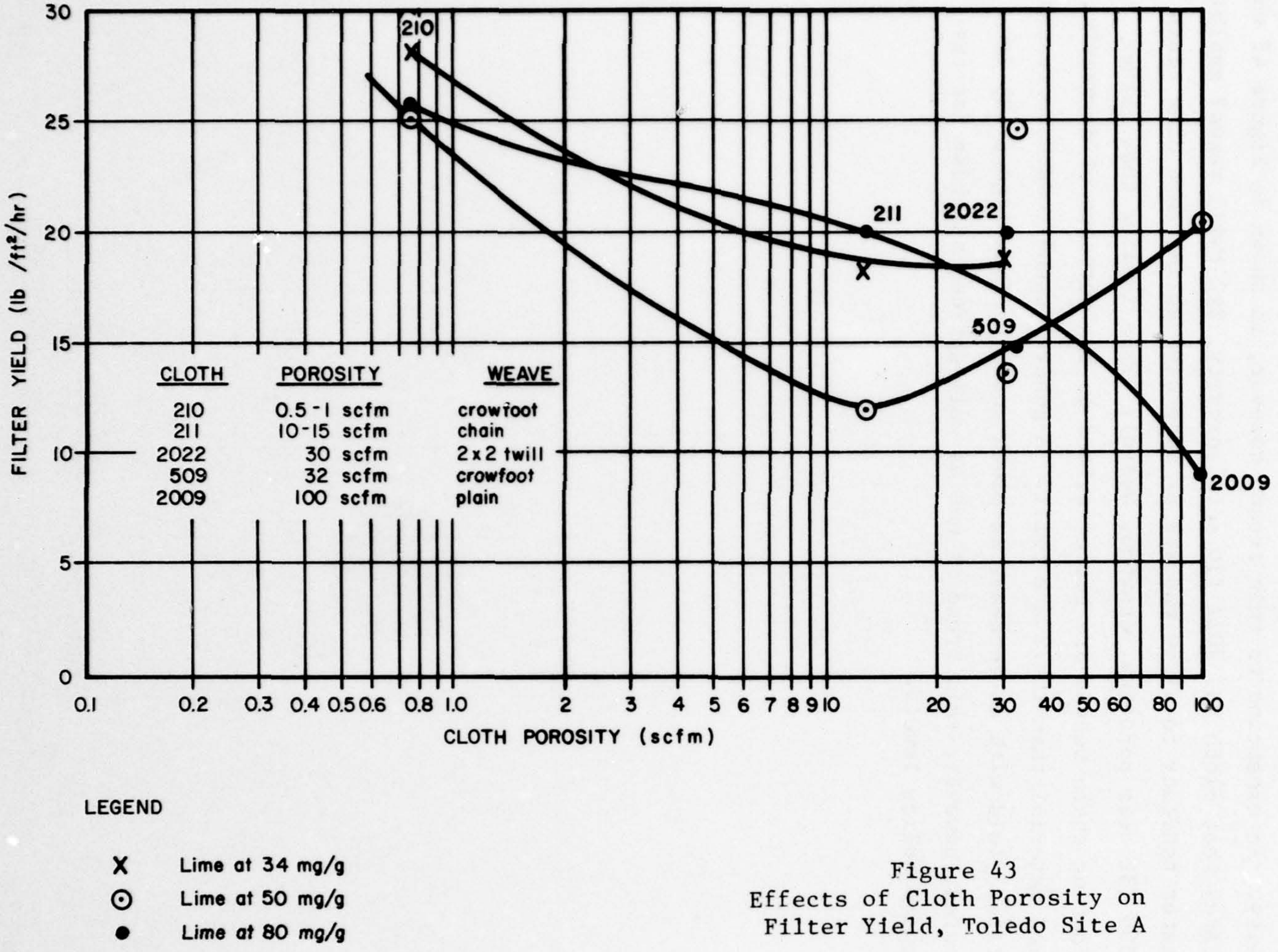


Figure 43
Effects of Cloth Porosity on
Filter Yield, Toledo Site A

97. Two general trends were observed during the correlation of cake yield and filtrate quality with porosity of filter cloth. In general, suspended solids levels in the filtrate increase with increasing cloth porosity. An exception to this trend, however, is shown in Figure 42 which indicates that cloth No. 2022 (30 scfm porosity, 2x2 twill weave) exhibited a greater tendency to allow passage of suspended solids than does cloth No. 509 (32 scfm porosity, crowfoot weave). This implies that either crowfoot or chain weaves are better suited to the purposes of dewatering dredged material than the 2 x 2 twill. A general trend toward decreases in filter yield with an increase in cloth porosity (see Figure 43) is indicated; however, this trend is not as well defined as those for the suspended solids levels.

PART VII: BENCH-SCALE VACUUM FILTRATION STUDIES

98. The purpose of the bench-scale vacuum filtration studies was to confirm the results of the preliminary Buchner funnel and filter leaf investigations and to identify any problems or deficiencies in actual vacuum filtration of dredged material. Seven sites were used to evaluate the bench-scale unit: Mobile Bay, Apalachicola Bay, Toledo Land Disposal, Toledo Site A, Toledo Site B, Penns Neck Spillway, and Browns Lake. Two coagulants were investigated: lime and Hercofloc 844. Three filter cloths were used for the samples: cloth 210, 211, and 525 with porosities of 0.5 to 1.0, 10 to 15, and 4 to 6 scfm, respectively.

99. All investigations were conducted at a 37.5-percent submergence with various drum speeds. This submergence was used rather than 60 percent due to the physical limitations of the bench-scale equipment; this is the highest submergence attainable with this unit. However, a standard flexible belt vacuum filter has a 37.5-percent submergence limitation. Filters capable of utilizing 60 percent are available only on a custom-built basis.

The Effects of Coagulant Dosage on Filter Yield

Mobile Bay

100. The sample from Mobile Bay was subjected to the most extensive range of lime coagulant dosages for two reasons. First, as confirmed in previous studies, trends shown by one sample could be extended to include other samples; second, Mobile Bay was selected so that the results attained could be used in conjunction with other investigations of dredged material dewatering now being conducted at the Mobile disposal area.

101. The results of the investigation of lime dosage effects on filter yield are illustrated in Figure 44. Notice that with increased lime dosage, the filter yield also increases rapidly until the dosage 100 mg/g is reached. At this point, the curve tends to flatten out. This confirms results obtained in the Buchner funnel study where the specific resistance curves flatten out at that same coagulant dosage.

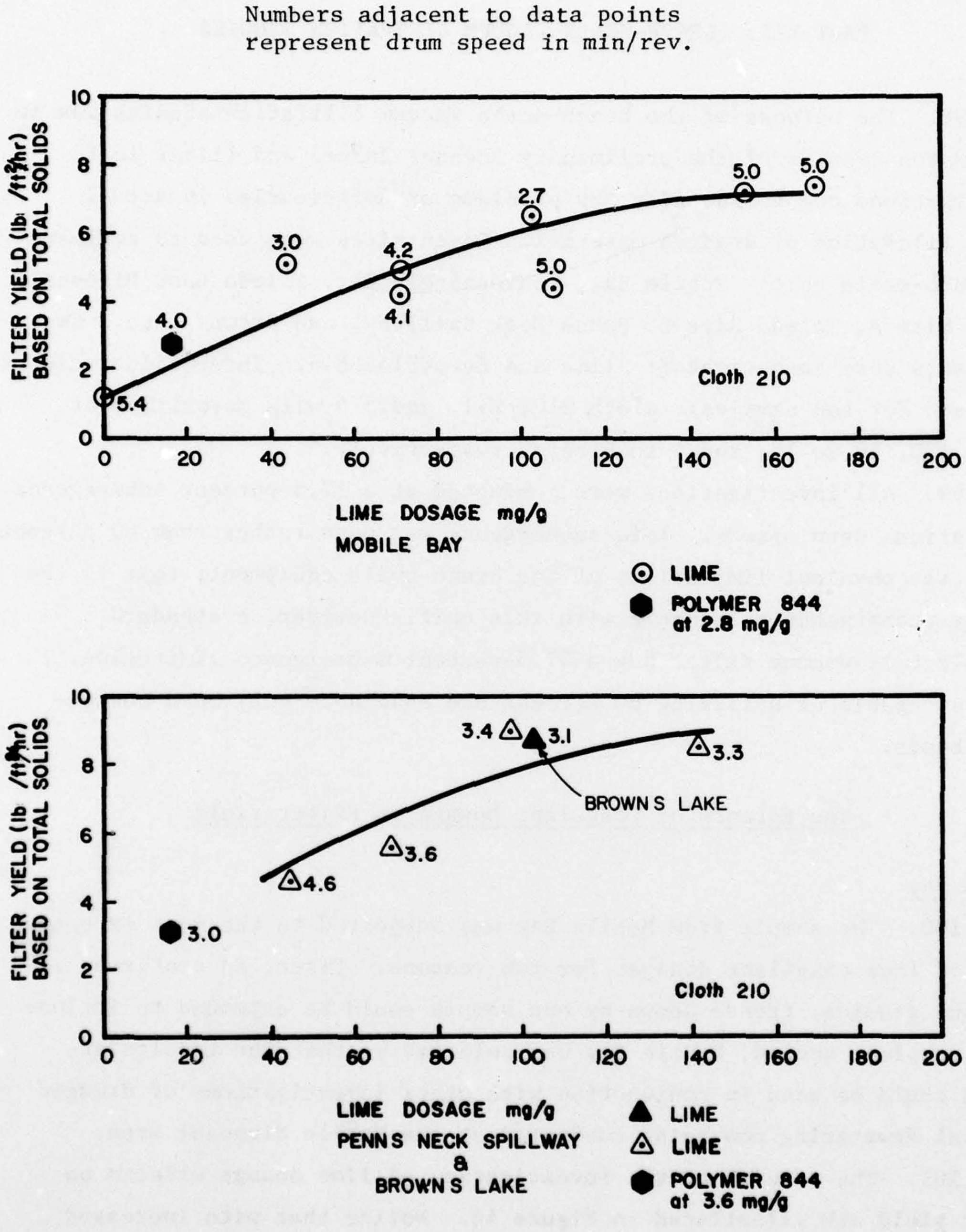


Figure 44
Correlation of Filter Yield With Lime Dosage for Mobile Bay, Penns Neck Spillway, and Browns Lake

102. The numbers adjacent to each data point indicate the average drum speed in minutes per revolution used during that particular run. Note that higher filter yields are attainable at higher drum speeds. This is exemplified by the two runs conducted near 100 mg/g. The first, at 5.0 min/rev, resulted in a yield of 4.72 $lb/ft^2/hr$, while at 2.7 min/rev the resulting yield was 6.93 $lb/ft^2/hr$.

103. Also shown in Figure 44 is a single point showing a run in which Hercofloc polymer 844 was used. The placement of this point is arbitrary and does not correspond to the horizontal axis. It is shown on this figure for comparison with the lime coagulant results. Only one polymer run was conducted for each sample. Cake discharge characteristics with polymer were extremely poor. The cake which formed was very sticky and did not produce the cracking phenomenon evident with lime coagulation. The cake had to be manually scraped from the filter cloth.

Penns Neck Spillway and Browns Lake

104. The results of the bench-scale studies for Penns Neck Spillway are also presented in Figure 44 along with the single run made on the Browns Lake sample. The trend shown in this figure follows closely that shown for Mobile Bay; that is, the filter yield increases with an increase in lime dosage.

105. Again, a single run was conducted using Hercofloc 844 at its optimum dosage, 3 mg/g. Note the difference in filter yield under optimum conditions for both lime and polymer, 9.0 and 3.14 $lbs/ft^2/hr$, respectively.

Apalachicola Bay and Toledo Harbor

106. The bench-scale results from the Apalachicola Bay samples and Toledo Land Disposal and Toledo Sites A and B presented in Figures 45 and 46 continue to follow the trends established in previous studies. The filter yield increased with increasing lime dosage. Also, in comparing the optimum doses of lime and polymer, use of lime resulted in greater filter yeilds.

Numbers adjacent to data points represent drum speed in min/rev.

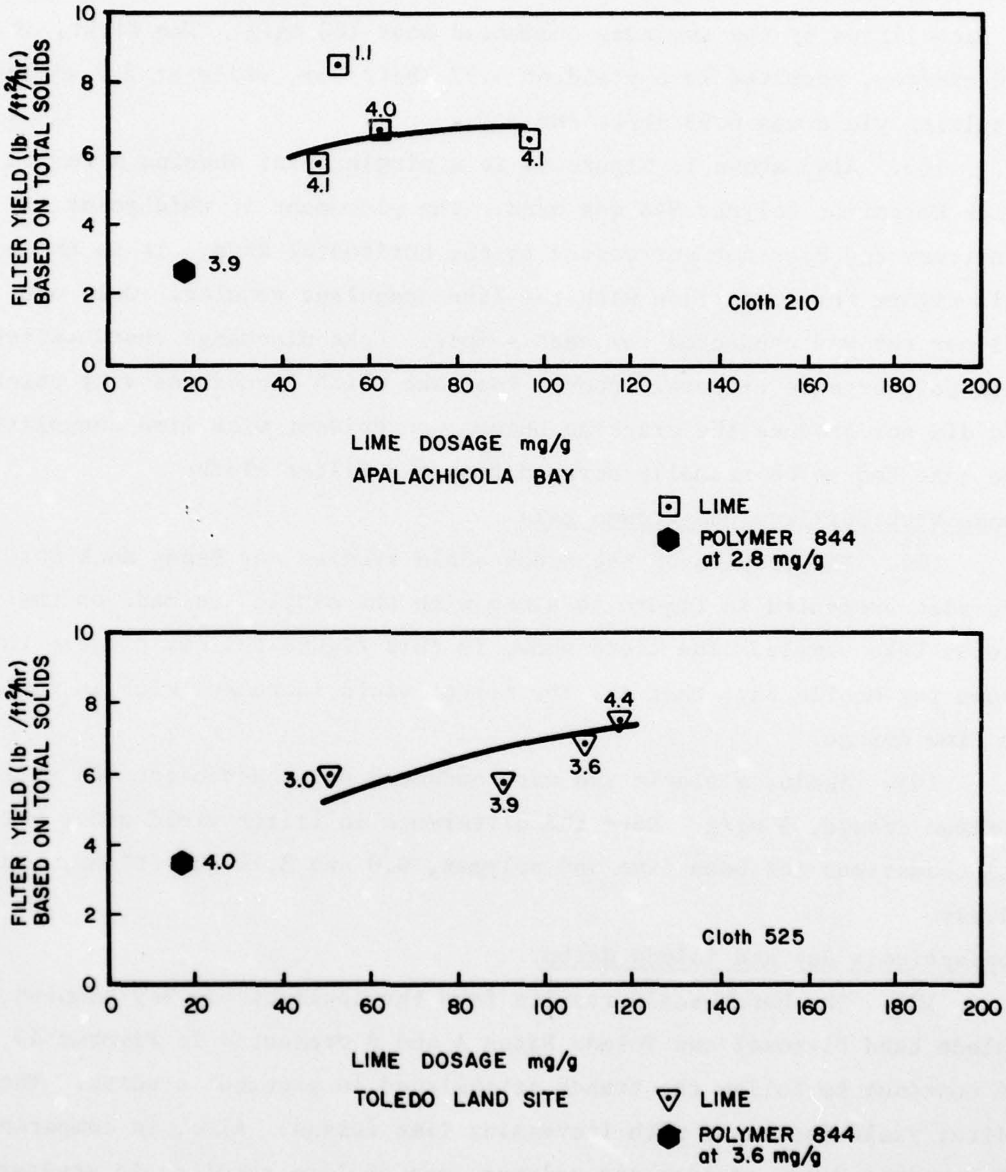
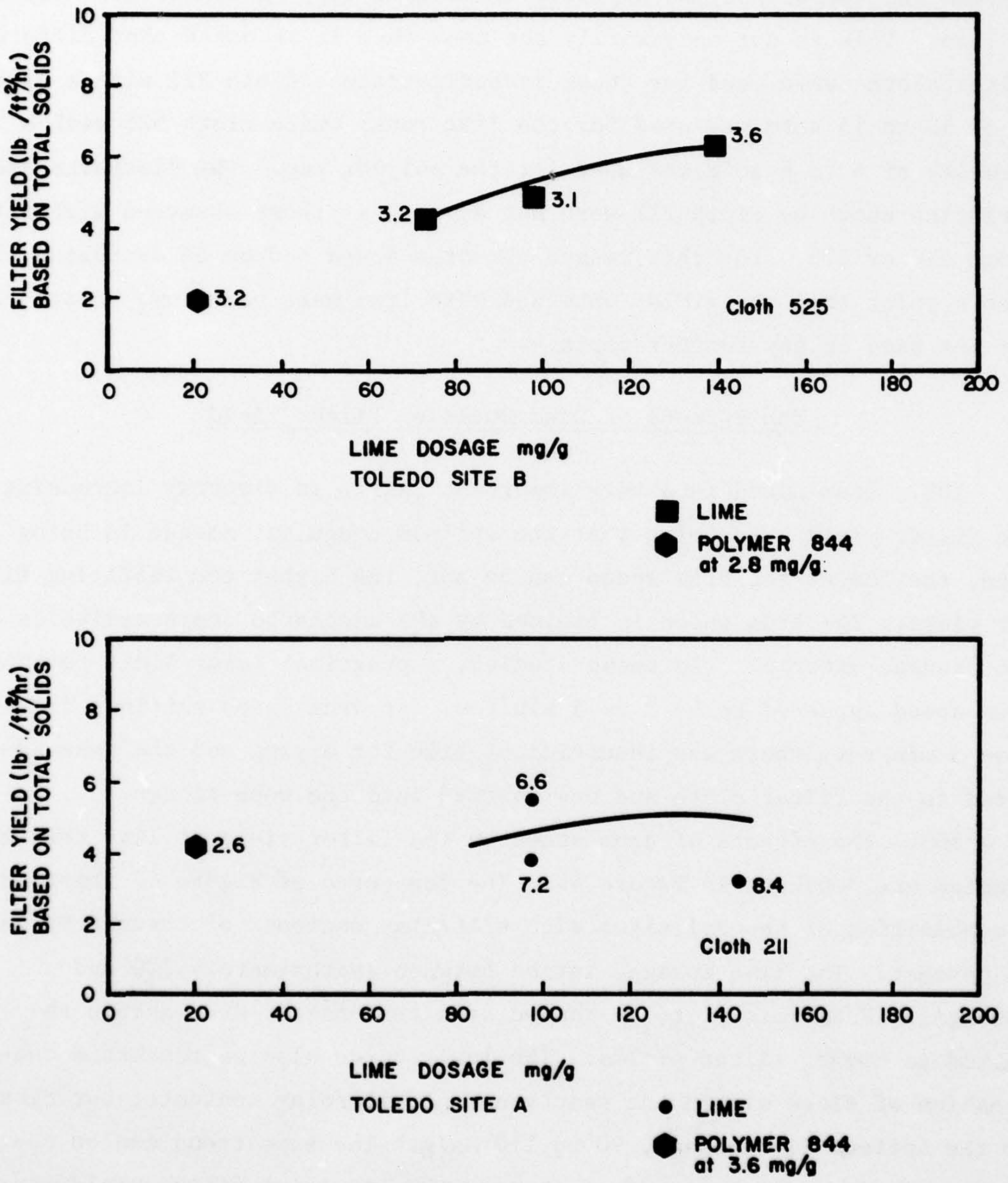


Figure 45
Correlation of Filter Yield With Lime Dosage for Apalachicola Bay and Toledo Land Site



Numbers adjacent to data points represent drum speed in min/rev.

