



US Army Corps  
of Engineers  
Waterways Experiment  
Station

Technical Report EL-94-12  
October 1994

6

# Evaluation of Operational Factors Contributing to Reduced Recharge Capacity, North Boundary Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado

by Cynthia L. Teeter, Mark E. Zappi, Douglas Gunnison,  
Norman R. Francingues, Jr., WES

David W. Strang, Thomas A. Brooks,  
Rocky Mountain Arsenal



Approved For Public Release; Distribution Is Unlimited

19941128 114

DTIC QUALITY INSPECTED 8

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.



PRINTED ON RECYCLED PAPER

# **Evaluation of Operational Factors Contributing to Reduced Recharge Capacity, North Boundary Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado**

by Cynthia L. Teeter, Mark E. Zappi,  
Douglas Gunnison, Norman R. Francingues, Jr.

U.S. Army Corps of Engineers  
Waterways Experiment Station  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199

David W. Strang, Thomas A. Brooks  
Rocky Mountain Arsenal  
Commerce City, CO 80022-2180

Final report

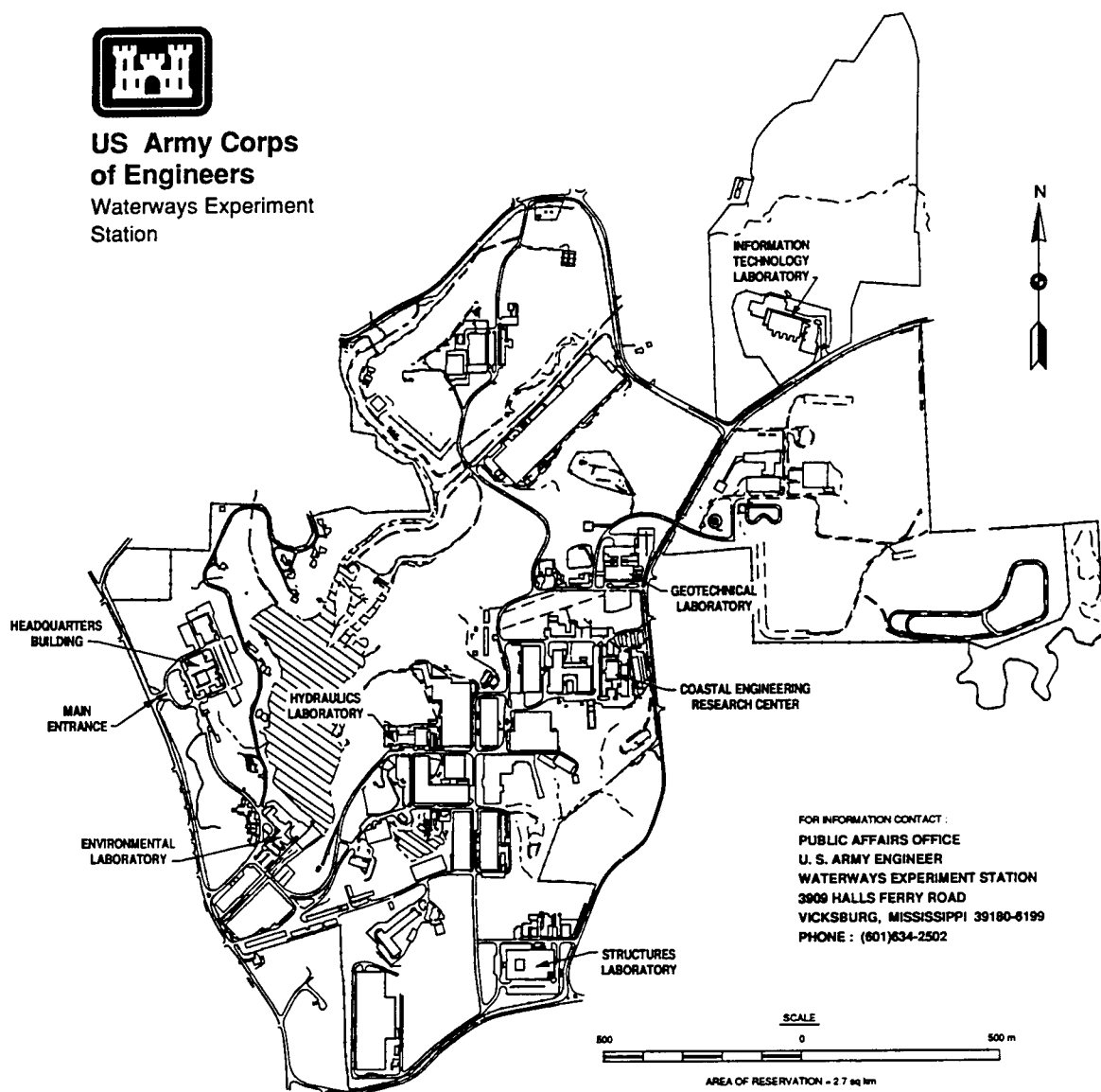
Approved for public release; distribution is unlimited

Prepared for U.S. Army Program Manager for Rocky Mountain Arsenal  
Commerce City, CO 80022-2180

Under Technical Support and Services  
Rocky Mountain Arsenal



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station



**Waterways Experiment Station Cataloging-in-Publication Data**

Evaluation of operational factors contributing to reduced recharge capacity, North Boundary Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado / by Cynthia L. Teeter ... [et al.] ; prepared for U.S. Army Program Manager for Rocky Mountain Arsenal under Technical Support and Services, Rocky Mountain Arsenal.

137 p. : ill. ; 28 cm. — (Technical report ; EL-94-12)

Includes bibliographical references.

1. Artificial recharge of groundwater — Colorado — Rocky Mountain Arsenal. 2. Groundwater — Purification — Colorado — Commerce City. 3. Fouling. 4. Carbon, Activated. I. Teeter, Cynthia L. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Environmental Laboratory (U.S. Army Engineer Waterways Experiment Station) V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; EL-94-12.

TA7 W34 no.EL-94-12

## PREFACE

This study was conducted by the US Army Engineer Waterways Experiment Station (WES) upon request from the Technical Operations Division (TOD) of the Program Manager Staff Office of the Rocky Mountain Arsenal (PMRMA) to assess the potential for reduced recharge capacity of the recharge system at the North Boundary, Rocky Mountain Arsenal (RMA). Funding for participation by WES was provided by the PMRMA via Military Interdepartmental Purchase Request No. 0722. Coordination and management support was provided by Rocky Mountain Arsenal. Project Management was provided by Messrs. David W. Strang, TOD, RMA, and Mark E. Zappi, Environmental Laboratory (EL), WES. This report covers work conducted during the period September 1988 through August 1992.

The study was conducted and the report prepared by Ms. Cynthia L. Teeter and Messrs. Mark E. Zappi and Norman R. Francingues of the Environmental Restoration Branch (ERB), Environmental Engineering Division (EED), and Dr. Douglas Gunnison of the Ecosystem Processes and Effects Branch (EPEB), Environmental Processes and Effects Division (EPED), EL. The Environmental Chemistry Branch, EED, under the supervision of Ms. Ann B. Strong, assisted with the chemical analysis of samples. Ms. Cynthia Price and Mr. Glenn Myrick, EPEB, and Mr. Buddy Ragsdale, ERB, assisted with sample collection and microbial investigations. The University of Mississippi Biology Department sampled the recharge wells for bacteriological enumeration and identification. Particle size analysis was conducted by Particle Data Laboratories Ltd., Elmhurst, Illinois.

The study was conducted under the general supervision of Mr. Norman R. Francingues, Jr., Chief, ERB, Dr. Richard Price, Chief, EPEB, Dr. Raymond L. Montgomery, Chief, EED, Mr. Donald L. Robey, Chief, EPED, and Dr. John Harrison, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as follows:

Teeter, Cynthia, L., Zappi, Mark E., Gunnison, Douglas, Francingues, Norman R., Jr., Strang, David W., and Brooks, Thomas A. 1994. "Evaluation of Operational Factors Contributing to Reduced Recharge Capacity, North Boundary Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado," Technical Report EL-94-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

# CONTENTS

|                                                                        | <u>Page</u> |
|------------------------------------------------------------------------|-------------|
| PREFACE . . . . .                                                      | 1           |
| LIST OF FIGURES . . . . .                                              | 3           |
| CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT . . . . | 4           |
| PART I: INTRODUCTION . . . . .                                         | 5           |
| Purpose of Report . . . . .                                            | 5           |
| Background . . . . .                                                   | 5           |
| Objectives . . . . .                                                   | 8           |
| Study Approach . . . . .                                               | 9           |
| System Configuration . . . . .                                         | 10          |
| PART II: MATERIALS AND METHODS . . . . .                               | 13          |
| Suspended Solids Analysis . . . . .                                    | 13          |
| Particle Size Determination and Distribution . . . . .                 | 13          |
| Microbiological Sampling of Recharge Wells . . . . .                   | 14          |
| Microbiological Sampling of Recharge Trenches . . . . .                | 15          |
| PART III: RESULTS . . . . .                                            | 16          |
| Mass Flux Analysis . . . . .                                           | 16          |
| Particle Size Analysis . . . . .                                       | 23          |
| Microbiology of Recharge Wells . . . . .                               | 25          |
| Bacteriological Enumeration Limitations . . . . .                      | 26          |
| Physical/Chemical Characteristics of Recharge Trenches . . . . .       | 29          |
| Microbiology of Recharge Trenches . . . . .                            | 31          |
| PART IV: CONCLUSIONS AND RECOMMENDATIONS . . . . .                     | 36          |
| General Conclusions . . . . .                                          | 36          |
| Specific Conclusions . . . . .                                         | 36          |
| Recommendations . . . . .                                              | 37          |
| REFERENCES . . . . .                                                   | 38          |
| TABLES 1-25                                                            |             |
| APPENDIX A: UNREDUCED PARTICLE DETERMINATION DATA . . . . .            | A1          |
| APPENDIX B: MICROBIOLOGICAL METHODS . . . . .                          | B1          |
| APPENDIX C: UNREDUCED SUSPENDED SOLIDS DATA . . . . .                  | C1          |
| APPENDIX D: AVERAGE WEEKLY RECHARGE WELL WATER VOLUMES . . . . .       | D1          |

# LIST OF FIGURES

| <u>No.</u> |                                                                                                                                  | <u>Page</u> |
|------------|----------------------------------------------------------------------------------------------------------------------------------|-------------|
| 1          | Definition sketch, North Boundary Treatment System, path of process water . . . . .                                              | 11          |
| 2          | Definition sketch, North Boundary Treatment System, carbon flow and water paths . . . . .                                        | 11          |
| 3          | Suspended solids versus time for prefilter A and NBS plant effluent . . . . .                                                    | 16          |
| 4          | NBS effluent and adsorbers A, B, and C effluent . . . . .                                                                        | 18          |
| 5          | Suspended solids concentrations versus time for prefilter A influent and effluent . . . . .                                      | 19          |
| 6          | Suspended solids concentration versus time for prefilter A influent and effluent (expanded plot) . . . . .                       | 20          |
| 7          | Suspended solids concentration versus time for NBS plant effluent . . . . .                                                      | 21          |
| 8          | Average heterotrophic bacteria population found in each well . .                                                                 | 25          |
| 9          | Average facultative population found in each well . . . . .                                                                      | 26          |
| 10         | Average fermenter population found in each well . . . . .                                                                        | 27          |
| 11         | North Boundary System recharge wells, average weekly recharged water volumes . . . . .                                           | 28          |
| 12         | Average recharged water volumes per week and facultative bacteria populations for wells sampled for microbial analysis . . . . . | 29          |

|                      |                                     |
|----------------------|-------------------------------------|
| <b>Accession For</b> |                                     |
| NTIS GRA&I           | <input checked="" type="checkbox"/> |
| DTIC TAB             | <input type="checkbox"/>            |
| Unannounced          | <input type="checkbox"/>            |
| Justification        |                                     |
| By                   |                                     |
| Distribution         |                                     |
| Availability Codes   |                                     |
| Dist                 | Avail and/or Special                |
| A-1                  |                                     |

CONVERSION FACTORS, NON-SI TO SI (METRIC)  
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI  
(metric) units as follows:

| <u>Multiply</u>     | <u>By</u> | <u>To Obtain</u> |
|---------------------|-----------|------------------|
| feet                | 0.3048    | meters           |
| gallons (US liquid) | 3.785412  | liters           |
| pounds (mass)       | 0.4535924 | kilograms        |

EVALUATION OF OPERATIONAL FACTORS CONTRIBUTING TO REDUCED  
RECHARGE CAPACITY, NORTH BOUNDARY TREATMENT SYSTEM,  
ROCKY MOUNTAIN ARSENAL, COMMERCE CITY, COLORADO

PART I: INTRODUCTION

Purpose of Report

1. Since 1988, the US Army Engineer Waterways Experiment Station (WES) has been assessing the performance of the solids removal and recharge capacity of the North Boundary System (NBS) at the Rocky Mountain Arsenal (RMA). Three separate but interrelated tasks have been completed by WES between 1988 and 1992. To date, the results of these tasks have been relayed to RMA personnel in the form of on-site briefings and project summaries. These tasks have contributed to the redesign and improvement of the NBS undertaken by RMA and Shell Chemical as part of an Interim Response Action (IRA) at the North Boundary. The three tasks discussed in this report are:

- a. Assessment of the fate of carbon fines throughout the NBS.
- b. Evaluation of the potential for reduced recharge capacity of the recharge wells because of excessive microbial growth within the wells.
- c. Evaluation of the potential for reduced recharge capacity of the recharge trenches because of excessive microbial growth within the trenches.

2. The findings of these three tasks may be applicable to other pump-and-treat systems operating at RMA. Therefore, at the request of the Office of Program Manager, RMA (PMRMA), this report has been prepared to document the results of various efforts undertaken by PMRMA and WES to date at the NBS concerning carbon fine fate and reductions in recharge system capacity.

Background

3. The NBS was designed to collect and remove contaminated groundwater from the alluvial aquifer and inject treated groundwater back into the aquifer at RMA, Commerce City, Colorado. Before installation of the recharge trenches, the NBS has been unable to properly distribute the treated water

along the North Boundary because of continual clogging of the recharge wells (Thompson et al. 1985).

4. In most cases, reductions in flow capacity of recharge wells can be attributed to one or more of the following: air binding, sodium adsorption, metal precipitation, deposition of cementing agents, straining of suspended solids, and microbial fouling (Todd 1960; Sniegocki 1965). Air binding was ruled out because the plant effluent has sufficient time in the NBS effluent sump to reach air adsorption equilibrium with the atmosphere. The adsorption of sodium by the aquifer surrounding the recharge wells can cause a reduction in permeability (Todd 1960); however, this does not seem likely because the same groundwater is removed from the alluvial aquifer, treated, and then recharged back into the alluvial aquifer without significantly changing sodium concentration. Precipitation of metals and deposition of cementing agents is possible, but based on the effluent pH and hydraulic retention time within the wells, probably not significant. Therefore, the main focus of this study was directed toward assessing the potential for clogging of the recharge wells with carbon fines and/or microbial fouling.

5. A 1988 evaluation of operational problems at the NBS concluded that periodic cleaning of the recharge wells produced limited success in rejuvenating the wells, as carbon fines were responsible for clogging (Environmental Science and Engineering, Inc. 1988). However, some studies on recharging effluent to impede saltwater intrusion suggested that rather large amounts of suspended solids could be tolerated without clogging (Lavery et al. 1961).

6. Particles that are not removed in the postfilter system and pass the recharge well screens will cause some clogging of the aquifer. Particles that are deposited in the immediate vicinity of the recharge well are expected to reduce the well's recharge rate the most. Smaller particles are expected to be carried deeper into the aquifer than larger particles; therefore, their impact on reducing the well's recharge rate is expected to be less when compared with that of the larger particles. Microbial fouling may complicate the above generalizations, as microbes are expected to attach to the carbon particles and increase the particle's effective size. If microbes attach preferentially to small particles, then the clogging effect of the small particles would be enhanced. Particle binding can be electrostatic in nature because of charges associated with microbial produced glycocalyx (e.g., capsule, slime) (Costerton, Irvin, and Cheng 1981; Lewis and Gattie 1990).

7. Work by Jubboori, Stewart, and Adrian (1974) indicated that microbial growth could decrease recharge well capacity in models of recharge wells sometimes in as little as a few hours, especially when the recharge wells had resting periods. They found that short periods of recharge water containing 250 mg/l of sodium hypochlorite caused the recharge rate to increase dramatically, apparently because of the germicidal effect of the oxidizer on the microbial populations.

8. Kawanishi et al. (1990), using small soil columns, concluded that excessive microbial growth within the soil matrix could significantly impact soil hydraulic conductivity by as much as two orders of magnitude in as little as 40 days. They further concluded that the amount of substrate in the permeant did not impact the rate and density of biological growth in soil systems.

9. Ghiorse (1986) evaluated the composition and microbial type association of sheathing bacteria. He summarized that cation-based oxides produced by various bacterial groups can result in significant masses of extracellular materials that can significantly impact plugging of porous media.

10. Research suggests that *Pseudomonas* secretes a sticky slime that builds up on pipe interiors. This creates a continuous reservoir of microorganisms that could contaminate water flowing through pipes (Fackelmann 1990). Bacteria generally do not move large distances in fine-textured soil (less than a few meters, for example); but they can migrate much larger distances in coarse-textured or fractured materials (Bitton and Marshall 1980). Bacterial growth that coats the gravel in the packing material may slough off and be carried farther out in the packing material where it may accumulate and eventually cause fouling.

11. Active microbial systems require the presence of four primary environmental factors (Zappi et al. 1991). These factors are the presence of appropriate microbial types, food sources, electron acceptors, and nutrients. Natural soils systems typically contain numerous populations of native bacteria that are capable of existing in saturated aquifers (Alexander 1977). Other potential sources of bacteria that may contribute to excessive microbial growth in recharge wells are populations growing within activated carbon adsorbers that detach from the activated carbon particles within the adsorber and are transported via the effluent into the well. Activated carbon adsorbers provide ideal conditions for growth of high populations of microbes that are acclimated to the site contaminants (Kim and Pirbazari 1989). In some

cases, microbial metabolic activity is high enough to result in the regeneration of spent adsorption sites (Goeddertz, Matsumoto, and Weber 1988).

12. Food sources for microbial populations growing within recharge systems are the contaminants either flowing by the microbial colonies or adsorbed onto carbon fines migrating into the wells from the treatment system. Contaminants flowing by microbial colonies are capable of assimilation into the cell capsules within short periods of water-microbe contact. Contact stabilization is a biotreatment process that uses this phenomenon for treatment of contaminated waters (Metcalf and Eddy, Inc. 1979). Microbes are also capable of using adsorbed contaminants as food sources (Schultz and Keinath 1984; Kim and Pirbazari 1989).

13. Growth of microbial populations within activated carbon adsorbers without the benefit of nutrient addition has been documented (Faust and Aly 1987). Potential nutrient sources for microbial populations within well systems are available from nutrients leached into the groundwater from the aquifer soils. All forms of microbial activity require the presence of an electron acceptor required for the maintenance and synthesis of cell mass. Aerobic biodegradation requires the presence of oxygen as an electron acceptor. Anaerobic degradation occurs without the presence of oxygen but instead uses inorganic compounds such as nitrates and iron complexes as electron acceptors (Zappi et al. 1991). The type and extent of biological activity occurring within recharge wells is dependent on the fate of the groundwater within the treatment system. If the influent or effluent is allowed appreciable contact time with oxygen-containing gases such as air, then aerobic degradation is possible. On the other hand, if alternate electron acceptors such as nitrates are present in the effluent and oxygen is not present, then anaerobic degradation will proceed within the wells if the other environmental factors are present.

### Objectives

14. The overall objective of the three tasks was to determine which factors, both operational and natural in nature, were or will be responsible for reductions of recharge capacity at the NBS. Individual objectives of each task are discussed below.

- a. Fate of carbon fines at the pre-IRA NBS. The objectives of the fate of carbon fines at the pre-IRA NBS were to: (1) identify the source(s) of carbon fines in the recharge wells, (2) evaluate solids-removal equipment at the pre-IRA NBS, and (3) identify alternatives to improve solids-removal efficiency.
- b. Reduced recharge well capacity. The objective of this task was to assess potential causes of reduced recharge well capacity.
- c. Reduced recharge trench capacity. The objective of this task was to assess the potential for excessive microbial growth that potentially may reduce the recharge capacity of the newly installed recharge trenches.

### Study Approach

#### Fate of carbon fines at the pre-IRA NBS

15. Observing the system and the standard operating and maintenance (O&M) procedures used by RMA personnel was necessary to accomplish the above stated objectives for this task. WES engineers and scientists visited the RMA NBS and interviewed plant personnel to obtain information concerning the O&M procedures and probable causes of recharge capacity reductions. During this visit, water samples were collected at various locations throughout the NBS. These samples were used to determine if standard analytical techniques could be used to measure carbon fines concentrations for the NBS.

16. To determine the magnitude and amount of carbon fines migrating into the recharge wells, a mass flux analysis of suspended solids throughout the NBS was performed. The mass flux analysis is described in detail in Part II. All suspended solids concentrations measured during mass flux analysis were assumed to be carbon fines. Carbon mass flux pathways through the NBS were determined by using suspended solids concentration as a direct indicator of carbon fines concentrations.

17. Solids-removal assessment was based on results from the mass flux analysis and on observations made during various field trips. The results of this assessment are presented and discussed in Part III of this report.

#### Reduced recharge well capacity

18. Potential microbial fouling of the recharge wells was investigated by collecting water samples from eight recharge wells for microbial enumeration. The samples were collected by personnel from WES and personnel from the University of Mississippi working under contract with the WES. Samples were

analyzed for pH, reduction/oxidation (redox) potential, microbial enumeration, and bacterial group identification.

#### Reduced recharge trench capacity

19. Potential microbial fouling of the recharge trenches was examined by the collection of water samples from the recharge trenches piezometer tubes. The samples were collected by personnel from WES and personnel working under contract with WES. The samples were analyzed for pH, conductivity, salinity, temperature, nutrients, metals, and microbial enumeration.

#### System Configuration

20. A process flowchart for the pre-IRA NBS is shown in Figure 1. Figure 2 illustrates the carbon flow and water flow paths at the pre-IRA NBS. Organic contaminants in the groundwater are removed using activated carbon. The activated carbon adsorption system is configured with three pulsed-bed adsorbers. At the time this study was conducted, the influent to the adsorbers was passed through a system of 100- $\mu$ m cartridge prefilters. The effluent from the three adsorbers was composited in a common effluent piping manifold, then filtered through the posttreatment filters consisting of a 10- $\mu$ m bag and cartridge filters. The treated water was collected in an effluent sump before distribution to 38 recharge wells and 15 gravel-packed recharge trenches.

21. In FY89, the NBS was reconfigured as part of the IRA undertaken by the PMRMA and Shell Chemical. Therefore, during performance of the three annual enumeration efforts of microbial populations in the recharge trenches (FY89-FY91), the NBS had already been modified as part of the IRA. As part of the IRA, a common influent was used for all three absorbers by conversion of the three-manifold influent system into a common line. Also, all cartridge filters were replaced with bag filters. Finally, 10 gravel-filled trenches were installed in 1988; and an additional 5 gravel-filled trenches were installed in 1990. The trenches were installed as part of the IRA to improve the capacity for recharging the treated groundwater. An implementation document (RIC 89139R01) is on file at the Rocky Information Center (RIC). The description of the system and its start-up performance is summarized in Lutton (1989).

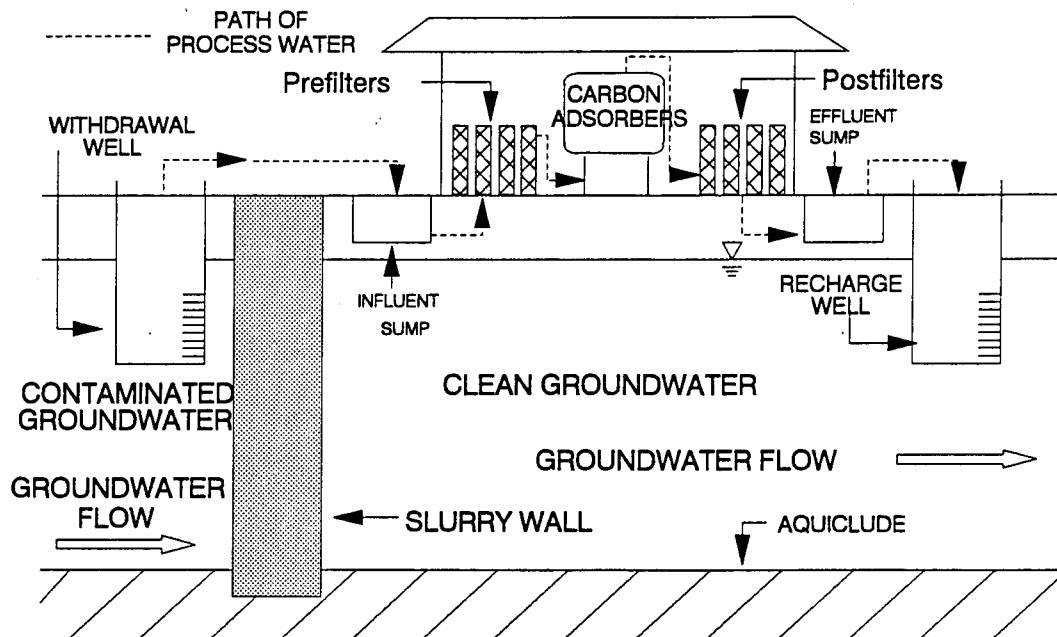


Figure 1. Definition sketch, North Boundary Treatment System, path of process water

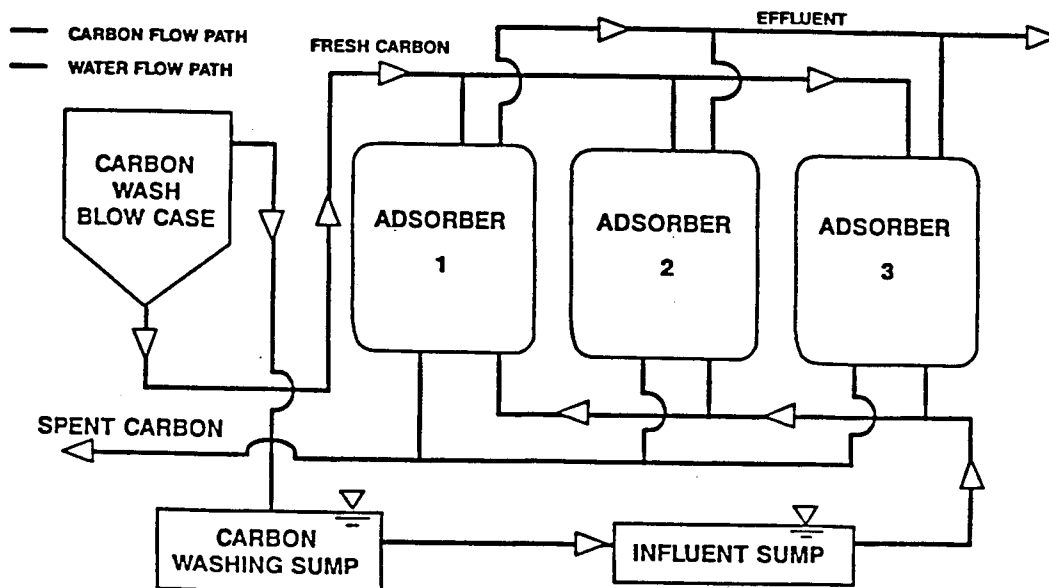


Figure 2. Definition sketch, North Boundary Treatment System, carbon flow and water paths

22. The design consists of gravel-filled trenches penetrating into the alluvial aquifer stratum. Recharge water is fed longitudinally through a perforated plastic pipe near the top of the gravel interval. A filter fabric sheet separates the gravel interval from silty soil placed to the surface as backfill above.

## PART II: MATERIALS AND METHODS

### Suspended Solids Analysis

23. Samples for mass flux analysis were collected by WES personnel during the period of September 13-23, 1988, at various locations throughout the NBS. These sampling points are listed in Table 1, along with the number and frequency of the samples collected at each location.