Figure 46
Correlation of Filter Yield With
Lime Dosage for Toledo Sites A and B

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FEASIBILITY STUDY OF VACUUM FILTRATION SYSTEMS FOR DEWATERING D--ETC(U)
FEB 78 B W LONG, D J GRANA DACW39-75-C-0124
UNCLASSIFIED WES-TR-D-78-5 NL

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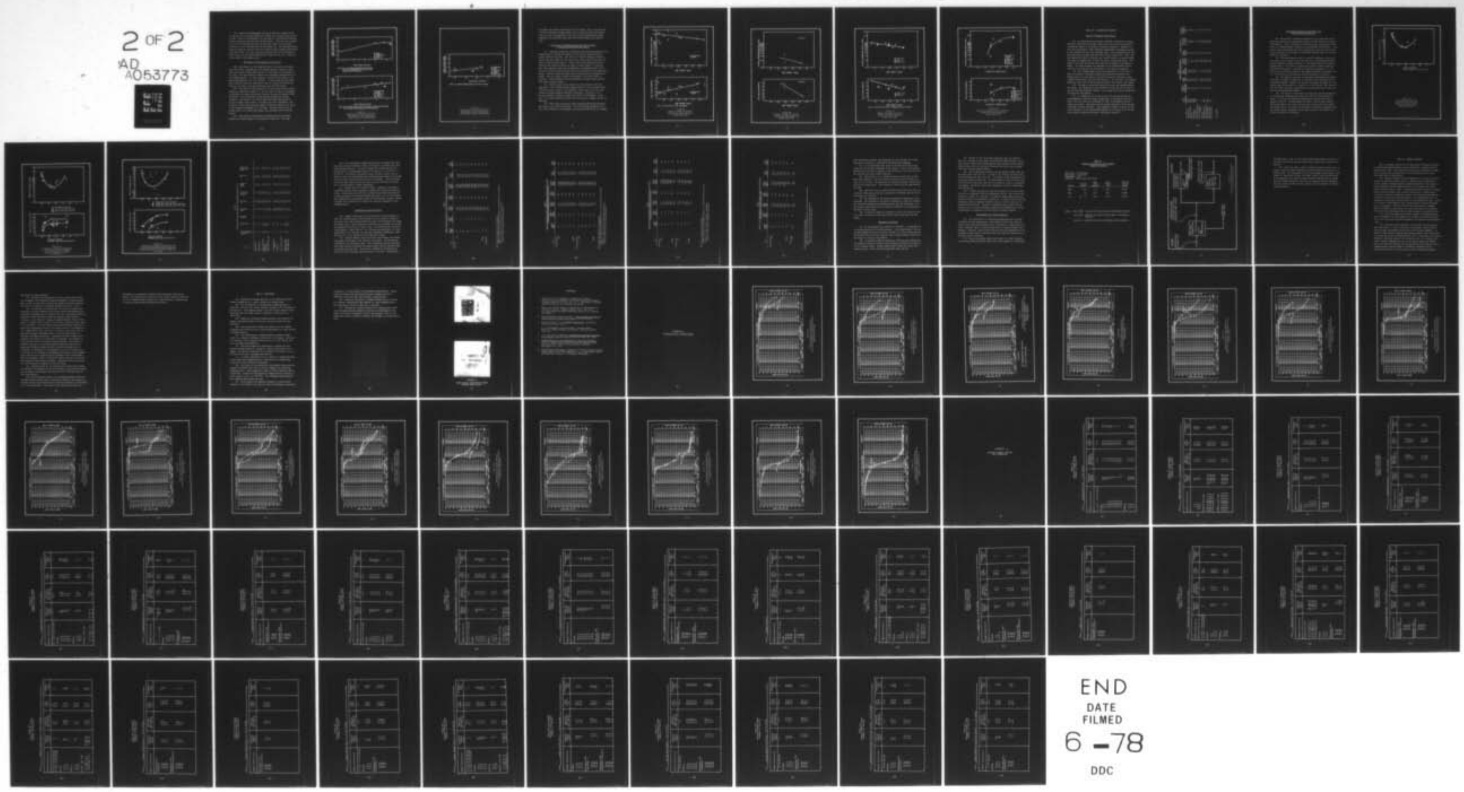

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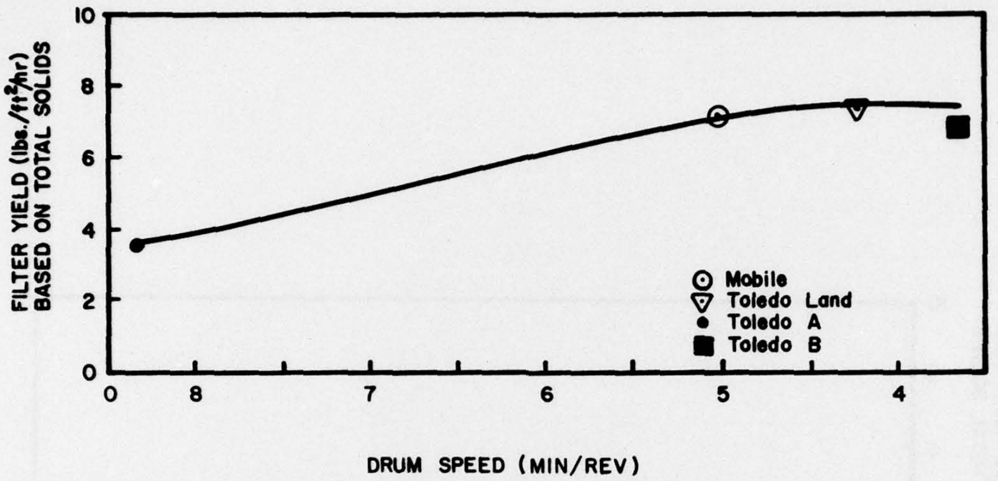
107. Results from experiments with the Toledo Site A sample differ in that the use of polymer appeared to compare very favorably with the use of lime. This is not necessarily the case when it is noted that different filter cloths were used for these investigations. Cloth 211 with a porosity of 10 to 15 scfm was used for the lime runs; while cloth 525 with a porosity of 4 to 6 scfm was used for the polymer run. The discharge characteristics shown by cloth 211 were not as good as those observed with either cloth 210 or 525. For this reason the drum speed had to be decreased to such a point that the yields obtained with lime were very low. Cloth 211 was not used in any further tests.

The Effects of Drum Speed on Filter Yield

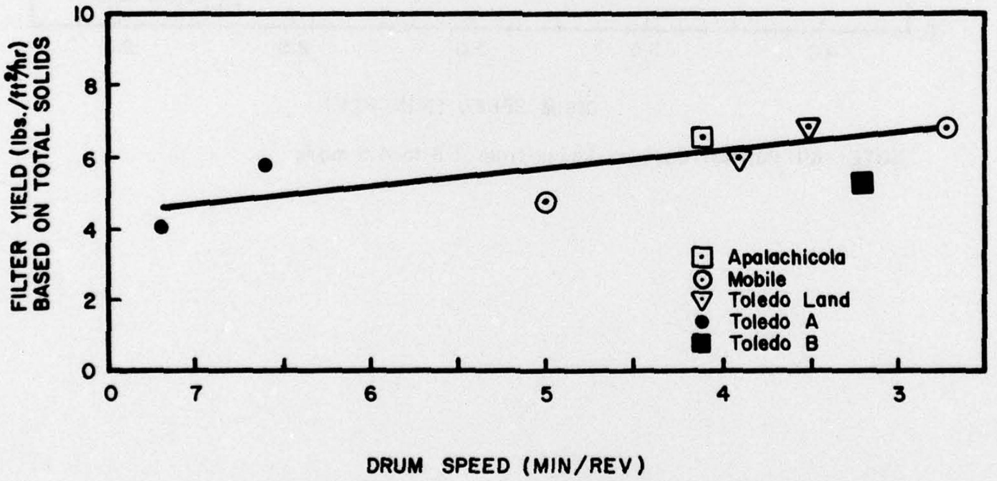
108. Drum speed is a very important factor in directly increasing the filter yield. Assuming that the optimum coagulant dosage is being used, the faster the drum speed can be set, the higher the resulting filter yield. The drum speed is limited by the discharge characteristics of the dredged material. In these studies, a practical lower limit to the drum speed appeared to be 3 to 4 min/rev. At drum speed settings faster than 3 min/rev, there was insufficient time for drying and the cake adhered to the filter cloth and was carried into the wash trough.

109. The effects of drum speed on the filter yield of lime treated samples are depicted in Figure 47. The top curve of Figure 47 represents a combination of several sites with silt/clay contents of between 95 and 98 percent. The lime dosages varied between approximately 120 and 160 mg/g. From this plot, it can be seen that faster drum speeds resulted in higher filter yields. The lower curve also represents a combination of sites within the same range of silt/clay contents, but closer to the optimum lime dosage, 90 to 110 mg/g. The same trend can be observed; that is, at faster drum speeds, the resulting filter yield was greater.

110. Correlation of drum speed with filter yield for Hercofloc polymer 844 treated samples is illustrated in Figure 48. The range

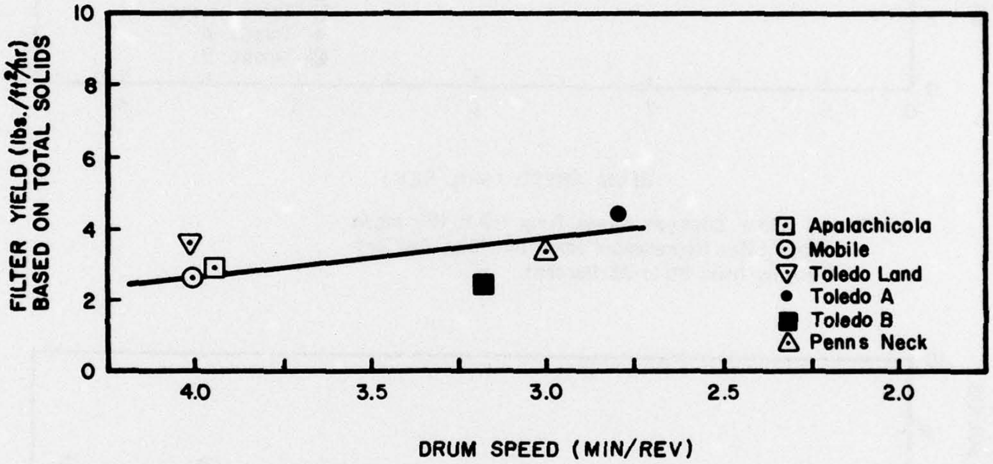


NOTE: All Lime Dosages Range from 119 to 157 mg/g.
Those Sites Represented Have Silt/Clay Content
Ranging from 95 to 98 Percent.



NOTE: All Lime Dosages Range from 90 to 110 mg/g. Those Sites Represented
Have Silt/Clay Content Ranging from 95 to 98 Percent.

Figure 47
Correlation of Filter Yield With
Drum Speed for the Bench-Scale
Study Using Lime Conditioning



NOTE: All Polymer Dosages Range from 2.8 to 4.5 mg/g

Figure 48
Correlation of Filter Yield With
Drum Speed for the Bench-Scale
Study Using Polymer Conditioning

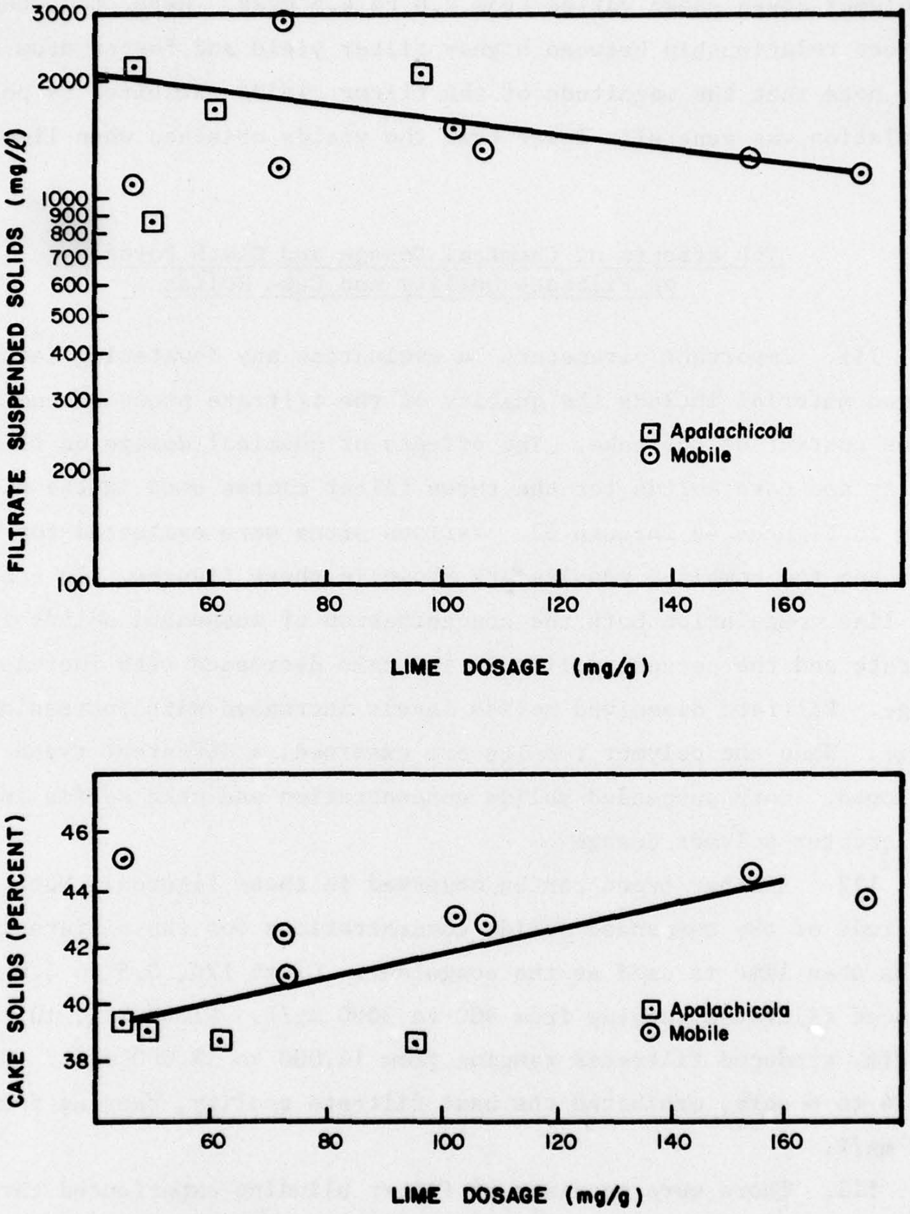
of polymer doses shown varied from 2.8 to 4.5 mg/g. Here, too, there was a direct relationship between higher filter yield and faster drum speed. Also, note that the magnitude of the filter yields exhibited by polymer coagulation was generally lower than the yields obtained when lime was used.

The Effects of Chemical Dosage and Cloth Porosity on Filtrate Quality and Cake Solids

111. Important parameters in evaluating any dewatering technique for dredged material include the quality of the filtrate produced and the solids content of the cake. The effects of chemical dosage on filtrate quality and cake solids for the three filter cloths used in the study are shown in Figures 49 through 52. Various sites were evaluated for each cloth and the combined results are shown in these figures. In general, with lime coagulation both the concentration of suspended solids in the filtrate and the percent solids in the cake decreased with increasing lime dosage. Filtrate dissolved solids levels increased with increasing lime dosage. When the polymer results are examined, a different trend is developed. Both suspended solids concentration and cake solids increase with greater polymer dosage

112. Another trend can be observed in these figures. Note the magnitude of the suspended solids concentrations for the different filter cloths when lime is used as the coagulant. Cloth 120, 0.5 to 1.0 scfm, produced filtrates ranging from 900 to 3000 mg/ℓ. Cloth 211, 10 to 15 scfm, produced filtrates ranging from 16,000 to 38,000 mg/ℓ. Cloth 525, 4 to 6 scfm, exhibited the best filtrate quality, ranging from 700 to 1000 mg/ℓ.

113. There were no cases of filter blinding experienced throughout the course of the bench-scale study. The cloth washing mechanism of the test filter appeared to be adequate in preventing problems due to blinding.



NOTE: All Data Taken at 37½% Submergence.

Figure 49
Effects of Lime on Filtrate
Quality and Cake Solids for
Filter Cloth 210

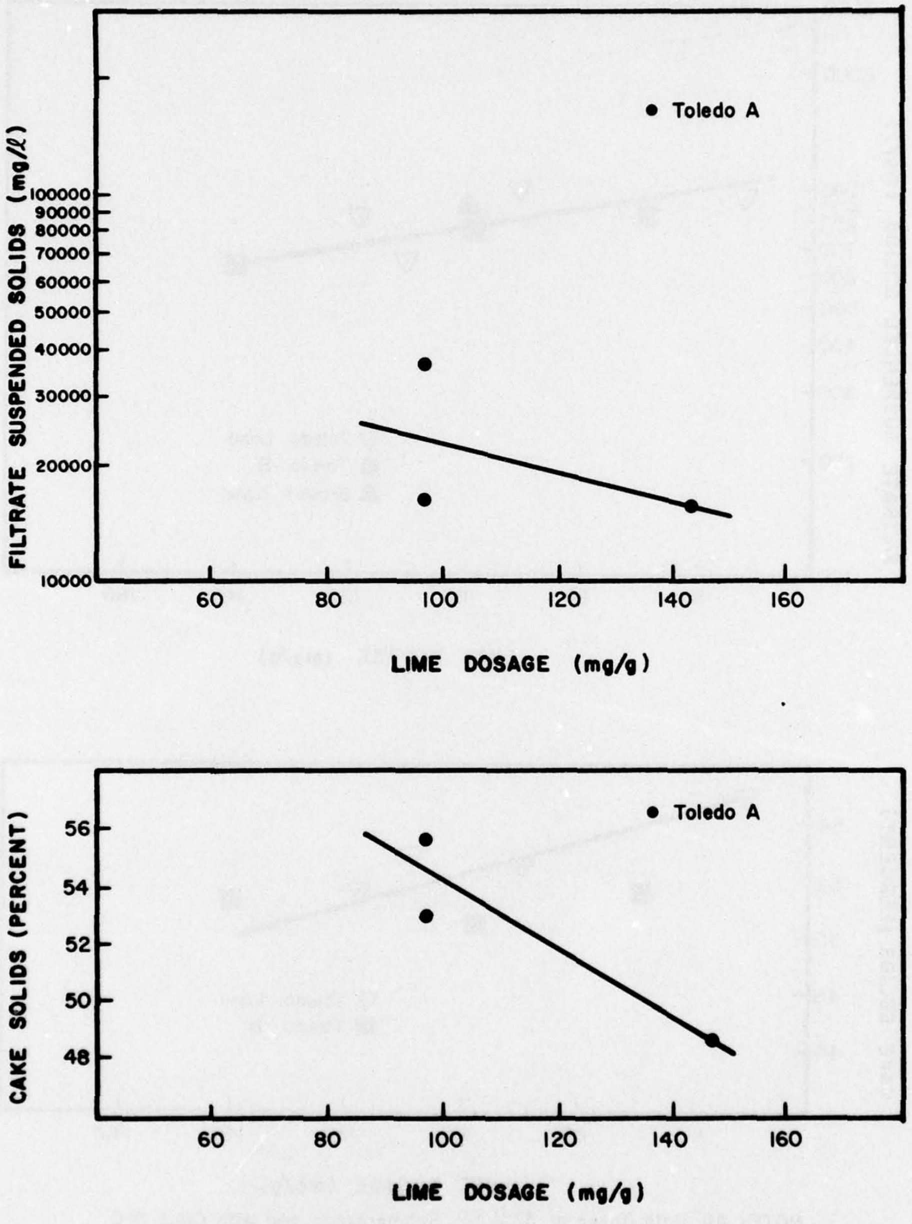
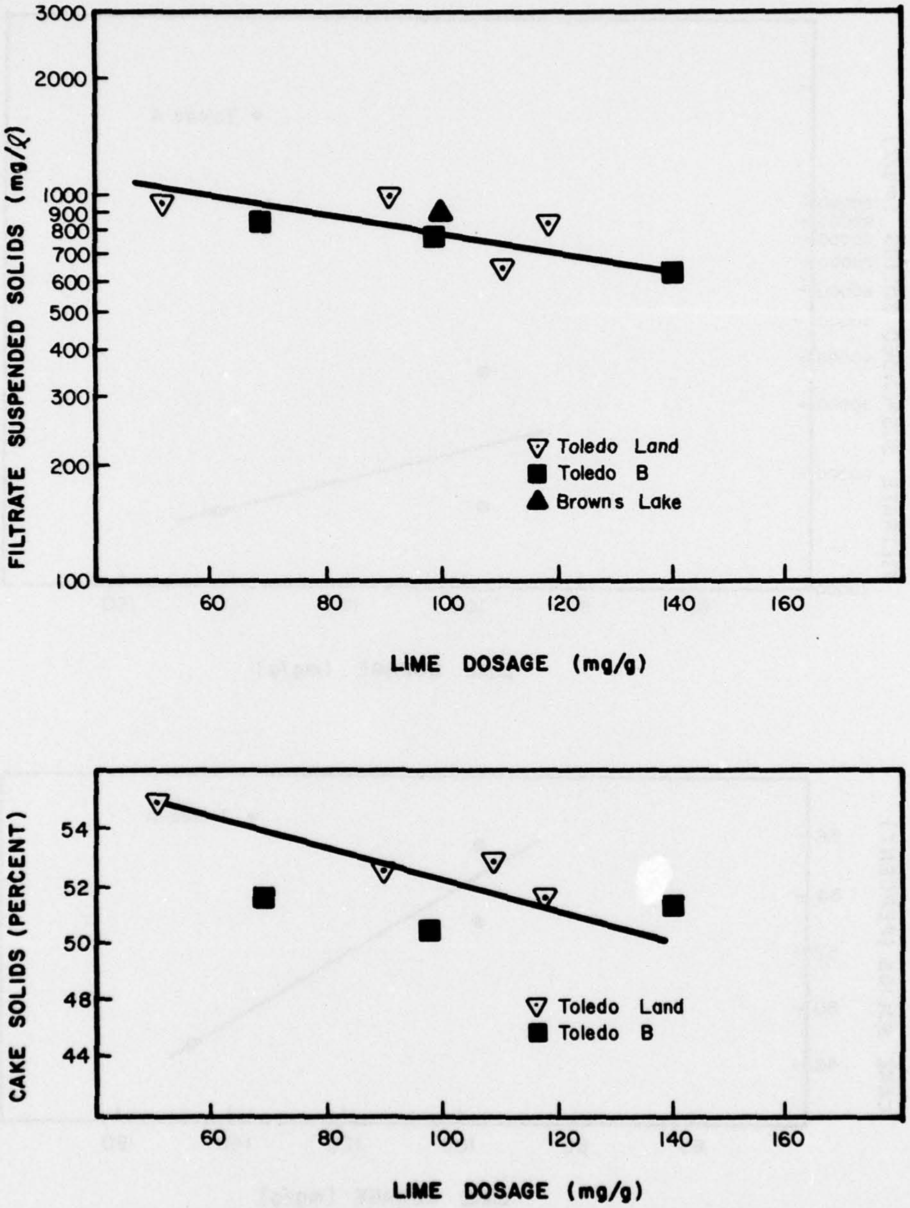


Figure 50
Effects of Lime on Filtrate
Quality and Cake Solids for
Filter Cloth 211



NOTE: All Data Taken at 37½ % Submergence and with Cloth 525.