24. Suspended solids samples were collected in 1-gal\* plastic jugs with plastic caps. Samples were transported by WES personnel to WES for suspended solids analysis. The samples were stored at room temperature until analyzed for suspended solids concentrations. All filtrate (water) was returned to the NBS upon completion of suspended solids analysis.

25. Suspended solids analysis was performed according to the procedures described in Standard Methods For the Examination of Water and Wastewater (American Water Works Association 1985). Millipore type HA filter pads with a nominal pore size of 0.45  $\mu\text{m}$  were used during filtration of suspended solids samples. Suspended solids analyses were performed using at least three replicates. Weight determinations were made using a Sartorius Model 195917 analytical balance with a 0.00001-g minimum scale capability. Based on balance accuracy and statistical evaluation of the suspended solids data, a test accuracy of 0.5 mg/l was used for evaluating mass flux data. Suspended solids values less than 0.5 mg/l were assigned a suspended solids concentration of 0.0 mg/l.

### Particle Size Determination and Distribution

26. Particle size analysis was conducted by Particle Data Laboratories (PDL) LTD., Elmhurst, Illinois. Six samples were sent to PDL for analysis. These samples included a carbon wash rinse water collected approximately 5 min into carbon wash activities, a sample of the floor drain input to the floor drain sump during carbon change activities, a sample of the input from the floor drain sump to sump A, two samples from the bottom of the effluent sump, and a sample of carbon fines collected from the in-line Y-screen at Well 21.

---

\* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

Upon completion of particle size analysis by PDL, the samples were returned to WES for later disposal at the NBS, RMA.

27. The analytical technique used by PDL known as electrozone particle counting measures the difference between the electroconductivity of water and carbon to determine particle sizes and distribution (see Appendix A for details). Water containing the carbon fines is passed through an orifice in which an electrical field exists across the orifice plate opening. The change in electrical potential is recorded as each particle passes through the orifice. Any change in potential correlates to a respective particle size. The output of an electrozone unit is a series of pulses that are electronically amplified, scaled, and counted.

28. There are two methods of presenting fine particle size analysis data. One method is based on the frequency distribution of the particle sizes. This method of data presentation is analogous to counting and sizing each particle under observation with a microscope. The second method of data presentation is mass distribution. Mass distribution is analogous to weighing and sizing the particles retained on a sieve. The data from PDL are presented using both methods.

#### Microbiological Sampling of Recharge Wells

29. To determine the potential for fouling of recharge wells, water samples were collected from eight recharge wells by WES personnel during the week of December 12, 1988. Water samples were collected from recharge Wells 1, 3, 5, 17, 19, 24, and 26. Water samples were collected at depths of 3 and 15 ft (measured from the top of the well cavity). Samples from various depths were collected from each well to determine if stratified populations of various microbes existed in the NBS recharge wells. Well 5 had a piezometric level of approximately 10 ft below the surface (as measured from the top of the tube); therefore, only one sample was collected at a depth of 15 ft. Samples were analyzed immediately for pH and by WES personnel using a portable Fisher Model 955 pH meter and Fisher Brand probes. Samples were prepared in the field for bacteriological enumeration and identification at the University of Mississippi Biological Laboratories in Oxford, Mississippi. Bacteriological identification and enumeration procedures are described in Appendix B.

### Microbiological Sampling of Recharge Trenches

30. In 1989, Trenches 3, 5, and 7 of the 10 trenches were evaluated for microbial fouling. In 1990, all 10 of the trenches were evaluated for microbial fouling. Five new trenches (11-15) were installed in 1991. The 1991 and 1992 sampling effort was expanded to include all 15 trenches of the NBS. Water samples from all of the trenches were collected from the middle of the piezometer tubes water column. Samples were analyzed in the field for pH using a Fisher Model 107 Portable pH Meter. Temperature, conductivity, and salinity were evaluated using a YSI Model 33 Portable Conductivity/Salinity Meter with a S-C-T probe. The dissolved oxygen content of the water in the piezometer tubes was measured using a YSI Model 57 Dissolved Oxygen Meter. Samples for nutrients and metals were collected and preserved in the field. Chemical analysis of the samples was performed by the Analytical Laboratory Group at WES. Samples for bacteriological enumeration and identification were prepared in the field. Inoculated media were returned to WES for incubation, enumeration, and identification.

### PART III: RESULTS

#### Mass Flux Analysis

31. Tables 2-9 present a summary of the mass flux results for each major solids removal and treatment unit at the NBS. Unreduced suspended solids analytical data are presented in Appendix C. Each table lists the date, sample time, cumulative time, influent and effluent suspended solids concentrations, and the average influent and effluent suspended solids concentrations along with the respective standard deviation associated with each average value. Variability in the number of samples collected is due to the uncertainty of the amount and frequency of sample collection required to completely characterize the solids flux through the NBS. Cumulative time represents the accumulated time (in hours) that had elapsed from the initiation of the field study to the collection of the sample.

32. Figure 3 presents cumulative time versus suspended solids concentrations for prefilter A influent and effluent and plant effluent. At the beginning of the study, water from the floor drain sump, which is high in solids concentration, was pumped into sump A to lower the water level in the floor drain sump. The appropriate water level in the floor drain sump is maintained by periodically pumping water into sump A. Although a makeshift bag filter was located at this input, considerable overflow around the bag filter and into the sump was observed by WES personnel.

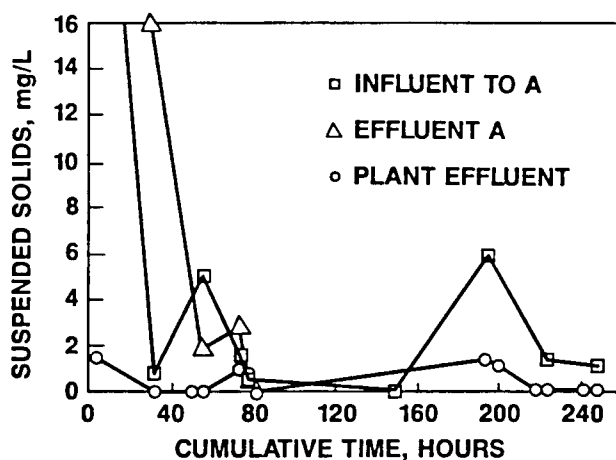


Figure 3. Suspended solids versus time for prefilter A and NBS plant effluent

33. Figure 3 indicates a high solids loading on the NBS prefilters because of the input of water from the floor drain sump. A water sample from the water flowing into sump A from the floor drain sump was collected near the termination of floor drain sump pump-down activities. This sample had a suspended solids concentration of approximately 38 mg/l. Since the floor drain sump is essentially quiescent, with little or no flow, the suspended solids within the sump are allowed to settle to the bottom. Therefore, the initial suspended solids concentration in water from the floor drain sump probably was significantly higher because the water is pumped into sump A using a submersible pump, which is located on the sump bottom. It is evident that a high solids loading on the prefilters affects system effluent.

34. The reason for the peak plant effluent suspended solids concentration at 200 hr in Figure 3 is not known. During this period, a load of fresh carbon was washed and pulsed into adsorber B. One possible reason for the peak at 200 hr could be that the carbon washing and transfer operations interrupt total system flow, which in some way impacts solids-removal efficiency. Another possible reason for the peak at 200 hr could be that carbon fines trapped on the prefilters, which are 100- $\mu$ m spiral-wound cartridge filters, are forced through the spiral windings by the momentum forces of the flowing water while the filters are in operation. Transport of carbon fines through the filter weaving was observed by WES and PMRMA personnel during an inspection of spent cartridges from NBS filters.

35. Figure 4 presents the time variation of suspended solids concentrations for adsorbers A, B, and C effluents. The effluent suspended solids concentrations from the adsorbers were all less than 2.0 mg/l throughout the course of the sampling effort except during the initial stages of the mass flux sampling. The peak in Figure 4 is similar to the peak in Figure 3. This point represents the period when water from the floor drain sump water was pumped into sump A, indicating that high solid loadings were carried throughout the system and ultimately affected plant effluent suspended solids concentration. These data show that carbon washing activities directly impacts the solids loading on the postfilter system as well as plant effluent. After washing loads of fresh carbon for adsorbers A or B, the effluent from the adsorber receiving the fresh carbon and the plant effluent showed suspended solids concentrations that were elevated relative to normal operations. This indicates that incomplete carbon washing is occurring along with carbon fines generation during transfer operations. This increase in absorber and plant

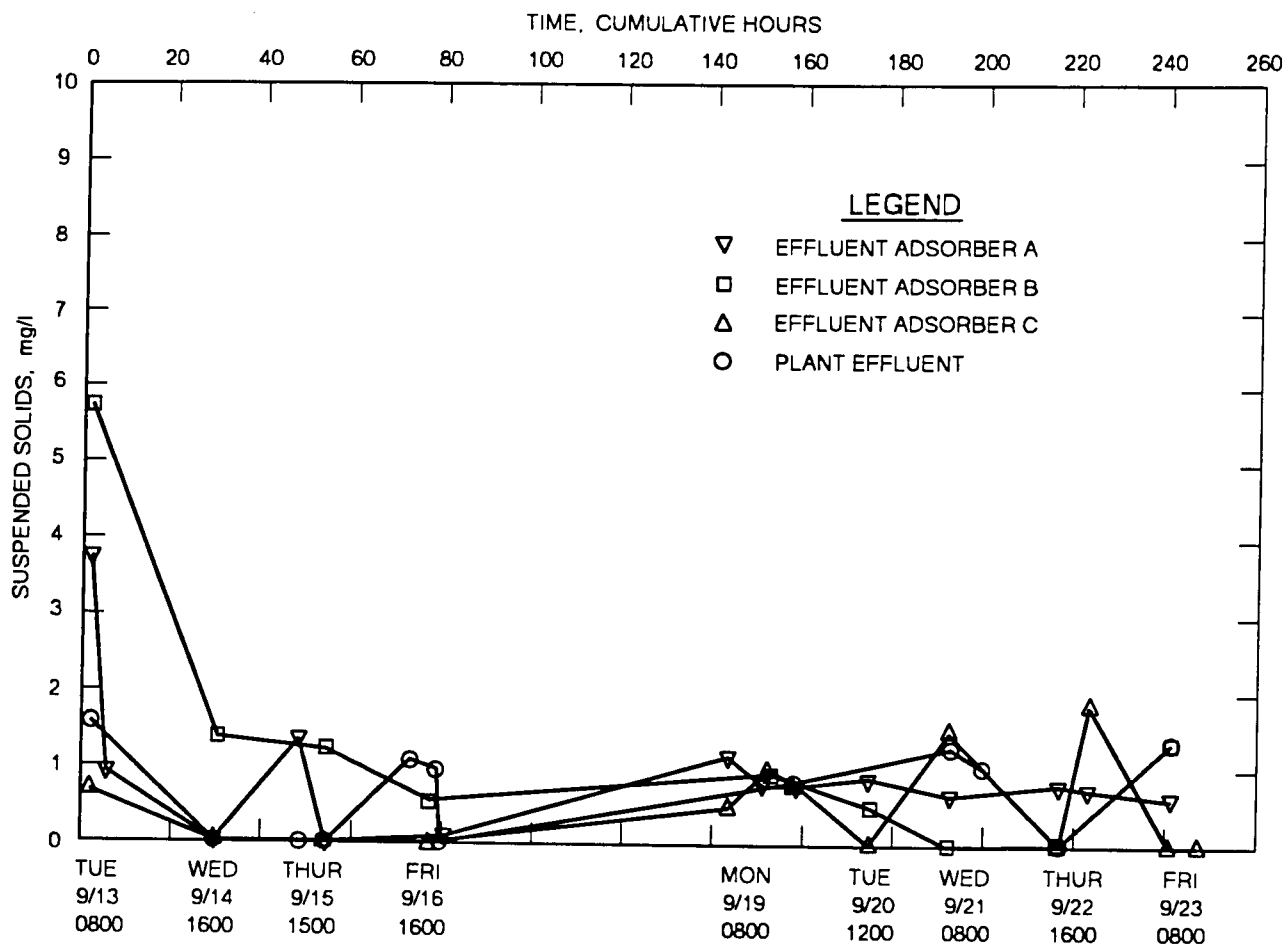


Figure 4. NBS effluent and adsorbers A, B, and C effluent

effluent concentrations is evident in Figure 4. Adsorber A had fresh carbon added at approximately 20 hr, while absorber B had fresh carbon added at approximately 190 hr.

36. Average influent and effluent suspended solids concentrations were calculated along with the respective standard deviations for the prefilters, adsorbers, postfilters, and the NBS plant effluent. These data are presented in Table 10. The prefilters had an 86-percent solids removal efficiency.

37. The high standard deviations listed in Table 10 for influents to the prefilters indicate a wide range in suspended solids concentrations. When solids loadings on the prefilters were high, the effluent suspended solids concentrations were as high or higher than the respective influent concentrations. This condition is best illustrated in a plot of suspended solids concentrations versus time in cumulative hours for prefilter A influent and

effluent (Figure 5). At 30 hr, the effluent suspended solids concentration is approximately 16 times that of the time respective influent concentration. The effluent suspended solids concentration is also greater at approximately 75 hr. One explanation for these two events is that trapped solids on the filter cartridge surface migrate through the spiral weaving of the cartridge filter to the filtrate. The data in Figure 6 is an expanded plot of Figure 5, which includes all the prefilter A samples collected during the field study. The data in Figure 5, show that after the initial high loadings, the influent suspended solids concentrations were higher than the effluent concentrations, indicating that under lower solids loadings, the prefilters functioned properly.

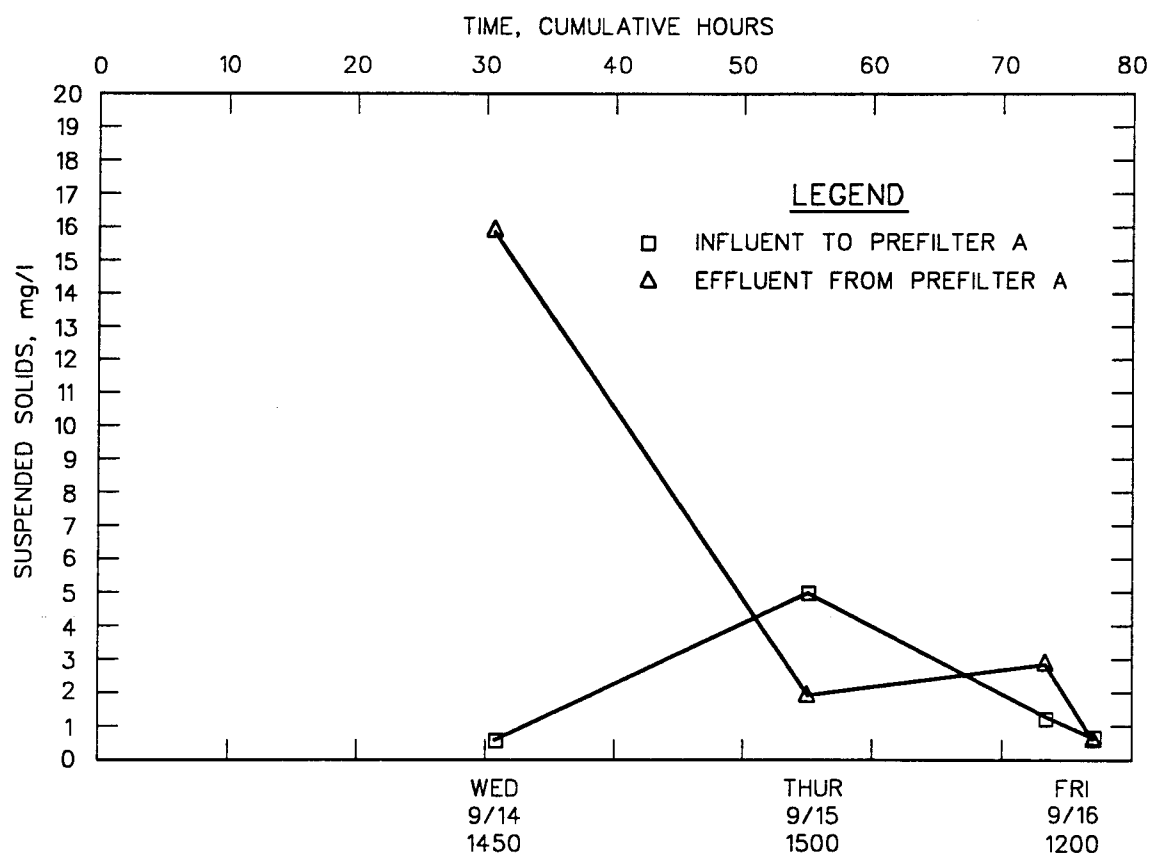


Figure 5. Suspended solids concentrations versus time for prefilter A influent and effluent

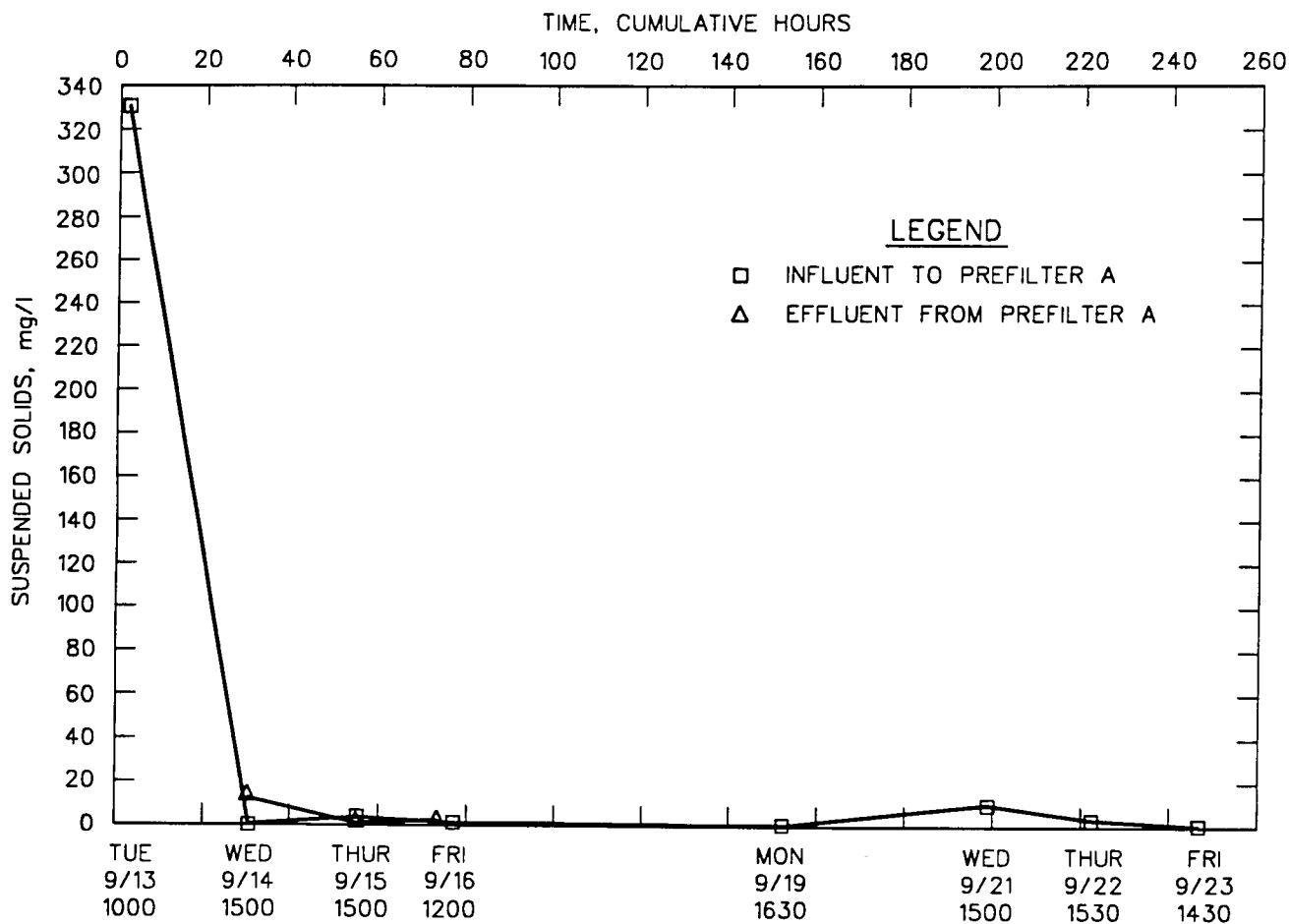


Figure 6. Suspended solids concentration versus time for prefilter A influent and effluent (expanded plot)

38. The average effluent suspended solids concentrations for adsorbers A and C were higher than the average influent concentration for adsorber B. These values indicate that carbon fines trapped in the fresh carbon at the top of the adsorbers are leaving with the adsorber effluent. The data were inconclusive regarding the fate of suspended solids in the adsorbers and whether or not the adsorbers were a source of suspended solids. The data show, however, that some carbon fines are being transported to the postfilters in the adsorber effluent. The mass flux data presented in Figure 4 for adsorbers A and B indicate that suspended solids concentrations were greater initially when fresh carbon was added to the adsorbers.

39. Postfilter performance (see Table 10) was evaluated by collecting effluent samples from the discharge into the NBS effluent sump. Postfilter influent suspended solids concentrations were calculated using a flow-weighted

average of the three average adsorber effluent concentrations. The post-filters removed approximately 58 percent of the solids from the influent.

40. Figure 7 presents suspended solids concentrations versus time in cumulative hours for the NBS effluent. From Table 10, the average effluent suspended solids concentration was 0.5 mg/l with a standard deviation of 0.6 mg/l. The high standard deviation associated with average NBS effluent suspended solids concentration is due to the three peaks found in Figure 7. During this study, the NBS effluent suspended solids concentrations were less than 0.5 mg/l, the study analytical detection limit for suspended solids. The first peak in Figure 7 at the beginning of the study was due to carbon fines input into sump A from the floor drain sump. The other two peaks coincide with carbon transfer operations for adsorbers A and B.

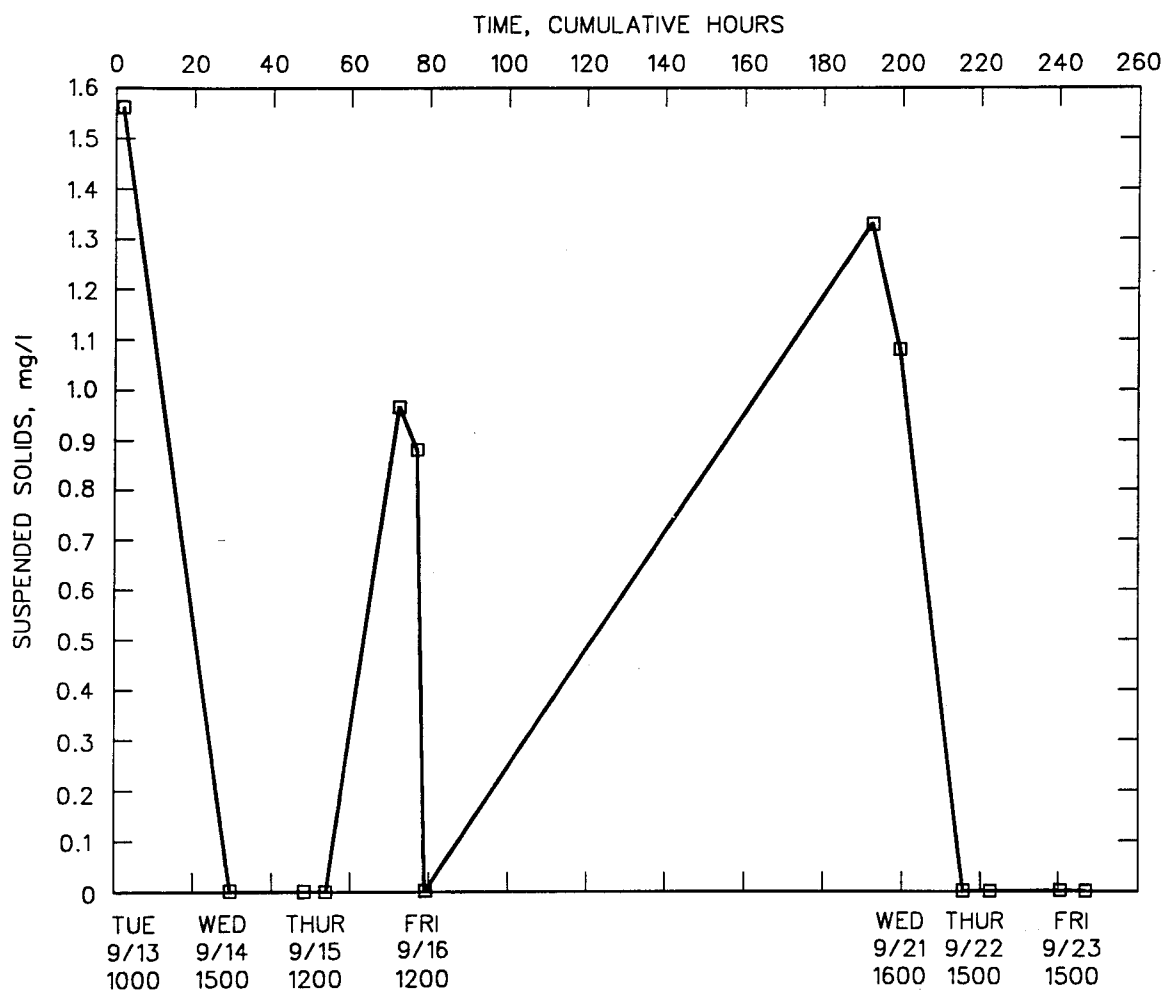


Figure 7. Suspended solids concentration versus time for NBS plant effluent

41. Carbon washing activities at the NBS are considered complete when the rinse water from the blow case runoff pipe does not contain carbon fines that can be visually observed by the plant operators. WES personnel collected samples of blow case rinse water after it was considered "clean" by the operators. A suspended solids concentration of approximately 22 mg/l was detected in the "clean" rinse water. On one occasion during the study, the operators visually inspected the rinse water inside the facility, which has relatively poor lighting. Visual inspection of the same rinse water sample in bright sunlight showed carbon fines still present in the sample. This incomplete carbon washing allows carbon fines to be transferred to the adsorbers undetected. Use of a multi-probe, in-line turbidimeter may eliminate problems associated with incomplete washing of the fresh carbon. Set time sequences for carbon washing may not completely remove carbon fines if a fresh batch of carbon has unusually high amounts of carbon fines.

42. Carbon fines were not detected in the input to any of the recharge wells sampled during the study. The NBS sumps were cleaned in 1986; however, carbon fines were observed in all of the sumps at the NBS during the sampling effort. The effluent sump had surprisingly high suspended solids concentrations of 229 mg/l on September 15, 1988, and 2,192 mg/l on September 23, 1988. These samples were collected from the bottom of the sump using a standard 3-ft-long well bailer. The concentrations of carbon fines in the other sumps were not measured, but carbon fines were found to be present on the bottom of the sumps by observing water samples collected from the sump bottoms with the well bailer.

43. Based on an effluent suspended solids concentration of 0.5 mg/l and a total system flow rate of 230 gpm, the average annual solids loading to each of the 38 recharge wells is approximately 13.5 lb/year (NOTE: 0.5 mg/l effluent solids concentration is high, indicating that the 13.5 lb/year is conservatively high). Although conservatively high, this is approximately half the estimated loading reported in Task 36 (Environmental Science and Engineering, Inc. 1988). The impact of carbon fines on recharge well packings and the surrounding aquifer of this solids loading is unclear. Therefore, suspended solids plugging of the well packing and the aquifer must be considered as contributing to the problem of reduced recharge capacity at the NBS.

### Particle Size Analysis

44. Results of particle size analysis on the six samples analyzed by PDL are presented in Table 11. The unreduced data as well as a description of the analytical procedures used by PDL are presented in Appendix A. Table 11 presents statistics for the particles on a mass (or volume) basis and on a frequency (or population) basis. A few large particles can have as much mass as a large number of small particles. Therefore, the size of a particle on a mass basis data presentation (whether measured as the geometric mean diameter, the median diameter, or the modal diameter) will be larger than the corresponding sizes measured on a frequency basis data presentation. The single size that presents the most information about the sample is the arithmetic mean diameter. The following discussion will refer to the arithmetic diameter when mention is made of particle size.