Figure 51
Effects of Lime on Filtrate
Quality and Cake Solids for
Filter Cloth 525

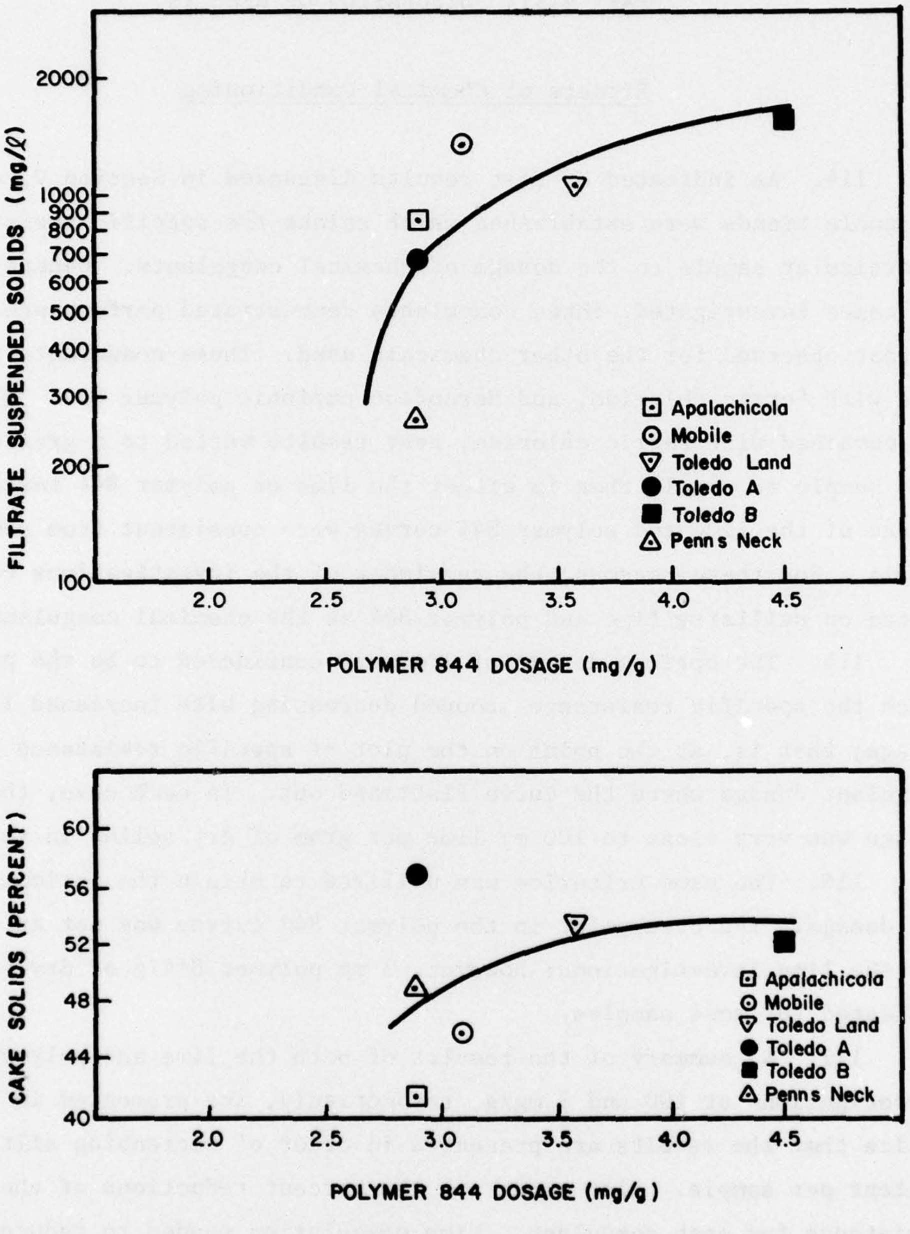


Figure 52
Effects of Herofloc 844 on Filtrate
Quality and Cake Solids for
Filter Cloth 525

PART VIII: DISCUSSION OF RESULTS

Effects of Chemical Conditioning

114. As indicated by test results discussed in Section V, certain definable trends were established which relate the specific resistance of a particular sample to the dosage of chemical coagulants. Generally, in all cases investigated, three coagulants demonstrated performance superior to that observed for the other chemicals used. These coagulants were lime, lime with ferric chloride, and Hercofloc cationic polymer 844. When lime was combined with ferric chloride, test results varied to a greater extent from sample to sample than in either the lime or polymer 844 tests. The shapes of the lime and polymer 844 curves were consistent from sample to sample. For these reasons, the remainder of the investigations concentrated on utilizing lime and polymer 844 as the chemical coagulants.

115. The optimum dosage of lime was considered to be the point at which the specific resistance stopped decreasing with increased lime dosage; that is, at the point on the plot of specific resistance versus coagulant dosage where the curve flattened out. In each case, this optimum dosage was very close to 100 mg lime per gram of dry solids in the sample.

116. The same criterion was utilized to obtain the optimum polymer 844 dosage. The breakpoint in the polymer 844 curves was not as sharp as for the lime investigations; however, 3 mg polymer 844/g of dry solids was indicated for most samples.

117. A summary of the results of both the lime and polymer 844 investigations at 100 and 3 mg/g, respectively, are presented in Table 4. Notice that the results are presented in order of decreasing silt/clay content per sample. Also shown are the percent reductions of the specific resistance for each coagulant. Lime coagulation tended to reduce the specific resistance of the unconditioned samples by an average of 91 percent while polymer coagulation produced a 96-percent reduction.

Table 4

Summary of Buchner Funnel Studies

Site	Unified Soil Classification	Silt/Clay Content (% Finer than No. 200 Sieve)	Solids Content (%)	Specific Resistance				
				Uncon-ditioned (10^8 sec^2/g)	With Lime 100 mg/g (10^8 sec^2/g)	Percent Reduction with Lime	with Polymer 844-3 mg/g (10^8 sec^2/g)	Percent Reduction with Polymer 844
Apalachicola Bay	OH-MH	98	16.9	15.1	1.5	90	0.71	95
Toledo Land Disposal	OH-MH	98	16.7	15.9	1.3	92	0.56	96
Mobile Bay	OH-MH	96	17.6	19.6	1.8	91	0.40	98
Toledo Harbor A	OH-MH	95	22.4	12.2	0.8	93	0.55	95
Toledo Harbor B	OH-MH	95	17.8	12.2	1.2	90	--	--
Ninety Percent Silt/Clay	*	90	25.7	9.6	0.82	91	0.24	98
Seventy-Five Percent Silt/Clay	*	73	24.2	5.2	0.52	90	0.50	90
Browns Lake	*	71	20.5	5.6	0.40	93	0.40	93
Craney Island Site 2	SM-SC	62	21.6	4.9	0.37	92	0.13	97
Sixty Percent Silt/Clay	*	58	17.7	5.0	0.65	97	0.60	97
Penns Neck Spillway	OH-MH	55	24.5	8.0	0.80	90	0.07	99
Craney Island Site 4	SC	30	16.8	10.8	1.2	89	0.31	97
Craney Island Site 1	SC	26	20.5	6.4	0.86	87	0.60	91

* Not Applicable

Relationships Between Filterability and Particle-Size Distribution

118. The specific resistances exhibited by the conditioned and unconditioned samples are compared with their silt/clay contents in Figures 53 through 55. These are important correlations since the specific resistance of a dredged material indicates its approximate filterability. Also, particle-size distribution and, more specifically, silt/clay content provides a measure of that portion of the dredged material which is the most difficult to dewater.

119. The characteristic curve for specific resistance versus silt/clay content over a range of 98 to 26 percent for unconditioned dredged material samples is shown in Figure 53. The lowest specific resistances, approximately 5 x 10^8 sec^2/g occurred when silt/clay content ranged between 60 and 70 percent. The specific resistance increased to 2 x 10^9 sec^2/g as the silt/clay content in the sample increased to 98 percent and to 1 x 10^9 sec^2/g as the silt/clay content decreased to 26 percent.

120. The shape of the curve for optimally lime-conditioned samples (100 mg/g), presented in Figure 54 is the same as that exhibited for unconditioned samples. However, the specific resistance decreased over the entire range by 90 percent to a value of 4.5 x 10^7 sec^2/g. The results of the study with lime show a small amount of data scatter which is not evident in the unconditioned samples.

121. The results of the filter leaf study for lime and polymer 844 at 37.5-percent submergence and using only cloth 525 are presented in Table 5. The data are graphically presented in the lower portions of Figures 54 and 55. Two drum speeds are shown, 1 min/rev and 2 min/rev. Notice the shape of the curves and the point at which the curve reaches the highest yield. For both 1 and 2 min/rev, this point corresponds with the lowest specific resistance in the upper portion of the figure, or a silt/clay content of 75 percent.

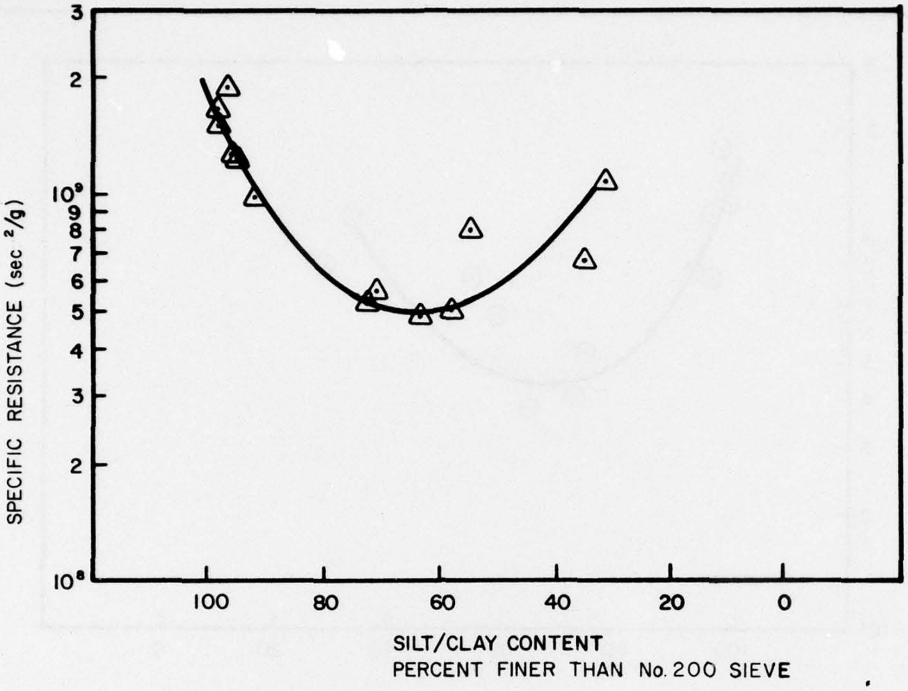


Figure 53
Correlation of Specific
Resistance With Silt/Clay
Content of Unconditioned
Dredged Material

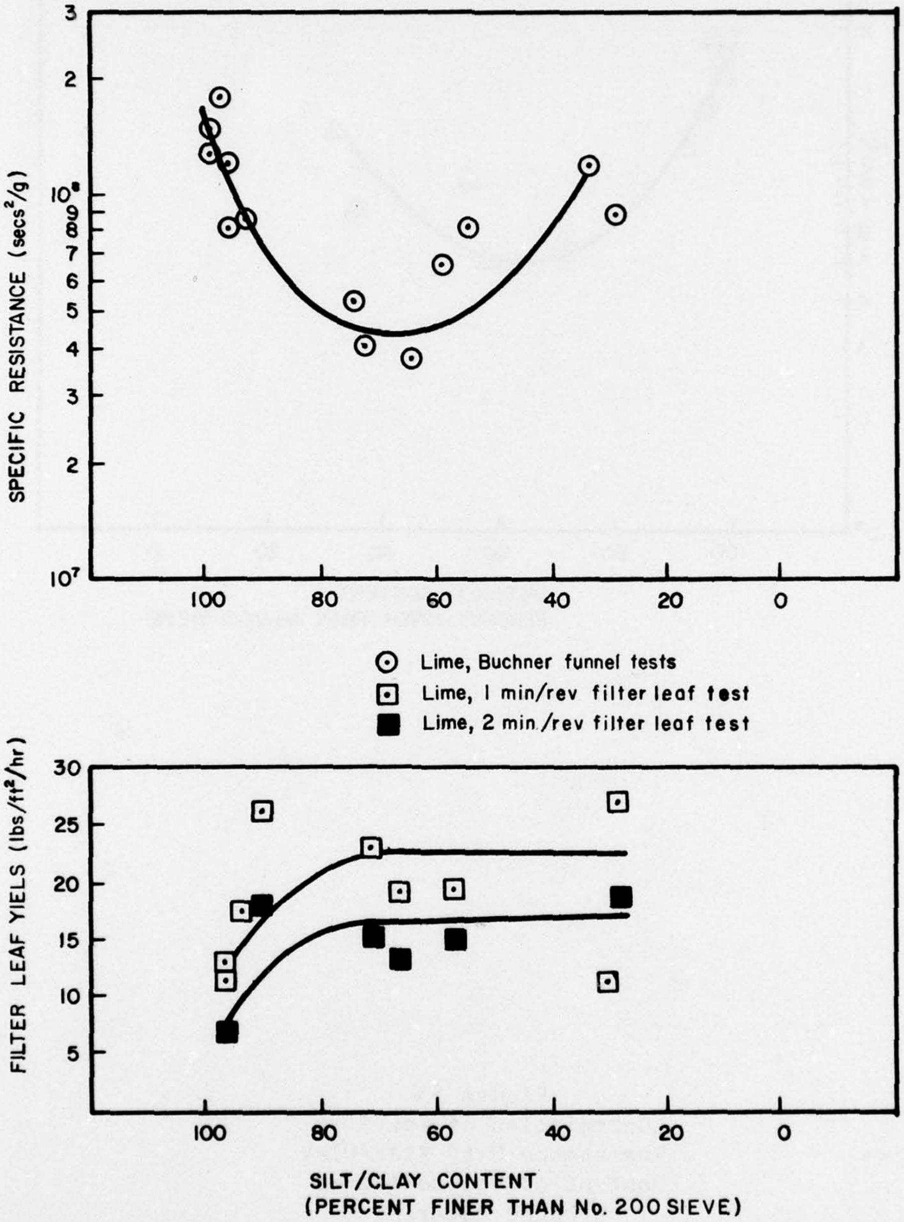


Figure 54
Correlation of Specific Resistance
and Filter Content of Dredged
Material Treated With Lime
at 100 mg/g

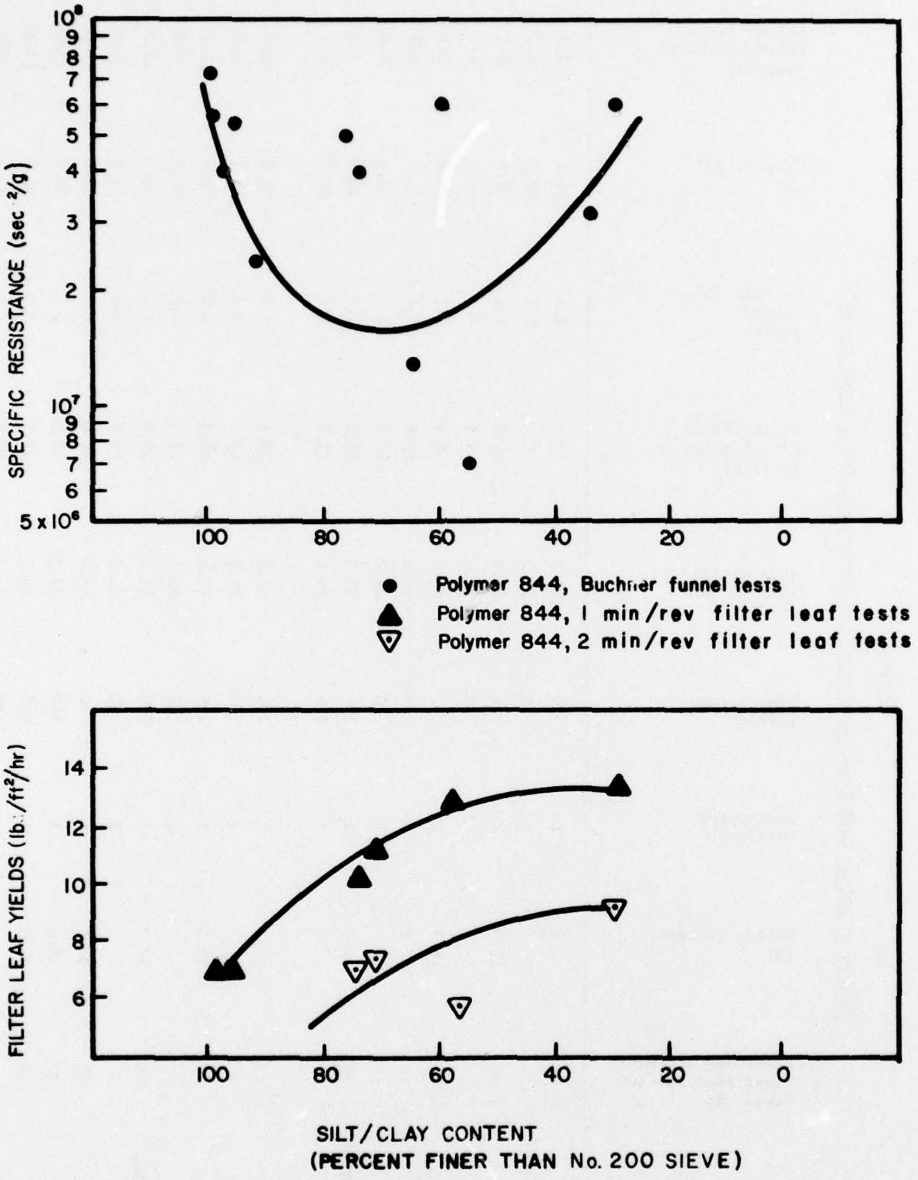


Figure 55
Correlation of Specific Resistance and Filter Yield With Silt/Clay Content of Dredged Material Treated With Polymer 844 at 3 mg/g

Table 5

Summary of Filter Leaf Yield Results, 37.5% Submergence Using Cloth No. 525

Site	Silt/Clay Content Finer than No. 200 Sieve (%)	Solids Content (%)	Drum Speed (min/rev)	Lime Dosage (mg/g)	Cake Solids (%)	Filter Yield Lime Treated (psf/hr)	Polymer 844 Dosage (mg/g)	Cake Solids (%)	Filter Yield Polymer Treated (psf/hr)
Hopper Overflow	98	4.4	1	30	50.2	2.5	0.4	55.6	1.2
			2	30	51.5	1.1	0.4	52.9	0.7
Apalachicola Bay	98	16.9	1	70	38.1	11.2	1.1	39.9	7.1
			2	70	37.4	6.8	--	--	--
Toledo Land Disposal	98	16.7	1	92	48.7	8.4	2.5	52.0	6.8
Mobile Bay	96	17.6	1	55	44.5	13.6	4.4	42.4	6.8
Toledo Harbor A	95	22.4	1	70	48.7	17.0	1.5	52.6	8.4
Ninety Percent Silt/Clay	90	25.7	1	100	55.3	26.3	1.5	55.5	8.0
			2	100	56.1	17.7	1.5	60.1	2.5
Seventy-Five Percent Silt/Clay	73	24.2	1	100	51.6	23.4	3.0	50.8	10.1
			2	100	51.5	15.5	3.0	54.1	7.0
Browns Lake	71	20.5	1	100	59.6	18.5	3.0	65.6	11.1
			2	100	60.1	12.7	3.0	64.3	7.4
Sixty Percent Silt/Clay	58	17.7	1	100	61.1	19.0	3.0	58.1	12.8
			2	100	61.3	15.0	3.0	59.8	5.9
Penns Neck Spillway	55	24.5	1	40	56.0	41.0	1.1	55.1	7.2
Craney Island Site 4	30	16.8	1	100	57.5	11.0	1.0	51.7	5.8
Craney Island Site 1	26	20.5	1	100	56.1	27.6	3.0	50.6	13.3
			2	100	56.1	18.9	3.0	54.5	9.0

122. The relationships between both specific resistance and filter yield and silt/clay content are shown in Figure 55 for polymer 844 conditioned dredged material. The use of polymer 844 reduced the specific resistance of an unconditioned sample by 96 percent, to a value of 1.7 x 10^7 sec^2/g. The specific resistance versus silt/clay content curve is similar to both the unconditioned and lime-conditioned curves, even though there is quite a bit more data scatter for the polymer. This was caused by factors other than particle size which may have affected the results due to the mechanism of polymer coagulation.

123. Polymer 844 is a cationic polymer. Therefore, its greatest coagulating ability would correspond to negatively charged colloidal particles. Interference with effective coagulation may have been caused by a large percentage of positively charged particles in some of the samples. This phenomenon was not pursued during the investigation, however, because a polymer can be identified to produce the required coagulation in any dredged material.

Bench-Scale Vacuum Filtration

124. Summary tabulations of the bench-scale vacuum filtration results for dredged material are presented by site in Tables 6 through 9. The filter leaf study indicated that the faster the drum speed, the higher the filter yield. This conclusion is qualified by the ability of the cake to discharge freely from the filter cloth. In conducting the bench-scale investigation, a lower limit of 3 to 4 min/rev was experienced. At drum speeds below 3 to 4 min/rev, the cake was discharged sporadically, allowing much of it to be carried into the wash water trough.

125. Based on Buchner funnel and filter leaf studies, the optimum lime dosage is 100 mg/g of dry solids in the samples. This dosage was confirmed by the bench-scale study. The preliminary work also indicated that lower specific resistance and higher yields could be obtained using the polymer Hercofloc 844. This was not confirmed by the bench-scale study due to the discharge characteristics of the cake. Although good

Table 6

Summary of Vacuum Filter Results for Mobile Bay Dredge Material 96 Percent Silt/Clay Content

Site		Coagulant Dosage (mg/g)	Average Drum Speed (min/rev)	Slurry Solids Content (%)*	Cake Solids Content (%)*	Filtrate Solids Content (mg/ℓ)*	Filter Yield (psf/hr)*	Filter Cloth Used(1)
Mobile Bay								
	Lime	174	5	19.3	43.7	13,500	7.75	210
				(13.5)		(1120)	(5.68)	
		157	5	24.7	44.7	16,150	7.60	210
				(17.3)		(1300)	(5.63)	
		107	5	18.1	42.8	8,500	4.72	210
				(12.7)		(1340)	(3.43)	
		102	2.7	17.2	43.0	(32,900)	6.93	210
				(15.1)		(1510)	(6.70)	
		74	4.2	14.4	42.4	11,500	5.06	210
				(12.9)		(1162)	(4.84)	
		74	4.1	15.5	41.2	(19,800)	4.33	210
				(13.2)		(2,940)	(4.03)	
		43	3.0	15.0	45.0	6,150	5.40	525
				(14.6)		(1010)	(5.43)	
	Polymer	3.1	4.0	12.7	45.7	4,490	2.48	525
				(12.0)		(1410)	(2.40)	
	Unconditioned	5.4	--	13.3	47.4	3,360	1.09	525
				(13.0)		(1400)	(1.05)	

NOTE: All runs were conducted at 37-1/2% submergence.

*Numbers in parenthesis indicate suspended solids basis - all others indicate total solids basis.

(1) Cloth 210: porosity 0.5-1.0 sctm; crowfoot weave; dacron material.

Cloth 525: porosity 4-6 scfm; satin weave; nylon material.

Table 7

Summary of Vacuum Filter Results for Apalachicola Bay, 98 Percent Silt/Clay Content and Toledo Harbor Land Disposal, 98 Percent Silt/Clay Content

Site	Coagulant Dosage (mg/g)	Average Drum Speed (min/rev)	Slurry Solids Content (%)*	Cake Solids Content (%)*	Filtrate Solids Content (mg/ℓ)*	Filter Yield (psf/hr)*	Filter Cloth Used(1)
Apalachicola Bay							
Lime	96	4.1	16.4	38.5	13,400	6.56	210
			(15.0)		(2050)	(6.33)	
	61	4.0	16.3	38.6	15,000	6.67	210
			(14.4)		(1075)	(6.00)	
	50	1.8	15.4	39.1	12,600	8.50	210
			(13.9)		(885)	(8.17)	
	46	4.1	15.8	39.4	16,700	5.87	210
			(15.6)		(2125)	(6.24)	
Polymer	2.8	3.9	13.9	41.8	6,900	2.87	525
			(12.4)		(810)	(2.64)	
Toledo Land Disposal							
Lime	119	4.4	11.5	51.7	7,400	7.51	525
			(11.2)		(850)	(7.64)	
	110	3.6	13.6	52.8	6,400	6.87	525
			(13.6)		(630)	(7.19)	
	90	3.9	10.5	52.3	5,220	5.93	525
			(9.4)		(990)	(5.63)	
	52	3.0	12.6	54.9	4,600	6.0	525
			(12.5)		(930)	(6.08)	
Polymer	3.6	4.0	9.9	53.8	1,430	3.63	525
			(9.4)		(1030)	(3.48)	

NOTE: All runs were conducted at 37-1/2% submergence.

*Numbers in parentheses indicate suspended solid basis. All others indicate total solids basis.

(1) Cloth 210: porosity 0.5-1.0 scfm; crowfoot weave; dacron material.
Cloth 525: porosity 4-6 scfm; satin weave; nylon material.

Table 8

Summary of Vacuum Filter Results for Toledo Site A, 95 Percent Silt/Clay Content and Toledo Site B, 95 Percent Silt/Clay Content

Site	Coagulant Dosage (mg/g)	Average Drum Speed (min/rev)	Slurry Solids Content (%)*	Cake Solids Content (%)*	Filtrate Solids Content (mg/ℓ)*	Filter Yield (psf/hr)*	Filter Cloth Used(1)
Toledo Site A							
Lime	144	8.4	12.2	48.4	25,500	3.77	211
			(12.1)		(16,800)	(4.10)	
	96	7.2	15.5	53.0	45,000	4.0	211
			(13.1)		(38,100)	(3.40)	
	96	6.6	13.3	55.9	23,900	5.97	211
			(13.1)		(16,500)	(6.10)	
Polymer	2.8	2.6	13.5	57.0	1,960	4.10	525
			(12.5)		(670)	(3.68)	
Toledo Site B							
Lime	140	3.6	10.3	51.7	5,520	6.75	525
			(9.0)		(620)	(6.27)	
	98	3.1	8.7	50.3	6,300	5.34	525
			(7.4)		(770)	(4.83)	
	70	3.2	9.6	51.7	23,400	4.60	525
			(8.0)		(810)	(4.93)	
Polymer	4.5	3.2	8.0	52.0	1,820	2.10	525
			(7.9)		(1,680)	(2.05)	

NOTE: All runs conducted at 37-1/2% submergence.

*Numbers in parentheses indicate suspended solids basis. All others indicate total solids basis.

(1) Cloth 211: porosity 10-15 scfm: chainweave: dacron material.

Cloth 525: porosity 4-6 scfm: satin weave: nylon material.

Table 9

Summary of Vacuum Filter Results for Penns Neck Spillway, 55 Percent Silt/Clay Content and Browns Lake, 71 Percent Silt/Clay Content

Site	Coagulant Dosage (mg/g)	Average Drum Speed (min/rev)	Slurry Solids Content (%)*	Cake Solids Content (%)*	Filtrate Solids Content (mg/ℓ)*	Filter Yield (psf/hr)*	Filter Cloth Used (1)
Penns Neck Spillway							
Lime	141	3.3	18.2	50.5	9,630	8.46	210
			(13.1)		(1,170)	(6.32)	
	94	3.4	17.4	48.9	10,000	9.0	210
			(11.9)		(500)	(6.45)	
	70	3.6	15.4	47.2	16,100	5.31	210
			(12.0)		(560)	(4.59)	
	43	4.6	15.4	48.2	14,800	4.73	210
			(10.9)		(1,560)	(3.65)	
Polymer	2.8	3.0	13.0	49.0	730	3.14	525
			(12.0)		(260)	(3.18)	
Browns Lake							
Lime	100	3.1	20.3	62.4	5,390	8.50	525
			(20.8)		(908)	(9.0)	

NOTE: All runs conducted at 37-1/2% submergence.

*Numbers in parentheses indicate suspended solids base. All others indicate total solids basis.

(1) Cloth 210: porosity 0.5-1.0 scfm; crowfoot weave; dacron material.

Cloth 525: porosity 4+6 scfm; satin weave; nylon material.

cake solids were reported, the consistency of the cake was very sticky, resisting the effects of cracking and the helix/roll discharge.

126. It was determined that cloth 525 provided both high filter yields and low filtrate suspended solids contents. The best performance appeared to be not only a function of the porosity of the cloth, but also the thickness and type of weave involved.

127. Cloth 210 (0.1- to 1.0-scfm porosity) was the least porous media used; however, it did not perform as well as cloth 525 with a porosity of 4 to 6 scfm. The weaves for the cloths were dacron crowfoot and nylon satin, respectively. The thickness of each cloth was approximately the same.

128. Cloth 211 (10 to 15 scfm) was more porous than cloth 525, but the dacron chain weave resulted in much greater thickness than the nylon satin weave of cloth 525.

129. The thickness of the media was especially important to cake discharge. The thickness of the dacron chainweave of cloth 211 prevented the cake from cracking and discharging freely over the helix/roll. For this reason, drum speeds had to be reduced, resulting in a corresponding decrease in filter yield.

130. As shown in Figures 49 through 52 of Part VII, filtrate quality is more a function of the type of filter media used than the lime dosage.

Sequential Filtration

131. An investigation was conducted to determine the advantages of a two-stage sequential filtration process. In this application, the conditioned dredged material was vacuum filtered on a cloth of high porosity. The filtrate from this first stage was then filtered without further conditioning on a cloth of low porosity.

132. A treatment scheme for sequential filtration was simulated in the laboratory using the Buchner Funnel Apparatus and Mobile Bay material at 22.4 percent solids. Several high-porosity cloths were tested with varying success. These cloths included 2009, 2002, and 211.

133. Results of the first-stage filtration tests are shown in Table 10. As shown in this table, cloth 2009 and 2002 resulted in poor cake solids contents (30 percent) and very high filtrate solids contents. However, when cloth 211 was used, 34 percent cake solids were obtained with lower filtrate solids contents.

134. The second-stage filtration was run without further lime conditioning using cloth 210 (0.5 - 1 scfm) on the filtrate collected from the first-stage runs with cloth 211. The results of the second-stage filtration are shown in Figure 56. The cake formed on cloth 211 was so thin that sufficient quantities could not be scraped off to give a representative sample. Therefore, results are presented in terms of second-stage filtrate quality.

135. A simple settling test was also conducted on the first-stage filtrate for comparison with the second-stage results. The filtrate was settled in a beaker for 5 minutes. Supernatant solids samples were analyzed and results are presented in Figure 56. It should be noted that the supernatant quality compares favorably with the filtrate quality of the second-stage filtration. Therefore, considering these results and the relative costs of vacuum filtration compared with sedimentation, further consideration of sequential filtration was not deemed necessary.

Pretreatment for Vacuum Filtration

136. The applicability of dewatering dredged material by vacuum filtration has been demonstrated. The material used in this study was usually taken from diked disposal areas, resulting in a sample which contains a narrower range of particle sizes than is actually dredged from a waterway. Therefore, since vacuum filtration has been demonstrated to be feasible for this range of particle sizes, some form of treatment may be necessary before filtration.

137. These pretreatment steps could consist of a short detention time settling tank which would function as a grit chamber in a wastewater

Table 10

Sequential Filtration (First-Stage) Summary of Results

Mobile Bay - 22.4% Solids
Drum Speed - 1.0 min/rev
Submergence - 60%
Coagulant - Lime 80 mg/g Dry Solids

Cloth*	Porosity (scfm)	Cake Yield (psf/hr)	Cake Solids (%)	Filtrate Solids (mg/ℓ)
2009	100	14.1	30.7	35,000
2022	30	13.8	30.7	12,000
211	10 - 15	16.1	33.6	12,200

NOTES: *Cloth 2009: porosity 100; plain weave; polypropylene material.

Cloth 2022: porosity 30 scfm; 2x2 twill weave; polypropylene material.

Cloth 211: porosity 10-15 scfm; chainweave; dacron material.

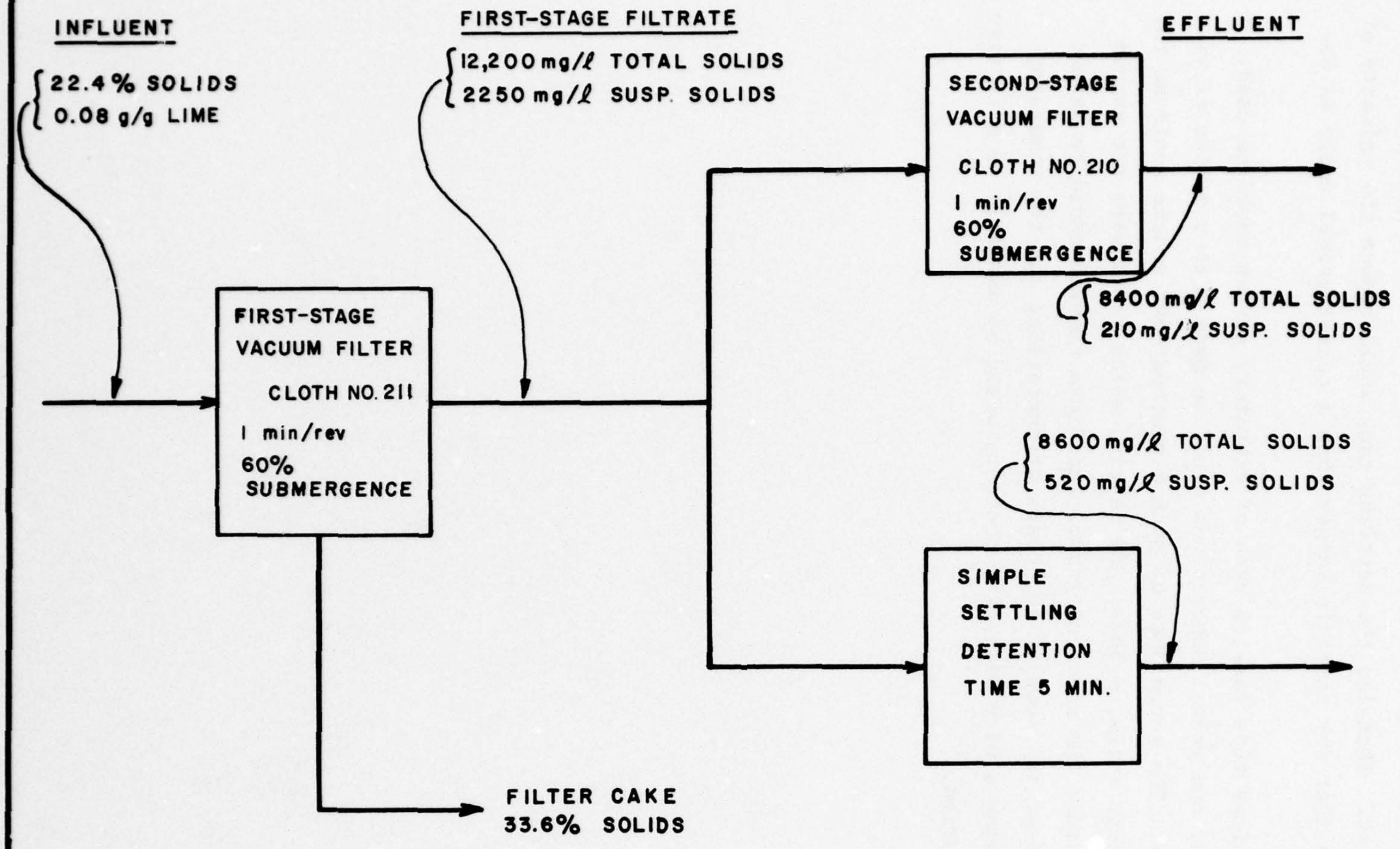


Figure 56
Results of Second-Stage Filtration
and Second-Stage Settling

treatment plant. That is, the settling tank would reduce the velocity of the slurry so that any particle larger than a coarse gravel would be deposited.

138. After this tank, a bank of vibratory screen could be used. A number of sand and gravel seperations could be made with a series of vibrating trays. The advantages of such a pretreatment scheme would be the removal of large rocks, stones, and debris, which could harm the vacuum filter apparatus; the sand and gravel fractions removed could be washed and sold, offsetting some of the costs of operation; and the remaining fraction, having a high silt/clay content, would be amenable to effective vacuum filtration.

PART IX: ECONOMIC ANALYSIS

139. An economic analysis of the application of vacuum filtration for dewatering dredged material must be prepared on a disposal site by disposal site basis. This analysis should include a comparison of benefits resulting from the application of vacuum filtration with costs associated with the application.

140. Benefits resulting from the application of vacuum filtration include increasing the useful life of a disposal site by reducing the initial volume of dredged material requiring disposal and the volume of water remaining with the dredged material in the disposal site after surface material forms a crust. Increasing the solids content of dredged material before disposal from 5 percent solids prior to dewatering to 45 percent solids after filtration results in a twelve-fold decrease in the volume of material requiring disposal. The corresponding cost of dredging is reduced due to the increase in the disposal site life. Travel to a second or third disposal site, necessitated by filling the primary site, is postponed. Filtrate from the vacuum filtration of dredged material contains, in most cases, less than 1,000 mg/ℓ total suspended solids and can be discharged without prior storage in the disposal site.

141. Costs associated with vacuum filtration of dredged material prior to disposal in a land disposal site include the installed capital cost of the filter and associated equipment, and operation and maintenance costs.

142. Installed capital equipment costs include filtration equipment consisting of a filter, drum drive, vacuum pump, vacuum receiver, filtrate pump, instrumentation and other filter-related equipment. In addition, lime storage, handling and feeding equipment, and a blend tank for mixing lime with the dredged material prior to filtration are required. Additional installed capital costs include the cost of a settling tank sized to permit sedimentation of rocks and sticks larger than medium grain size sand (2mm diameter) and an equalization tank which will store dredged material and aid solids in suspension, permitting feed of dredged material over 24 hours per day on days during which dredging

operations are being conducted.

143. Operation and maintenance costs will include power filtration equipment, lime feeding and handling equipment, and mixing equipment, as well as lime costs, salaries and benefits of filter operators, and costs for transport of filtration equipment from site to site.