45. The most important statistics from the viewpoint of aquifer clogging are the particle sizes in the effluent sump and at the recharge well screens. The two samples taken on September 15 and 23, 1988, from the bottom of the effluent sump had arithmetic mean diameters of 10.80  $\mu\text{m}$  and 2.42  $\mu\text{m}$ , respectively. The recharge well screen sample showed an arithmetic mean particle size of 11.48  $\mu\text{m}$  on a frequency basis. Thus, a large number of relatively large particles are escaping through the postfilters.

46. Particles that are not removed in the postfilter system and that pass the recharge well screens will cause some clogging of the aquifer. Particles that are deposited in the immediate vicinity of the recharge well are expected to reduce the well's recharge rate the most. Smaller particles are expected to be carried deeper into the aquifer than larger particles; therefore, their impact on reducing the well's recharge rate is expected to be reduced when compared with that of the larger particles. However, biological fouling may complicate the above generalizations, as microbes can attach to the carbon particles and increase the particles's effective size. If microbes attach preferentially to small particles, then the clogging effect of the small particles would be enhanced. Increased growth on or around carbon particles is possible because carbon adsorbs organic contaminants, thus providing concentrated food sources for growth. This increased availability of food source can add to the potential for fouling.

47. The particle size analysis data for samples collected during the carbon wash activities when presented on a frequency basis indicate that most

of the carbon fines generated during carbon washing activities are less than 1.0  $\mu\text{m}$ . A 5.0- $\mu\text{m}$  filter is the minimal filter size that can be efficiently operated at the plant flow rate. This strengthens the conclusion that the connection between the floor drain sump and sump A should be eliminated. The sample taken from the carbon wash blowcase rinse water had extremely small particles when viewed from a frequency basis, but easily removable particles using a 5- $\mu\text{m}$  filter based on the mass basis presentation. Both reporting methods indicate that the input to the floor drain sump from the floor drains contain relatively large particles of carbon fines. These data do indicate possible success in removing a high percentage of the carbon fines from the waste stream into the floor drain sump. Particle input into sump A is relatively consistently sized. Therefore, a 5- $\mu\text{m}$  filter would effectively remove a high percentage of the solids.

48. It was assumed that a 5- and 10- $\mu\text{m}$  filter would remove all particles having a diameter greater than the respective pore sizes of each filter. The results indicate that a 10- $\mu\text{m}$  filter would remove a large percent of the carbon fines mass but a relatively small percent of the total number of particles. A 5- $\mu\text{m}$  filter would remove a large mass of particles and a rather variable number of particles depending upon which process stream is evaluated. Based on the mass basis particle data, the most difficult particles to remove are the carbon wash activity input to the floor drains and input to sump A from the floor drain sump. The 5- $\mu\text{m}$  filter will remove in excess of 68 percent of carbon fines mass in the floor drain sump water versus 25 percent for the 10- $\mu\text{m}$  filter. On a mass basis, the 10- $\mu\text{m}$  filter would perform approximately the same for removing carbon fines from the other five samples as a 5- $\mu\text{m}$  filter, because removal efficiencies for the 5- and 10- $\mu\text{m}$  filters do not vary greatly except for the input stream to sump A from the floor drain sump. The mass basis of data presentation is skewed toward the larger carbon fines, thus, indicating relatively high removal percentages for both filter pore sizes. On a frequency basis, it is apparent that a 5- $\mu\text{m}$  filter would be much more effective than a 10- $\mu\text{m}$  filter for removing carbon fines in all of the samples. Based on a frequency basis of data presentation, the 5- $\mu\text{m}$  filter would remove an average of 16 percent more carbon fines than the 10- $\mu\text{m}$  filter. Sixteen percent of carbon fines based on frequency analysis is a substantial number of carbon fines. Therefore, the conversion of the filter systems to 5- $\mu\text{m}$  effective pore size could significantly reduce the amount of carbon migrating through the NBS.

### Microbiology of Recharge Wells

49. The recharge well water samples had an average pH of 7.7, which is considered a near neutral Ph. This Ph value is within a range most conducive to microbial growth. The average redox potential was +153 Mv indicating a mildly reduced water. This redox potential is reasonable in that the water taken from the dewatering wells is borderline aerobic because of limited contact with the atmosphere while in the influent and effluent sumps.

50. Microbiological results show some fungal growth in the recharge wells sampled. The fungi were enumerated using simple enumeration methods for general indication of fungi presence and not precise enumeration; however, rough estimates indicate that they are sufficiently abundant to pose potential well fouling problems. This conclusion is based on previous experience with pressure relief wells along levees of flood control systems operated by the US Army Corps of Engineers.

51. Heterotrophic aerotolerant bacteria were found in all wells sampled (Figure 8). Heterotrophic bacteria are indicative of wells with relatively low organic content and may add to the biofouling of the recharge wells. The range of heterotrophic bacteria is within the "expected" range of populations found in most groundwater wells. The population levels observed in the NBS recharge well samples are considered too low to cause significant recharge well capacity reductions.

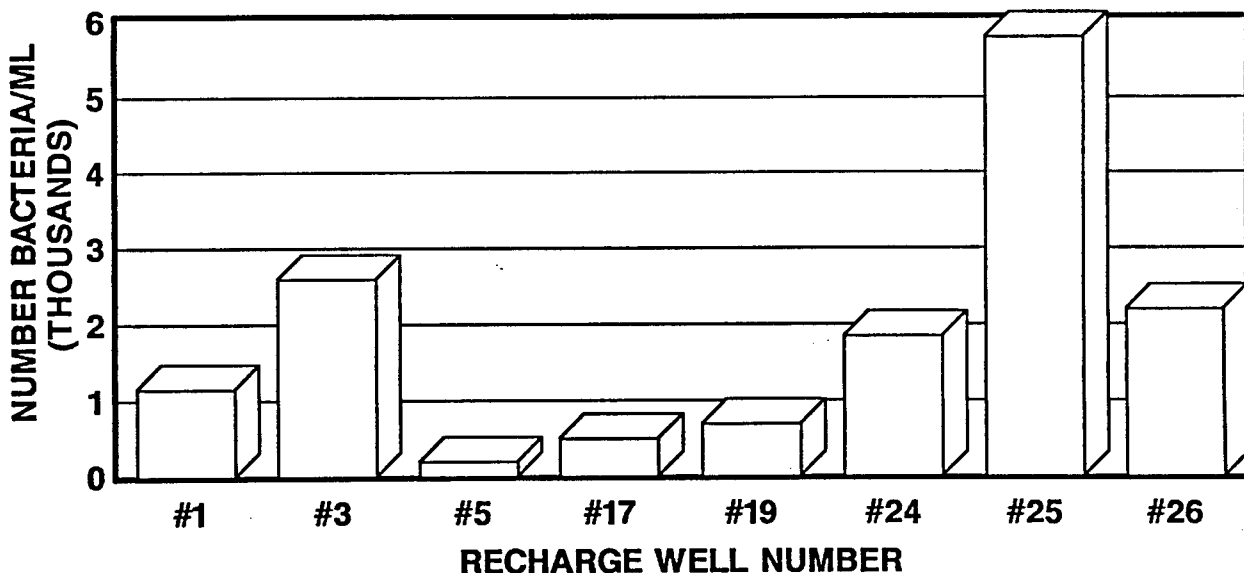


Figure 8. Average heterotrophic bacteria population found in each well

52. Very large populations of facultative bacteria were found in all the wells sampled except Well 17 (Figure 9). Well 17 also had relatively small populations of the other microorganisms sampled (see Figures 8 and 10). Facultative bacteria are typically found in wells receiving water of high organic content. In contrast to the level of heterotrophic aerotolerants enumerated in the wells, the number of facultative bacteria are considered extremely high. This indicates a very high potential for well clogging because of biofouling with these organisms.

53. Extremely high populations of fermenters were detected in Well 3, while somewhat lower levels were observed in Wells 1, 24, 25, and 26 (Figure 10). Fermenters are part of the facultative class of microbes, but differ from the other facultative types because of their characteristic acidic by-products and slime production. In addition to the highest level of fermenters measured, Well 3 also has one of the lowest recharge capacities of the NBS recharge wells.

#### Bacteriological Enumeration Limitations

54. Several factors are to be considered when determining the effects that various levels of populations have on the recharge capacity of groundwater wells. One such factor is bacteria type. The water samples collected were used to enumerate and identify only certain general bacteriological groups. However, these groups do not include all possible types of bacteria

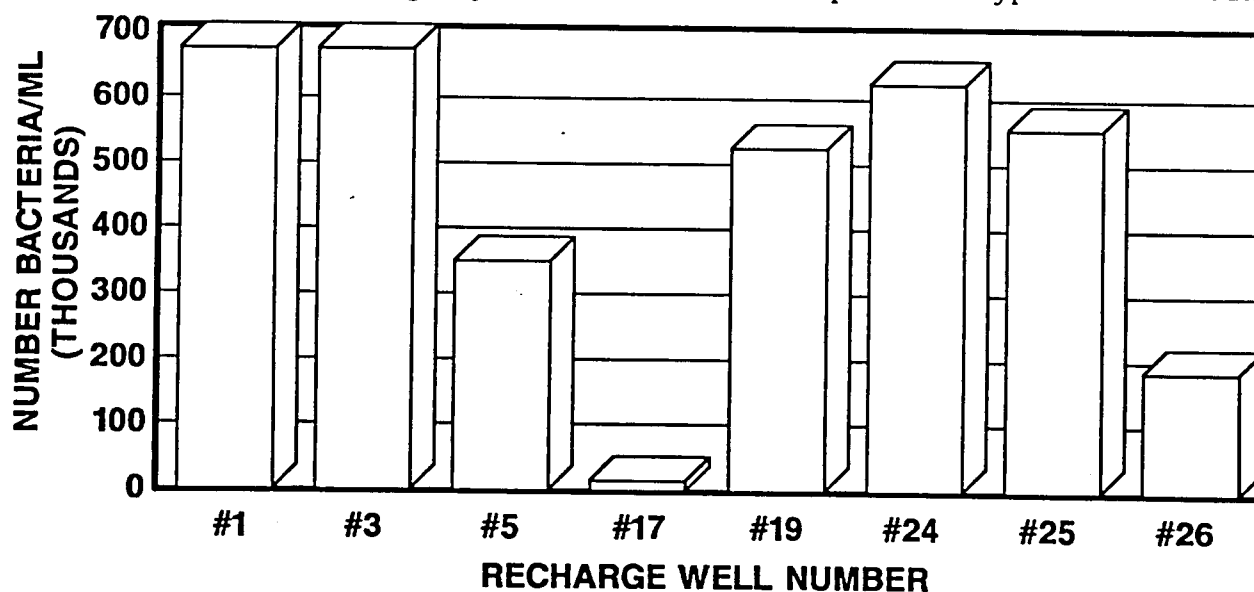


Figure 9. Average facultative population found in each well

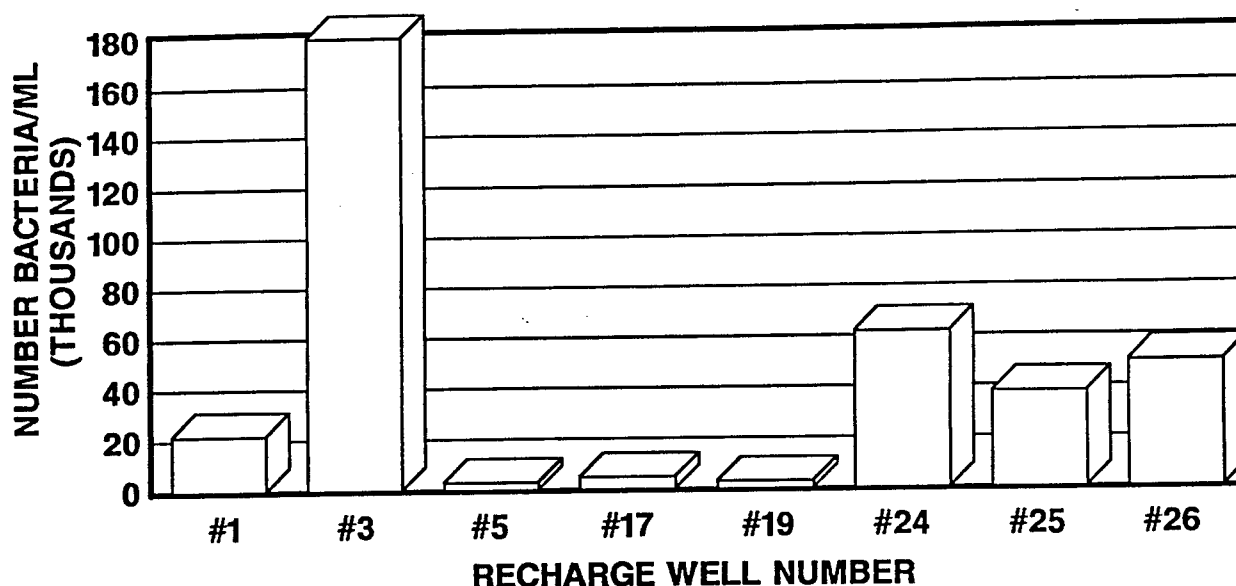


Figure 10. Average fermenter population found in each well

that can be found in soil-aquifer environments. Other bacteriological types, such as iron-reducing bacteria, could be present. Since iron-reducing bacteria are very difficult to culture under laboratory conditions, enumeration and identification of iron reducers were not attempted during this phase of study. Another factor to consider is that each bacterial cell typically produces 500 times its cell volume of slime material (Lehr and Hackett 1985). If bacteriological populations multiply, slime generation increases and the recharge capacity of a system of wells decreases significantly because of increased clogging by the slime by-products in the pore spaces surrounding the well packings.

55. The final factor pertinent to evaluating population data is that the samples collected during this study were water samples and not soil samples. Water-borne bacteria represent only a small portion of the total amount of microbes surrounding a well screen and packing. A large percentage, if not a majority, of the microorganisms present are likely adsorbed to the solid materials surrounding the well. The reported population estimates are thus quite conservative, and actual soil populations are expected to be significantly higher.

56. Figure 11 presents the average amount of water recharged through each well weekly from the period of August 3, 1988, to November 2, 1988 (NOTE: the data from the week of October 12 was not included in the calculation of these averages because of incomplete data for that week). Average weekly volumes of recharge water received by each of the NBS recharge wells are

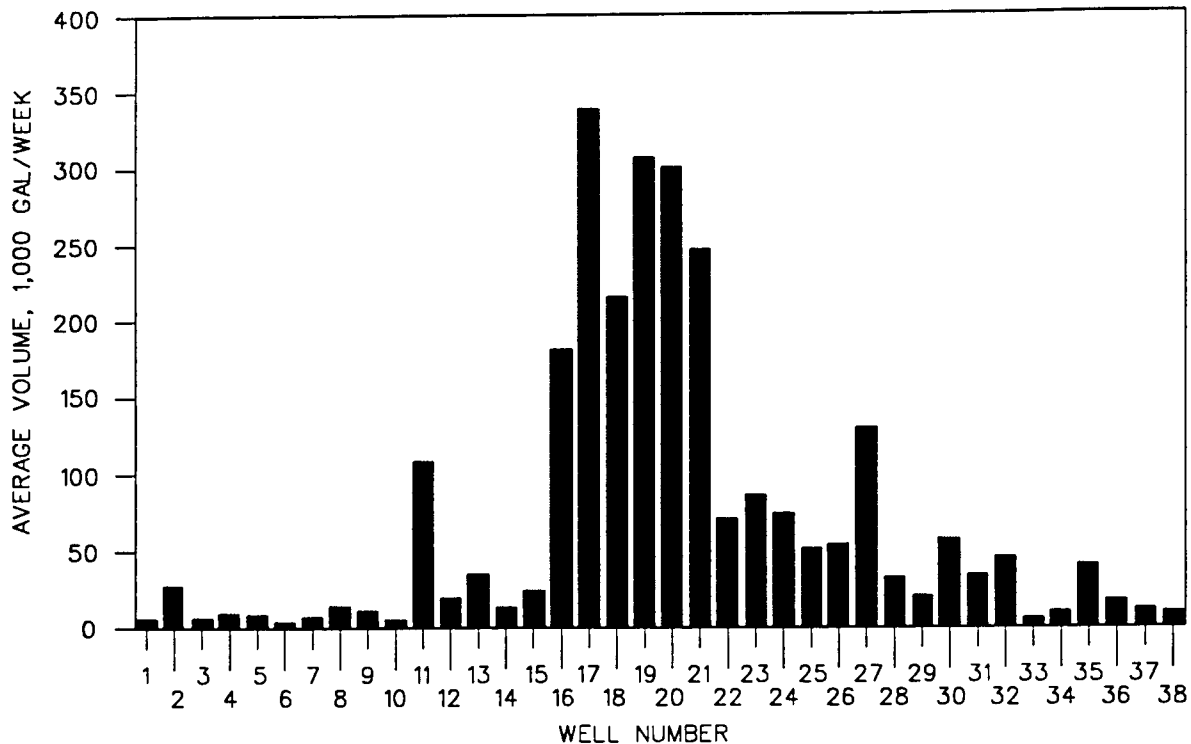


Figure 11. North Boundary System recharge wells, average weekly recharged water volumes

presented in Appendix D for informational purposes. Figure 11 reveals that Wells 16-21 are wells receiving the highest volumes of recharge water. Well 17 receives the highest volume, with Well 19 being the second.

57. Figure 12 presents the bacterial populations for wells sampled for analysis and average weekly volume of recharge water along with facultative populations for each well sampled for enumeration and identification. Well 17 had no appreciable amount of microbes and had the highest recharge volume. Conversely, Wells 1 and 3 had the highest populations and the lowest amount of water recharged. The relationship between population and well recharge capacity is consistent for all wells sampled except for Well 19, which had a relatively high population with high recharge capacity. However, because longterm monitoring information is not available for these wells, it is not possible to determine whether the high population level in Well 19 is a transitory peak or an indication of a long-term trend. Differences in recharged water volumes could be associated with differences in microbial population levels; however, possible local differences in the porosity of aquifer soil types and/or location of the well screen in each of the wells may also have been important.

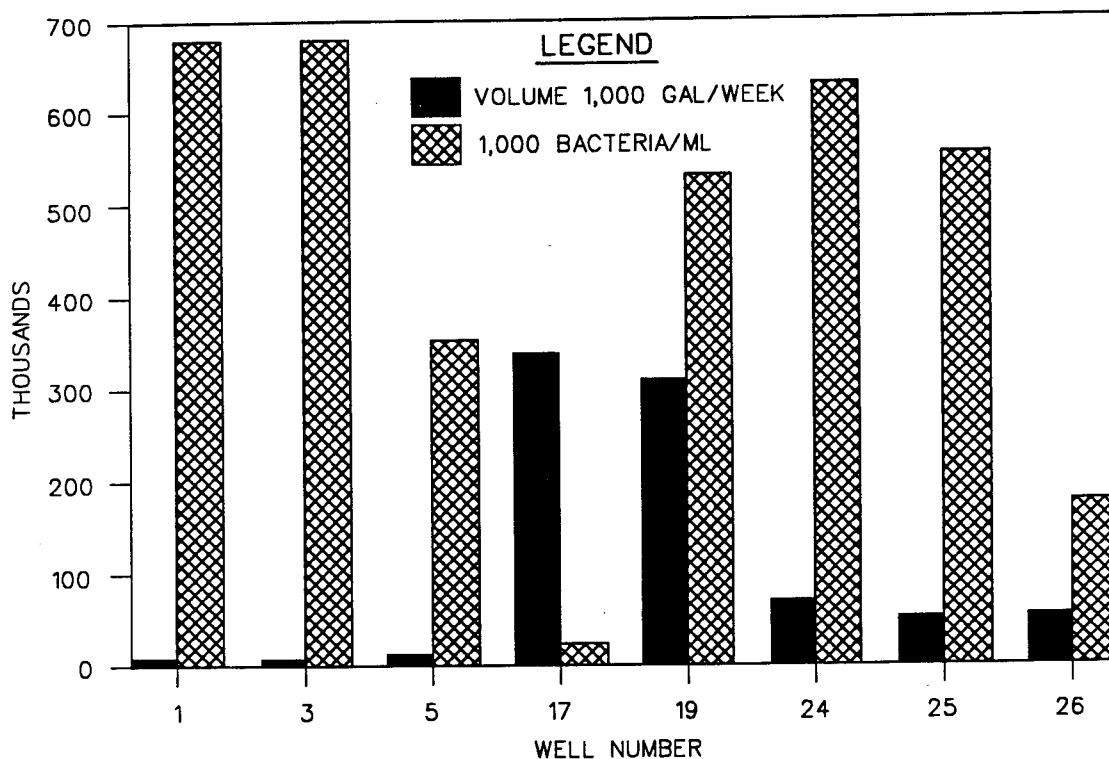


Figure 12. Average recharged water volumes per week and facultative bacteria populations for wells sampled for microbial analysis

Differences in aquifer soil types versus well screen locations were not evaluated in this study but should be examined in future investigations. Also, Well 19 is located next to the bog and is probably in hydraulic contact with the bog. Hydraulic contact reduces the hydraulic gradient (hydraulic gradient is head divided by length of travel) required to move a given quantity of water through the well.

#### Physical/Chemical Characteristics of Recharge Trenches

58. Physical and chemical data on the water collected from the trenches in 1990, 1991, and 1992 are summarized in Tables 12, 13, and 14, respectively. Water temperatures in the trenches remained relatively constant over the 3 years of sampling. The temperature ranged from 11 to 14 °C in 1990, 13 to 23 °C in 1991, and 14 to 22 °C in 1992. These temperatures are within the acceptable range supporting mesophilic to psychrophilic microbial growth. Although all the trenches were sampled in the summer months, little variation

in temperature is expected, because groundwater environments tend to maintain a consistent temperature in the 15 °C range.

59. The dissolved oxygen (DO) content in 1990 ranged from 1.7 mg/l in Trench 1 to 4.9 mg/l in Trench 2. All of the remaining trenches had very similar DO values, averaging 2.5 mg/l. In 1991, the DO content of Trenches 11-15 ranged from 3.7 mg/l in Trench 11 to 2.7 mg/l in Trench 13. In 1992, the DO content ranged from 2.7 mg/l in Trench 12 to 5.5 mg/l in Trench 15. The DO values in Trenches 11-15 measured in 1991 and 1992 are very similar to those measured in Trenches 1-10 in 1990. The DO levels in Trenches 1-10 measured in 1991 and 1992 averaged much less than in 1990 (Table 15). This may be due to the addition of Trenches 11-15 at the NBS, which has diverted much of the flow into these trenches. The DO levels measured in the trench piezometer tubes in 1990, 1991, and 1992 are capable of supporting aerotolerant and facultative bacteria populations. Finally, the DO levels measured in the trench piezometer tubes in 1990, 1991, and 1992 compare with the oxidative conditions detected in the recharge wells in 1989, indicating similar oxidative conditions.

60. Adsorption of bacteria to surfaces is greatly affected by pH. The pH values for optimum adsorption depend on the relative isoelectric points of the microbial cells and the adsorbent. The strongest adsorption of bacterial cells generally occurs at a pH range of 3 to 6 (Bitton and Marshall 1980). The pH of the water in the trenches measured during 1990, 1991, and 1992 ranged from 6.3 to 7.6. The pH of the trenches indicates that some adsorption to surfaces may occur over time, thereby adversely affecting the recharge capacity of the trenches. Comparison of mean pH values for Trenches 1-10 in 1990 and 1991 indicates that the mean pH had dropped by one full unit. In 1992, the pH values for Trenches 1-10 were the same as the pH values for Trenches 1-10 in 1990. The pH of the water in Trenches 11-15 measured in 1991 and 1992 was similar to the pH values measured in Trenches 1-10 during the 1990 sampling.

61. The conductivity in 1990 ranged from 1,400  $\mu$ mhos in Trench 6 to 2,400  $\mu$ mhos in Trench 9. The conductivity for Trenches 1-15 in 1991 ranged from 1,200  $\mu$ mhos in Trench 1 to 2,300  $\mu$ mhos in Trench 9. In 1992, the conductivity was highest in Trench 3 at 2,400  $\mu$ mhos to a low of 1,800  $\mu$ mhos in Trench 12. The conductivity of the water samples from Trenches 1-10 in 1990 was nearly identical to those values measured in water samples from Trenches 11-15 in 1991 and 1992 (Table 15). However, conductivity values for

Trenches 1-10 increased in 1991 and 1992 as compared with the 1990 values. Significant difference did not occur in salinity between the salinity values measured for Trenches 1-10 in 1990 and those determined for either Trenches 1-10 or Trenches 1-15 in 1991 and 1992 (Table 15). Both the conductivity and salinity values are all within the range of values found in groundwater and should not adversely affect the microbial populations.

62. The physical and chemical conditions observed in Trenches 1-10 have changed from 1990 to 1992. However, the data cannot be used to definitely determine whether this is a result of changing flow rates or aging and changing environmental conditions in the trenches. The change may be attributable to increased microbial activity and buildup of oxidized sludge within the trenches. In 1991 and 1992, the new trenches (11-15) had similar physical/chemical characteristics as did Trenches 1-10 after they were operational for approximately 1 year (1990). For example, the decline in pH in Trenches 1-10 observed in 1991 may possibly result from organic acid production by fermenters under reduced oxygen tension. However, the number of fermenters observed in these trenches in 1991 and 1992 declined from the 1990 values. In summary, the physical and chemical data collected from 1990 to 1992 indicate that environmental conditions within the trenches were generally conducive to microbial growth.

#### Microbiology of Recharge Trenches

63. Table 16 presents the number of fermenters enumerated in the trenches over 3 years of sampling. The 1990 sampling had the highest number of fermenters enumerated. The 1990 enumeration effort measured a net increase in fermenter numbers compared with the 1989 sampling. However, the population of fermenters enumerated in 1991 declined by one to two orders of magnitude as compared with 1990 values, and the 1992 population of fermenters declined one or two orders of magnitude from 1991. During the 1991 sampling effort, the DO levels of Trenches 1-10 were predominantly anerobic or nearly so. Therefore, in 1992 the enumeration of facultative anaerobes was conducted under conditions designed to maintain their anaerobic integrity. Samples collected in the field for facultative anaerobes were done so in nitrogen-purged collection flasks. A nitrogen-purged glove box was used for inoculation of media. Inoculated media were incubated under a nitrogen atmosphere. There were no positive results for sulfate reducers in samples from previous years.

64. Table 17 presents the number of aerotolerant heterotrophs enumerated in water samples collected from the trenches during 1989, 1990, 1991, and 1992. The highest number of aerotolerant heterotrophs were found in 1989 and 1991 over the 4-year sampling period. However, the levels varied only slightly during the 4 years of sampling. This uniformity suggests little change in the available substrate and environmental conditions required to support the growth of these organisms.

65. Facultative anaerobes were not enumerated in 1990. The 1989, 1991, and 1992 facultative enumeration data are presented in Table 18. A decrease of one to three orders of magnitude of these microorganisms enumerated in Trenches 4, 5, and 7 occurred from 1989 to 1991. In 1992, there was a decrease of one to four orders of magnitude from the previous year, 1991.

66. Table 18 presents the levels of fungi enumerated from water samples collected from the 1989, 1990, 1991, and 1992 sampling efforts. As with the bacteria enumeration data, the levels of fungi enumerated from Trenches 1-10 were highest in 1990. Fungi populations enumerated in the water samples from Trenches 11-15 in 1991 were comparable with the 1990 levels of Trenches 1-10. The fungi levels enumerated in Trenches 1-10 decreased from 1990 to 1992. The predominant fungus identified in 1989 and 1990 was *Aspergillus niger*. Since fungi such as *Aspergillus* do well under moist, but not flooded conditions, the increased numbers in 1990 suggest that water levels in the piezometer tubes remained at low levels for several days at a time so that fungus can grow.

67. Very few iron bacteria (Table 21), were found in 1990. Trenches 3, 5, and 8 were the only trenches in which iron bacteria were found. Because of the low numbers in 1990, iron bacteria enumeration was not performed in 1991 or 1992.