144. For purposes of illustration, the cost of a vacuum filter installation has been prepared for the Lower Polecat Bay Disposal area based upon a dredging rate of 25,000 yd^3 per day. The design losses for sizing the filter facilities include an influent solids content of 5 percent, a lime dosage of 75 mg/g of dredged material solids, a drum speed of 4 min/rev, use of filter cloth 210 and a resultant filter yield of 5.0 $lb/ft^2/hr$. The total filter area required would be 18,860 ft^2, which would necessitate the use of 25 filters each of 12 ft diameter by 20 ft length filter face. The cost of a filter of this size, with all associated equipment identified above, in 316 stainless steel, is $250,000, excluding installation. Therefore, the total vacuum filter equipment cost would be 25 x $250,000 or $6,250,000. The addition of three back-up filters to maintain filtering capacity in the event of mechanical failure or routine maintenance operations would cost an additional $750,000, raising the total filtration equipment cost to $7,000,000. Installation of the equipment at a site, on a barge or on a railroad car is estimated at approximately 50 percent of the equipment cost, resulting in an installed filter equipment cost of $10,050,000. Lime feed equipment capable of feeding 80 ton/day lime will be required plus associated lime storage facilities. Additional costs include cost of a settling tank for removal of rocks and sticks.

145. Operating costs for the vacuum filter facility will include the salaries of 9 operators per day (3 per shift), 79 ton/day of hydrated lime at $30/ton ($2,370/day), and power costs for 72,000 hp-hr/day for the vacuum filters.

146. The illustration used in the preceding paragraphs shows that although vacuum filtration may be technically feasible, this approach to treatment should not be selected until economic feasibility is established on a case by case basis. The scope of this study did not permit the

development of economically feasible vacuum filtration alternatives. However, the technical data presented in this report should be sufficient for use in making economic analyses for vacuum filtration considerations in specific dredged material disposal activities.

PART X: CONCLUSIONS

147. Dewatering of dredged material can be effectively accomplished through use of a rotary, endless belt vacuum filter.

148. The filterability of unconditioned dredged material is affected by the silt-clay content (percent passing the No. 200 sieve) of the material. Those samples having a silt/clay content between 50 and 80 percent show the lowest specific resistance to filtration (5×10^8 sec^2/g).

149. Chemically conditioned dredged material also exhibits the highest filterability when the silt/clay content is between 50 and 80 percent.

150. Lime and Hercofloc polymer 844 appear to be the chemical coagulants best suited for use as conditioning agents for a wide variety of dredged material.

151. Lime conditioning of dredged material achieves optimum results at a dosage of 100 mg/g of dry solids in the sample. The specific resistance can be reduced by 90 percent to 4.5×10^7 sec^2/g, over that of unconditioned material.

152. Hercofloc polymer 844 conditioning of dredged material achieves optimum results at a dosage of 3 mg/g of dry solids in the sample. The specific resistance can be reduced by 96 percent, to 1.7×10^7 sec^2/g over that of unconditioned material.

153. A physical limitation of 3 to 4 min/rev is experienced when a well-conditioned dredged material is dewatered on an endless belt vacuum filter with a helix/roll discharge.

154. The results of the bench-scale investigation using lime and polymer 844 indicate that lime is the best coagulant for dewatering dredged material. Lime coagulation results in filter yields as high as 9 $lb/ft^2/hr$. Polymer 844 conditioning of dredged material resulted in filter yields of up to 4.1 $lb/ft^2/hr$. Poor discharge characteristics were exhibited when polymer was used.

155. Filter media is an important parameter in vacuum filter operation. Specifically, the porosity, type, and thickness of the weave

contribute to filtrate quality and discharge characteristics. Filter cloth 525 produced the best quality filtrate ranging from 700 to 1000 mg/ℓ SS with the best cake discharge characteristics.

156. Sequential filtration of dredged material does not seem to be a feasible consideration when compared to simple sedimentation of the first-stage filtrate if land area is available.

157. Although the technical feasibility of using vacuum filtration in dredged material disposal activities was established by this study, the economic feasibility is still questionable. Case by case studies will have to be made to evaluate the economics of vacuum filtration.

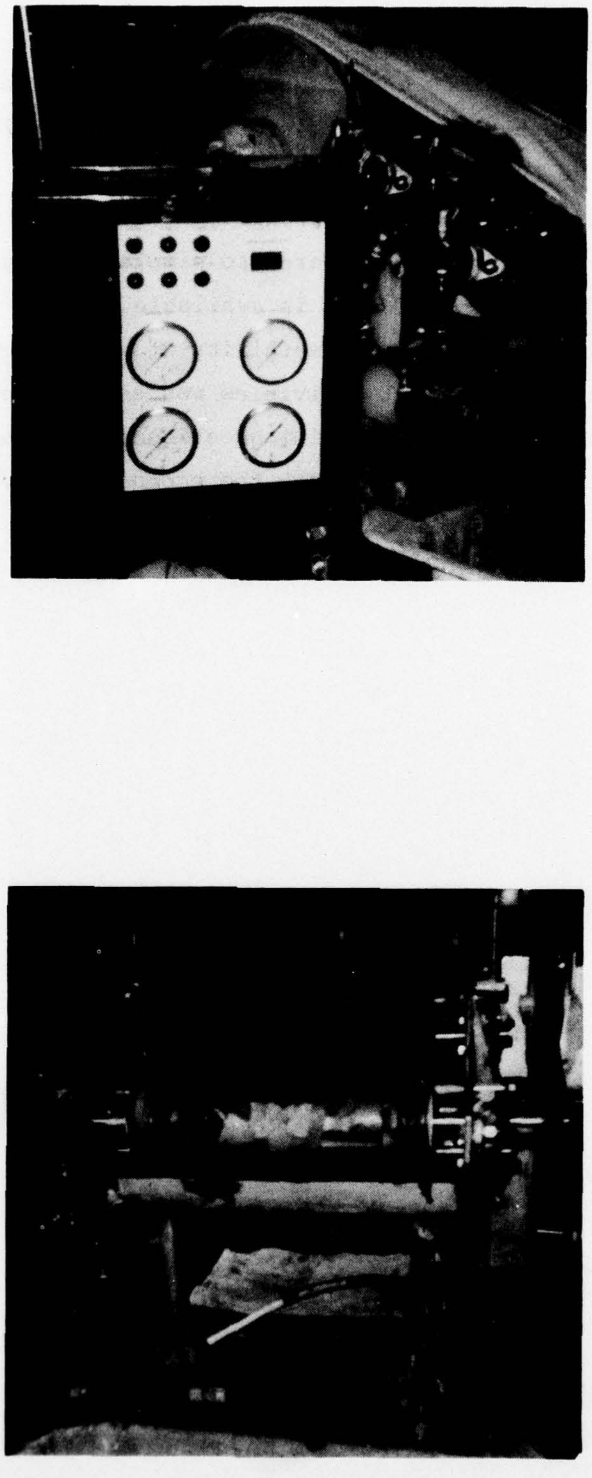


FIGURE 57

BENCH-SCALE CONTINUOUS ROTARY
VACUUM DRUM FILTER

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1. Boyd, M.B. et al., "Disposal of Dredge Spoil; Problem Identification and Assessment and Research Program Development," Technical Report H-72-8, Nov. 1972, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi.

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APPENDIX A:
PARTICLE-SIZE DISTRIBUTIONS

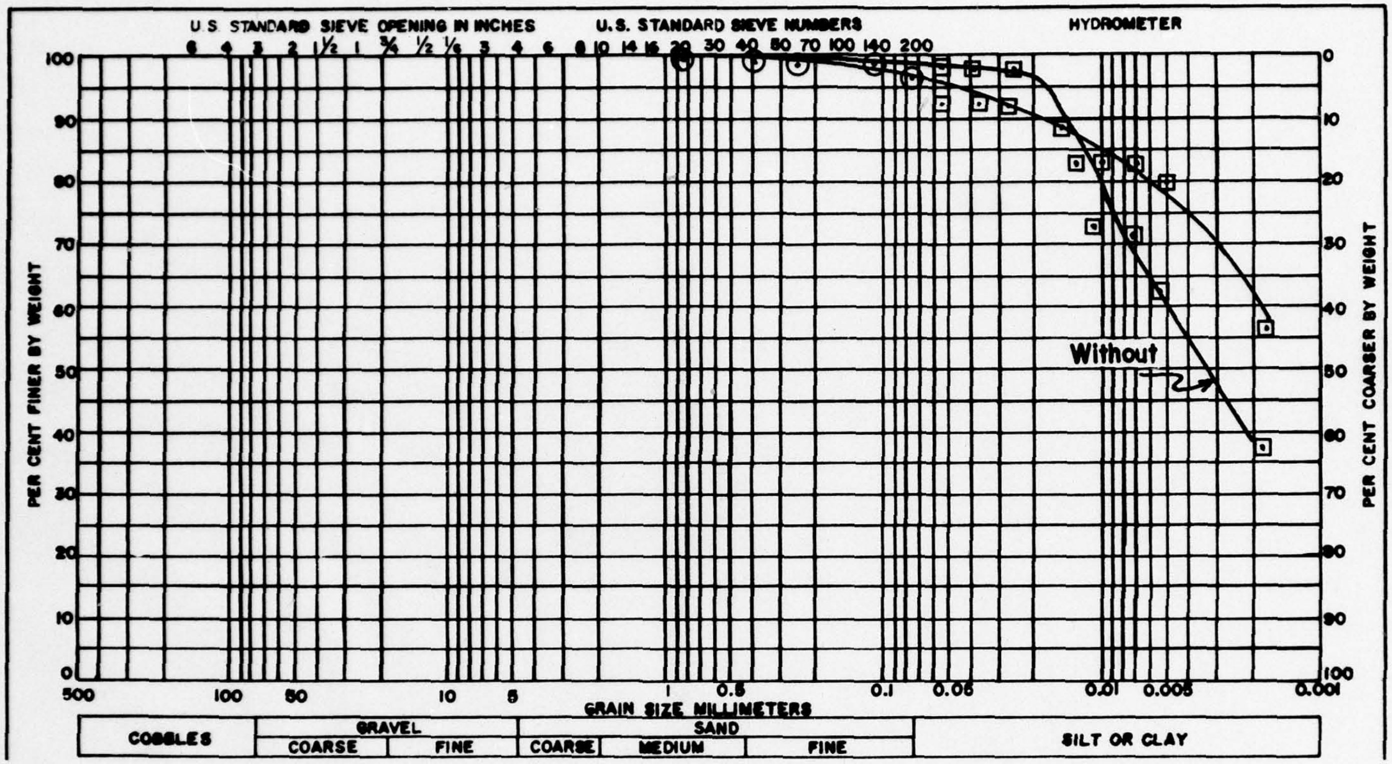

Plate A1

Particle-Size Distribution
With and Without Dispersing Agent,
Apalachicola Bay

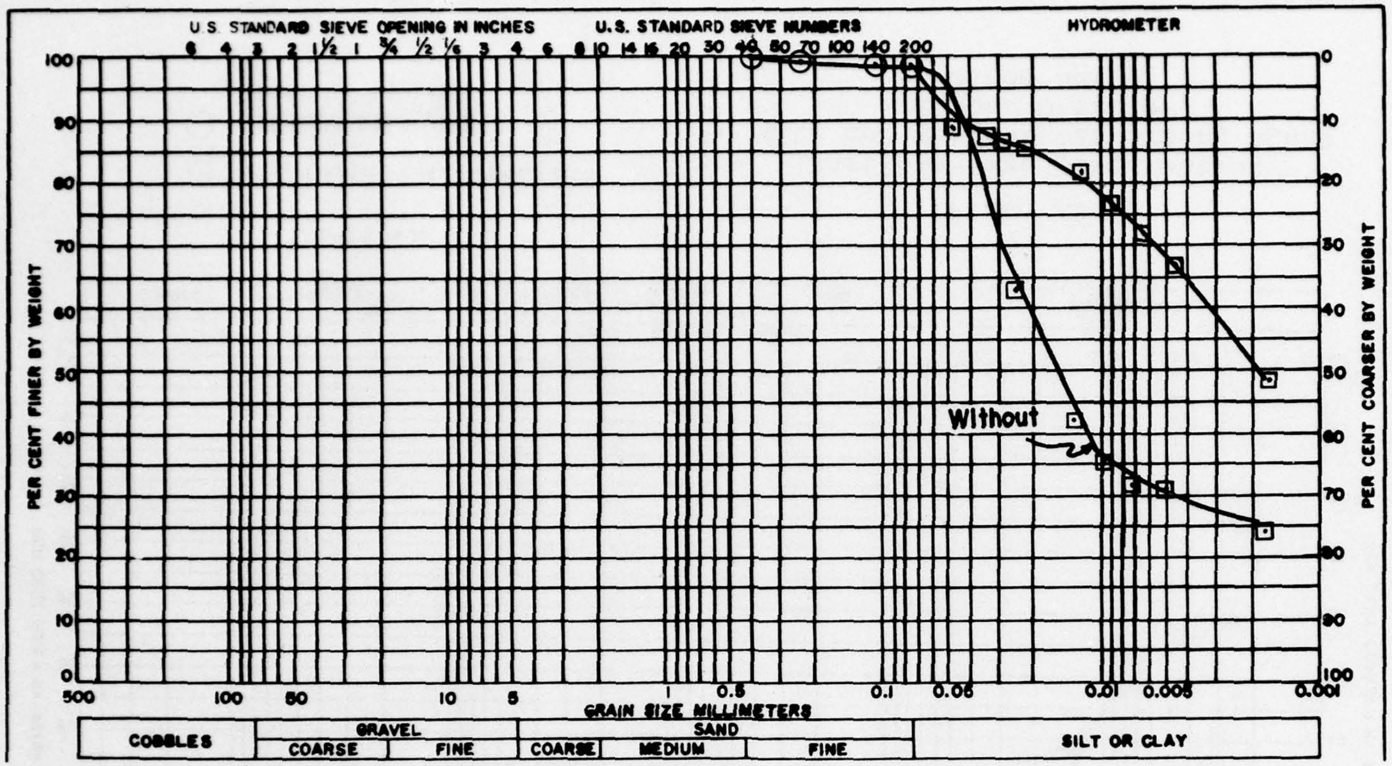

Plate A2

Particle-Size Distribution
With and Without Dispersing Agent,
Toledo Land Disposal Site

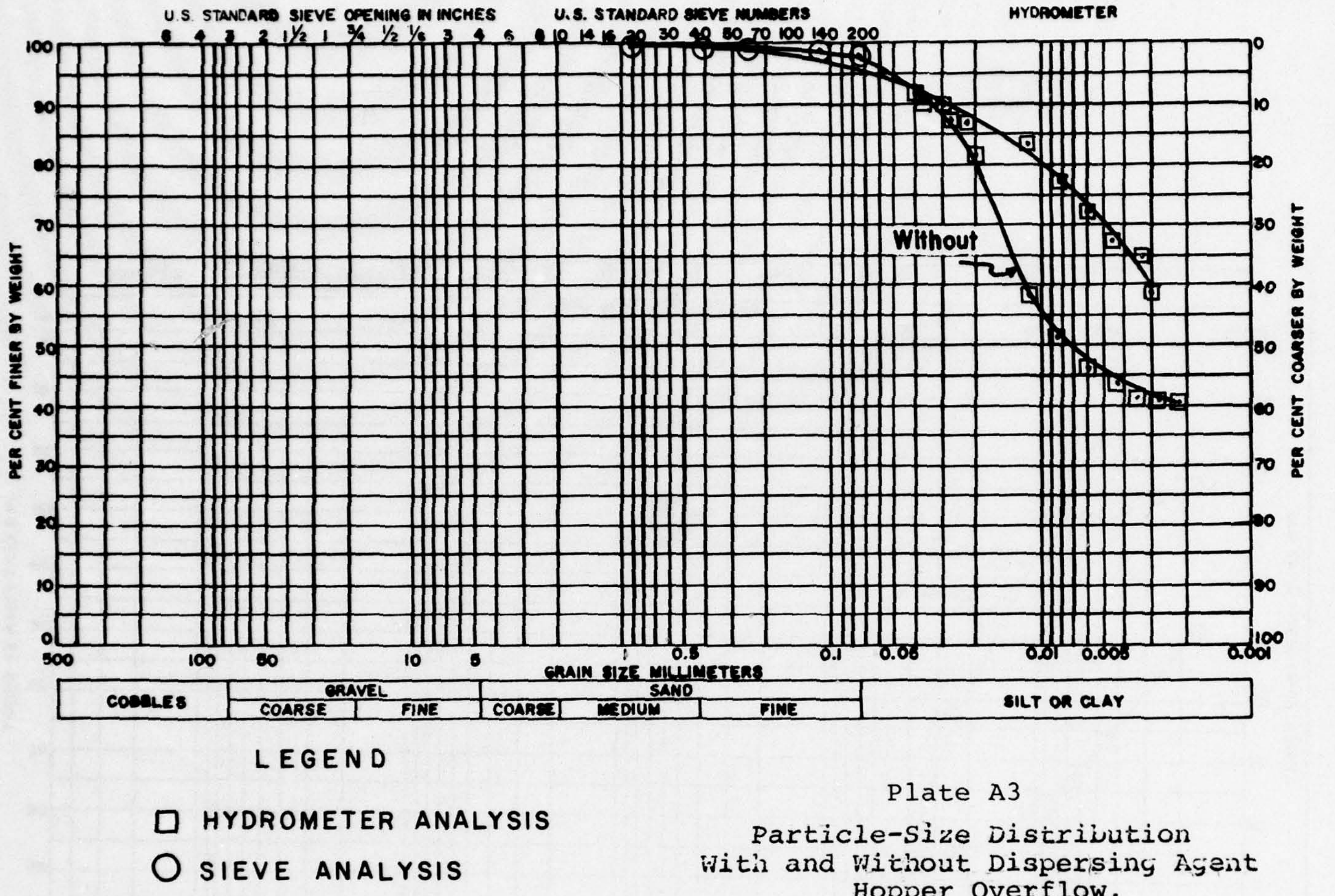

Plate A3

Particle-Size Distribution
With and Without Dispersing Agent
Hopper Overflow,
Toledo Harbor