68. Collection of water samples from Trench 1 in 1989 was unsuccessful because of lack of water within the trench. A significant quantity of orange-red sludge was observed on the bottom of Trench 1, while none of the other trenches sampled in 1989 had any observable amounts of sludge present. Subsequent chemical analysis of the sludge verified the sludge as iron oxide. The 1990, 1991, and 1992 sampling indicated iron oxides present in all the trenches. Based on field observations, the amount of iron oxide appeared to have increased from 1989 to 1991. However, the amount of sludge in 1992 was less than observed in 1991 or 1990. During all four sampling efforts, iron oxide appeared on the bottom of all water samples left open to the atmosphere. The development of iron oxide at the bottom of sample bottles indicates that

iron is generally reduced upon entering the trench. The buildup of oxidized iron in the trenches is probably due to the partial oxidation of the reduced iron once the water enters the trenches (reduced iron in solution is very labile in the presence of oxygen). However, the presence of the iron oxide in the sample bottles indicates that much of the reduced iron is probably passed through the trench sides and bottom without precipitation as an oxide. The air may be introduced in the treated reinjection water through the numerous pipes and piezometer tubes penetrating and/or through the ground itself. The large excursions in water levels in the piezometer tubes themselves create the opportunity for air to move in and out of the trenches. Microorganisms may also impact the fate of iron within the trench environment by reduction of the iron as an electron acceptor for the facultative and fermenters during periods of low oxygen tension. Once aerobic conditions return, iron oxidizing autotrophic populations may then oxidize as an energy source.

69. Nutrients are required for microbial metabolism and reproduction. The specific nutritional requirements for different organisms vary greatly (Atlas 1988). Nitrogen and phosphorus along with hydrogen, carbon, oxygen, and sulfur constitute 95 percent of the cellular dry weight of organisms. Calcium, iron, manganese, and a few other elements are also required in trace amounts. Nutrient data collected (Table 20) indicate that several of these nutrients are present in substantial quantities in several of the trenches.

70. Nitrogen and phosphate data of 1990 and 1991 are presented in Table 22. Mean levels for various forms of nitrogen and phosphorus present in Trenches 1-10 from 1990 to 1992 and Trenches 11-15 in 1991 and 1992 are presented in Table 23. The low total kjeldahl nitrogen values indicate that the bulk of the nitrogen present is in inorganic form, mostly nitrate-nitrogen. The low values for ammonia-nitrogen and high values for nitrate-nitrogen suggest that some level of oxygen is present. Determining from the data whether or not nitrification (i.e., conversion of ammonia to nitrate by microorganisms) may be actively occurring within the trenches is not possible. Significant changes did not occur in the various forms of nitrogen present in Trenches 1-10 from 1990 to 1992. A considerably larger amount of total phosphorus than orthophosphate phosphorus was present in Trenches 1-10 in 1990, but not in 1991 or 1992. Calcium, iron, and manganese data are presented in Table 24. The calcium levels remained constant during the 3 years of sampling. The amount of total iron and manganese present in water samples collected from Trenches 1-10 increased by approximately two orders of magnitude

from 1990 to 1991 and returned to the 1990 levels in 1992. The concentrations of nutrients varied from year to year; however, the levels found are not limiting to the various types of microorganisms enumerated. Fluctuations in nutrient concentrations with time are common in microbial ecosystems. The concentration, rate of formation, or absence of a nutrient may determine the composition of a community (Alexander 1971). The dominance of different microbial types from year to year is indicative of the changing environment.

71. The design of the piezometer tubes in the five new trenches (11-15) differs from the piezometer tubes in the original ten trenches (1-10). In the original 10 trenches, the piezometer tubes are bottom screened. In Trenches 11-15, the piezometer tubes are fully screened. Because of this new design, microbial samples from Trench 12 were collected at three locations: the top, middle, and the bottom of the piezometer tube. This was done to evaluate if microbial populations varied with depth. Table 25 presents these data. These data indicate that there is no correlation between piezometer depth and microbial population.

72. The microbial activity of the piezometer tubes and the trenches can be formulated based on sample collection and analysis of the past 4 years. When the water level is down, the piezometer tubes are moist, but not dry, creating favorable conditions for the growth of fungi and aerobes and the oxidation of reduced iron. When the water levels move up, the opportunity for fresh oxygen to enter the system decreases; low dissolved oxygen levels or anaerobic conditions can gradually develop in the system. Under these conditions, first aerobes, then fermenters and facultative anaerobes grow. Even though conditions are adequate to support microbial growth, presently consistent increase does not occur in microorganisms that may lead to microbial fouling of the trenches.

73. Physical and chemical data collected to date indicate that the trenches may be going through a dynamic period of aging. Physical and chemical data from Trenches 11-15 are similar to those values measured in Trenches 1-10 when they were approximately 1 year old. The older trenches show an increase in iron, magnesium, and conductivity and a reduction in pH. The impact of this aging process on trench performance is not known, nor is it known if it is biotic or abiotic in nature.

74. An increase in the observed amount of iron oxide present on the trench bottoms in 1991 was noted; however, the amount decreased in 1992. Whether or not this apparent increase in iron oxides is occurring within the

whole trench or just in the general proximity of the piezometer tubes is not known. If it is a localized phenomenon, then it should not have an adverse effect on trench performance. However, if the buildup is trench wide, then it may have a serious impact on trench performance by reducing the hydraulic conductivity of the trench/aquifer interface. Reduction in hydraulic conductivity will result in a net reduction in recharge capacity.

## PART IV: CONCLUSIONS AND RECOMMENDATIONS

### General Conclusions

75. An overall assessment of the NBS solids removal and recharge system can be concluded as follows:

- a. The average suspended solids concentration of plant effluent using the old design was not as high as expected.
- b. The changes in system design implemented as an IRA should improve the solids retention capacity of the NBS.
- c. Reduction in recharge well capacity is probably due to a combination of both carbon fines and microbial fouling.
- d. The data collected to date is inconclusive in terms of the potential for reductions in recharge trench performance to occur with time.

### Specific Conclusions

76. The following specific conclusions can be made based on the results of the various efforts at the NBS to date:

#### Conclusions on pre-IRA system configuration

- a. High solids loading at the head of the treatment plant adversely affected plant effluent suspended solids concentrations.
- b. Carbon fines may be migrating through the spiral-wound cartridge filters under high solids loading conditions.
- c. On average, carbon fines concentrations for adsorber influents and effluents were of similar magnitudes, although two of the adsorbers released more solids than they received. Inefficient defining of the fresh carbon prior to transfer may be responsible for the release of carbon fines from the top of the adsorbers.
- d. All sumps sampled contained carbon fines and require cleaning.
- e. Although no carbon fines were detected in well water samples collected during this study, carbon fines were found in the recharge well in-line Y-strainers. Relatively large carbon fine particles are reaching the wells, indicating postfilters are failing periodically. Therefore, some carbon fines are reaching the wells on an intermittent basis.
- f. Particle size analysis indicates that conversion from a 10- $\mu$ m filter to a 5- $\mu$ m filter size for the postfilters should improve the overall solids removal efficiency at the NBS by approximately 16 percent.

- g. The NBS effluent has a neutral pH (7.7) and may be considered in a borderline oxidized state.
- h. Fungi and heterotrophic aerotolerants were not enumerated at significant levels in water samples collected from the recharge wells sampled.
- i. Facultative and fermenters were enumerated at very high populations in the recharge well water.

#### Conclusions on post-IRA system configuration

- a. Physical/chemical data indicate that the trenches may be undergoing an aging process.
- b. To date, microbial populations indicate no observable trends, thereby indicating that the potential for reduction in recharge trench capacity because of excessive microbial growth is small.
- c. There are sufficient quantities of both micronutrients and macronutrients to support microbial activity.
- d. Iron and manganese oxides are fluctuating within the piezometer tubes. The extent of cation oxide sludge buildup is not known.
- e. The changing water levels in the piezometer tubes create an environment where aerobes, fermenters, and facultative anaerobes can coexist.

#### Recommendations

77. The following recommendations for improving post-IRA system performance include:

- a. A comprehensive evaluation of both influent and effluent filter performance should be considered to determine if maximum solids removal efficiency has been obtained with IRA improvements.
- b. Installation of a multichannel turbidity unit may significantly improve defining efficiency. This installation will ensure that varying fresh carbon quality does not reduce defining efficiency with increased fines content.
- c. If degradation in recharge well persists, then a well cleaning procedure capable of destroying microbiological growth and removing carbon fines should be investigated for restoring well recharge capacities to near design capabilities.
- d. A method for assessing changes in trench recharge capacity should be developed. A quarterly assessment of trench recharge capacity should be performed to determine if reductions in trench recharge capacity is occurring with time.
- e. Evaluation of the microbiological, physical, and chemical characteristics of the recharge trenches should be made every 2 years to determine if reduced capacity is occurring.

## REFERENCES

- Alexander, M. 1977. Introduction to Soil Microbiology. 2d ed., John Wiley and Sons, Inc., New York.
- Alexander, Martin. 1971. Microbial Ecology. John Wiley and Sons, Inc., New York.
- American Water Works Association. 1985. Standard Methods of Water and Wastewater. American Public Health Association, Water Pollution Control Association, 16th ed.
- Atlas, Ronald M. 1988. Microbiology Fundamentals and Application. 2d ed., Macmillan Publishing Company, New York.
- Bitton, Gabriel, and Marshall, Kevin. 1980. Adsorption of Microorganisms to Surfaces. John Wiley and Sons, Inc., New York.
- Costerton, J. W., Irvin, R. T., and Cheng, K. J. 1981. "The Bacterial Glycocalyx in Nature and Disease," Annual Reviews of Microbiology.
- Environmental Science and Engineering, Inc. 1988. North Boundary System Component Response Action Assessment. Task 36. Office of Program Manager, Rocky Mountain Arsenal, Aberdeen Proving Ground, MD.
- Fackelmann, K. A. 1990 (Sep). "Pipe-dwelling Bacteria Use Slimy Strategy," Science News, Vol 137.
- Faust, S. D., and Aly, O. M. 1987. Adsorption Processes for Wastewater Treatment. Butterworth Publishers, Stoneham, MA.
- Ghiorse, W. C. 1986. "Biology of *Leptothrix*, *Gallianella*, and *Crenothrix*: Relationship to Plugging," Proceedings of 1980 International Symposium on Biofouled Aquifers: Prevention and Restoration, American Water Resources Association.
- Goeddertz, J. G., Matsumoto, M. R., and Weber, A. S. 1988. "Offline Bioregeneration of Granular Activated Carbon," ASCE Journal of Environmental Engineering.
- Jubboori, S. A., Stewart, G. L., and Adrian, D. D. 1974. Aquifer Clogging in Combined Wastewater Recharge, Journal of the Water Pollution Control Federation, Vol 46, No. 12, pp 2732-2744.
- Kawanishi, T., Kawashishi, H., Kazuyuki, C., and Suzuki, M. 1990. "Effect of Biological Clogging on Infiltration Rate in Soil Treatment Systems," Water Science Technology, Vol 22, No. 2.
- Kim, S. H., and Pirbazari, M. 1989. "Bioactive Adsorber Model for Industrial Wastewater Treatment," ASCE Journal of Environmental Engineering.
- Laverty, F. B., et al. 1961. "Reclaiming Hyperion Effluent," Journal, Sanitary Engineering Division, Proceedings American Society of Civil Engineers, Vol SA6, No. 1.
- Lehr, Jay H., and Hackett, Glen. 1985. "Iron Bacteria Occurrence, Problems, and Potential Solutions in Water Wells," US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lewis, D. L., and Gattie, D. K. 1990. "Effects of Cellular Aggregation on the Ecology of Microorganisms," ASM News, Vol 56.

Lutton, R. J. 1989. "Start-up Performance of Groundwater Recharge Trenches Rocky Mountain Arsenal," Technical Report GL-89-11, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Metcalf and Eddy, Inc. 1979. Wastewater Engineering: Treatment, Disposal, and Reuse, McGraw-Hill Book Company, New York.

Schultz, J. R., and Keinath, T. M. 1984 (Feb). "Powdered Activated Carbon Treatment Process Mechanisms," Journal, Water Pollution Control Federation.

Sniegocki, T. R. 1963-1965. Artificial Recharge in the Grand Prairie Region, Arkansas. US Geological Survey, Water Supply Papers 1615A-G.

Thompson, Douglas W., Berry, Edwin W., Anderson, Brian L., May, Jim H., and Hunt, Richard L. 1985. "North Boundary Containment/Treatment System Performance Report," Office of Program Manager, Rocky Mountain Arsenal, Commerce City, CO.

Todd, David K. 1960. Ground Water Hydrology, John Wiley and Sons, New York.

Zappi, M. E., Teeter, C. L., Gunnison, D., and Cullinane, M. J. 1991. "An Assessment of In-situ Biological Treatment of Contaminated Aquifers," Proceedings from the 15th Annual Army Environmental Research and Development Symposium, US Army Toxic and Hazardous Materials Agency, Williamsburg, VA.

Table 1  
North Boundary Treatment System  
Mass Flux Sampling Points

| <u>Sample Location</u>             | <u>Number Collected</u> | <u>Frequency</u>     |
|------------------------------------|-------------------------|----------------------|
| Influent to prefilter A            | 10                      | 9/13 - 9/23          |
| Influent to prefilter B            | 10                      | 9/13 - 9/23          |
| Influent to prefilter C            | 10                      | 9/13 - 9/23          |
| Influent to adsorber A             | 5                       | 9/13 - 9/16          |
| Influent to adsorber B             | 5                       | 9/13 - 9/16          |
| Influent to adsorber C             | 5                       | 9/13 - 9/16          |
| Prefilter A effluent               | 4                       | 9/14 - 9/16          |
| Prefilter B effluent               | 3                       | 9/14 - 9/16          |
| Prefilter C effluent               | 3                       | 9/14 - 9/16          |
| Adsorber A effluent                | 9                       | 9/13 - 9/23          |
| Adsorber B effluent                | 9                       | 9/13 - 9/23          |
| Adsorber C effluent                | 9                       | 9/13 - 9/23          |
| Floor drain sump input into sump A | 1                       | 9/13                 |
| Carbon wash rinse water            | 5                       | 9/13 and 9/16        |
| Bottom effluent sump               | 2                       | 9/15 and 9/23        |
| Recharge well No. 8                | 4                       | 9/19 - 9/22          |
| Recharge well No. 19               | 9                       | 9/13 - 9/23          |
| Recharge well No. 21               | 5                       | 9/13 - 9/23          |
| Recharge well No. 24               | 6                       | 9/16 and 9/19 - 9/23 |
| Floor drain input to flood drain   | 1                       | 9/13 sump            |
| Plant effluent                     | 13                      | 9/13 - 9/23          |

Table 2  
Mass Flux around Prefilter A

| <u>Date</u>                    | <u>Time<br/>hr</u> | <u>Cumulative<br/>Time<br/>hr</u> | <u>(SS)<br/>Influent<br/>mg/l</u> | <u>(SS)<br/>Effluent<br/>mg/l</u> |
|--------------------------------|--------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 13 Sep                         | 1000               | 2.00                              | 329.93                            |                                   |
| 14 Sep                         | 1450               | 30.83                             | 0.74                              | 15.97                             |
| 15 Sep                         | 1500               | 55.00                             | 5.01                              | 1.93                              |
| 16 Sep*                        | 0930               | 73.50                             | 1.30                              | 2.90                              |
| 16 Sep*                        | 1320               | 77.33                             | 0.66                              | 0.57                              |
|                                |                    |                                   | (0.98)*                           | (1.74)*                           |
| 19 Sep                         | 1630               | 152.50                            | 0.00                              |                                   |
| 21 Sep                         | 1500               | 199.00                            | 6.40                              |                                   |
| 22 Sep                         | 1520               | 223.33                            | 2.32                              |                                   |
| 23 Sep                         | 1425               | 246.42                            | 1.62                              |                                   |
| Average influent concentration |                    |                                   | 38.67                             |                                   |
| Standard deviation influent    |                    |                                   | 102.99                            |                                   |
| Average effluent concentration |                    |                                   | 5.34                              |                                   |
| Standard deviation effluent    |                    |                                   | 6.19                              |                                   |

\* Indicates the average of multiple readings.

Table 3  
Mass Flux around Adsorber A

| <u>Date</u>                    | <u>Time<br/>hr</u> | <u>Cumulative<br/>Time<br/>hr</u> | <u>(SS)<br/>Influent<br/>mg/l</u> | <u>(SS)<br/>Effluent<br/>mg/l</u> |
|--------------------------------|--------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 13 Sep                         | 1000               | 2.00                              | 5.16                              | 3.77                              |
| 13 Sep                         | 1410               | 6.17                              | 0.00                              | 0.94                              |
|                                |                    |                                   |                                   | (2.36)*                           |
| 14 Sep                         | 1450               | 30.83                             | 0.00                              | 0.00                              |
| 15 Sep                         | 0900               | 49.00                             | 0.00                              | 1.42                              |
| 15 Sep                         | 1500               | 55.00                             | 1.41                              | 0.00                              |
|                                |                    |                                   |                                   | (0.71)*                           |
| 16 Sep                         | 1320               | 77.33                             | 1.44                              | 0.00                              |
| 19 Sep                         | 0905               | 145.00                            | --                                | 1.22                              |
| 19 Sep                         | 1615               | 152.25                            | --                                | 0.84                              |
|                                |                    |                                   | --                                | (1.03)*                           |
| 20 Sep                         | 1510               | 175.17                            | --                                | 0.90                              |
| 21 Sep                         | 0830               | 192.50                            | --                                | 0.64                              |
| 22 Sep                         | 0855               | 219.92                            | --                                | 0.80                              |
| 22 Sep                         | 1525               | 223.40                            | --                                | 0.73                              |
|                                |                    |                                   | --                                | (0.77)*                           |
| 23 Sep                         | 0900               | 241.00                            | --                                | 0.66                              |
| 23 Sep                         | 1455               | 246.92                            | --                                | 0.52                              |
|                                |                    |                                   | --                                | (0.59)*                           |
| Average effluent concentration |                    |                                   | 0.89                              |                                   |
| Standard deviation effluent    |                    |                                   | 0.90                              |                                   |
| Average influent concentration |                    |                                   | 1.34                              |                                   |
| Standard deviation influent    |                    |                                   | 1.83                              |                                   |

\* Indicates the average of multiple readings.

Table 4  
Mass Flux around Prefilter B

| <u>Date</u>                    | <u>Time</u><br><u>hr</u> | <u>Cumulative</u><br><u>Time</u><br><u>hr</u> | <u>(SS)</u><br><u>Influent</u><br><u>mg/l</u> | <u>(SS)</u><br><u>Effluent</u><br><u>mg/l</u> |
|--------------------------------|--------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 13 Sep                         | 1000                     | 2.00                                          | 431.13                                        |                                               |
| 14 Sep                         | 1450                     | 30.83                                         | 0.00                                          | 29.50                                         |
| 15 Sep                         | 1500                     | 55.00                                         | 0.54                                          | 0.78                                          |
| 16 Sep                         | 1320                     | 77.33                                         | 0.00                                          | 0.83                                          |
| 19 Sep                         | 1630                     | 152.50                                        | 0.00                                          |                                               |
| 21 Sep                         | 1500                     | 199.00                                        | 1.73                                          |                                               |
| 22 Sep                         | 1520                     | 223.33                                        | 0.00                                          |                                               |
| 23 Sep                         | 1425                     | 246.42                                        | 0.00                                          |                                               |
| Average influent concentration |                          |                                               | 54.18                                         |                                               |
| Standard deviation influent    |                          |                                               | 142.48                                        |                                               |
| Average effluent concentration |                          |                                               | 10.37                                         |                                               |
| Standard deviation effluent    |                          |                                               | 13.53                                         |                                               |

Table 5  
Mass Flux around Adsorber B

| <u>Date</u>                    | <u>Time</u><br><u>hr</u> | <u>Cumulative</u><br><u>Time</u><br><u>hr</u> | <u>(SS)</u><br><u>Influent</u><br><u>mg/l</u> | <u>(SS)</u><br><u>Effluent</u><br><u>mg/l</u> |
|--------------------------------|--------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 13 Sep                         | 1000                     | 2.00                                          | 2.62                                          | 5.70                                          |
| 14 Sep                         | 1450                     | 30.83                                         | 0.73                                          | 1.42                                          |
| 15 Sep                         | 1500                     | 55.00                                         | 1.62                                          | 1.29                                          |
| 16 Sep                         | 1320                     | 77.33                                         | 0.00                                          | 0.60                                          |
| 19 Sep                         | 1615                     | 152.25                                        | --                                            | 1.00                                          |
| 20 Sep                         | 1510                     | 175.17                                        | --                                            | 0.51                                          |
| 21 Sep                         | 0830                     | 192.50                                        | --                                            | 0.00                                          |
| 22 Sep                         | 0855                     | 216.92                                        | --                                            | 0.00                                          |
| 23 Sep                         | 0900                     | 241.00                                        | --                                            | 1.42                                          |
| Average effluent concentration |                          |                                               | 1.33                                          |                                               |
| Standard deviation effluent    |                          |                                               | 1.63                                          |                                               |
| Average influent concentration |                          |                                               | 1.24                                          |                                               |
| Standard deviation influent    |                          |                                               | 0.98                                          |                                               |

Table 6  
Mass Flux around Prefilter C

| <u>Date</u>                    | <u>Time</u><br><u>hr</u> | <u>Cumulative</u><br><u>Time</u><br><u>hr</u> | <u>(SS)</u><br><u>Influent</u><br><u>mg/l</u> | <u>(SS)</u><br><u>Effluent</u><br><u>mg/l</u> |
|--------------------------------|--------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 13 Sep                         | 1000                     | 2.00                                          | 189.03                                        | --                                            |
| 14 Sep                         | 1450                     | 30.83                                         | 4.19                                          | 2.08                                          |
| 15 Sep                         | 1500                     | 55.00                                         | 0.72                                          | 1.18                                          |
| 16 Sep                         | 1320                     | 77.33                                         | 0.69                                          | 0.92                                          |
| 19 Sep                         | 1630                     | 152.50                                        | 1.26                                          | --                                            |
| 21 Sep                         | 1500                     | 199.00                                        | 1.36                                          | --                                            |
| 22 Sep                         | 1520                     | 223.33                                        | 10.29                                         | --                                            |
| 23 Sep                         | 1425                     | 246.42                                        | 0.00                                          | --                                            |
| Average influent concentration |                          |                                               | 25.94                                         |                                               |
| Standard deviation influent    |                          |                                               | 61.72                                         |                                               |
| Average effluent concentration |                          |                                               | 1.39                                          |                                               |
| Standard deviation effluent    |                          |                                               | 0.50                                          |                                               |

Table 7  
Mass Flux around Adsorber C

| <u>Date</u> | <u>Time<br/>hr</u> | <u>Cumulative<br/>Time<br/>hr</u> | <u>(SS)<br/>Influent<br/>mg/l</u> | <u>(SS)<br/>Effluent<br/>mg/l</u> |
|-------------|--------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 13 Sep      | 1000               | 2.00                              | 2.66                              | 0.72                              |
| 14 Sep      | 1450               | 30.83                             | 0.53                              | 0.00                              |
| 15 Sep      | 1500               | 55.00                             | 0.00                              | 0.00                              |
| 16 Sep      | 1320               | 77.33                             | --                                | 0.00                              |
| 19 Sep      | 0905               | 145.08                            | --                                | 0.52                              |
| 19 Sep      | 1615               | 152.25                            | --                                | 1.09                              |
|             |                    |                                   | --                                | (0.81)*                           |
| 20 Sep      | 1510               | 175.17                            | --                                | 0.00                              |
| 21 Sep      | 0830               | 192.50                            | --                                | 1.55                              |
| 22 Sep      | 0855               | 216.92                            | --                                | 0.00                              |
| 22 Sep      | 1525               | 223.42                            | --                                | 1.88                              |
|             |                    |                                   |                                   | (0.94)*                           |
| 23 Sep      | 0900               | 241.00                            | --                                | 0.00                              |
| 23 Sep      | 1500               | 247.00                            | --                                | 0.00                              |
|             |                    |                                   |                                   | (0.00)*                           |

|                                |      |
|--------------------------------|------|
| Average effluent concentration | 0.48 |
| Standard deviation influent    | 0.65 |

|                                |      |
|--------------------------------|------|
| Average influent concentration | 1.06 |
| Standard deviation effluent    | 1.15 |

---

\* Indicates the average of multiple readings.

Table 8  
Mass Flux Postbag Filter

| <u>Date</u>                    | <u>Time<br/>hr</u> | <u>Cumulative<br/>Time<br/>hr</u> | <u>(SS)<br/>Effluent<br/>mg/l</u> |
|--------------------------------|--------------------|-----------------------------------|-----------------------------------|
| 13 Sep                         | 1000               | 2.00                              | 2.39                              |
| 14 Sep                         | 1450               | 30.83                             | 0.00                              |
| 15 Sep*                        | 0920               | 49.33                             | 0.69                              |
| 15 Sep*                        | 1500               | 55.00                             | 0.77                              |
|                                |                    |                                   | (0.73)*                           |
| 16 Sep                         | 1320               | 77.33                             | 0.00                              |
| 20 Sep                         | 1505               | 175.08                            | 0.00                              |
| 22 Sep                         | 1510               | 223.17                            | 0.00                              |
| 23 Sep                         | 1420               | 246.33                            | 0.00                              |
| Average effluent concentration |                    | 0.48                              |                                   |
| Standard deviation             |                    | 0.78                              |                                   |

---

\* Indicates the average of multiple readings.

Table 9  
Mass Flux Plant Effluent

| <u>Date</u>                    | <u>Time<br/>hr</u> | <u>Cumulative<br/>Time<br/>hr</u> | <u>(SS)<br/>Effluent<br/>mg/l</u> |
|--------------------------------|--------------------|-----------------------------------|-----------------------------------|
| 13 Sep                         | 1000               | 2.00                              | 1.56                              |
| 14 Sep                         | 1450               | 30.83                             | 0.00                              |
| 15 Sep                         | 0920               | 49.33                             | 0.00                              |
| 15 Sep                         | 1500               | 55.00                             | 0.00                              |
|                                |                    |                                   | (0.00)*                           |
| 16 Sep                         | 0900               | 73.00                             | 0.96                              |
| 16 Sep                         | 1320               | 77.33                             | 0.87                              |
| 16 Sep                         | 1618               | 80.30                             | 0.00                              |
|                                |                    |                                   | (0.61)*                           |
| 21 Sep                         | 0840               | 192.67                            | 1.32                              |
| 21 Sep                         | 1518               | 199.30                            | 1.08                              |
|                                |                    |                                   | (1.20)*                           |
| 22 Sep                         | 0850               | 216.83                            | 0.00                              |
| 22 Sep                         | 1515               | 223.25                            | 0.00                              |
|                                |                    |                                   | (0.00)*                           |
|                                |                    |                                   | 0.00                              |
| 23 Sep                         | 0905               | 241.08                            | 0.00                              |
| 23 Sep                         | 1455               | 246.92                            | 0.00                              |
|                                |                    |                                   | (0.00)*                           |
| Average effluent concentration |                    | 0.45                              |                                   |
| Standard deviation             |                    | 0.58                              |                                   |

\* Indicates the average of multiple readings.

Table 10

Average Influent and Effluent Concentrations, Standard  
Deviation and Removal Efficiencies for NBS

Process Equipment

|                | <u>Average<br/>Influent<br/>Conc.</u> | <u>Influent<br/>Std. Dev.</u> | <u>Average<br/>Effluent<br/>Conc.</u> | <u>Effluent<br/>Std. Dev.</u> | <u>Removal<br/>Efficiency<br/>%</u> |
|----------------|---------------------------------------|-------------------------------|---------------------------------------|-------------------------------|-------------------------------------|
| Prefilter A    | 38.7                                  | 103.0                         | 5.3                                   | 6.2                           | 86.3                                |
| Adsorber A     | 0.9                                   | 0.9                           | 1.3                                   | 1.8                           | -44.4                               |
| Prefilter B    | 54.2                                  | 142.5                         | 10.4                                  | 13.5                          | 80.8                                |
| Adsorber B     | 1.3                                   | 1.6                           | 1.2                                   | 1.0                           | 7.7                                 |
| Prefilter C    | 25.9                                  | 61.7                          | 1.4                                   | 0.5                           | 94.6                                |
| Adsorber C     | 0.5                                   | 0.7                           | 1.1                                   | 1.1                           | -120.0                              |
| Postbag        | 1.2*                                  | --                            | 0.5                                   | 0.8                           | 58.3                                |
| Plant Effluent | --                                    | --                            | 0.5                                   | 0.6                           | --                                  |

\* Flow weighted average based on flows of 50, 90, and 90 gpm for adsorbers A, B, and C, respectively.

Table 11  
Particle Sizes on a Mass (Volume) and Frequency (Population)  
Basis for Selected Locations

| <u>Sampling Location</u>                    | <u>Sample No.</u> | <u>Mass Basis Statistics</u>    |            |            |            | <u>Frequency Basis Statistics</u> |           |           |           |
|---------------------------------------------|-------------------|---------------------------------|------------|------------|------------|-----------------------------------|-----------|-----------|-----------|
|                                             |                   | <u><math>\mu\text{m}</math></u> |            |            |            | <u><math>\mu\text{m}</math></u>   |           |           |           |
|                                             |                   | <u>Dg*</u>                      | <u>Dm*</u> | <u>Da*</u> | <u>Dd*</u> | <u>Dg</u>                         | <u>Dm</u> | <u>Da</u> | <u>Dd</u> |
| Carbon wash<br>Initial rinse                | RMA-5             | 15.8                            | 27.6       | 44.9       | 88.1       | 0.84                              | 0.82      | 0.97      | 0.79      |
| Carbon change<br>Floor drain                | RMA-4             | 54.1                            | 71.6       | 78.6       | 123.4      | 2.40                              | 1.94      | 3.24      | 1.29      |
| Input to A-Sump<br>from carbon<br>wash sump | RMA-6             | 6.8                             | 6.6        | 8.0        | 5.3        | 2.67                              | 2.54      | 3.21      | 1.95      |
| Bottom of E-Sump<br>(9-15-88)               | RMA-2             | 61.5                            | 66.6       | 74.6       | 87.7       | 7.92                              | 6.60      | 10.80     | 3.50      |
| Bottom of E-Sump<br>(9-23-88)               | RMA-3             | 57.6                            | 66.4       | 78.0       | 98.6       | 1.80                              | 1.43      | 2.42      | 1.17      |
| Recharge Well 21<br>Screen                  | RMA-1             | 47.4                            | 51.8       | 64.7       | 56.7       | 5.34                              | 4.43      | 11.48     | 3.59      |

\* Dg = the geometric mean size. Dm = the median size. Da = the arithmetic average size. Dd = the mode size.

Table 12  
Recharge Trench Physical Data for 1990

| <u>Trench<br/>Number</u> | <u>Water<br/>Depth*</u> | <u>Temp<br/>°C</u> | <u>DO<br/>mg/l</u> | <u>pH</u> | <u>Cond.<br/>μmhos</u> | <u>Salinity<br/>ppt</u> |
|--------------------------|-------------------------|--------------------|--------------------|-----------|------------------------|-------------------------|
| 1                        | 5' 4"                   | 12                 | 1.7                | 7.4       | 1625                   | 0.5                     |
| 2                        | 4' 5"                   | 11                 | 4.9                | 7.4       | 1725                   | 0.8                     |
| 3                        | 4' 0"                   | 12                 | 2.4                | 7.6       | 1850                   | 0.9                     |
| 4                        | 6' 0"                   | 12                 | 2.1                | 7.5       | 1975                   | 0.5                     |
| 5                        | 10' 2"                  | 12                 | 2.7                | 7.2       | 1550                   | 0.5                     |
| 6                        | 10' 2"                  | 12                 | 2.7                | 7.4       | 1400                   | 0.5                     |
| 7                        | 5' 0"                   | 12                 | 2.9                | 6.7       | 1650                   | 0.5                     |
| 8                        | 4' 1"                   | 13                 | 2.9                | 6.9       | 1900                   | 0.5                     |
| 9                        | 4' 7"                   | 14                 | 2.4                | 6.3       | 2400                   | 1.0                     |
| 10                       | 7' 0"                   | 13                 | 2.2                | 6.4       | 2000                   | 1.0                     |

---

\* Measured from top of the polyvinyl chloride (PVC) tubes.

Table 13  
Recharge Trench Physical Data for 1991

| <u>Trench<br/>Number</u> | <u>Water<br/>Depth*</u> | <u>Temp<br/>°C</u> | <u>DO<br/>mg/l</u> | <u>pH</u> | <u>Cond.<br/>μmhos</u> | <u>Salinity<br/>ppt</u> |
|--------------------------|-------------------------|--------------------|--------------------|-----------|------------------------|-------------------------|
| 1                        | 2' 0"                   | 23                 | 0.8                | 6.8       | 1200                   | 0.5                     |
| 2                        | 1' 6"                   | 18                 | 0.7                | 6.5       | 1900                   | 1.2                     |
| 3                        | 6' 4"                   | 18                 | 0.8                | 7.1       | 2100                   | 1.0                     |
| 4                        | 10' 7"                  | 19                 | 0.5                | 7.2       | 2150                   | 1.5                     |
| 5                        | 15' 9"                  | 19                 | 0.3                | 7.0       | 2100                   | 1.0                     |
| 6                        | 7' 5"                   | 17                 | 0.6                | 6.5       | 2100                   | 1.0                     |
| 7                        | 5' 1"                   | 17                 | 0.8                | 6.6       | 2100                   | 1.5                     |
| 8                        | 3' 2"                   | 18                 | 0.2                | 6.5       | 2200                   | 1.5                     |
| 9                        | 3' 5"                   | 18                 | 0.4                | 6.7       | 2300                   | 1.5                     |
| 10                       | 8' 8"                   | 16                 | 0.6                | 7.0       | 2100                   | 1.5                     |
| 11                       | 8' 9"                   | 14                 | 3.7                | 7.5       | 1500                   | 1.0                     |
| 12                       | 9' 7"                   | 16                 | 3.6                | 7.3       | 1800                   | 1.0                     |
| 13                       | 10' 10"                 | 14                 | 2.7                | 7.5       | 1550                   | 1.0                     |
| 14                       | 9' 11"                  | 13                 | 2.9                | 7.6       | 1950                   | 1.5                     |
| 15                       | 1' 0"                   | 13                 | 2.9                | 7.6       | 1950                   | 1.5                     |

---

\* Measured from top of the PVC tubes.

Table 14  
Recharge Trench Physical Data for 1992

| <u>Trench<br/>Number</u> | <u>Water<br/>Depth*</u> | <u>Temp<br/>°C</u> | <u>DO<br/>mg/l</u> | <u>pH</u> | <u>Cond.<br/>μmhos</u> | <u>Salinity<br/>ppt</u> |
|--------------------------|-------------------------|--------------------|--------------------|-----------|------------------------|-------------------------|
| 1                        | 0.5' 0"                 | ND**               | 0.6                | ND        | ND                     | ND                      |
| 2                        | 0.5' 0"                 | ND                 | 0.5                | ND        | ND                     | ND                      |
| 3                        | 2' 5"                   | 22                 | 0.7                | 7.1       | 2400                   | 1.5                     |
| 4                        | 8' 0"                   | 21                 | 1.0                | 7.2       | 2200                   | 1.5                     |
| 5                        | 12' 5"                  | 21                 | 1.5                | 6.9       | 2000                   | 1.2                     |
| 6                        | 11' 0"                  | 16                 | 1.5                | 7.0       | 2000                   | 1.2                     |
| 7                        | 6' 2"                   | 16                 | 0.3                | 7.0       | 2000                   | 1.2                     |
| 8                        | 5' 6"                   | 17                 | 0.5                | 7.0       | 1995                   | 1.1                     |
| 9                        | 4' 8"                   | 14                 | 0.5                | 7.0       | 1900                   | 0.9                     |
| 10                       | 7' 3"                   | 14                 | 0.3                | 6.9       | 1900                   | 1.0                     |
| 11                       | 5' 9"                   | 14                 | 3.8                | 6.9       | 1900                   | 1.0                     |
| 12                       | 7' 9"                   | 14                 | 2.7                | 6.9       | 1800                   | 1.0                     |
| 13                       | 3' 4"                   | 15                 | 3.5                | 7.0       | 2000                   | 2.0                     |
| 14                       | 13' 1"                  | 16                 | 3.0                | 6.9       | 2100                   | 2.0                     |
| 15                       | 10' 7"                  | 16                 | 5.5                | 6.9       | 2000                   | 1.2                     |

\* Measured from top of the PVC tubes.

\*\* ND = Not determined because of insufficient water in piezometer tube.

Table 15

Comparison of 1990, 1991, and 1992, Data for Temperature, Dissolved Oxygen,

Conductivity, and Salinity

| Constituent              | 1990 Value*<br>Trenches 1-10 | 1991 Value*<br>Trenches 1-15 | 1991 Value*<br>Trenches 1-10 | 1991 Value*<br>Trenches 11-15 | 1992 Value*<br>Trenches 1-15 |
|--------------------------|------------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|
| Temperature<br>°C        | 12 ± 0.3                     | 17 ± 0.7                     | 18 ± 0.6                     | 14 ± 0.5                      | 17 ± 0.79                    |
| Dissolved Oxygen<br>mg/ℓ | 2.5 ± 0.37                   | 1.4 ± 0.34                   | 0.6 ± 0.10                   | 3.2 ± 0.20                    | 1.7 ± 0.4                    |
| pH                       | 7.1 ± 0.15                   | 6.4 ± 0.48                   | 6.1 ± 0.66                   | 7.5 ± 0.06                    | 7.0 ± 0.03                   |
| Conductivity<br>μmhos    | 1808 ± 90                    | 1667 ± 170                   | 2025 ± 97                    | 1750 ± 96                     | 2046 ± 41                    |
| Salinity, ppt            | 1.9 ± 0.90                   | 1.2 ± 0.08                   | 1.3 ± 0.13                   | 1.2 ± 0.12                    | 1.32 ± 0.09                  |
| Temperature<br>°C        | 18 ± 0.91                    | 16 ± 1.23                    |                              |                               |                              |
| Dissolved Oxygen<br>mg/ℓ | 0.74 ± 0.5                   | 3.7 ± 0.71                   |                              |                               |                              |
| pH                       | 7.04 ± 0.03                  | 6.96 ± 0.04                  |                              |                               |                              |
| Conductivity<br>μmhos    | 2090 ± 47                    | 1956 ± 65.0                  |                              |                               |                              |
| Salinity, ppt            | 1.26 ± 0.11                  | 1.09 ± 0.16                  |                              |                               |                              |

\* Values are mean ± standard error.

Table 16  
Recharge Trench Fermenter Enumeration Results

| Trench<br>Number | Number of Bacteria per Milliliter of Groundwater |                   |                   |                      |
|------------------|--------------------------------------------------|-------------------|-------------------|----------------------|
|                  | 1989                                             | 1990              | 1991              | 1992                 |
| 1                | NM*                                              | $2.2 \times 10^4$ | $9.0 \times 10$   | NM                   |
| 2                | NM                                               | $1.3 \times 10^4$ | $1.3 \times 10^2$ | $1.8 \times 10$      |
| 3                | NM                                               | $1.8 \times 10^4$ | $1.7 \times 10^2$ | $6.0 \times 10^{-1}$ |
| 4                | $1.3 \times 10^2$                                | $1.8 \times 10^5$ | $2.4 \times 10^3$ | $3.5 \times 10$      |
| 5                | $1.3 \times 10^2$                                | $9.4 \times 10^4$ | $3.5 \times 10^3$ | $2.4 \times 10$      |
| 6                | NM                                               | $2.3 \times 10^4$ | $1.7 \times 10^2$ | $2.4 \times 10$      |
| 7                | $2.2 \times 10^3$                                | $2.3 \times 10^4$ | $1.7 \times 10^3$ | $9.2 \times 10$      |
| 8                | NM                                               | $4.3 \times 10^4$ | NM                | $1.4 \times 10^0$    |
| 9                | NM                                               | $2.3 \times 10^4$ | $2.7 \times 10^2$ | $1.3 \times 10^0$    |
| 10               | NM                                               | $2.3 \times 10^4$ | $1.1 \times 10^2$ | $9.2 \times 10$      |
| 11               | NM                                               | NM                | $2.4 \times 10^3$ | $1.7 \times 10^0$    |
| 12               | NM                                               | NM                | $4.9 \times 10^3$ | $6.0 \times 10^{-1}$ |
| 13               | NM                                               | NM                | $5.4 \times 10^3$ | $4.0 \times 10^{-1}$ |
| 14               | NM                                               | NM                | $2.3 \times 10^4$ | $6.0 \times 10^{-1}$ |
| 15               | NM                                               | NM                | $9.2 \times 10^3$ | $3.1 \times 10^0$    |

---

\* NM = not measured.

Table 17

Recharge Trench Aerotolerant Heterotroph Enumeration Results

| Trench<br>Number | Number of Bacteria per Milliliter of Groundwater |                   |                   |                   |
|------------------|--------------------------------------------------|-------------------|-------------------|-------------------|
|                  | 1989                                             | 1990              | 1991              | 1992              |
| 1                | NM*                                              | $4.9 \times 10^2$ | $1.7 \times 10^3$ | NM                |
| 2                | NM                                               | $3.5 \times 10^3$ | $2.4 \times 10^3$ | $3.5 \times 10^2$ |
| 3                | NM                                               | $3.1 \times 10^4$ | $4.6 \times 10^3$ | $3.3 \times 10$   |
| 4                | $1.3 \times 10^3$                                | $1.8 \times 10^3$ | $5.4 \times 10^3$ | $1.7 \times 10^2$ |
| 5                | $7.9 \times 10^3$                                | $2.3 \times 10^2$ | $1.7 \times 10^2$ | $2.4 \times 10^2$ |
| 6                | NM                                               | $9.0 \times 10^1$ | $2.3 \times 10^2$ | $7.9 \times 10^4$ |
| 7                | $2.3 \times 10^4$                                | $2.2 \times 10^4$ | $2.4 \times 10^3$ | $2.3 \times 10^2$ |
| 8                | NM                                               | $7.9 \times 10^3$ | $5.4 \times 10^3$ | $7.9 \times 10$   |
| 9                | NM                                               | $2.3 \times 10^4$ | $4.9 \times 10^2$ | $2.3 \times 10^2$ |
| 10               | NM                                               | $2.3 \times 10^4$ | $5.4 \times 10^3$ | $1.7 \times 10^2$ |
| 11               | NM                                               | NM                | $1.6 \times 10^4$ | $3.5 \times 10$   |
| 12               | NM                                               | NM                | $9.2 \times 10^3$ | $1.8 \times 10^4$ |
| 13               | NM                                               | NM                | $2.3 \times 10^2$ | $2.8 \times 10^2$ |
| 14               | NM                                               | NM                | $2.4 \times 10^4$ | $1.4 \times 10^2$ |
| 15               | NM                                               | NM                | NM                | $3.5 \times 10^3$ |

\* NM = not measured.

Table 18

Recharge Trench Facultative Anaerobe Enumeration Results

| <u>Trench<br/>Number</u> | <u>Number of Bacteria per Milliliter of Groundwater</u> |                   |                   |
|--------------------------|---------------------------------------------------------|-------------------|-------------------|
|                          | <u>1989</u>                                             | <u>1991</u>       | <u>1992</u>       |
| 1                        | NM*                                                     | $2.4 \times 10^3$ | NM                |
| 2                        | NM                                                      | $2.4 \times 10^3$ | $2.3 \times 10^2$ |
| 3                        | NM                                                      | $2.4 \times 10^3$ | $2.2 \times 10$   |
| 4                        | $5.4 \times 10^4$                                       | $3.5 \times 10^3$ | $2.2 \times 10^3$ |
| 5                        | $2.3 \times 10^4$                                       | $7.0 \times 10^3$ | $9.2 \times 10$   |
| 6                        | NM                                                      | $2.0 \times 10$   | $2.3 \times 10^2$ |
| 7                        | $1.3 \times 10^6$                                       | $1.3 \times 10^3$ | $1.6 \times 10^2$ |
| 8                        | NM                                                      | $2.4 \times 10^3$ | $3.5 \times 10$   |
| 9                        | NM                                                      | $5.4 \times 10^3$ | $3.5 \times 10$   |
| 10                       | NM                                                      | $1.4 \times 10^3$ | $2.2 \times 10^2$ |
| 11                       | NM                                                      | $3.5 \times 10^3$ | $5.4 \times 10$   |
| 12                       | NM                                                      | $1.6 \times 10^4$ | $4.6 \times 10$   |
| 13                       | NM                                                      | $5.4 \times 10^3$ | $3.3 \times 10^2$ |
| 14                       | NM                                                      | $3.5 \times 10^4$ | $3.5 \times 10$   |
| 15                       | NM                                                      | $3.5 \times 10^3$ | $7.9 \times 10$   |

\* NM = not measured.

Table 19

1992 Anaerobically Incubated Facultative Anaerobes and Sulfate Reducers

| <u>Trench Number</u> | <u>Number of Microorganisms per<br/>Milliliter of Groundwater</u> |                         |
|----------------------|-------------------------------------------------------------------|-------------------------|
|                      | <u>Facultative<br/>Anaerobes</u>                                  | <u>Sulfate Reducers</u> |
| 1                    | NM*                                                               | NM                      |
| 2                    | $2.7 \times 10^3$                                                 | 0                       |
| 3                    | $2.2 \times 10$                                                   | 0                       |
| 4                    | $2.2 \times 10^3$                                                 | 0                       |
| 5                    | $7.9 \times 10$                                                   | 0                       |
| 6                    | $2.3 \times 10$                                                   | 5                       |
| 7                    | $3.3 \times 10^3$                                                 | 0                       |
| 8                    | $6.3 \times 10$                                                   | 0                       |
| 9                    | $6.3 \times 10$                                                   | 0                       |
| 10                   | $2.2 \times 10^3$                                                 | 0                       |
| 11                   | $4.9 \times 10$                                                   | 0                       |
| 12                   | $4.6 \times 10$                                                   | 0                       |
| 13                   | $3.5 \times 10^2$                                                 | 0                       |
| 14                   | $6.3 \times 10$                                                   | 0                       |
| 15                   | $7.9 \times 10$                                                   | 0                       |

---

\* NM = not measured.

Table 20  
Recharge Trench Fungi Enumeration Results

| <u>Trench Number</u> | <u>Number of Fungi per 100 ml* of Groundwater</u> |             |             |             |
|----------------------|---------------------------------------------------|-------------|-------------|-------------|
|                      | <u>1989</u>                                       | <u>1990</u> | <u>1991</u> | <u>1992</u> |
| 1                    | NM**                                              | 94.0        | 28          | NM          |
| 2                    | NM                                                | 129.0       | 2           | 0           |
| 3                    | NM                                                | 188.0       | 18          | 30          |
| 4                    | 8.2                                               | 0.0         | 40          | 0           |
| 5                    | 9.9                                               | 140.0       | 18          | 8           |
| 6                    | NM                                                | NM          | 2           | 7           |
| 7                    | 4.0                                               | 4.0         | 6           | 1           |
| 8                    | NM                                                | 106.0       | 36          | 4           |
| 9                    | NM                                                | 47.0        | 38          | 4           |
| 10                   | NM                                                | 753.0       | NM          | 7           |
| 11                   | NM                                                | NM          | 182         | 5           |
| 12                   | NM                                                | NM          | 92          | 7           |
| 13                   | NM                                                | NM          | 56          | 40          |
| 14                   | NM                                                | NM          | 19          | 51          |
| 15                   | NM                                                | NM          | 62          | 500         |

---

\* Because of expected low population of fungi, 100 ml was analyzed.  
 \*\* NM = not measured.

Table 21

1990 Recharge Trench Iron BacteriaEnumeration Results

| <u>Trench<br/>Number</u> | <u>Number of Bacteria<br/>per 100 ml of Groundwater</u> |
|--------------------------|---------------------------------------------------------|
| 1                        | 0                                                       |
| 2                        | 0                                                       |
| 3                        | 2                                                       |
| 4                        | 0                                                       |
| 5                        | 1                                                       |
| 6                        | 0                                                       |
| 7                        | 0                                                       |
| 8                        | 1                                                       |
| 9                        | 0                                                       |
| 10                       | 0                                                       |

Table 22

Nutrient Analysis (Milligrams per Liter) of Recharge Trenches in 1990, 1991, and 1992

| Trench | Total Kjeldahl Nitrogen |        |       |       |       |       | Total Phosphorus |       |       | Orthophosphate |        |        | Nitrite Nitrogen |        |        | Nitrate Nitrogen |        |       | Ammonia Nitrogen |        |        |
|--------|-------------------------|--------|-------|-------|-------|-------|------------------|-------|-------|----------------|--------|--------|------------------|--------|--------|------------------|--------|-------|------------------|--------|--------|
|        | 1990                    | 1991   | 1992  | 1990  | 1991  | 1992  | 1990             | 1991  | 1992  | 1990           | 1991   | 1992   | 1990             | 1991   | 1992   | 1990             | 1991   | 1992  | 1990             | 1991   | 1992   |
|        |                         |        |       |       |       |       |                  |       |       |                |        |        |                  |        |        |                  |        |       |                  |        |        |
| 1      | 1.120                   | 1.400  | NM*   | 3.01  | 2.850 | NM    | 0.348            | 3.680 | NM    | <0.01          | 0.014  | NM     | <0.01            | 0.014  | NM     | 1.16             | 1.200  | NM    | <0.010           | <0.010 | NM     |
| 2      | 1.120                   | 0.362  | NM    | 1.91  | 0.153 | NM    | 0.029            | 0.168 | NM    | <0.01          | <0.005 | NM     | <0.01            | <0.005 | NM     | 1.14             | 1.190  | NM    | 0.673            | <0.010 | NM     |
| 3      | 1.040                   | 0.661  | 1.21  | 2.05  | 1.230 | 2.230 | 0.132            | 1.610 | 3.028 | <0.01          | 0.006  | 0.051  | <0.01            | 0.006  | 0.051  | 0.90             | 0.571  | 0.373 | <0.010           | <0.010 | 0.233  |
| 4      | 1.290                   | 0.403  | 0.823 | 7.64  | 0.644 | 1.770 | 0.380            | 0.851 | 2.751 | <0.01          | <0.005 | <0.010 | <0.01            | <0.005 | <0.010 | 0.73             | 1.240  | 1.11  | 0.022            | <0.010 | 0.143  |
| 5      | 1.080                   | 0.642  | 0.612 | 4.24  | 1.350 | 1.260 | 0.870            | 1.810 | 1.497 | <0.01          | <0.005 | <0.010 | <0.01            | <0.005 | <0.010 | 0.97             | 1.090  | 1.12  | 0.063            | <0.010 | 0.138  |
| 6      | 1.040                   | 0.539  | 1.160 | 5.52  | 3.800 | 0.779 | 0.410            | 5.070 | 0.806 | <0.01          | 0.022  | <0.010 | <0.01            | 0.022  | <0.010 | 0.97             | 0.481  | 1.23  | 0.017            | <0.010 | <0.010 |
| 7      | 0.996                   | 0.545  | 0.594 | 2.80  | 0.871 | 0.198 | 0.460            | 1.120 | 0.039 | <0.01          | <0.005 | <0.010 | <0.01            | <0.005 | <0.010 | 1.01             | 1.230  | 1.3   | 0.025            | <0.010 | 0.292  |
| 8      | 0.983                   | 0.778  | 1.000 | 3.40  | 3.900 | 2.950 | 0.249            | 4.960 | 3.999 | <0.01          | 0.019  | <0.010 | <0.01            | 0.019  | <0.010 | 0.92             | 0.427  | 1.33  | 0.016            | <0.010 | 0.115  |
| 9      | 1.160                   | 0.472  | 0.547 | 10.60 | 4.140 | 0.639 | 0.161            | 4.320 | 0.549 | <0.01          | 0.007  | <0.010 | <0.01            | 0.007  | <0.010 | 0.99             | 0.618  | 1.21  | <0.010           | <0.010 | 0.115  |
| 10     | 0.886                   | 0.575  | 0.452 | 2.53  | 1.580 | 0.451 | 0.161            | 1.870 | 0.308 | <0.01          | 0.015  | <0.010 | <0.01            | 0.015  | <0.010 | 0.10             | 0.674  | 1.16  | 0.692            | <0.010 | 0.101  |
| 11     | NIE                     | 0.641  | 0.350 | NIE   | 0.422 | 0.398 | NIE              | 0.352 | 0.285 | NIE            | <0.005 | <0.010 | NIE              | <0.005 | <0.010 | NIE              | 0.205  | 1.44  | NIE              | <0.010 | 0.055  |
| 12     | NIE                     | 0.574  | 0.295 | NIE   | 0.303 | 0.308 | NIE              | 0.274 | 0.256 | NIE            | <0.005 | <0.010 | NIE              | <0.005 | <0.010 | NIE              | 1.630  | 1.41  | NIE              | <0.010 | 0.049  |
| 13     | NIE                     | 0.707  | 0.490 | NIE   | 0.375 | 0.383 | NIE              | 0.251 | 0.294 | NIE            | <0.005 | <0.010 | NIE              | <0.005 | <0.010 | NIE              | 0.938  | 1.44  | NIE              | <0.010 | 0.052  |
| 14     | NIE                     | <0.050 | 0.508 | NIE   | 0.549 | 0.321 | NIE              | 0.377 | 0.218 | NIE            | <0.005 | <0.010 | NIE              | <0.005 | <0.010 | NIE              | 0.945  | 1.31  | NIE              | 0.169  | 0.092  |
| 15     | NIE                     | 0.602  | 0.606 | NIE   | 0.112 | 0.341 | NIE              | 0.062 | 0.258 | NIE            | 0.006  | <0.010 | NIE              | 0.006  | <0.010 | NIE              | <0.005 | 1.44  | NIE              | 0.089  | 0.079  |

\* NM = not measured; NIE = not in existence.

Table 23

Mean Levels of Nutrients and Metal Present in Recharge  
Trenches during 1990, 1991, and 1992

| <u>Parameter</u>              | <u>1990 Values* for<br/>Trenches 1-10</u> | <u>1991 Values* for<br/>Trenches 1-10</u> | <u>1991 Values* for<br/>Trenches 11-15</u> | <u>1992 Values* for<br/>Trenches 1-10</u> | <u>1992 Values* for<br/>Trenches 11-15</u> |
|-------------------------------|-------------------------------------------|-------------------------------------------|--------------------------------------------|-------------------------------------------|--------------------------------------------|
| Total Kjeldahl<br>Nitrogen    | 1.072 ± 0.035                             | 0.638 ± 0.093                             | 0.505 ± 0.128                              | 0.800 ± 0.097                             | 0.450 ± 0.050                              |
| Nitrate-Nitrogen              | 0.889 ± 0.096                             | 0.872 ± 0.109                             | 0.744 ± 0.292                              | 1.058 ± 0.144                             | 1.408 ± 0.022                              |
| Ammonia-Nitrogen              | 0.151 ± 0.089                             | 0                                         | 0.052 ± 0.034                              | 0.143 ± 0.029                             | 0.065 ± 0.008                              |
| Total Phosphorus              | 4.37 ± 0.888                              | 2.05 ± 0.470                              | 0.352 ± 0.072                              | 1.285 ± 0.317                             | 0.350 ± 0.016                              |
| Orthophosphate-<br>Phosphorus | 0.320 ± 0.075                             | 2.55 ± 0.568                              | 0.262 ± 0.055                              | 1.622 ± 0.483                             | 0.262 ± 0.012                              |
| Calcium                       | 154 ± 4.51                                | 136 ± 28.6                                | 159 ± 17.7                                 | 161.750 ± 2.370                           | 161.385 ± 1.641                            |
| Iron                          | 79.4 ± 30.3                               | 2303 ± 2046                               | 41.4 ± 23.3                                | 94.150 ± 25.897                           | 60.091 ± 19.921                            |
| Manganese                     | 0.062 ± 0.019                             | 1.03 ± 0.615                              | 1.64 ± 0.484                               | 0.181 ± 0.024                             | 0.245 ± 0.069                              |

\* Values given are milligrams per liter ± standard error.