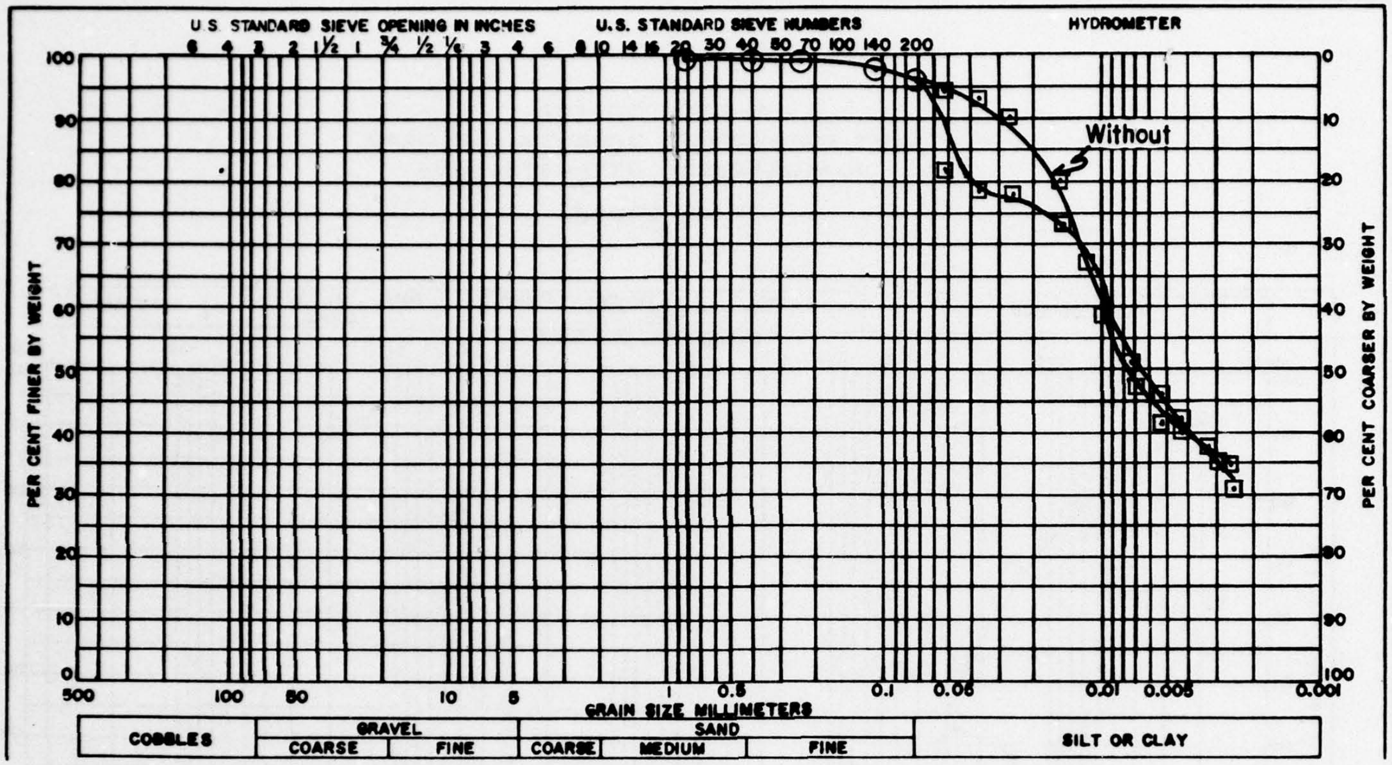

Plate A4

Particle-Size Distribution
With and Without Dispersing Agent,
Mobile Bay

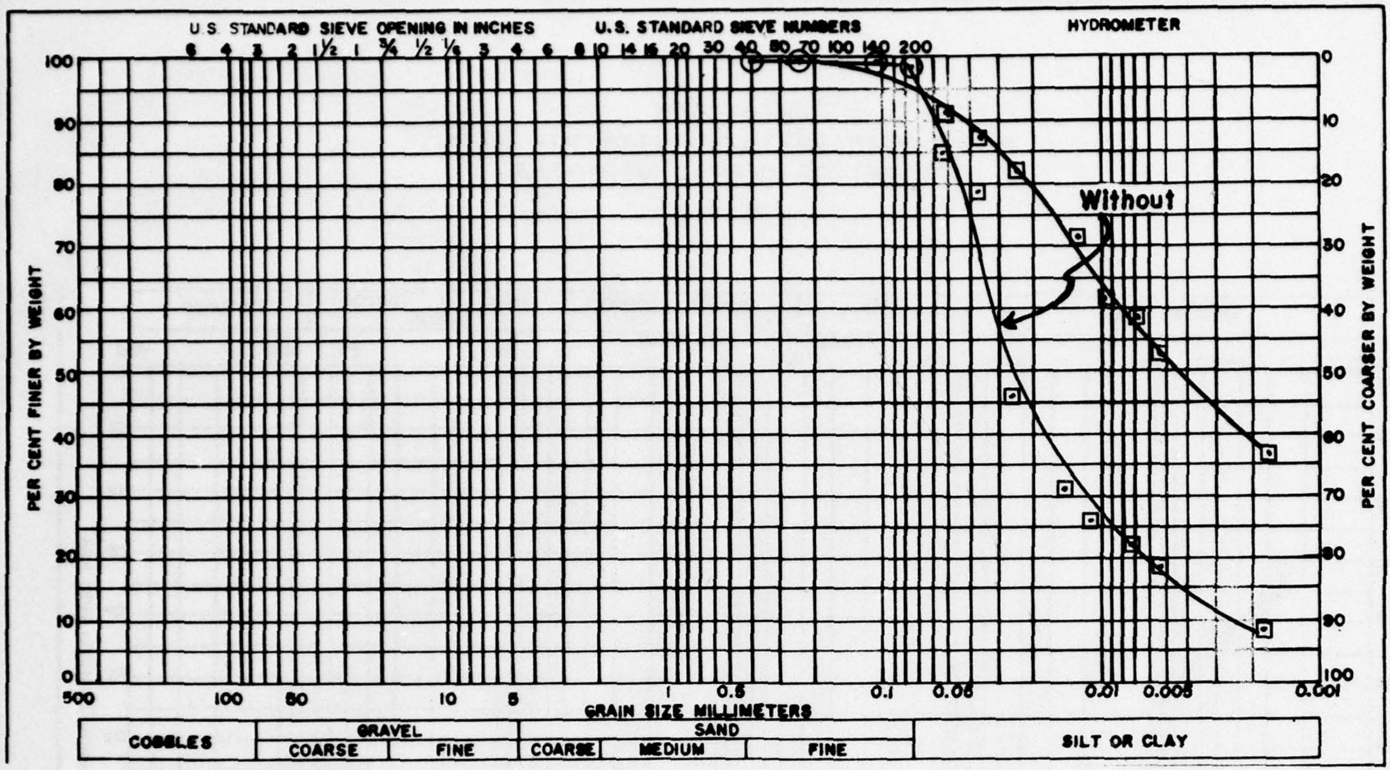

Plate A5

Particle-Size Distribution
With and Without Dispersing Unit,
Toledo Site A

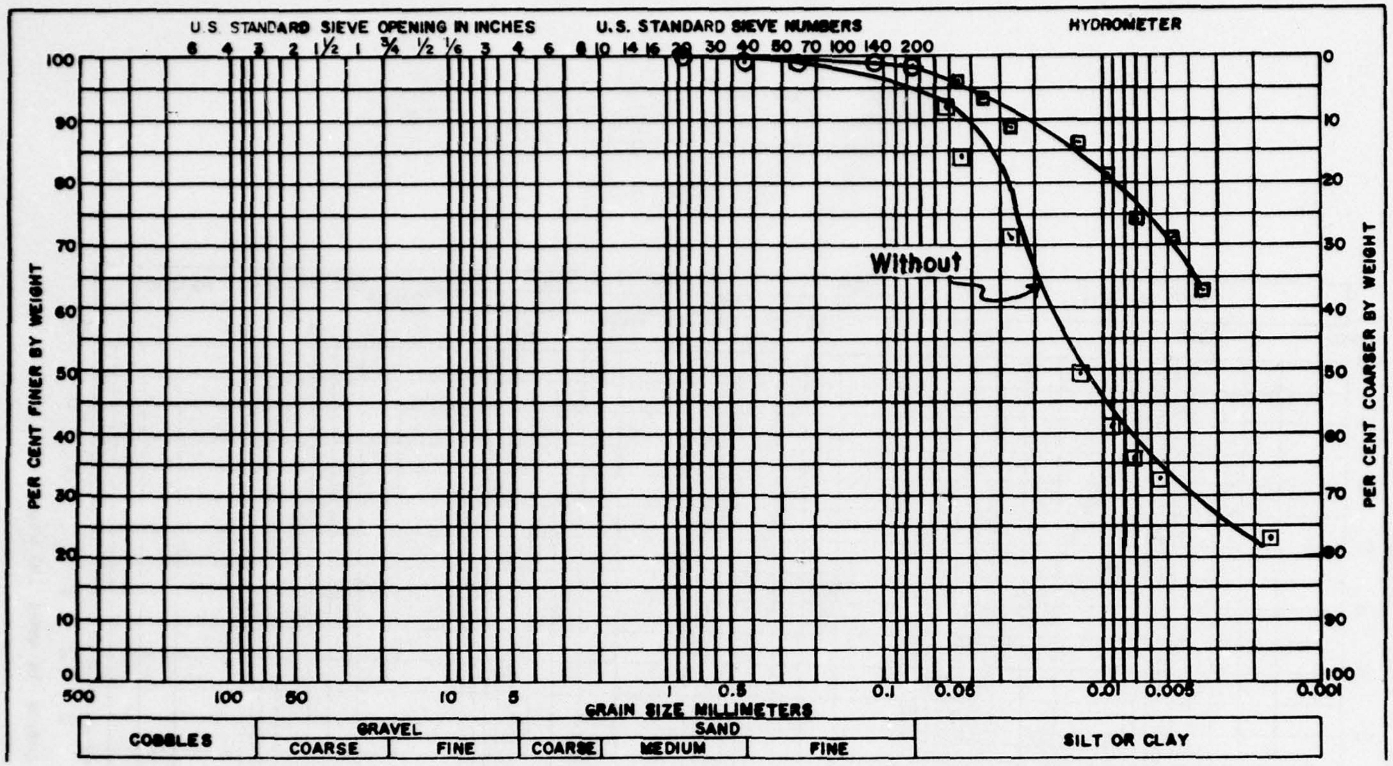

Plate A6

Particle-Size Distribution
With and Without Dispersing Agent,
Toledo Site B

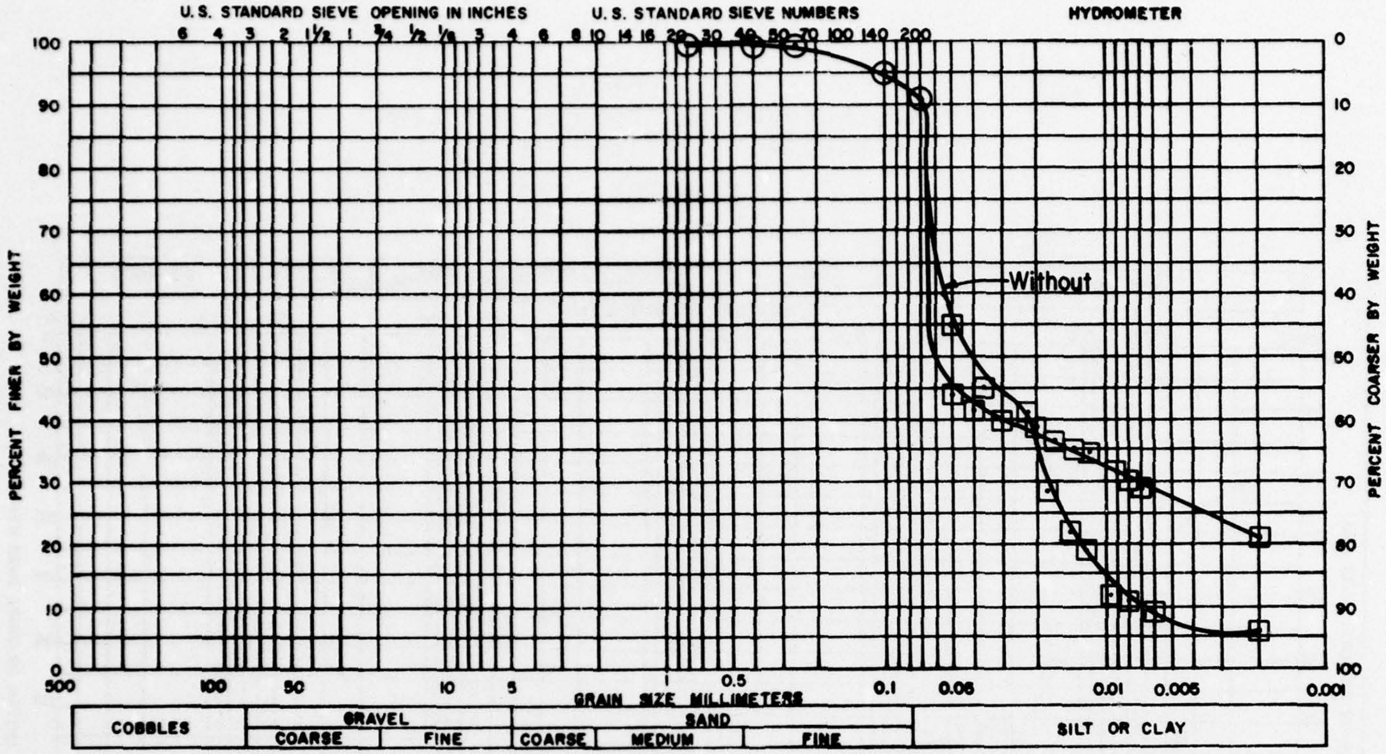

Plate A7

Particle-Size Distribution
With and Without Dispersing Agent,
Ninety Percent Silt/Clay Content

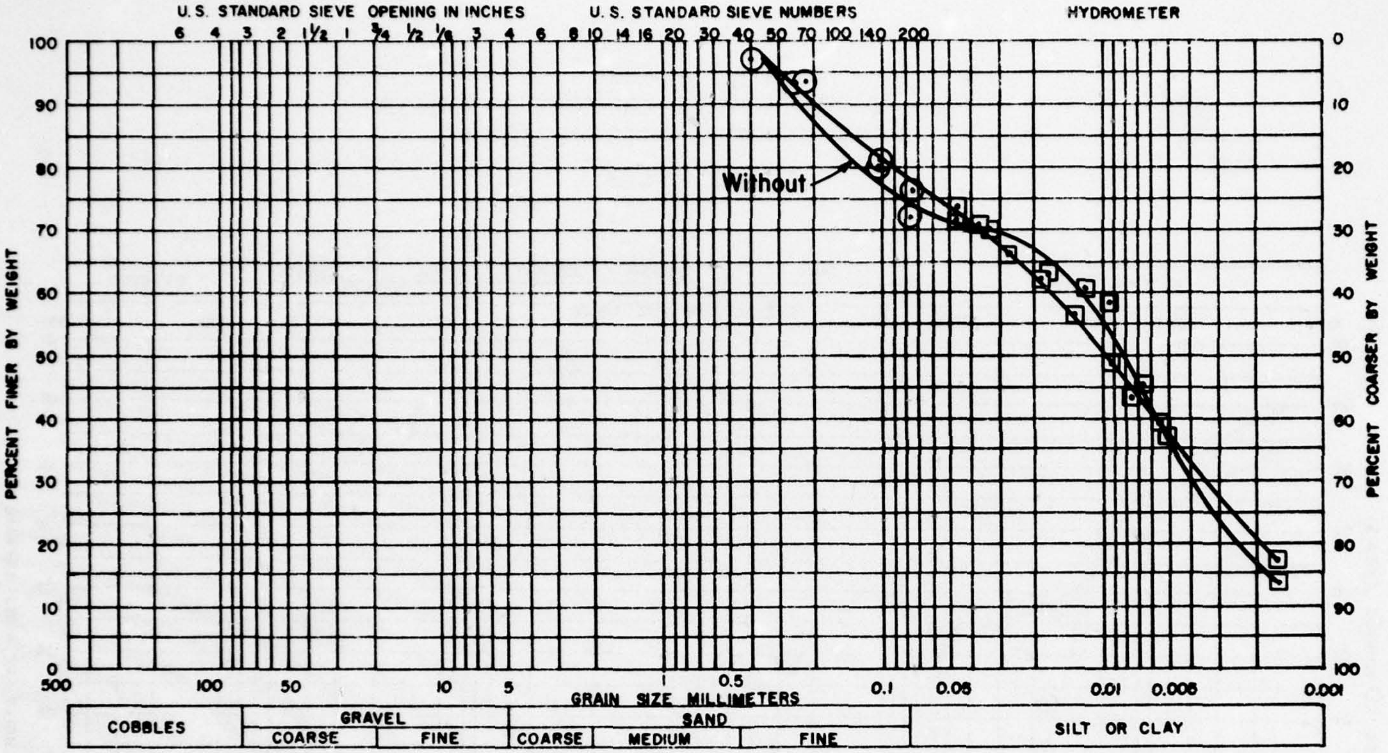

Plate A8

Particle-Size Distribution
With and Without Dispersing Agent,
Seventy-Five Percent Silt/Clay
Content

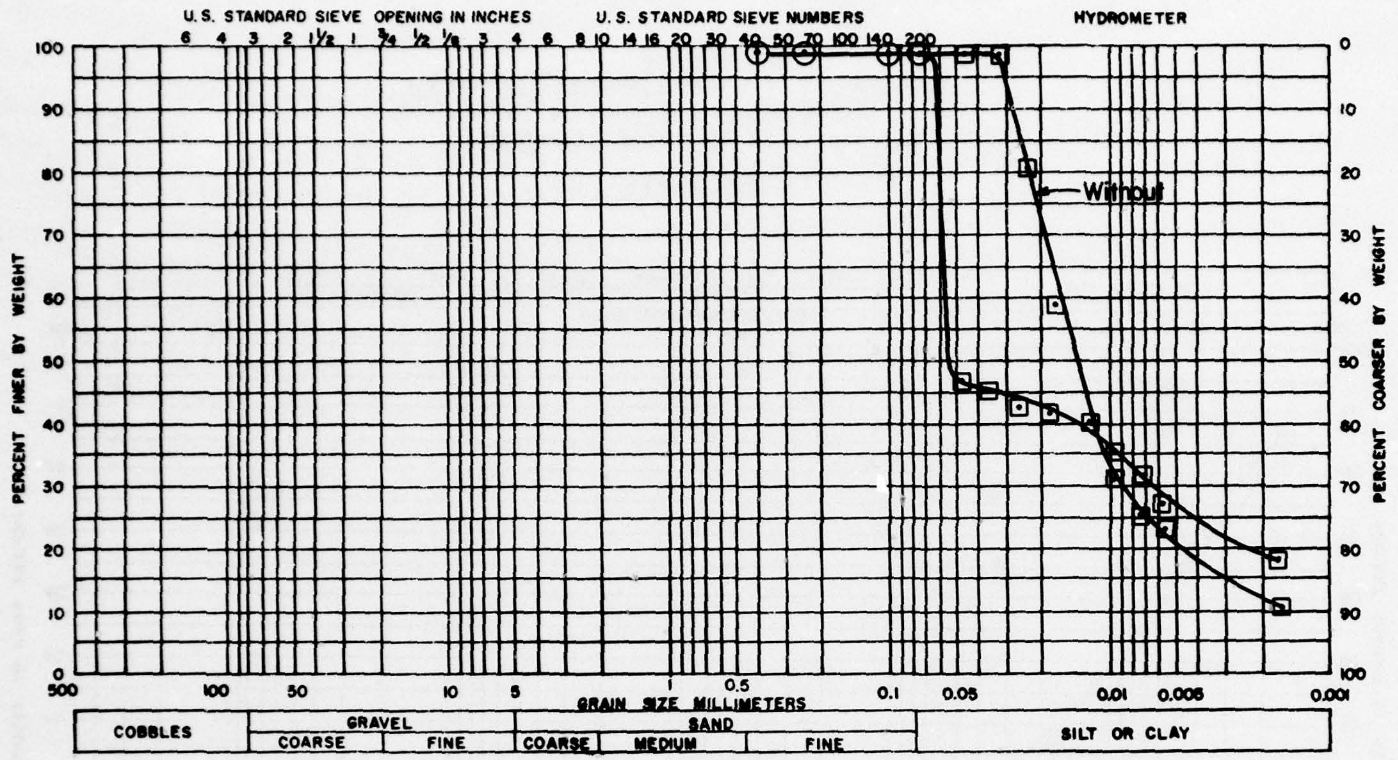

Plate A9

Particle-Size Distribution
With and Without Dispersing Agent,
Browns Lake

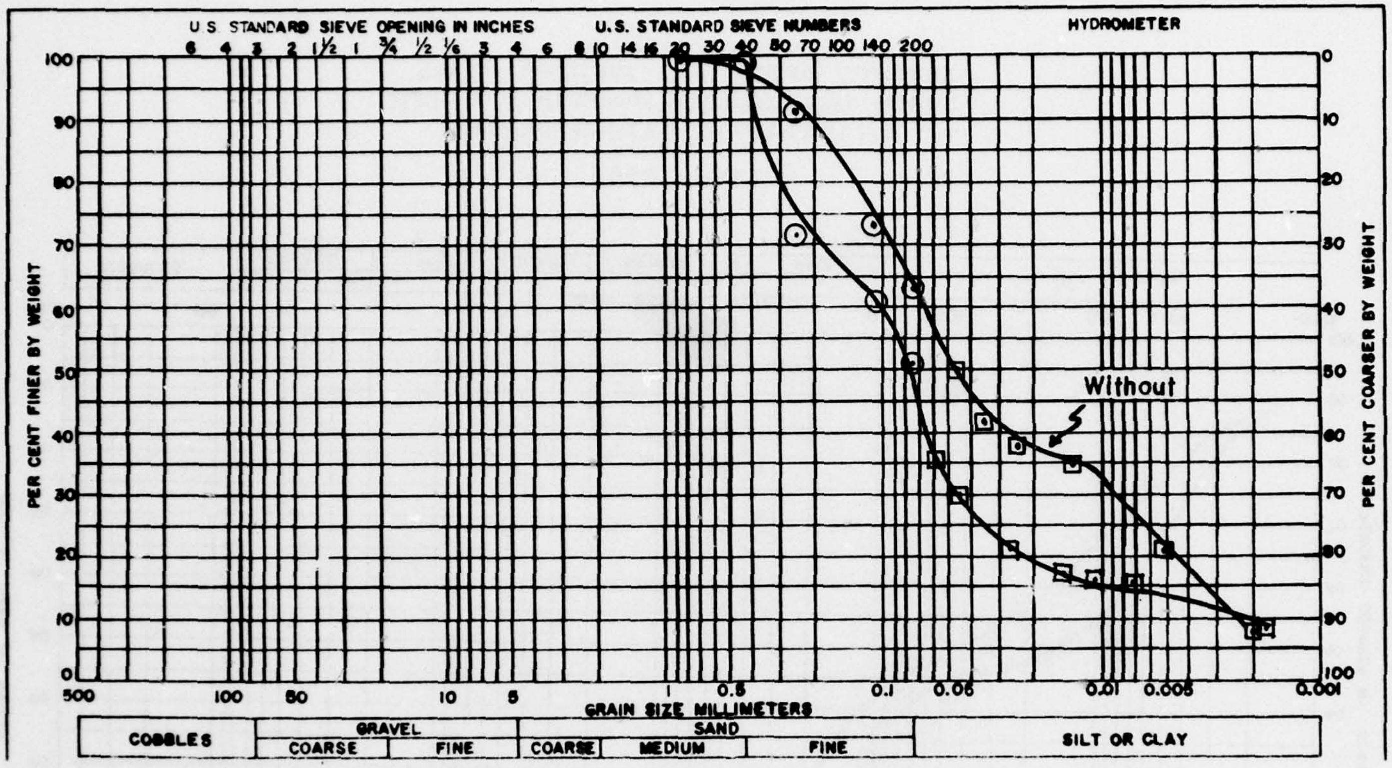

Plate A10

Particle-Size Distribution
With and Without Dispersing Agent,
Craney Island Site 2