Table 24

Calcium, Iron, and Manganese concentrations, mg/l

| <u>Trench<br/>Number</u> | <u>Calcium</u> |             |             | <u>Iron</u> |             |             | <u>Manganese</u> |             |             |
|--------------------------|----------------|-------------|-------------|-------------|-------------|-------------|------------------|-------------|-------------|
|                          | <u>1990</u>    | <u>1991</u> | <u>1992</u> | <u>1990</u> | <u>1991</u> | <u>1992</u> | <u>1990</u>      | <u>1991</u> | <u>1992</u> |
| 1                        | 146            | 186.0       | NM*         | 5.6         | 329.0       | NM          | 0.021            | 0.939       | NM          |
| 2                        | 151            | 131.0       | NM          | 54.1        | 330.0       | NM          | 0.081            | 0.498       | NM          |
| 3                        | 150            | 157.0       | 162         | 57.1        | 321.0       | 139.0       | 0.053            | 0.133       | 0.258       |
| 4                        | 184            | 120.0       | 169         | 139.0       | 80.3        | 86.3        | 0.124            | 0.260       | 0.123       |
| 5                        | 170            | 74.1        | 167         | 11.8        | 4.9         | 76.8        | 0.024            | 0.067       | 0.199       |
| 6                        | 138            | 37.7        | 152         | 45.9        | 27.3        | 63.8        | 0.013            | 0.167       | 0.219       |
| 7                        | 147            | 166.0       | 155         | 63.2        | 201.0       | 23.5        | 0.078            | 0.436       | 0.139       |
| 8                        | 164            | 136.0       | 172         | 80.2        | 1000.0      | 268.0       | 0.090            | 1.070       | 0.293       |
| 9                        | 146            | 338.0       | 161         | 328.0       | 20700.0     | 56.0        | 0.117            | 6.480       | 0.101       |
| 10                       | 145            | 13.3        | 156         | 8.64        | 39.8        | 39.8        | 0.020            | 0.262       | 0.113       |
| 11                       | NIE            | 130.0       | 164         | NIE         | 5.06        | 9.43        | NIE              | 0.521       | 0.202       |
| 12                       | NIE            | 131.0       | 154         | NIE         | 131.0       | 5.52        | NIE              | 1.520       | 0.246       |
| 13                       | NIE            | 130.0       | 166         | NIE         | 4.0         | 4.46        | NIE              | 1.960       | 1.080       |
| 14                       | NIE            | 205.0       | 162         | NIE         | 30.8        | 5.53        | NIE              | 0.888       | 0.052       |
| 15                       | NIE            | 200.0       | 158         | NIE         | 35.9        | 3.04        | NIE              | 3.300       | 0.162       |

\* NM = not measured; NIE = not in existence.

Table 25

Comparison of Microbial Numbers at Various Sampling Depths within  
the Piezometer Tube of Trench 12

| <u>Trench Location</u> |        | <u>Fermenters</u> | <u>Aerotolerant<br/>Heterotroph</u> | <u>Facultative<br/>Anaerobe</u> |
|------------------------|--------|-------------------|-------------------------------------|---------------------------------|
| 12                     | Top    | $1.7 \times 10^4$ | $7.9 \times 10^3$                   | $9.2 \times 10^3$               |
| 12                     | Middle | $4.9 \times 10^3$ | $9.2 \times 10^3$                   | $1.6 \times 10^4$               |
| 12                     | Bottom | $4.9 \times 10^4$ | $1.2 \times 10^2$                   | $2.8 \times 10^4$               |

APPENDIX A: UNREDUCED PARTICLE SIZE DETERMINATION DATA

## Basic Electrozone Technology

and

### Explanation of Report

The electric sensing zone analytical technique has developed rapidly over the past 20 years. In this technique, particles suspended in a conductive fluid flow serially through an orifice under a differential pressure. Electrodes are immersed on each side of the orifice as shown in Figure A1. As each particle passes through the aperture, it replaces its own volume of electrolyte within the aperture, momentarily changing the resistance value between the electrodes. This change produces a voltage pulse of short duration having a magnitude proportional to particle volume. The resulting series of pulses is electronically amplified, scaled, and counted. Raw data processing is performed by a PDP-1103 minicomputer in such a manner that a population histogram of 128 or 256 channels of information can be acquired. Acquired data is conditioned by applying calibration, extrapolation, volume (weight), or area conversions. Normalization of size and quantity axes to the types of scales required by the researcher is also possible.

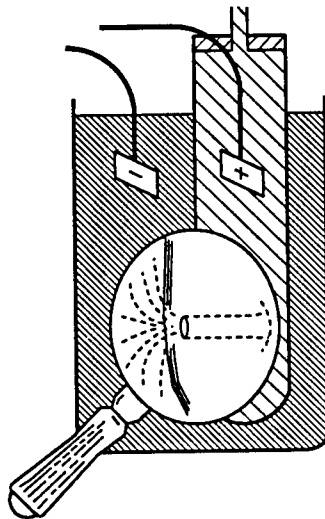


Figure A1. Basic detection mechanism

The conductive particle suspension medium is an important consideration in electrozone technology. Typically, aqueous isotonic saline (0.9 percent by weight) or a 4 percent by weight sodium pyrophosphate is used as a dispersing and particle suspension medium. For certain analyses that cannot be run in an

aqueous media, 4 percent weight/volume lithium chloride in isopropyl alcohol is effective.

Figure A2 is a cross section of the orifice shown in Figure A1. In this configuration, no particle is shown in the orifice. Since a constant current is established in the conductive liquid and through the sapphire orifice, a constant voltage potential is represented as the product of the current (I) and Resistance (R).

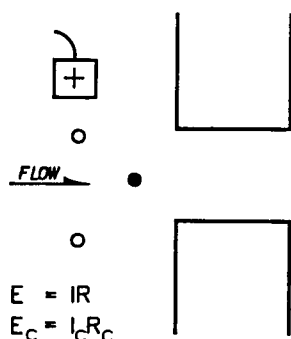


Figure A2. Cross section of orifice

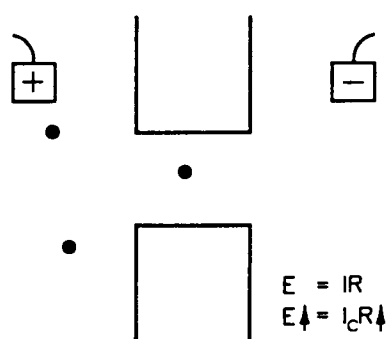


Figure A3. Cross section of orifice with particle

Figure A3 is the same condition except with a particle in the orifice or sensing zone. Since almost all particles act as insulators, the electrical resistance increases in the orifice. Under the conditions of a constant current and increased resistance, the product of these two must rise according to Ohm's Law. Since the particles traverse the orifice in about 20  $\mu$ sec, a voltage pulse is produced. The magnitude of this voltage pulse is proportional to the envelope volume of the particle. That is, a small particle yields a small voltage pulse, while a large particle yields a large pulse. The particle may be irregular in shape (spheres are seldom encountered), but since the volume of that particle has been measured, the diameter of a sphere of equal volume can be assigned to the particle. This method of expressing data as the "Diameter of a Sphere of Equal Volume" is used throughout all of "Fine Particle Technology."

Now that a way of measuring discrete events rapidly and accurately exists, presenting a representative population to the detector is all that has to be done. The technologist must sample the powder in a meaningful manner

and disperse the powder so that only individual particles are monitored by the instrument. When all of these conditions have been met, the suspension is analyzed by counting and sizing no fewer than 50,000 particles of the sample. Since the accuracy and precision of the measurement is affected by the sample size, counting such a high number of particles is elected. When a present number of particles has been acquired, the computer stops the analysis. At this point, pertinent calibration information is added from the keyboard, and the frequency (population) statistics are generated. The information is then converted to a volume (mass) basis, and these statistics are reported.

These are two classic methods of fine particle size analysis:

- a. Frequency distribution (Microscope counting).
- b. Mass distribution (Sieves of Andreason sedimentation).

In the first method, the number of particles of a specific size are tabulated by the microscopist. He scans a microscope slide while randomly searching for a particle in the prepared slide. When one is located, it is sized using an eyepiece micrometer and counted as a frequency of occurrence. Soon a frequency distribution is established for the sample of interest. The microscopist can now calculate the relative percent of particles within a given size interval, or he can sum the data and report the percentage greater than an indicated size. Table A1 is a brief example of this procedure. Following the statistical treatment, he can plot the data to locate the geometric median diameter and then derive other statistical parameters.

Table A1  
Example of Frequency Distribution Data

| <u>(<math>\mu\text{m}</math>)<br/>Particle Size<br/>Interval</u> | <u>d<br/>Mid<br/>Size</u> | <u>N<br/>Frequency of<br/>Occurrence</u> | <u><math>N \geq</math><br/>Cumulative<br/>Frequency</u> | <u>Cumulative<br/>Frequency<br/><math>\geq</math> Indicated %</u> |
|------------------------------------------------------------------|---------------------------|------------------------------------------|---------------------------------------------------------|-------------------------------------------------------------------|
| 1.0 - 1.4                                                        | 1.2                       | 10                                       | 100                                                     | 100                                                               |
| 1.4 - 2.0                                                        | 1.7                       | 15                                       | 90                                                      | 90                                                                |
| 2.0 - 2.8                                                        | 2.4                       | 50                                       | 75                                                      | 75                                                                |
| 2.8 - 4.0                                                        | 3.2                       | 15                                       | 25                                                      | 25                                                                |
| 4.0 - 5.6                                                        | 4.8                       | 10                                       | 10                                                      | 10                                                                |

What this data indicates is that 100 percent of the data measured is greater than or equal to 1.0  $\mu\text{m}$ . Ninety percent is greater than 1.4  $\mu\text{m}$  in diameter. This information when plotted on log-probability paper will yield a

straight line if the distribution is truly log normal (most samples are). Once that data is plotted, many statistical parameters are available to the analyst from standard formulas.

The second method of analysis is performed by a standard sieving technique. In this method, a known weight of dry sample is passed through nested precision sieves, and the weight percent retained on each sieve is calculated. Data is handled as above in Table A1 except data is expressed on a weight basis.

Since the Elzone technique determines the volume of individual particles, frequency data can be converted directly into mass or into area. Part of the job of the technologist is to determine which data format is appropriate to his application.

The Elzone data report is broken down as follows:

| <u>Page</u> | <u>Description</u>                                                                   |
|-------------|--------------------------------------------------------------------------------------|
| 1           | Frequency and Volume (Mass) Statistics                                               |
| 2           | Plot of Differential Frequency Distribution                                          |
| 3           | Tabulation of Channel Number, Diameter, and Count (Number of particles at that size) |
| 4           | Plot of Differential Mass Distribution                                               |
| 5           | Tabulation of Channel Number, Diameter, and Mass (relative units at that size)       |

Each page will be described below:

Page 1

The top section of this page is devoted to the volume (mass) statistics. The definitions of the terms used are as follows:

Volume Mode - The diameter size in microns of a spherical particle that contains the largest total mass value. It is always the peak of a distribution curve.

Volume Median -  
That point in the distribution curve that splits the data into two equal areas. One half is larger and one half is smaller than the indicated size on a mass basis.

Geometric Volume Mean -  
The size of an average particle calculated on a log basis.

Arithmetic Volume Mean -  
The size of an average particle calculated on an arithmetic scale.

+/-XXX - One sigma interval of standard deviation.

- (XX.XXX) - Coefficient of variation. This is the Standard Deviation divided by Mean multiplied by 100 to yield percentage.
- Skewness - This term denotes symmetry. If the curve is perfectly Gaussian, geometric skewness will be 0.00. If the curve is biased towards the fines, skewness will be negative.

For Plotting on Log Probability Paper -

This data is presented at 0.77 sigma intervals across a normal curve. It expresses the percent of mass at or greater than the indicated size from a cumulative curve.

The bottom of this page is just like the top except that it expresses the statistics on a frequency (count) basis.

Remember that the frequency basis will always be smaller than mass basis, because the mass data rises as a function of the diameter cubed. It takes one million one micron diameter particles by count to equal the same mass as a single one hundred micron diameter particle.

#### Page 2

This page is a plot of the frequency distribution as a function of size. Each plus (+) represents a specific number of particles at a given size. The size scale is a log scale, because a Gaussian curve plotted on an arithmetic scale would be skewed towards the larger sizes. Typically, data is plotted on a log scale.

#### Page 3

This is the "Tabulation" page by frequency (count). The number after "Total =" represents the number of particles counted in a particular analysis. This number is usually modified by some factor so that the graph routine will be represented as a full-scale plot. The tabulation informs the client how many particles (count) he could expect to find at any indicated micron size if he had counted the number of particles indicated under "Total In Tabulation."

#### Page 4

This page is a plot of the mass (volume) distribution mathematically derived from the count (frequency) distribution. It reveals the distribution of mass as a function of particle size. Usually, this data is more relevant to a particular industrial process.

#### Page 5

The last page in the report is a tabulation of data in a mass (volume) format. It is exactly like the count tabulation except that it provides the relative mass (grams, micrograms, pounds, or tons) of material at each micron

size if one had a pile of material weighing the same as that figure displayed under "Total -."

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

Job No: ID-14966

Technician: L.W

Special Comments

geometric mean size = 15.79  
 standard deviation = 57.33  
 median size = 27.61

arithmetic mean size = 44.87  
 coeff.of variation = 363.2  
 mode size = 88.11

Total = 423535030

Coincidence Corrected: No

Extrapolated above: 1.060

VOLUME DISTRIBUTION DATA

| Chnl | Size  | Volume  | % >    | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   |
|------|-------|---------|--------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|-------|
| 1    | 0.298 | 15821   | 100.00 | 33   | 1.619 | 5411643 | 87.19 | 65   | 8.791 | 1164338 | 60.44 | 97   | 47.75 | 6072993 | 38.38 |
| 2    | 0.314 | 21822   | 99.99  | 34   | 1.706 | 5506658 | 85.91 | 66   | 9.269 | 1235325 | 60.15 | 98   | 50.34 | 6207510 | 36.93 |
| 3    | 0.331 | 29829   | 99.99  | 35   | 1.799 | 5589736 | 84.60 | 67   | 9.772 | 1294188 | 59.86 | 99   | 53.08 | 6416115 | 35.44 |
| 4    | 0.349 | 40406   | 99.98  | 36   | 1.897 | 5703100 | 83.26 | 68   | 10.30 | 1335574 | 59.55 | 100  | 55.96 | 6583898 | 33.91 |
| 5    | 0.368 | 54243   | 99.97  | 37   | 2.000 | 5665974 | 81.92 | 69   | 10.86 | 1477464 | 59.21 | 101  | 59.00 | 6709598 | 32.34 |
| 6    | 0.388 | 72163   | 99.95  | 38   | 2.108 | 5612183 | 80.59 | 70   | 11.45 | 1477103 | 58.87 | 102  | 62.20 | 6718553 | 30.76 |
| 7    | 0.409 | 95140   | 99.93  | 39   | 2.223 | 5419183 | 79.29 | 71   | 12.07 | 1558558 | 58.51 | 103  | 65.58 | 6900259 | 29.15 |
| 8    | 0.431 | 124306  | 99.91  | 40   | 2.344 | 5181590 | 78.03 | 72   | 12.73 | 1672970 | 58.13 | 104  | 69.14 | 7086558 | 27.50 |
| 9    | 0.455 | 160953  | 99.87  | 41   | 2.471 | 5156018 | 76.81 | 73   | 13.42 | 1768220 | 57.72 | 105  | 72.90 | 7126717 | 25.82 |
| 10   | 0.480 | 206529  | 99.83  | 42   | 2.605 | 4958740 | 75.62 | 74   | 14.15 | 1825678 | 57.30 | 106  | 76.86 | 7233109 | 24.12 |
| 11   | 0.506 | 262629  | 99.78  | 43   | 2.747 | 4824927 | 74.46 | 75   | 14.92 | 1893283 | 56.86 | 107  | 81.03 | 7300450 | 22.41 |
| 12   | 0.533 | 330965  | 99.71  | 44   | 2.896 | 4526966 | 73.36 | 76   | 15.73 | 2003765 | 56.40 | 108  | 85.43 | 7310379 | 20.68 |
| 13   | 0.562 | 413332  | 99.62  | 45   | 3.053 | 4449241 | 72.30 | 77   | 16.58 | 2042117 | 55.92 | 109  | 90.07 | 7325533 | 18.96 |
| 14   | 0.593 | 511558  | 99.51  | 46   | 3.219 | 4328051 | 71.26 | 78   | 17.48 | 2169702 | 55.42 | 110  | 94.96 | 7235531 | 17.24 |
| 15   | 0.625 | 627433  | 99.37  | 47   | 3.394 | 4062762 | 70.27 | 79   | 18.43 | 2261290 | 54.90 | 111  | 100.1 | 7097169 | 15.54 |
| 16   | 0.659 | 762638  | 99.21  | 48   | 3.578 | 3906436 | 69.33 | 80   | 19.43 | 2302687 | 54.36 | 112  | 105.6 | 6921355 | 13.89 |
| 17   | 0.695 | 918644  | 99.01  | 49   | 3.772 | 3768094 | 68.43 | 81   | 20.49 | 2425946 | 53.80 | 113  | 111.3 | 6777164 | 12.27 |
| 18   | 0.732 | 1096615 | 98.77  | 50   | 3.977 | 3683640 | 67.55 | 82   | 21.60 | 2588653 | 53.21 | 114  | 117.3 | 6551842 | 10.70 |
| 19   | 0.772 | 1297296 | 98.49  | 51   | 4.193 | 3270074 | 66.72 | 83   | 22.77 | 2729135 | 52.58 | 115  | 123.7 | 6184155 | 9.194 |
| 20   | 0.814 | 1520903 | 98.16  | 52   | 4.421 | 3023636 | 65.98 | 84   | 24.01 | 2864561 | 51.92 | 116  | 130.4 | 5885811 | 7.768 |
| 21   | 0.858 | 1767023 | 97.77  | 53   | 4.661 | 2855995 | 65.29 | 85   | 25.32 | 3009126 | 51.23 | 117  | 137.5 | 5436805 | 6.431 |
| 22   | 0.905 | 2034514 | 97.32  | 54   | 4.914 | 2637442 | 64.64 | 86   | 26.69 | 3201945 | 50.50 | 118  | 145.0 | 4887577 | 5.211 |
| 23   | 0.954 | 2321437 | 96.81  | 55   | 5.181 | 2497031 | 64.03 | 87   | 28.14 | 3454516 | 49.71 | 119  | 152.8 | 4323477 | 4.123 |
| 24   | 1.006 | 2625012 | 96.23  | 56   | 5.462 | 2227798 | 63.47 | 88   | 29.67 | 3756016 | 48.86 | 120  | 161.1 | 3981702 | 3.142 |
| 25   | 1.060 | 2941599 | 95.57  | 57   | 5.759 | 1911858 | 62.98 | 89   | 31.28 | 3987257 | 47.95 | 121  | 169.9 | 3448868 | 2.264 |
| 26   | 1.118 | 3489451 | 94.81  | 58   | 6.071 | 1673397 | 62.56 | 90   | 32.98 | 4169902 | 46.98 | 122  | 179.1 | 2915380 | 1.512 |
| 27   | 1.179 | 3904370 | 93.94  | 59   | 6.401 | 1502803 | 62.19 | 91   | 34.77 | 4495004 | 45.96 | 123  | 188.8 | 2125980 | 0.915 |
| 28   | 1.243 | 4211486 | 92.98  | 60   | 6.749 | 1323991 | 61.85 | 92   | 36.66 | 4832878 | 44.86 | 124  | 199.1 | 1376207 | 0.501 |
| 29   | 1.310 | 4574031 | 91.95  | 61   | 7.115 | 1271012 | 61.54 | 93   | 38.65 | 5082888 | 43.69 | 125  | 209.9 | 888252  | 0.233 |
| 30   | 1.381 | 4667224 | 90.85  | 62   | 7.502 | 1171705 | 61.26 | 94   | 40.75 | 5388852 | 42.46 | 126  | 221.3 | 457407  | 0.073 |
| 31   | 1.456 | 5105207 | 89.70  | 63   | 7.909 | 1104715 | 60.99 | 95   | 42.96 | 5657703 | 41.15 | 127  | 233.3 | 78463   | 0.009 |
| 32   | 1.535 | 5360723 | 88.47  | 64   | 8.339 | 1192309 | 60.72 | 96   | 45.29 | 5859559 | 39.79 | 128  | 246.0 | 0       | 0.000 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 MAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

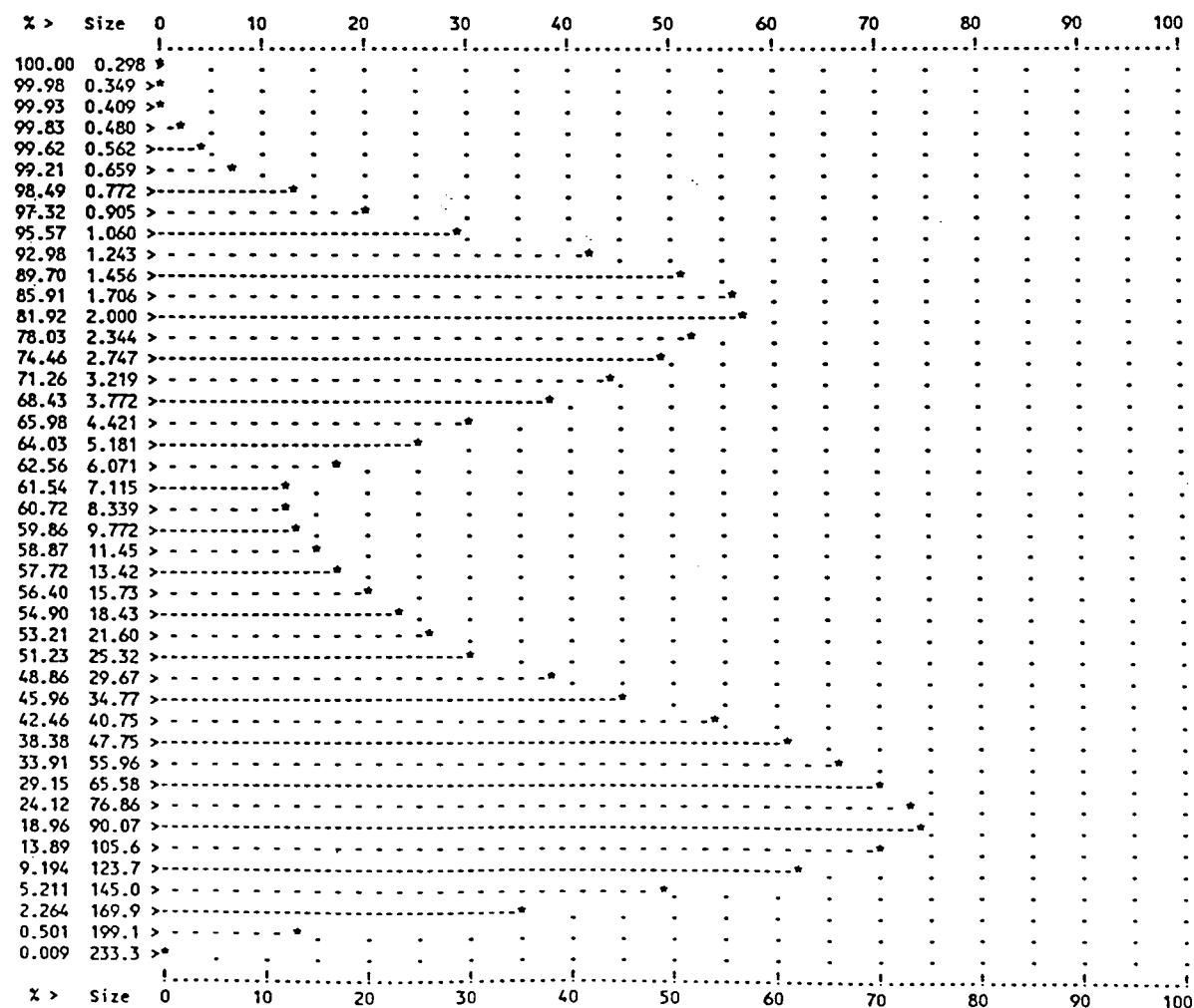
Job No: ID-14966

Technician: L.W

Special Comments

Low at 1 0.298 15821 High at 128 246.0 0 Top of scale is 9830400

Graph of DIAM Size vs. Differential Volume From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

Job No: ID-14966

Technician: L.W

Special Comments

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | above | 218.3 um |
| 1.00%  | Volm | above | 187.0 um |
| 6.00%  | Volm | above | 139.6 um |
| 22.00% | Volm | above | 81.88 um |
| 50.00% | Volm | above | 27.60 um |
| 78.00% | Volm | above | 2.344 um |
| 94.00% | Volm | above | 1.173 um |
| 99.00% | Volm | above | 0.696 um |
| 99.90% | Volm | above | 0.437 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

Job No: ID-14966

Technician: L.W

Special Comments

geometric mean size = 0.838  
 standard deviation = 0.644  
 median size = 0.822

arithmetic mean size = 0.966  
 coeff.of variation = 76.83  
 mode size = 0.794

Total = 3967213

Coincidence Corrected: No

Extrapolated above: 1.060

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|
| 1    | 0.298 | 32554  | 99.60 | 29   | 1.310 | 110790 | 19.46 | 57   | 5.759 | 545    | 0.068 | 85   | 25.32 | 10     | 0.002 |
| 2    | 0.314 | 38315  | 98.70 | 30   | 1.381 | 96463  | 16.85 | 58   | 6.071 | 407    | 0.056 | 86   | 26.69 | 9      | 0.002 |
| 3    | 0.331 | 44690  | 97.66 | 31   | 1.456 | 90036  | 14.50 | 59   | 6.401 | 312    | 0.047 | 87   | 28.14 | 8      | 0.002 |
| 4    | 0.349 | 51656  | 96.44 | 32   | 1.535 | 80673  | 12.35 | 60   | 6.749 | 235    | 0.040 | 88   | 29.67 | 7      | 0.002 |
| 5    | 0.368 | 59172  | 95.05 | 33   | 1.619 | 69492  | 10.45 | 61   | 7.115 | 192    | 0.035 | 89   | 31.28 | 6      | 0.001 |
| 6    | 0.388 | 67172  | 93.46 | 34   | 1.706 | 60338  | 8.814 | 62   | 7.502 | 151    | 0.030 | 90   | 32.98 | 5      | 0.001 |
| 7    | 0.409 | 75568  | 91.66 | 35   | 1.799 | 52263  | 7.393 | 63   | 7.909 | 122    | 0.027 | 91   | 34.77 | 4      | 0.001 |
| 8    | 0.431 | 84250  | 89.65 | 36   | 1.897 | 45501  | 6.160 | 64   | 8.339 | 112    | 0.024 | 92   | 36.66 | 3      | 0.001 |
| 9    | 0.455 | 93084  | 87.41 | 37   | 2.000 | 38573  | 5.099 | 65   | 8.791 | 93     | 0.021 | 93   | 38.65 | 2      | 0.001 |
| 10   | 0.480 | 101920 | 84.96 | 38   | 2.108 | 32602  | 4.201 | 66   | 9.269 | 84     | 0.019 | 94   | 40.75 | 1      | 0.001 |
| 11   | 0.506 | 110592 | 82.28 | 39   | 2.223 | 26862  | 3.451 | 67   | 9.772 | 76     | 0.017 | 95   | 42.96 | 0      | 0.001 |
| 12   | 0.533 | 118922 | 79.39 | 40   | 2.344 | 21917  | 2.835 | 68   | 10.30 | 66     | 0.015 | 96   | 45.29 | 0      | 0.001 |
| 13   | 0.562 | 126730 | 76.30 | 41   | 2.471 | 18609  | 2.324 | 69   | 10.86 | 63     | 0.014 | 97   | 47.75 | 0      | 0.000 |
| 14   | 0.593 | 133837 | 73.01 | 42   | 2.605 | 15272  | 1.896 | 70   | 11.45 | 54     | 0.012 | 98   | 50.34 | 0      | 0.000 |
| 15   | 0.625 | 140072 | 69.56 | 43   | 2.747 | 12680  | 1.543 | 71   | 12.07 | 48     | 0.011 | 99   | 53.08 | 0      | 0.000 |
| 16   | 0.659 | 145279 | 65.97 | 44   | 2.896 | 10151  | 1.255 | 72   | 12.73 | 44     | 0.010 | 100  | 55.96 | 0      | 0.000 |
| 17   | 0.695 | 149325 | 62.25 | 45   | 3.053 | 8513   | 1.020 | 73   | 13.42 | 40     | 0.009 | 101  | 59.00 | 0      | 0.000 |
| 18   | 0.732 | 152104 | 58.45 | 46   | 3.219 | 7067   | 0.823 | 74   | 14.15 | 35     | 0.008 | 102  | 62.20 | 0      | 0.000 |
| 19   | 0.772 | 153542 | 54.60 | 47   | 3.394 | 5660   | 0.662 | 75   | 14.92 | 31     | 0.007 | 103  | 65.58 | 0      | 0.000 |
| 20   | 0.814 | 153600 | 50.73 | 48   | 3.578 | 4644   | 0.532 | 76   | 15.73 | 28     | 0.006 | 104  | 69.14 | 0      | 0.000 |
| 21   | 0.858 | 152277 | 46.88 | 49   | 3.772 | 3822   | 0.426 | 77   | 16.58 | 24     | 0.006 | 105  | 72.90 | 0      | 0.000 |
| 22   | 0.905 | 149607 | 43.07 | 50   | 3.977 | 3189   | 0.337 | 78   | 17.48 | 22     | 0.005 | 106  | 76.86 | 0      | 0.000 |
| 23   | 0.954 | 145663 | 39.35 | 51   | 4.193 | 2415   | 0.266 | 79   | 18.43 | 20     | 0.004 | 107  | 81.03 | 0      | 0.000 |
| 24   | 1.006 | 140548 | 35.74 | 52   | 4.421 | 1906   | 0.212 | 80   | 19.43 | 17     | 0.004 | 108  | 85.43 | 0      | 0.000 |
| 25   | 1.060 | 134394 | 32.28 | 53   | 4.661 | 1536   | 0.168 | 81   | 20.49 | 15     | 0.004 | 109  | 90.07 | 0      | 0.000 |
| 26   | 1.118 | 136036 | 28.87 | 54   | 4.914 | 1210   | 0.134 | 82   | 21.60 | 14     | 0.003 | 110  | 94.96 | 0      | 0.000 |
| 27   | 1.179 | 129882 | 25.51 | 55   | 5.181 | 978    | 0.106 | 83   | 22.77 | 13     | 0.003 |      |       |        |       |
| 28   | 1.243 | 119546 | 22.37 | 56   | 5.462 | 744    | 0.084 | 84   | 24.01 | 11     | 0.003 |      |       |        |       |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

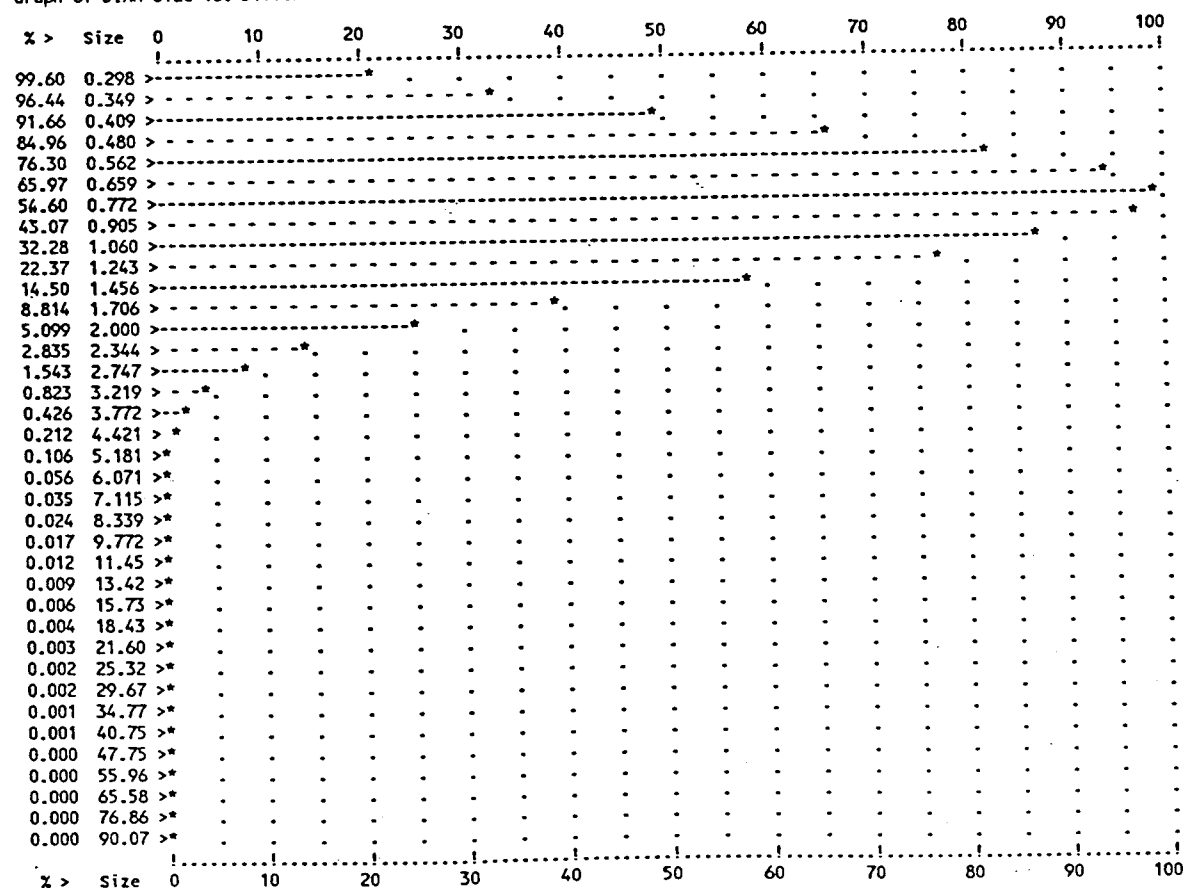
Job No: ID-14966

Technician: L.W

Special Comments

Low at 1 0.298 32554 High at 110 94.96 0 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 109 skip: 2



PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 1:01:00 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-5

Job No: ID-14966

Technician: L.W

Special Comments

PERCENTILES

|        |      |       |           |
|--------|------|-------|-----------|
| 0.10%  | Popl | above | 5.239 um  |
| 1.00%  | Popl | above | 3.063 um  |
| 6.00%  | Popl | above | 1.908 um  |
| 22.00% | Popl | above | 1.248 um  |
| 50.00% | Popl | above | 0.821 um— |
| 78.00% | Popl | above | 0.545 um— |
| 94.00% | Popl | above | 0.381 um  |
| 99.00% | Popl | above | 0.309 um  |
| 99.90% | Popl | above | 0.291 um  |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-4

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 54.13  
 standard deviation = 60.60  
 median size = 71.58

arithmetic mean size = 78.56  
 coeff.of variation = 111.9  
 mode size = 123.4

Total = 281215512

Coincidence Corrected: No

VOLUME DISTRIBUTION DATA

| Chnl | Size  | Volume | % >    | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   |
|------|-------|--------|--------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|-------|
| 1    | 1.000 | 0      | 100.0  | 33   | 4.118 | 306152  | 98.89 | 65   | 16.95 | 1865941 | 83.71 | 97   | 69.81 | 4827265 | 50.99 |
| 2    | 1.045 | 6911   | 100.00 | 34   | 4.304 | 344786  | 98.77 | 66   | 17.72 | 1874656 | 83.04 | 98   | 72.96 | 4922353 | 49.25 |
| 3    | 1.092 | 13822  | 100.00 | 35   | 4.498 | 372949  | 98.65 | 67   | 18.52 | 1865941 | 82.38 | 99   | 76.26 | 5155421 | 47.46 |
| 4    | 1.142 | 20733  | 99.99  | 36   | 4.702 | 412901  | 98.51 | 68   | 19.36 | 1867275 | 81.71 | 100  | 79.71 | 5355535 | 45.59 |
| 5    | 1.194 | 27644  | 99.98  | 37   | 4.914 | 460413  | 98.35 | 69   | 20.23 | 1878322 | 81.05 | 101  | 83.32 | 5636388 | 43.64 |
| 6    | 1.247 | 31099  | 99.97  | 38   | 5.137 | 531983  | 98.17 | 70   | 21.15 | 1886778 | 80.38 | 102  | 87.08 | 5925589 | 41.58 |
| 7    | 1.304 | 36471  | 99.96  | 39   | 5.369 | 585218  | 97.98 | 71   | 22.11 | 1896207 | 79.71 | 103  | 91.02 | 6058473 | 39.45 |
| 8    | 1.363 | 38958  | 99.94  | 40   | 5.612 | 658942  | 97.76 | 72   | 23.11 | 1935033 | 79.03 | 104  | 95.14 | 6299965 | 37.26 |
| 9    | 1.424 | 43952  | 99.93  | 41   | 5.865 | 760814  | 97.50 | 73   | 24.15 | 1973148 | 78.33 | 105  | 99.44 | 6542313 | 34.97 |
| 10   | 1.489 | 47752  | 99.91  | 42   | 6.131 | 833954  | 97.22 | 74   | 25.24 | 2071490 | 77.61 | 106  | 103.9 | 6850599 | 32.59 |
| 11   | 1.556 | 49483  | 99.90  | 43   | 6.408 | 920552  | 96.91 | 75   | 26.38 | 2191483 | 76.85 | 107  | 108.6 | 7021468 | 30.13 |
| 12   | 1.627 | 51832  | 99.88  | 44   | 6.698 | 1029300 | 96.56 | 76   | 27.58 | 2317720 | 76.05 | 108  | 113.5 | 7194496 | 27.60 |
| 13   | 1.700 | 56243  | 99.86  | 45   | 7.000 | 1128063 | 96.18 | 77   | 28.82 | 2381448 | 75.22 | 109  | 118.7 | 7246062 | 25.03 |
| 14   | 1.777 | 59950  | 99.84  | 46   | 7.317 | 1236812 | 95.76 | 78   | 30.13 | 2426416 | 74.36 | 110  | 124.1 | 7325533 | 22.44 |
| 15   | 1.857 | 68012  | 99.82  | 47   | 7.648 | 1332224 | 95.30 | 79   | 31.49 | 2581031 | 73.47 | 111  | 129.7 | 7221505 | 19.86 |
| 16   | 1.941 | 74792  | 99.79  | 48   | 7.994 | 1439092 | 94.81 | 80   | 32.91 | 2692284 | 72.54 | 112  | 135.5 | 6803050 | 17.36 |
| 17   | 2.029 | 76020  | 99.76  | 49   | 8.355 | 1516811 | 94.28 | 81   | 34.40 | 2709070 | 71.58 | 113  | 141.7 | 6512813 | 14.99 |
| 18   | 2.121 | 85854  | 99.73  | 50   | 8.733 | 1658615 | 93.72 | 82   | 35.96 | 2852014 | 70.59 | 114  | 148.1 | 6092864 | 12.75 |
| 19   | 2.217 | 86472  | 99.70  | 51   | 9.128 | 1732038 | 93.12 | 83   | 37.58 | 2965005 | 69.55 | 115  | 154.8 | 5422636 | 10.70 |
| 20   | 2.317 | 90991  | 99.67  | 52   | 9.541 | 1802846 | 92.49 | 84   | 39.28 | 3071056 | 68.48 | 116  | 161.8 | 5023716 | 8.844 |
| 21   | 2.422 | 96753  | 99.64  | 53   | 9.972 | 1865941 | 91.84 | 85   | 41.06 | 3174266 | 67.37 | 117  | 169.1 | 4535838 | 7.143 |
| 22   | 2.531 | 103663 | 99.60  | 54   | 10.42 | 1921229 | 91.16 | 86   | 42.92 | 3261942 | 66.23 | 118  | 176.7 | 3960719 | 5.632 |
| 23   | 2.646 | 110574 | 99.57  | 55   | 10.89 | 1948872 | 90.47 | 87   | 44.86 | 3373932 | 65.05 | 119  | 184.7 | 3648952 | 4.278 |
| 24   | 2.765 | 123954 | 99.52  | 56   | 11.39 | 1948872 | 89.78 | 88   | 46.89 | 3445751 | 63.83 | 120  | 193.1 | 3096080 | 3.078 |
| 25   | 2.891 | 136547 | 99.48  | 57   | 11.90 | 1954956 | 89.09 | 89   | 49.01 | 3548006 | 62.59 | 121  | 201.8 | 2721749 | 2.042 |
| 26   | 3.021 | 149684 | 99.43  | 58   | 12.44 | 1921229 | 88.40 | 90   | 51.22 | 3654433 | 61.31 | 122  | 210.9 | 1879763 | 1.223 |
| 27   | 3.158 | 168570 | 99.37  | 59   | 13.00 | 1907407 | 87.72 | 91   | 53.54 | 3812838 | 59.98 | 123  | 220.4 | 1271604 | 0.661 |
| 28   | 3.301 | 182409 | 99.31  | 60   | 13.59 | 1893585 | 87.04 | 92   | 55.96 | 3899087 | 58.61 | 124  | 230.4 | 663446  | 0.316 |
| 29   | 3.450 | 199136 | 99.24  | 61   | 14.20 | 1879763 | 86.37 | 93   | 58.49 | 3977245 | 57.21 | 125  | 240.8 | 387010  | 0.129 |
| 30   | 3.606 | 220615 | 99.17  | 62   | 14.85 | 1879763 | 85.70 | 94   | 61.13 | 4169398 | 55.76 | 126  | 251.7 | 165861  | 0.030 |
| 31   | 3.769 | 241544 | 99.08  | 63   | 15.52 | 1865941 | 85.04 | 95   | 63.90 | 4372025 | 54.24 | 127  | 263.1 | 0       | 0.000 |
| 32   | 3.939 | 272135 | 98.99  | 64   | 16.22 | 1865941 | 84.37 | 96   | 66.79 | 4564666 | 52.66 |      |       |         |       |

PARTICLE SIZE ANALYSIS BY ELETRONIC METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-4

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

|                             |                              |
|-----------------------------|------------------------------|
| geometric mean size = 2.402 | arithmetic mean size = 3.244 |
| standard deviation = 3.983  | coeff.of variation = 165.9   |
| median size = 1.942         | mode size = 1.287            |

Total = 3500511

Coincidence Corrected: No

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|
| 1    | 1.000 | 0      | 100.0 | 32   | 3.939 | 41562  | 23.01 | 63   | 15.52 | 4664   | 1.136 | 94   | 61.13 | 171    | 0.046 |
| 2    | 1.045 | 56506  | 99.20 | 33   | 4.118 | 40946  | 21.83 | 64   | 16.22 | 4082   | 1.011 | 95   | 63.90 | 156    | 0.041 |
| 3    | 1.092 | 98967  | 96.99 | 34   | 4.304 | 40383  | 20.67 | 65   | 16.95 | 3573   | 0.902 | 96   | 66.79 | 142    | 0.037 |
| 4    | 1.142 | 130008 | 93.72 | 35   | 4.498 | 38252  | 19.55 | 66   | 17.72 | 3143   | 0.806 | 97   | 69.81 | 132    | 0.033 |
| 5    | 1.194 | 151806 | 89.70 | 36   | 4.702 | 37089  | 18.47 | 67   | 18.52 | 2742   | 0.722 | 98   | 72.96 | 117    | 0.029 |
| 6    | 1.247 | 149557 | 85.40 | 37   | 4.914 | 36219  | 17.42 | 68   | 19.36 | 2405   | 0.648 | 99   | 76.26 | 108    | 0.026 |
| 7    | 1.304 | 153600 | 81.07 | 38   | 5.137 | 36649  | 16.38 | 69   | 20.23 | 2117   | 0.584 | 100  | 79.71 | 98     | 0.023 |
| 8    | 1.363 | 143686 | 76.82 | 39   | 5.369 | 35304  | 15.35 | 70   | 21.15 | 1862   | 0.527 | 101  | 83.32 | 93     | 0.020 |
| 9    | 1.424 | 141961 | 72.74 | 40   | 5.612 | 34816  | 14.35 | 71   | 22.11 | 1638   | 0.477 | 102  | 87.08 | 83     | 0.018 |
| 10   | 1.489 | 135073 | 68.78 | 41   | 5.865 | 35202  | 13.35 | 72   | 23.11 | 1467   | 0.432 | 103  | 91.02 | 73     | 0.015 |
| 11   | 1.556 | 122578 | 65.10 | 42   | 6.131 | 33794  | 12.37 | 73   | 24.15 | 1310   | 0.393 | 104  | 95.14 | 68     | 0.013 |
| 12   | 1.627 | 112444 | 61.74 | 43   | 6.408 | 32665  | 11.42 | 74   | 25.24 | 1203   | 0.357 | 105  | 99.44 | 64     | 0.012 |
| 13   | 1.700 | 106852 | 58.61 | 44   | 6.698 | 31985  | 10.49 | 75   | 26.38 | 1115   | 0.324 | 106  | 103.9 | 59     | 0.010 |
| 14   | 1.777 | 99739  | 55.65 | 45   | 7.000 | 30699  | 9.597 | 76   | 27.58 | 1031   | 0.293 | 107  | 108.6 | 49     | 0.008 |
| 15   | 1.857 | 99094  | 52.81 | 46   | 7.317 | 29477  | 8.738 | 77   | 28.82 | 929    | 0.265 | 108  | 113.5 | 44     | 0.007 |
| 16   | 1.941 | 95432  | 50.03 | 47   | 7.648 | 27806  | 7.919 | 78   | 30.13 | 826    | 0.240 | 109  | 118.7 | 39     | 0.006 |
| 17   | 2.029 | 84947  | 47.46 | 48   | 7.994 | 26305  | 7.146 | 79   | 31.49 | 772    | 0.217 | 110  | 124.1 | 34     | 0.005 |
| 18   | 2.121 | 84013  | 45.04 | 49   | 8.355 | 24281  | 6.423 | 80   | 32.91 | 704    | 0.196 | 111  | 129.7 | 29     | 0.004 |
| 19   | 2.217 | 74104  | 42.78 | 50   | 8.733 | 23249  | 5.744 | 81   | 34.40 | 621    | 0.177 | 112  | 135.5 | 24     | 0.003 |
| 20   | 2.317 | 68292  | 40.75 | 51   | 9.128 | 21265  | 5.108 | 82   | 35.96 | 572    | 0.160 | 113  | 141.7 | 20     | 0.002 |
| 21   | 2.422 | 63589  | 38.86 | 52   | 9.541 | 19383  | 4.527 | 83   | 37.58 | 523    | 0.144 | 114  | 148.1 | 20     | 0.002 |
| 22   | 2.531 | 59668  | 37.10 | 53   | 9.972 | 17569  | 3.999 | 84   | 39.28 | 474    | 0.130 | 115  | 154.8 | 15     | 0.001 |
| 23   | 2.646 | 55738  | 35.45 | 54   | 10.42 | 15843  | 3.521 | 85   | 41.06 | 430    | 0.117 | 116  | 161.8 | 10     | 0.001 |
| 24   | 2.765 | 54716  | 33.88 | 55   | 10.89 | 14074  | 3.094 | 86   | 42.92 | 386    | 0.105 | 117  | 169.1 | 10     | 0.001 |
| 25   | 2.891 | 52785  | 32.34 | 56   | 11.39 | 12324  | 2.717 | 87   | 44.86 | 347    | 0.095 | 118  | 176.7 | 5      | 0.001 |
| 26   | 3.021 | 50674  | 30.86 | 57   | 11.90 | 10828  | 2.386 | 88   | 46.89 | 313    | 0.086 | 119  | 184.7 | 5      | 0.000 |
| 27   | 3.158 | 49980  | 29.42 | 58   | 12.44 | 9317   | 2.098 | 89   | 49.01 | 284    | 0.077 | 120  | 193.1 | 5      | 0.000 |
| 28   | 3.301 | 47359  | 28.03 | 59   | 13.00 | 8100   | 1.849 | 90   | 51.22 | 254    | 0.069 | 121  | 201.8 | 5      | 0.000 |
| 29   | 3.450 | 45282  | 26.71 | 60   | 13.59 | 7044   | 1.632 | 91   | 53.54 | 230    | 0.062 | 122  | 210.9 | 0      | 0.000 |
| 30   | 3.606 | 43933  | 25.43 | 61   | 14.20 | 6125   | 1.444 | 92   | 55.96 | 205    | 0.056 |      |       |        |       |
| 31   | 3.769 | 42124  | 24.21 | 62   | 14.85 | 5363   | 1.280 | 93   | 58.49 | 186    | 0.051 |      |       |        |       |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-4

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | above | 242.7 um |
| 1.00%  | Volm | above | 213.7 um |
| 6.00%  | Volm | above | 174.6 um |
| 22.00% | Volm | above | 124.8 um |
| 50.00% | Volm | above | 71.58 um |
| 78.00% | Volm | above | 24.61 um |
| 94.00% | Volm | above | 8.548 um |
| 99.00% | Volm | above | 3.922 um |
| 99.90% | Volm | above | 1.541 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RHA-4

Job No: ID-14966

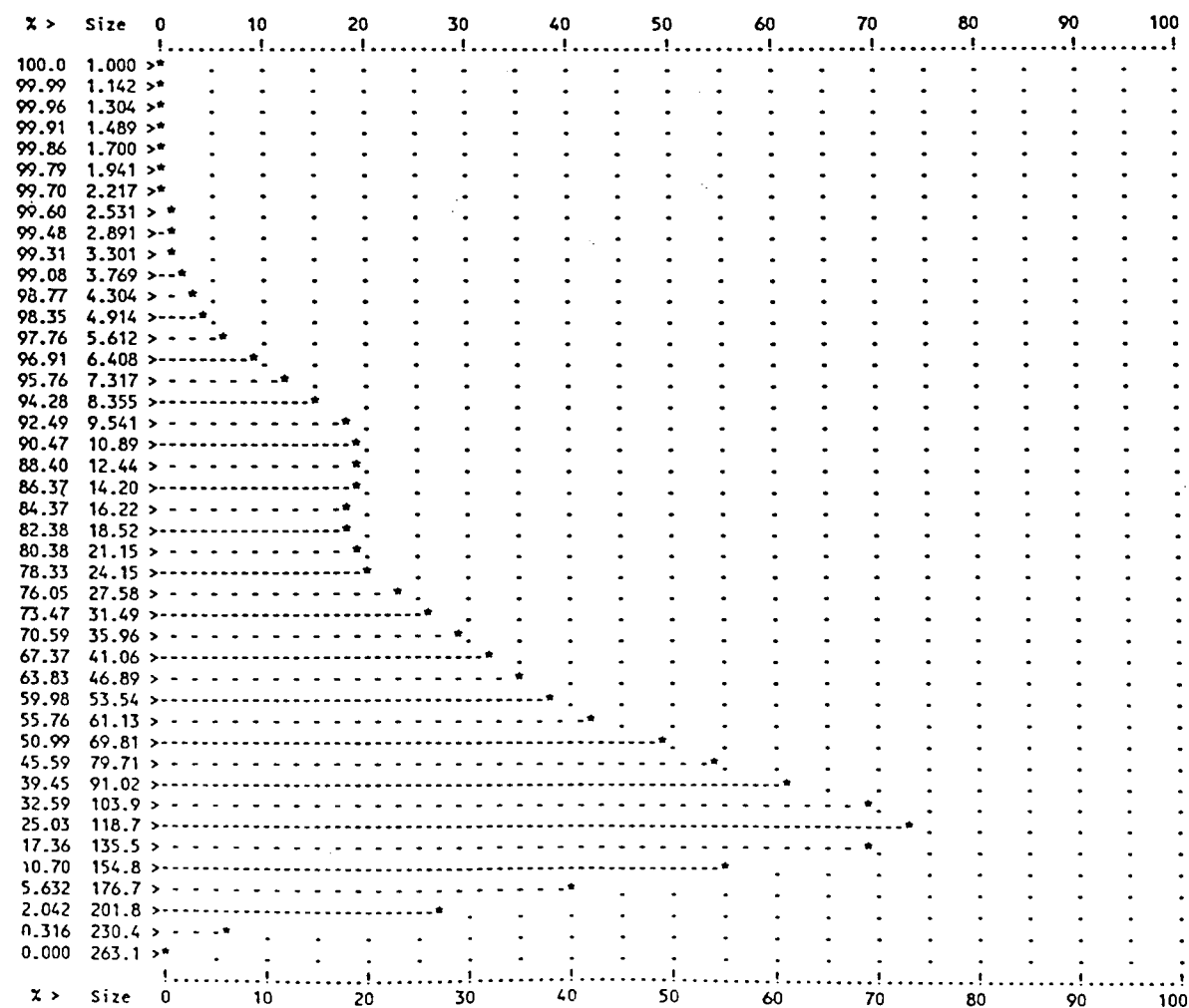
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 1.000 0 High at 127 263.1 0 Top of scale is 9830400

Graph of DIAM Size vs. Differential Volume From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-4

Job No: ID-14966

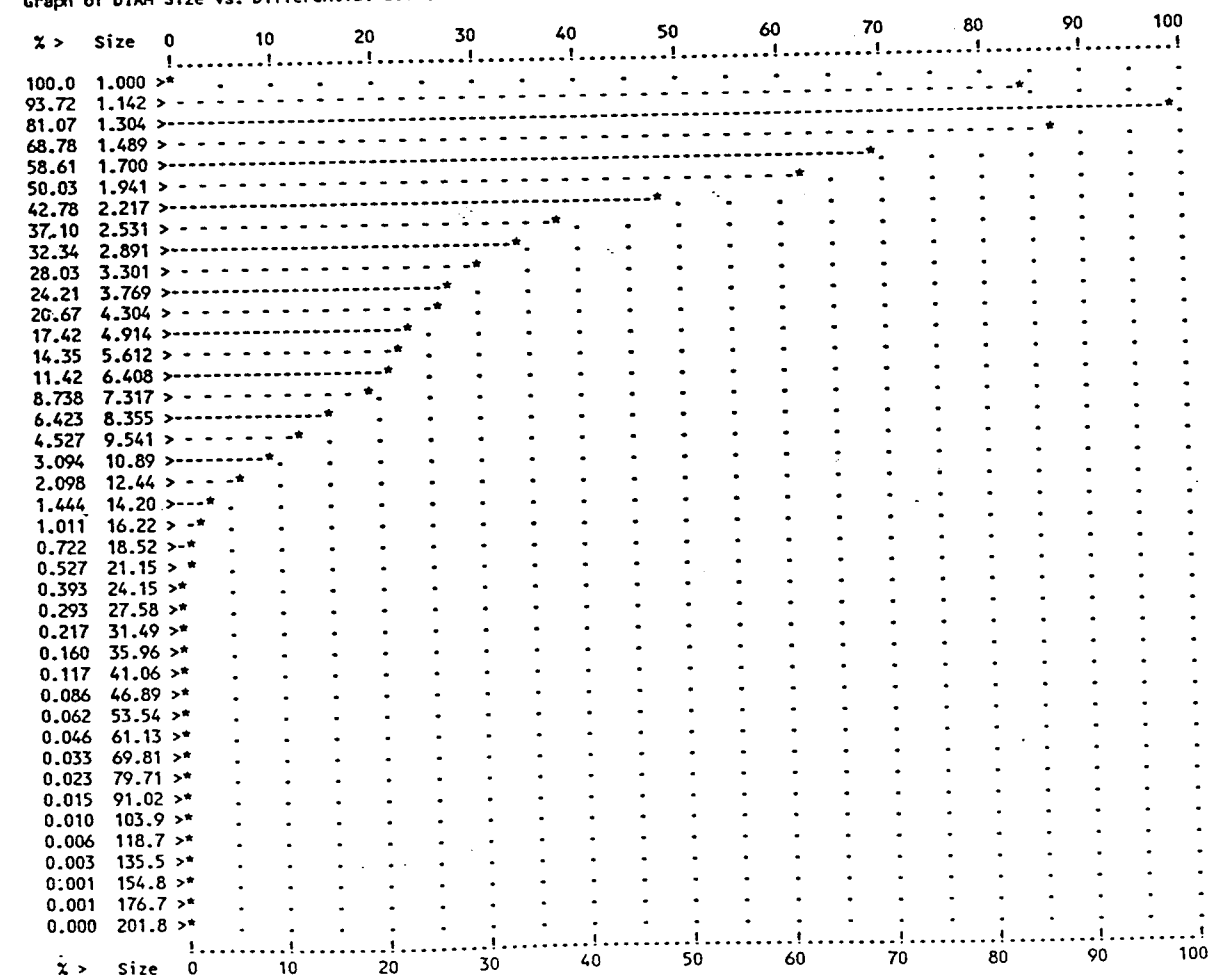
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 1.000 0 High at 122 210.9 0 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 121 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 9:59:42 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-4