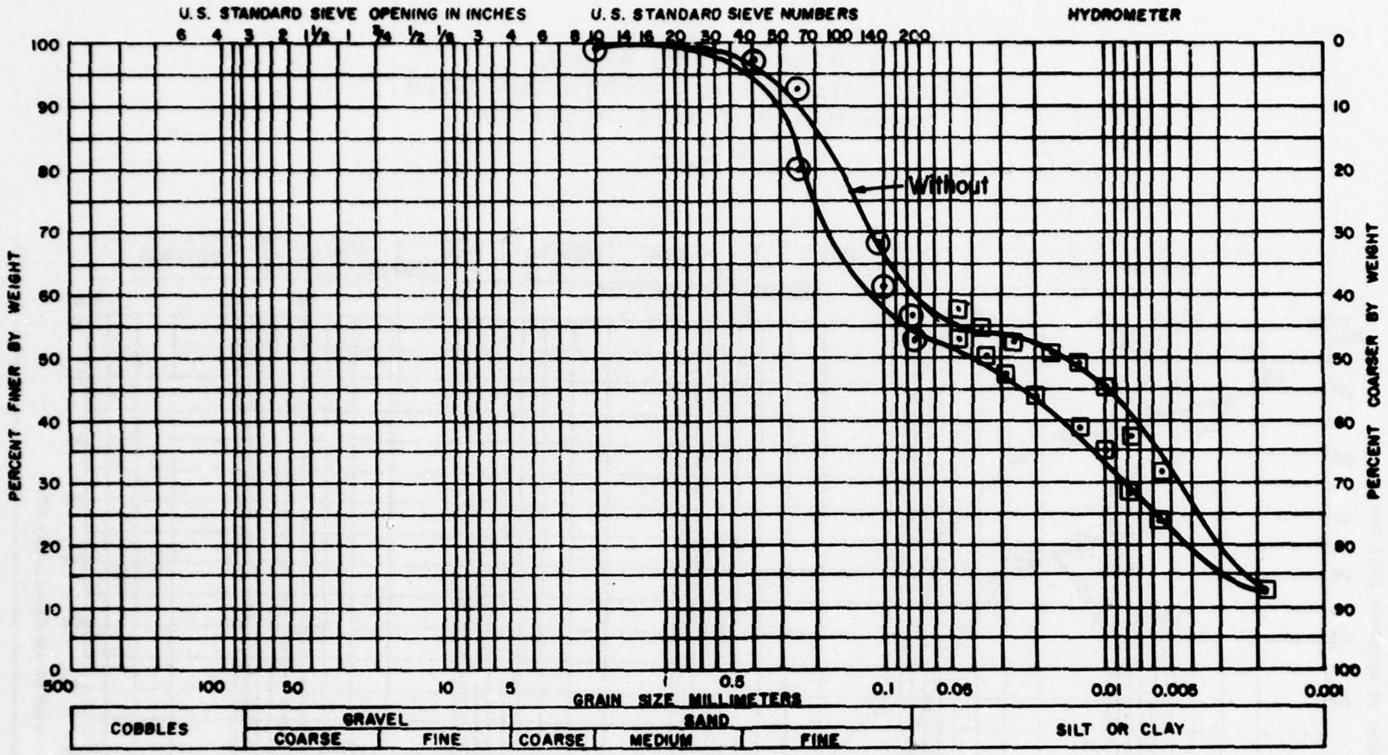

Plate A11

Particle-Size Distribution
With and Without Dispersing Agent,
Sixty Percent Silt/Clay Content

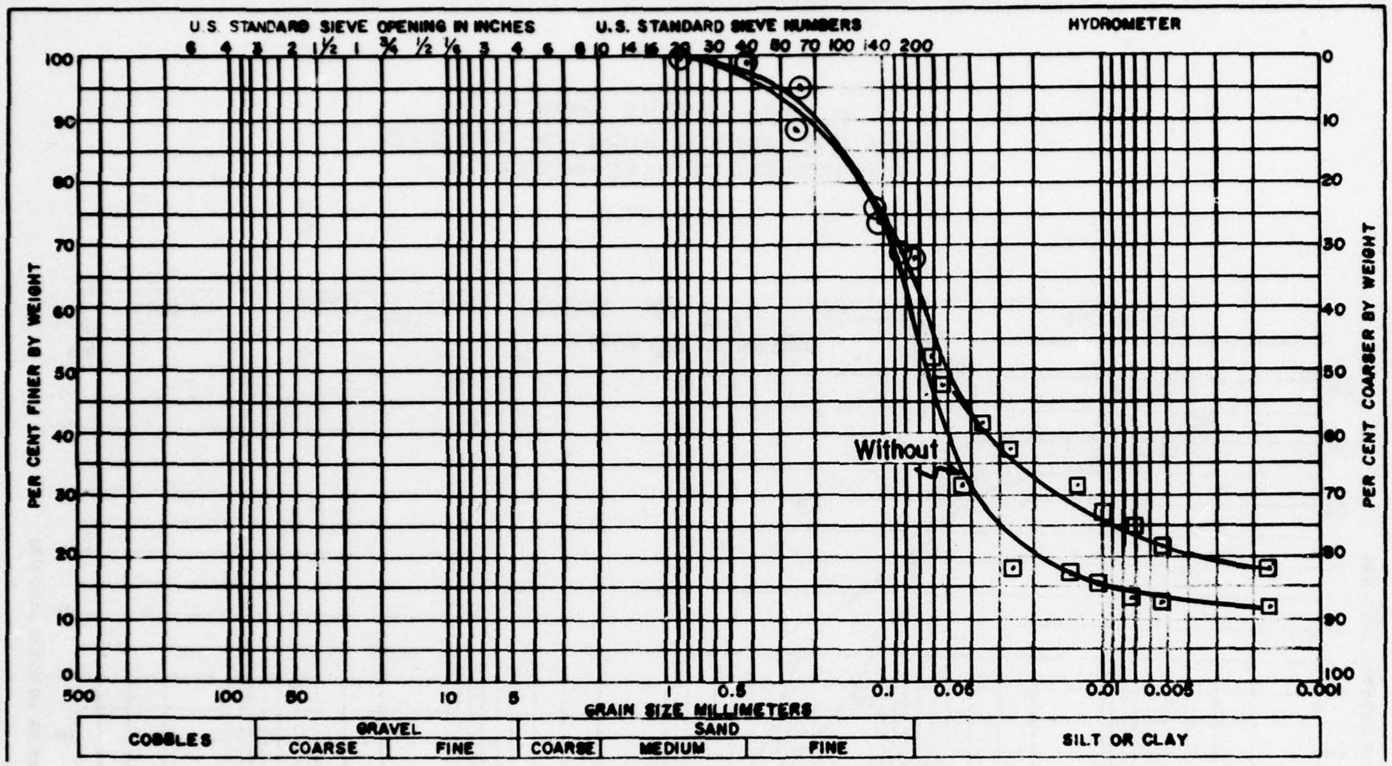

Plate A12

Particle-Size Distribution
With and Without Dispersing Agent,
Penns Neck Spillway

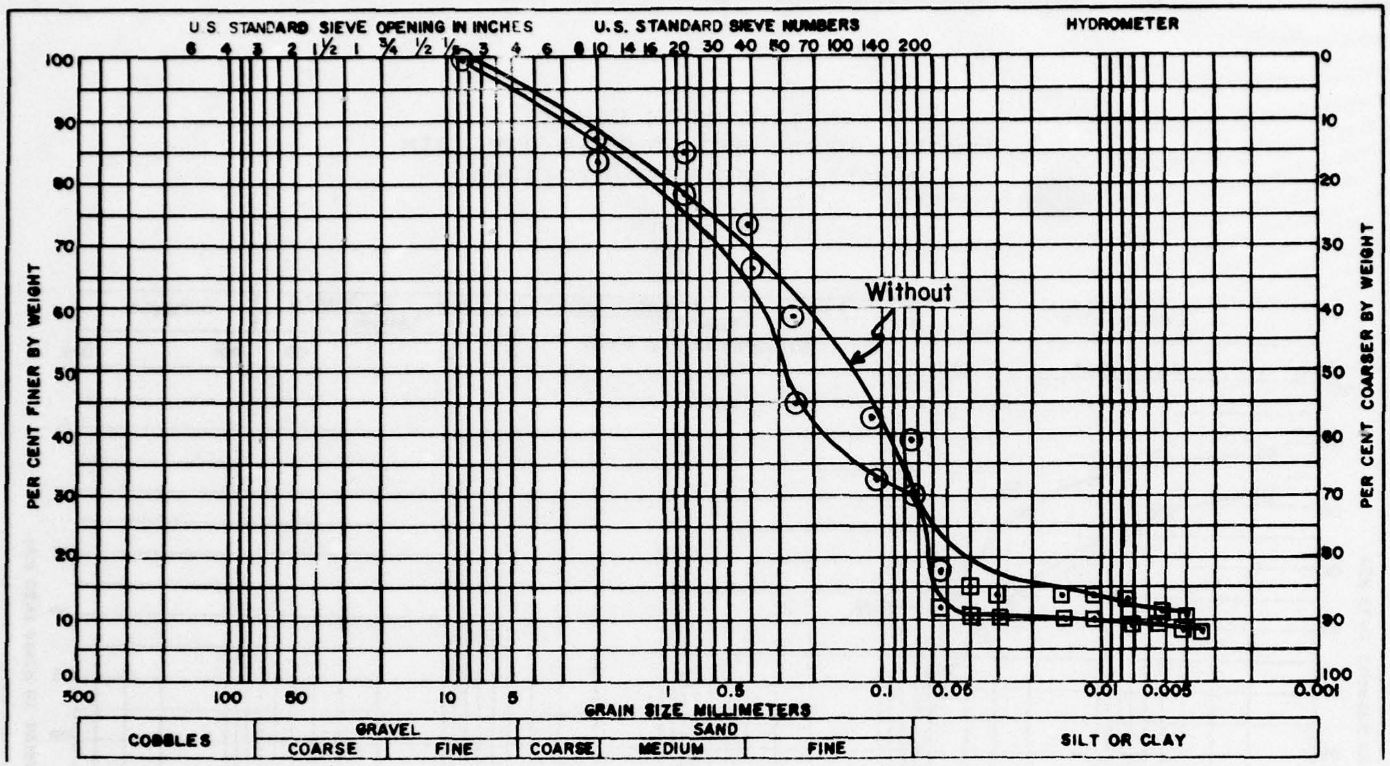

Plate A13

Particle-Size Distribution
With and Without Dispersing Agent,
Craney Island Site 4

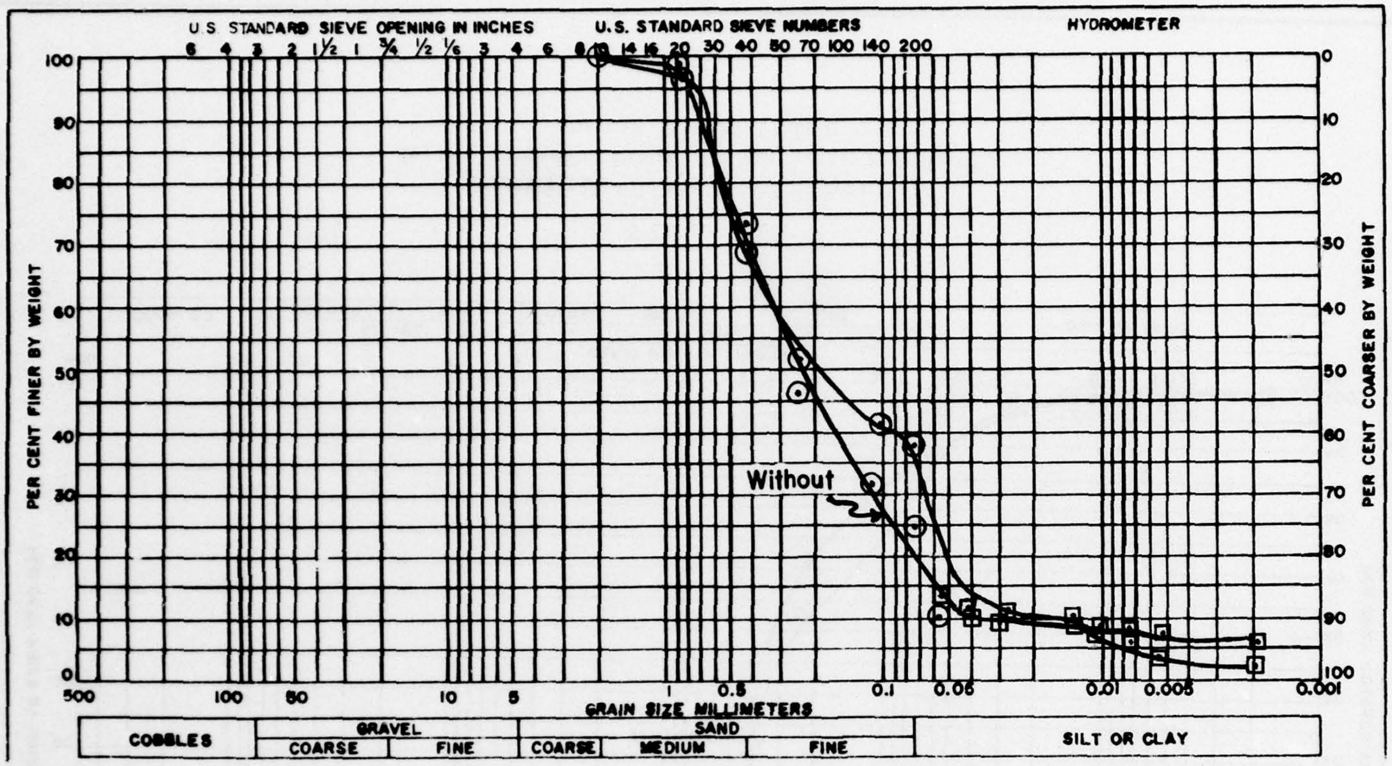

Plate A14

Particle-Size Distribution
With and Without Dispersing Agent,
Craney Island Site 1

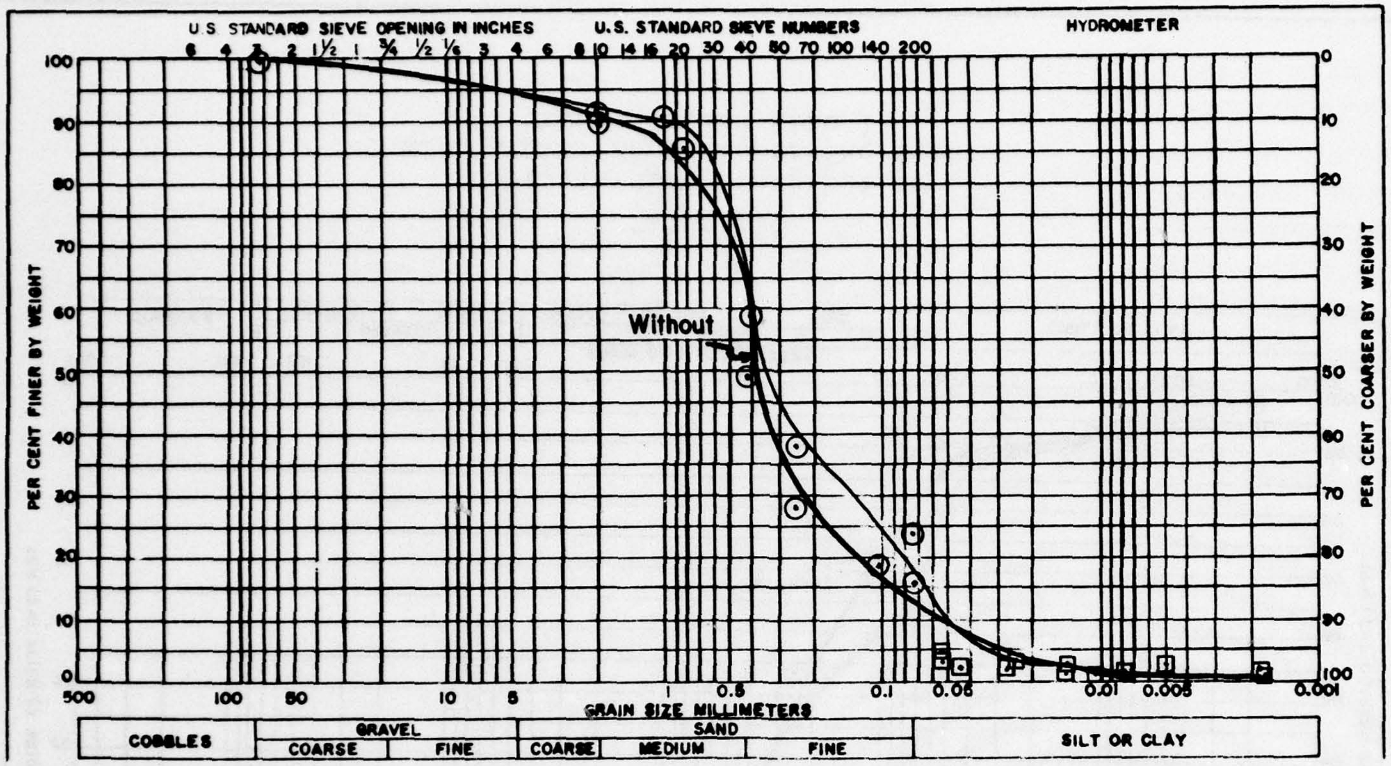

Plate A15

Particle-Size Distribution
With and Without Dispersing Agent,
Penns Neck Inlet

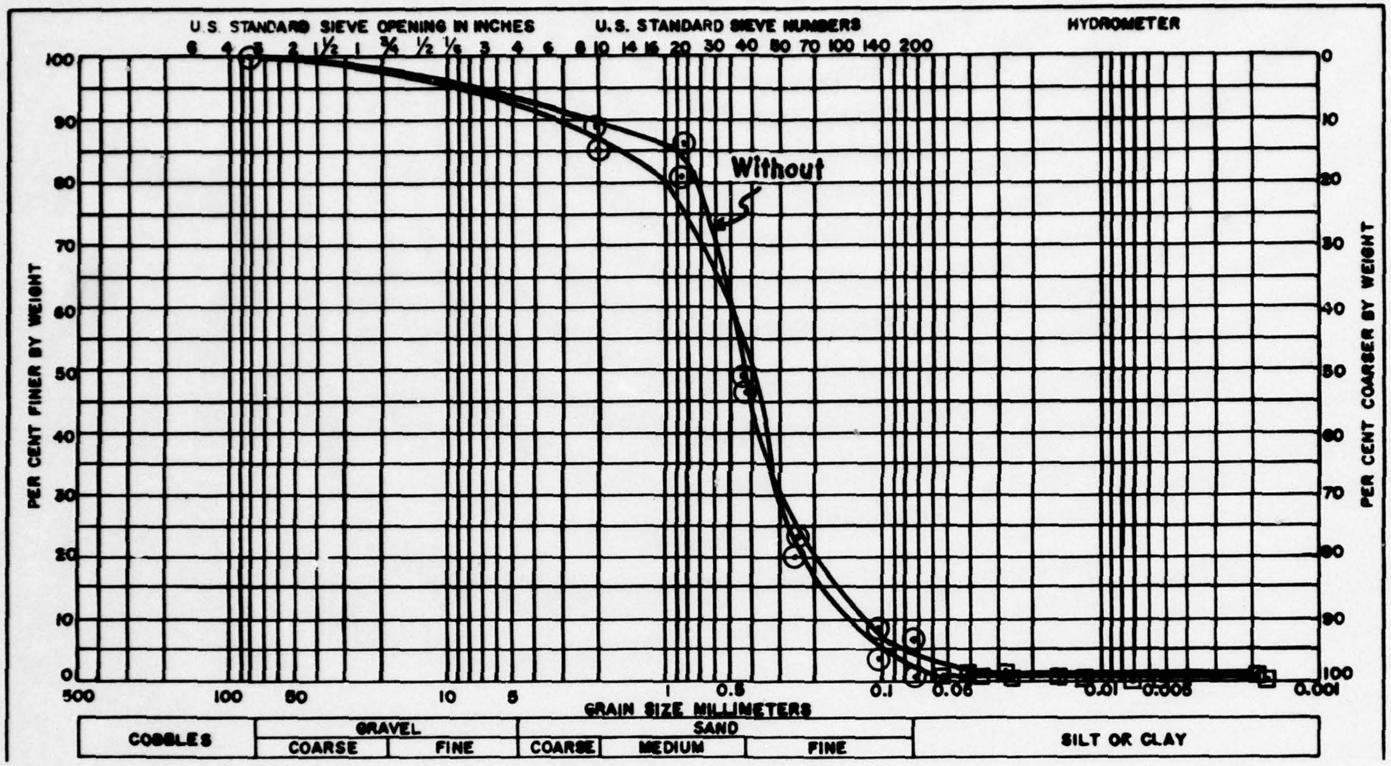

Plate A16

Particle-Size Distribution
With and Without Dispersing Agent,
Craney Island Site 3

APPENDIX B:

BUCHNER FUNNEL STUDIES-DATA SUMMARIES

Table B1
Buchner Funnel Tests
Summary of Results 8

SITE: Apalachicola Bay - 16.9% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil - 16.9% solids	--	15.1	33.3	--
W/Lime				
10 g	630	1.5	43.7	30
5 g	310	1.3	43.1	55
2 g	130	1.1	41.2	57
0.75 g	50	1.9	40.6	83
0.40 g	25	4.0	42.2	76
0.20 g	12	9.0	42.3	367
0.10 g	6	11.1	33.2	--
0.08 g	5	9.0	39.6	--
0.05 g	3	10.5	36.6	--
0.03 g	2	12.0	37.3	--
0.01 g	0.6	13.6	37.6	--
W/$FeCl_3$				
15 g	890	4.5	50.4	--
10 g	590	3.1	39.6	255
6 g	360	2.7	42.8	182
4 g	240	2.7	42.1	130

Table B1 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Apalachicola Bay - 16.9% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 g	120	1.7	41.1	202
1 g	60	3.0	43.5	223
0.5 g	30	4.2	44.2	269
0.25 g	15	7.2	42.3	--
W/$FeCl_3$ and Lime				
0.05 g and 0.4 g	30 and 24	2.0	42.5	101
0.25 g and 0.4 g	15 and 24	2.1	44.3	129
0.10 g and 0.4 g	6 and 24	2.1	43.5	123
0.03 g and 0.4 g	3 and 24	2.1	43.5	92
	2 and 24	4.0	42.7	164
W/$FeCl_3$ and Lime				
0.75 g and 0.75 g	44 and 44	1.5	41.5	175
0.50 g and 0.75 g	30 and 44	1.4	41.0	132
0.25 g and 0.75 g	15 and 44	1.3	40.6	132
0.10 g and 0.75 g	6 and 44	1.0	41.1	99

Table B1 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Apalachicola Bay - 16.9% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Alum				
10 g	590	5.3	38.2	--
8 g	470	5.9	40.3	--
6 g	360	5.4	41.5	--
2.5 g	150	4.1	41.6	174
1.0 g	60	3.7	40.8	208
0.5 g	30	4.1	40.8	206
0.25 g	15	6.6	40.9	--
W/Polymer 844 (Cationic)				
30 mg	1.8	0.70	43.2	34
20 mg	1.2	1.4	38.9	78
10 mg	0.6	4.4	43.2	--
5 mg	0.3	5.5	34.6	--

Table Bl (concluded)
Buchner Funnel Tests
Summary of Tesults

SITE: Apalachicola Bay - 16.9% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1036 (Moderately Anionic)				
50 mg	3.0	0.49	25.4	--
30 mg	1.8	0.99	37.9	73
20 mg	1.2	0.88	40.9	140
10 mg	0.6	4.9	32.7	--
5 mg	0.3	5.5	31.9	--
W/Polymer 1054 (Strongly Anionic)				
50 mg	3.2	3.6	41.3	--
20 mg	1.3	5.2	40.7	30
10 mg	0.6	19.4	41.6	175
5 mg	0.3	8.8	39.2	--

Table B2
Buchner Funnel Tests
Summary of Results[10]

SITE: Toledo Harbor Site A - 22.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
4 x Dil 22.4% Solids	--	12.2	54.5	--
W/Lime				
6.5 g	300	0.65	53.4	96
4.0 g	190	0.65	53.6	96
1.2 g	56	1.1	54.9	136
0.6 g	28	1.2	55.8	164
0.3 g	14	1.5	57.5	186
0.1 g	5	6.4	53.6	--
W/$FeCl_3$				
0.6 g	30	2.5	48.6	--
0.2 g	10	0.43	46.7	--
0.04 g	2	7.7	48.7	--
W/$FeCl_3$ and Lime				
0.6 g and 1.2 g	30 and 50	0.49	50.6	57
0.2 g and 1.2 g	10 and 50	0.86	53.4	89

Table B2 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Toledo Harbor Site A - 22.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
	2 and 50	0.68	54.2	80
-- 1.2 g Lime	- and 50	0.68	55.4	94
W/Alum				
12.8 g	570	8.6	40.6	--
6.4 g	290	1.8	45.8	178
3.2 g	140	1.7	47.5	179
1.1 g	50	2.4	53.6	--
0.2 g	9	0.68	50.3	--
W/Polymer 844 (Cationic)				
50 mg	2.5	0.68	54.7	--
35 mg	1.8	0.56	54.9	--
20 mg	1.0	0.5	41.7	--
10 mg	0.5	5.9	46.1	--
5 mg	0.25	6.0	44.3	--

Table B2 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Toledo Harbor Site A - 22.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1036 (Moderately Anionic)				
50 mg	2.6	1.3	27.1	--
20 mg	1.0	3.4	39.7	--
10 mg	0.5	6.1	45.7	--
W/Polymer 1054 (Strongly Anionic)				
50 mg	2.6	5.1	27.1	--
20 mg	1.0	2.0	38.1	--
10 mg	0.5	6.0	45.3	--
5 mg	0.26	7.5	47.8	--

Table B3
Buchner Funnel Tests
Summary of Results 8

SITE: Toledo Harbor Site B - 17.8% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil 17.8% Solids	--	12.2	46.2	--
W/Lime				
5.5 g	300	1.3	50.9	88
3.5 g	190	1.9	51.6	91
1.2 g	70	1.2	50.1	167
0.6 g	30	1.3	51.3	136
0.3 g	20	1.4	52.4	186
0.1 g	6	8.5	47.9	--
W/Alum				
10.0 g	560	0.40	33.8	--
3.0 g	170	1.0	45.2	--
1.0 g	60	4.3	47.4	--
0.2 g	10	6.2	46.9	--

Table B4
Buchner Funnel Tests
Summary of Results

SITE: Toledo Harbor Land Disposal Site - 16.7% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil 16.7% Solids	--	15.9	51.6	--
W/Lime				
5.0 g	320	1.2	50.9	91
3.0 g	190	1.2	51.6	91
1.2 g	80	1.3	53.2	126
0.6 g	40	1.5	53.7	117
0.3 g	20	1.9	54.9	130
0.1 g	6	6.3	54.8	--
W/$FeCl_3$				
0.5 g	29	5.9	35.7	--
0.15 g	9	5.6	43.2	--
0.03 g	2	7.5	31.7	--
W/$FeCl_3$ and Lime				
0.5 and 1.0 g	29 and 60	1.2	50.3	89
0.15 and 1.0 g	15 and 60	0.93	51.2	70
0.03 and 1.0 g	2 and 60	0.96	53.0	70
-- and 1.0 g	0 and 60	0.96	52.8	80

Table B4 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Toledo Harbor Land Disposal Site - 16.7% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Alum				
10.0 g	680	15.6	43.4	--
7.8 g	410	7.1	43.7	--
5.0 g	340	2.5	47.3	296
3.1 g	160	2.8	51.1	--
2.0 g	135	2.9	48.0	180
1.6 g	80	3.1	51.1	56
1.0 g	70	2.4	51.3	176
0.5 g	34	2.3	53.6	135
0.16 g	8	6.3	46.9	--
W/Polymer 844 (Cationic)				
50 mg	3.0	0.46	49.5	87
30 mg	1.8	1.4	43.3	--
20 mg	1.2	4.5	41.9	--
10 mg	0.6	6.2	44.7	--
5 mg	0.3	8.1	47.8	--

Table B4 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Toledo Harbor Land Disposal Site - 16.7% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1036 (Moderately Anionic)				
50 mg	--	--	--	--
30 mg	--	--	--	--
20 mg	--	3.9	--	--
10 mg	0.6	6.6	31.1	--
5 mg	0.3	--	29.4	--
W/Polymer 1054 (Strongly Anionic)				
50 mg	3.1	1.8	24.5	--
30 mg	1.9	3.7	33.0	--
20 mg	1.2	1.8	51.0	--
10 mg	0.6	7.7	42.7	--
5 mg	0.3	9.7	44.9	--

Table B5
Buchner Funnel Tests
Summary of Results

SITE: Hopper Overflow

Sample Description	Chemical Dosage (mg/g)	Special Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2% solids - no coag.	--	12.7	37	167
W/Lime				
100 mg	50	2.9	59	50
50 mg	25	2.9	58	58
20 mg	10	9.4	56	170
10 mg	5	10.7	57	180
W/Polymer 844				
3 mg	1.5	2.2	56	45
2 mg	1.0	2.2	61	45
1 mg	0.5	2.2	59	57
0.5 mg	0.25	3.0	59	82

Table B6
Buchner Funnel Tests
Summary of Results

SITE: Mobile Bay - 17.6% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil - 17.6% Solids	--	19.6	42.2	--
3 x Dil - 11.5% Solids	--	20.5	41.0	--
W/Lime				
2 g	120	1.8	44.7	83
1 g	60	2.0	46.8	83
0.5 g	30	2.4	49.6	101
0.25 g	15	3.6	37.5	--
W/$FeCl_3$				
0.5 g	30	3.7	33.7	--
0.2 g	12	7.4	37.5	--
0.1 g	6	11.0	39.5	--
W/$FeCl_3$ and Lime				
0.5 and 0.5 g	30 and 30	2.6	41.7	--
0.2 and 0.5 g	12 and 30	1.9	47.1	75
0.1 and 0.5 g	6 and 30	2.3	42.8	97

Table B6 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Mobile Bay - 17.6% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Alum				
3 g	150	3.7	42.4	--
1 g	50	2.9	44.0	--
0.2 g	12	7.3	36.3	--
W/Polymer 844 (Cationic)				
50 mg	2.6	1.1	32.7	--
30 mg	1.5	3.4	32.8	--
20 mg	1.0	5.6	34.9	--
10 mg	0.52	8.3	36.9	--
W/Polymer 1036 (Moderately Anionic)				
50 mg	2.7	0.5	25.6	--
30 mg	1.6	1.8	32.7	--
20 mg	1.1	3.7	31.0	--
10 mg	0.55	9.6	36.3	--

Table B6 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Mobile Bay - 17.6% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1054 (Strongly Anionic)				
50 mg	2.8	1.6	21.5	--
30 mg	1.7	2.0	28.2	--
20 mg	1.1	3.4	30.9	--
10 mg	0.55	7.1	35.9	--

Table B7
Buchner Funnel Tests
Summary of Results

SITE: Penns Neck Spillway - 24.5% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil - 24.5% Solids	--	8.0	52.8	--
3 x Dil - 16.2% Solids	--	9.2	44.0	--
W/Lime				
2 g	90	0.74	58.9	42
1 g	45	0.71	58.2	41
0.5 g	23	0.74	60.4	41
0.1 g	5	3.1	55.2	--
W/$FeCl_3$				
0.3 g	11	0.62	64.0	83
0.1 g	4	1.6	63.5	175
0.03 g	1	2.4	49.1	--

Table 37 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Penns Neck Spillway - 25.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/$FeCl_3$ and Lime				
0.8 g and 0.5 g	30 and 19	0.59	59.9	34
0.5 g and 0.5 g	19 and 19	0.43	60.7	55
0.3 g and 0.5 g	11 and 19	0.56	63.1	28
0.1 g and 0.5 g	4 and 19	0.62	57.8	38
0.03 g and 0.5 g	1 and 19	0.83	59.0	60
W/Alum				
3.0 g	125	1.4	64.6	138
1.0 g	41	0.71	63.1	108
0.2 g	8	1.7	64.8	120
W/Polymer 844 (Cationic)				
50 mg	2.2	0.07	56.3	30
30 mg	1.3	0.56	61.9	60
20 mg	0.88	1.4	55.8	--
10 mg	0.44	2.5	46.9	--

Table B7 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Penns Neck Spillway - 25.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1036 (Moderately Anionic)				
50 mg	1.9	3.1	29.9	--
30 mg	1.2	4.3	36.4	--
20 mg	0.8	2.6	37.7	--
10 mg	0.4	1.1	42.3	--
W/Polymer 1054 (Strongly Anionic)				
50 mg	2.2	1.4	30.2	--
30 mg	1.3	1.1	33.0	--
20 mg	0.84	1.5	30.2	--
10 mg	0.46	1.4	49.5	--

Table B8
Buchner Funnel Tests
Summary of Results[10]

SITE: Craney Island Site 1 - 20.5% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil 20.5% Solids	--	6.4	43.7	--
3 x Dil 11.7% Solids	--	8.1	52.9	--
4 x Dil 8.5% Solids	--	8.2	41.9	--
W/Lime				
2.0 g	98	0.86	47.9	72
1.0 g	49	0.86	47.5	82
0.5 g	24	0.90	49.4	89
W/$FeCl_3$				
0.3 g	16	1.7	54.4	--
0.1 g	5	2.2	47.9	--
0.03 g		2.4	50.9	--
W/$FeCl_3$ and Lime				
0.3 and 0.5 g	16 and 32	0.83	55.3	88
0.1 and 0.5 g	5 and 32	1.0	63.6	90
0.003 and 0.5 g	2 and 32	0.93	43.2	90

Table B8 (continued)
Buchner Funnel Tests
Summary of Results

SITE: Craney Island Site 1 - 20.5% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 844 (Cationic)				
75 mg	3.7	0.52	57.4	135
50 mg	2.4	0.74	54.8	96
30 mg	1.5	2.4	51.6	--
20 mg	1.0	3.7	59.0	--
W/Polymer 1036 (Moderately Anionic)				
50 mg	6.3	1.1	13.9	--
30 mg	3.8	0.86	30.8	--
20 mg	2.5	1.0	33.0	--
10 mg	1.3	1.6	56.1	73

Table B8 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Craney Island Site 1 - 20.5% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Polymer 1054 (Strongly Anionic)				
50 mg	7.1	4.8	39.9	--
30 mg	4.3	4.1	23.4	--
20 mg	2.9	2.1	45.5	--
10 mg	1.4	3.0	57.8	120

Table B9
Buchner Funnel Tests
Summary of Results

SITE: Craney Island Site 2 - 21.6% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
3 x Dil 21.6% Solids	--	4.9	72	73
W/Lime				
2.0 g	93	0.37	68.2	<30
1.0 g	46	0.34	66.0	<30
0.5 g	23	0.37	67.4	<30
W/Polymer 844 (Cationic)				
75 mg	3.5	0.12	61.6	<30
50 mg	2.3	0.15	66.7	<30
30 mg	1.4	0.22	65.8	<30
20 mg	0.9	0.25	57.9	<30

Table B10
Buchner Funnel Tests
Summary of Results

SITE: Craney Island Site 4 - 12.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
2 x Dil 16.8% Solids	--	10.8	55.8	--
3 x Dil 12.4% Solids	--	4.7	33.3	--
4 x Dil 5.7% Solids	--	10.3	49.0	--
W/Lime				
3.0 g	270	1.1	53.9	91
2.0 g	180	1.6	50.8	94
1.5 g	140	1.1	51.5	101
1.0 g	90	1.1	49.7	101
0.2 g	20	2.1	57.5	119
W/$FeCl_3$				
0.3 g	20	6.6	42.4	--
0.1 g	7	4.4	51.3	--
0.03 g	2	2.6	42.4	--
W/$FeCl_3$ and Lime				
0.3 and 0.5 g	20 and 35	0.52	50.7	56
0.1 and 0.5 g	7 and 35	0.37	55.6	61
0.03 and 0.5 g	2 and 35	0.40	50.7	88

Table B10 (concluded)
Buchner Funnel Tests
Summary of Results

SITE: Craney Island Site 4 - 12.4% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
W/Alum				
2.0 g	160	5.5	43.7	--
1.0 g	80	1.9	45.6	76
0.5 g	40	1.9	47.3	68
0.1 g	8	2.8	39.2	--
W/Polymer 844 (Cationic)				
50 mg	3.7	0.22	57.7	33
30 mg	2.2	0.49	53.8	64
20 mg	1.5	1.0	48.6	84
10 mg	0.7	1.4	39.2	136
W/Polymer 1036 (Moderately Anionic)				
50 mg	3.6	0.74	36	--
30 mg	2.2	0.68	60.3	--
20 mg	1.5	0.77	59.1	--
10 mg	0.7	3.4	42.3	--

Table B11
Buchner Funnel Tests
Summary of Results

SITE: Browns Lake Sample - 20.5% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
20.5% Solids	--	5.6	59.9	--
W/Lime				
2.5 g	122	0.39	60.3	40
2.0 g	97	0.39	59.8	45
1.5 g	73	0.68	60.1	59
1.0 g	49	0.40	60.5	54
0.5 g	24	0.74	63.0	78
0.25 g	12	0.77	66.4	82
W/Polymer 844 (Cationic)				
75 mg	3.7	0.40	65.9	75
50 mg	2.9	0.46	64.9	126
30 mg	2.0	1.6	64.2	262
20 mg	1.5	2.0	62.9	266
10 mg	1.0	2.7	60.3	--

Table B12
Buchner Funnel Tests
Summary of Results

SITE: Ninety Percent Silt/Clay - 25.7% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
25.7% Solids	--	9.6	49.6	--
W/Lime				
2.5 g	100	0.65	56.4	64
1.8 g	70	1.2	56.9	86
1.0 g	40	0.99	56.9	86
0.4 g	16	1.3	56.6	126
W/Polymer 844 (Cationic)				
50 mg	1.9	0.43	56.2	--
40 mg	1.5	0.24	56.4	91
25 mg	0.9	0.10	49.1	--
12 mg	0.5	2.9	45.1	--

Table B13
Buchner Funnel Tests
Summary of Results

SITE: Seventy-Five Percent Silt/Clay Content - 24.2% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
24.2% Solids	--	5.2	48.5	--
W/Lime				
2.0 g	83	0.43	50.9	75
1.0 g	41	1.0	53.9	121
0.5 g	21	1.0	51.8	121
W/Polymer 844 (Cationic)				
75 mg	3.1	0.46	51.1	--
50 mg	2.1	1.3	52.2	--
30 mg	1.2	2.3	45.2	--
20 mg	0.8	2.5	53.6	--

Table B14
Buchner Funnel Tests
Summary of Results

SITE: Sixty Percent Silt/Clay Content - 17.7% Solids

Sample Description	Chemical Dosage (mg/g)	Specific Resistance (10^8 sec^2/g)	Cake Solids (%)	Breakpoint Time (sec)
17.7% Solids	--	5.0	49.0	--
W/Lime				
2.0 g	112	0.65	55.5	72
1.0 g	56	0.71	55.8	60
0.5 g	28	0.71	55.4	71
W/Polymer 844 (Cationic)				
50 mg	2.8	0.62	60.5	92
30 mg	1.7	1.3	63.1	144
20 mg	1.1	3.0	55.7	--