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Popl | above | 43.77 um |
| 1.00%  | Popl | above | 16.27 um |
| 6.00%  | Popl | above | 8.582 um |
| 22.00% | Popl | above | 4.088 um |
| 50.00% | Popl | above | 1.941 um |
| 78.00% | Popl | above | 1.345 um |
| 94.00% | Popl | above | 1.137 um |
| 99.00% | Popl | above | 1.050 um |
| 99.90% | Popl | above | 1.025 um |

PARTICLE SIZE ANALYSIS BY ELETRONIC METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Tue Feb 28 1989

Time: 3:06:31 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-6

Job No: ID-14966

Technician: L.W

Special Comments

|                             |                              |
|-----------------------------|------------------------------|
| geometric mean size = 6.797 | arithmetic mean size = 8.019 |
| standard deviation = 4.966  | coeff.of variation = 73.06   |
| median size = 6.616         | mode size = 5.321            |

Total = 376504775

Coincidence Corrected: No

Extrapolated above: 1.619

VOLUME DISTRIBUTION DATA

| Chnl | Size  | Volume  | % >    | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   |
|------|-------|---------|--------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|-------|
| 1    | 1.000 | 34775   | 100.00 | 33   | 2.356 | 1187444 | 96.60 | 65   | 5.551 | 7220844 | 62.01 | 97   | 13.08 | 3643799 | 14.47 |
| 2    | 1.027 | 40125   | 99.99  | 34   | 2.420 | 1284838 | 96.27 | 66   | 5.702 | 7081624 | 60.11 | 98   | 13.43 | 3407063 | 13.53 |
| 3    | 1.055 | 46204   | 99.97  | 35   | 2.486 | 1397430 | 95.91 | 67   | 5.856 | 6962102 | 58.25 | 99   | 13.80 | 3227597 | 12.65 |
| 4    | 1.084 | 53135   | 99.96  | 36   | 2.553 | 1467587 | 95.53 | 68   | 6.015 | 6888418 | 56.41 | 100  | 14.17 | 3244741 | 11.79 |
| 5    | 1.113 | 60916   | 99.95  | 37   | 2.622 | 1583948 | 95.13 | 69   | 6.179 | 6804400 | 54.59 | 101  | 14.56 | 3025880 | 10.96 |
| 6    | 1.143 | 69792   | 99.93  | 38   | 2.694 | 1745176 | 94.69 | 70   | 6.346 | 6749441 | 52.79 | 102  | 14.95 | 2840091 | 10.18 |
| 7    | 1.174 | 79763   | 99.91  | 39   | 2.767 | 1893151 | 94.20 | 71   | 6.519 | 6714302 | 51.00 | 103  | 15.36 | 2926541 | 9.413 |
| 8    | 1.206 | 90949   | 99.89  | 40   | 2.842 | 2044165 | 93.68 | 72   | 6.696 | 6594414 | 49.23 | 104  | 15.78 | 2667677 | 8.670 |
| 9    | 1.239 | 103473  | 99.86  | 41   | 2.919 | 2178035 | 93.12 | 73   | 6.877 | 6567300 | 47.48 | 105  | 16.20 | 2558733 | 7.976 |
| 10   | 1.273 | 117577  | 99.83  | 42   | 2.998 | 2329901 | 92.52 | 74   | 7.064 | 6467961 | 45.75 | 106  | 16.64 | 2531861 | 7.300 |
| 11   | 1.307 | 133384  | 99.80  | 43   | 3.080 | 2509124 | 91.88 | 75   | 7.256 | 6323756 | 44.05 | 107  | 17.10 | 2537211 | 6.627 |
| 12   | 1.343 | 150893  | 99.76  | 44   | 3.163 | 2659895 | 91.19 | 76   | 7.453 | 6253356 | 42.38 | 108  | 17.56 | 2444438 | 5.965 |
| 13   | 1.379 | 170469  | 99.72  | 45   | 3.249 | 2785497 | 90.47 | 77   | 7.655 | 6187332 | 40.73 | 109  | 18.04 | 2360177 | 5.327 |
| 14   | 1.416 | 192112  | 99.67  | 46   | 3.337 | 2972502 | 89.70 | 78   | 7.863 | 6099058 | 39.10 | 110  | 18.53 | 2213783 | 4.720 |
| 15   | 1.455 | 216186  | 99.61  | 47   | 3.428 | 3177989 | 88.89 | 79   | 8.076 | 5970538 | 37.50 | 111  | 19.03 | 2162472 | 4.138 |
| 16   | 1.494 | 242693  | 99.55  | 48   | 3.521 | 3462022 | 88.01 | 80   | 8.295 | 5896125 | 35.92 | 112  | 19.54 | 1914794 | 3.597 |
| 17   | 1.535 | 271996  | 99.49  | 49   | 3.616 | 3826548 | 87.04 | 81   | 8.521 | 5777089 | 34.37 | 113  | 20.08 | 1839530 | 3.098 |
| 18   | 1.577 | 304217  | 99.41  | 50   | 3.715 | 3991910 | 86.00 | 82   | 8.752 | 5615618 | 32.86 | 114  | 20.62 | 1732045 | 2.624 |
| 19   | 1.619 | 339600  | 99.32  | 51   | 3.815 | 4150706 | 84.92 | 83   | 8.989 | 5445271 | 31.39 | 115  | 21.18 | 1504550 | 2.194 |
| 20   | 1.663 | 373523  | 99.23  | 52   | 3.919 | 4498817 | 83.77 | 84   | 9.233 | 5370128 | 29.95 | 116  | 21.75 | 1337608 | 1.816 |
| 21   | 1.709 | 433224  | 99.12  | 53   | 4.025 | 4881581 | 82.53 | 85   | 9.484 | 5252430 | 28.54 | 117  | 22.35 | 1208358 | 1.478 |
| 22   | 1.755 | 502044  | 99.00  | 54   | 4.135 | 5141905 | 81.19 | 86   | 9.741 | 5056305 | 27.17 | 118  | 22.95 | 1116071 | 1.169 |
| 23   | 1.803 | 561987  | 98.86  | 55   | 4.247 | 5329517 | 79.80 | 87   | 10.01 | 4905899 | 25.85 | 119  | 23.57 | 913625  | 0.899 |
| 24   | 1.851 | 615244  | 98.70  | 56   | 4.362 | 5843477 | 78.32 | 88   | 10.28 | 4837444 | 24.56 | 120  | 24.21 | 684793  | 0.687 |
| 25   | 1.902 | 674944  | 98.53  | 57   | 4.481 | 6199734 | 76.72 | 89   | 10.56 | 4694698 | 23.29 | 121  | 24.87 | 622539  | 0.513 |
| 26   | 1.953 | 746317  | 98.34  | 58   | 4.602 | 6413854 | 75.05 | 90   | 10.84 | 4577607 | 22.06 | 122  | 25.55 | 498031  | 0.364 |
| 27   | 2.006 | 790211  | 98.14  | 59   | 4.727 | 6506992 | 73.33 | 91   | 11.14 | 4441062 | 20.86 | 123  | 26.24 | 373523  | 0.248 |
| 28   | 2.061 | 809301  | 97.92  | 60   | 4.855 | 6844281 | 71.56 | 92   | 11.44 | 4274241 | 19.70 | 124  | 26.95 | 249016  | 0.166 |
| 29   | 2.117 | 917394  | 97.69  | 61   | 4.987 | 7041256 | 69.71 | 93   | 11.75 | 4184751 | 18.58 | 125  | 27.68 | 186762  | 0.108 |
| 30   | 2.174 | 956667  | 97.45  | 62   | 5.123 | 7239448 | 67.82 | 94   | 12.07 | 4014282 | 17.49 | 126  | 28.44 | 186762  | 0.058 |
| 31   | 2.233 | 1017462 | 97.18  | 63   | 5.262 | 7325533 | 65.88 | 95   | 12.40 | 3814389 | 16.45 | 127  | 29.21 | 62254   | 0.025 |
| 32   | 2.294 | 1105007 | 96.90  | 64   | 5.404 | 7311429 | 63.94 | 96   | 12.73 | 3730735 | 15.45 | 128  | 30.00 | 62254   | 0.008 |

PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Tue Feb 28 1989

Time: 3:06:31 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-6

Job No: ID-14966

Technician: L.W

Special Comments

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | above | 27.79 um |
| 1.00%  | Volm | above | 23.31 um |
| 6.00%  | Volm | above | 17.53 um |
| 22.00% | Volm | above | 10.85 um |
| 50.00% | Volm | above | 6.617 um |
| 78.00% | Volm | above | 4.384 um |
| 94.00% | Volm | above | 2.795 um |
| 99.00% | Volm | above | 1.753 um |
| 99.90% | Volm | above | 1.186 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Tue Feb 28 1989  
 Time: 3:06:31 p.m.  
 Client: U.S. ARMY ENGINEERS.  
 Sample Number: RMA-6  
 Job No: ID-14966  
 Technician: L.W  
 Special Comments

geometric mean size = 2.666      arithmetic mean size = 3.206  
 standard deviation = 2.853      coeff.of variation = 107.1  
 median size = 2.537              mode size = 1.950

Total = 8019373

Coincidence Corrected: No

Extrapolated above: 1.619

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|
| 1    | 1.000 | 53340  | 99.67 | 33   | 2.356 | 139263 | 55.11 | 65   | 5.551 | 64750  | 8.926 | 97   | 13.08 | 2499   | 0.862 |
| 2    | 1.027 | 56795  | 98.98 | 34   | 2.420 | 139051 | 53.37 | 66   | 5.702 | 58600  | 8.156 | 98   | 13.43 | 2156   | 0.833 |
| 3    | 1.055 | 60350  | 98.25 | 35   | 2.486 | 139561 | 51.64 | 67   | 5.856 | 53163  | 7.459 | 99   | 13.80 | 1884   | 0.808 |
| 4    | 1.084 | 64045  | 97.48 | 36   | 2.553 | 135253 | 49.92 | 68   | 6.015 | 48540  | 6.825 | 100  | 14.17 | 1748   | 0.786 |
| 5    | 1.113 | 67756  | 96.66 | 37   | 2.622 | 134707 | 48.24 | 69   | 6.179 | 44247  | 6.246 | 101  | 14.56 | 1504   | 0.765 |
| 6    | 1.143 | 71636  | 95.79 | 38   | 2.694 | 136961 | 46.55 | 70   | 6.346 | 40501  | 5.718 | 102  | 14.95 | 1303   | 0.748 |
| 7    | 1.174 | 75549  | 94.87 | 39   | 2.767 | 137104 | 44.84 | 71   | 6.519 | 37179  | 5.233 | 103  | 15.36 | 1239   | 0.732 |
| 8    | 1.206 | 79494  | 93.90 | 40   | 2.842 | 136612 | 43.13 | 72   | 6.696 | 33697  | 4.791 | 104  | 15.78 | 1042   | 0.718 |
| 9    | 1.239 | 83458  | 92.89 | 41   | 2.919 | 134321 | 41.44 | 73   | 6.877 | 30967  | 4.388 | 105  | 16.20 | 923    | 0.705 |
| 10   | 1.273 | 87513  | 91.82 | 42   | 2.998 | 132594 | 39.78 | 74   | 7.064 | 28144  | 4.019 | 106  | 16.64 | 842    | 0.694 |
| 11   | 1.307 | 91614  | 90.70 | 43   | 3.080 | 131769 | 38.13 | 75   | 7.256 | 25392  | 3.685 | 107  | 17.10 | 779    | 0.684 |
| 12   | 1.343 | 95638  | 89.54 | 44   | 3.163 | 128904 | 36.50 | 76   | 7.453 | 23171  | 3.382 | 108  | 17.56 | 692    | 0.675 |
| 13   | 1.379 | 99706  | 88.32 | 45   | 3.249 | 124569 | 34.92 | 77   | 7.655 | 21157  | 3.106 | 109  | 18.04 | 617    | 0.667 |
| 14   | 1.416 | 103690 | 87.05 | 46   | 3.337 | 122670 | 33.38 | 78   | 7.863 | 19244  | 2.854 | 110  | 18.53 | 534    | 0.660 |
| 15   | 1.455 | 107675 | 85.73 | 47   | 3.428 | 121025 | 31.86 | 79   | 8.076 | 17385  | 2.626 | 111  | 19.03 | 481    | 0.653 |
| 16   | 1.494 | 111545 | 84.37 | 48   | 3.521 | 121664 | 30.35 | 80   | 8.295 | 15843  | 2.418 | 112  | 19.54 | 394    | 0.648 |
| 17   | 1.535 | 115362 | 82.95 | 49   | 3.616 | 124092 | 28.82 | 81   | 8.521 | 14325  | 2.230 | 113  | 20.08 | 349    | 0.643 |
| 18   | 1.577 | 119067 | 81.49 | 50   | 3.715 | 119461 | 27.30 | 82   | 8.752 | 12849  | 2.061 | 114  | 20.62 | 303    | 0.639 |
| 19   | 1.619 | 122655 | 79.98 | 51   | 3.815 | 114624 | 25.84 | 83   | 8.989 | 11498  | 1.909 | 115  | 21.18 | 243    | 0.636 |
| 20   | 1.663 | 126492 | 78.44 | 52   | 3.919 | 114646 | 24.41 | 84   | 9.233 | 10464  | 1.772 | 116  | 21.75 | 199    | 0.633 |
| 21   | 1.709 | 133243 | 76.84 | 53   | 4.025 | 114796 | 22.98 | 85   | 9.484 | 9444   | 1.648 | 117  | 22.35 | 166    | 0.631 |
| 22   | 1.755 | 142489 | 75.12 | 54   | 4.135 | 111583 | 21.57 | 86   | 9.741 | 8389   | 1.536 | 118  | 22.95 | 141    | 0.629 |
| 23   | 1.803 | 147188 | 73.31 | 55   | 4.247 | 106726 | 20.21 | 87   | 10.01 | 7512   | 1.437 | 119  | 23.57 | 107    | 0.627 |
| 24   | 1.851 | 148697 | 71.47 | 56   | 4.362 | 107984 | 18.87 | 88   | 10.28 | 6835   | 1.348 | 120  | 24.21 | 74     | 0.626 |
| 25   | 1.902 | 150532 | 69.60 | 57   | 4.481 | 105723 | 17.53 | 89   | 10.56 | 6121   | 1.267 | 121  | 24.87 | 62     | 0.625 |
| 26   | 1.953 | 153600 | 67.71 | 58   | 4.602 | 100931 | 16.25 | 90   | 10.84 | 5508   | 1.194 | 122  | 25.55 | 46     | 0.625 |
| 27   | 2.006 | 150079 | 65.81 | 59   | 4.727 | 94492  | 15.03 | 91   | 11.14 | 4931   | 1.129 | 123  | 26.24 | 31     | 0.624 |
| 28   | 2.061 | 141838 | 63.99 | 60   | 4.855 | 91716  | 13.87 | 92   | 11.44 | 4379   | 1.071 | 124  | 26.95 | 19     | 0.624 |
| 29   | 2.117 | 148370 | 62.18 | 61   | 4.987 | 87072  | 12.75 | 93   | 11.75 | 3957   | 1.019 | 125  | 27.68 | 14     | 0.624 |
| 30   | 2.174 | 142777 | 60.37 | 62   | 5.123 | 82611  | 11.69 | 94   | 12.07 | 3502   | 0.973 | 126  | 28.44 | 13     | 0.624 |
| 31   | 2.233 | 140128 | 58.60 | 63   | 5.262 | 77140  | 10.70 | 95   | 12.40 | 3071   | 0.932 | 127  | 29.21 | 4      | 0.623 |
| 32   | 2.294 | 140436 | 56.85 | 64   | 5.404 | 71048  | 9.773 | 96   | 12.73 | 2772   | 0.895 | 128  | 30.00 | 49998  | 0.314 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 MAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Tue Feb 28 1989

Time: 3:06:31 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-6

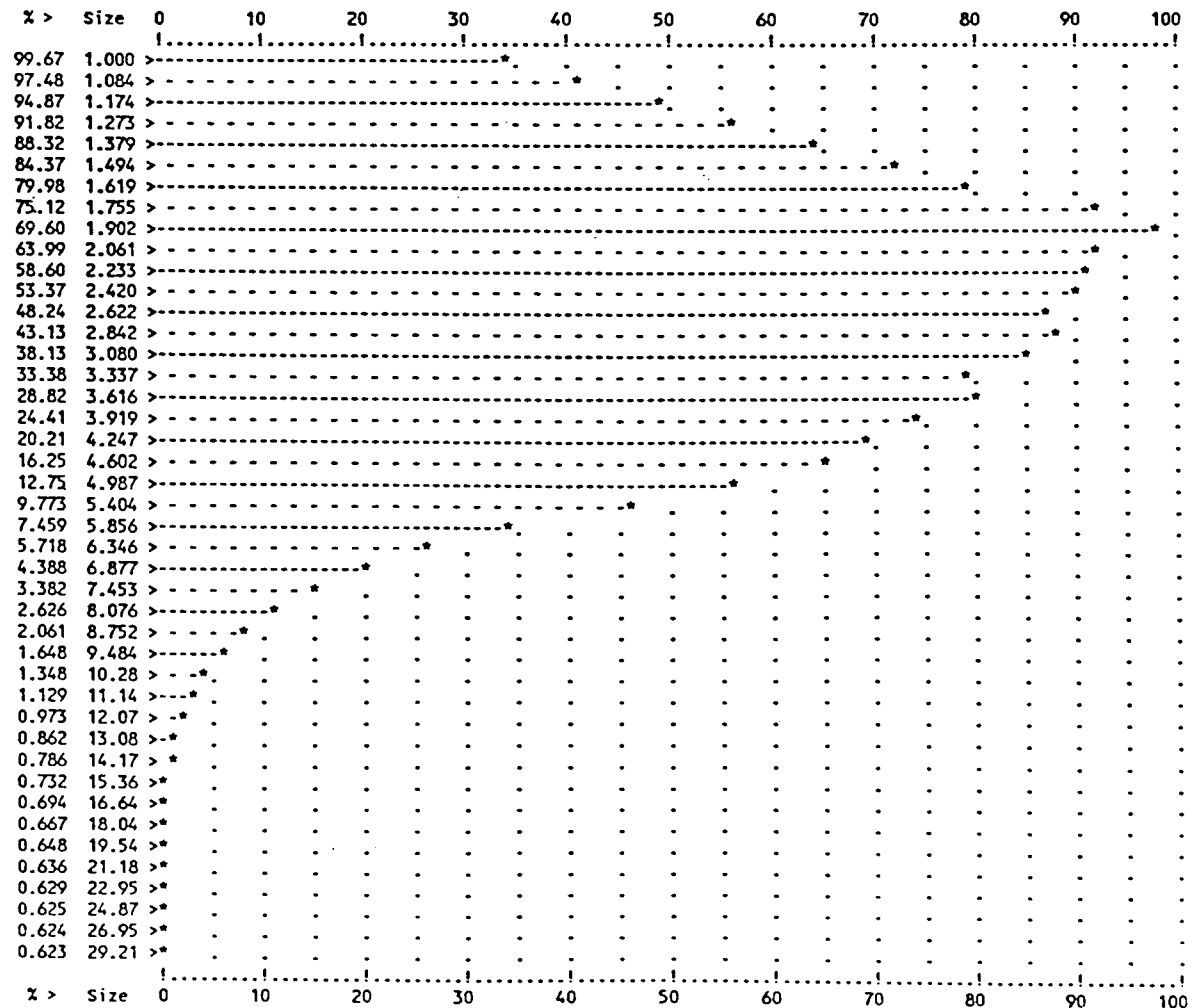
Job No: ID-14966

Technician: L.W

Special Comments

Low at 1 1.000 53340 High at 128 30.00 49998 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Tue Feb 28 1989

Time: 3:06:31 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-6

Job No: ID-14966

Technician: L.W

Special Comments

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Popl | above | 30.26 um |
| 1.00%  | Popl | above | 11.87 um |
| 6.00%  | Popl | above | 6.248 um |
| 22.00% | Popl | above | 4.100 um |
| 50.00% | Popl | above | 2.549 um |
| 78.00% | Popl | above | 1.675 um |
| 94.00% | Popl | above | 1.203 um |
| 99.00% | Popl | above | 1.026 um |
| 99.90% | Popl | above | 0.989 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 MAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 12:45:03 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-2

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 61.45  
 standard deviation = 45.45  
 median size = 66.62

arithmetic mean size = 74.56  
 coeff.of variation = 73.96  
 mode size = 87.74

Total = 338866636

Coincidence Corrected: No

VOLUME DISTRIBUTION DATA

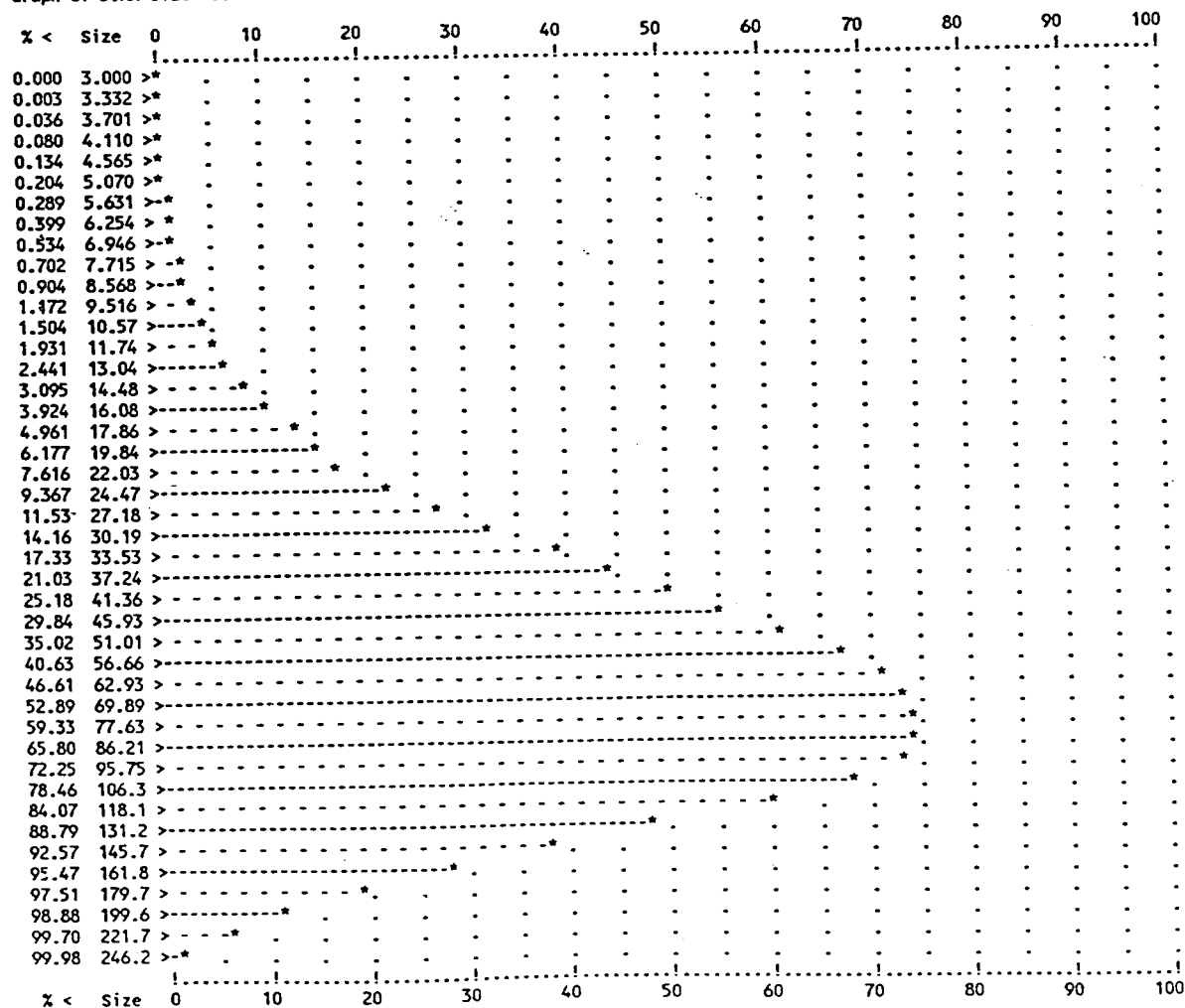
| Chnl | Size  | Volume | % <   | Chnl | Size  | Volume  | % <   | Chnl | Size  | Volume  | % <   | Chnl | Size  | Volume  | % <   |
|------|-------|--------|-------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|-------|
| 1    | 3.000 | 0      | 0.000 | 33   | 9.189 | 322023  | 1.078 | 65   | 28.15 | 2922736 | 12.36 | 97   | 86.21 | 7325533 | 65.80 |
| 2    | 3.107 | 129    | 0.000 | 34   | 9.516 | 312866  | 1.172 | 66   | 29.15 | 3029435 | 13.24 | 98   | 89.28 | 7325533 | 67.96 |
| 3    | 3.217 | 535    | 0.000 | 35   | 9.855 | 358156  | 1.271 | 67   | 30.19 | 3193187 | 14.16 | 99   | 92.46 | 7286703 | 70.11 |
| 4    | 3.332 | 19447  | 0.003 | 36   | 10.21 | 397786  | 1.383 | 68   | 31.26 | 3484824 | 15.14 | 100  | 95.75 | 7208324 | 72.25 |
| 5    | 3.451 | 41139  | 0.012 | 37   | 10.57 | 428637  | 1.504 | 69   | 32.37 | 3725449 | 16.21 | 101  | 99.16 | 7076620 | 74.36 |
| 6    | 3.573 | 40414  | 0.024 | 38   | 10.95 | 478521  | 1.638 | 70   | 33.53 | 3856455 | 17.33 | 102  | 102.7 | 6972262 | 76.43 |
| 7    | 3.701 | 42347  | 0.036 | 39   | 11.34 | 498140  | 1.782 | 71   | 34.72 | 4103120 | 18.50 | 103  | 106.3 | 6739490 | 78.46 |
| 8    | 3.832 | 47451  | 0.049 | 40   | 11.74 | 510230  | 1.931 | 72   | 35.96 | 4312266 | 19.74 | 104  | 110.1 | 6446469 | 80.40 |
| 9    | 3.969 | 51656  | 0.064 | 41   | 12.16 | 535564  | 2.085 | 73   | 37.24 | 4420765 | 21.03 | 105  | 114.1 | 6212052 | 82.27 |
| 10   | 4.110 | 54365  | 0.080 | 42   | 12.59 | 629390  | 2.257 | 74   | 38.56 | 4634721 | 22.37 | 106  | 118.1 | 5977635 | 84.07 |
| 11   | 4.256 | 59476  | 0.096 | 43   | 13.04 | 616800  | 2.441 | 75   | 39.93 | 4748716 | 23.75 | 107  | 122.3 | 5450197 | 85.76 |
| 12   | 4.408 | 64731  | 0.115 | 44   | 13.50 | 692611  | 2.634 | 76   | 41.36 | 4971948 | 25.18 | 108  | 126.7 | 5157175 | 87.32 |
| 13   | 4.565 | 68600  | 0.134 | 45   | 13.98 | 781088  | 2.851 | 77   | 42.83 | 5246214 | 26.69 | 109  | 131.2 | 4805550 | 88.79 |
| 14   | 4.727 | 76518  | 0.156 | 46   | 14.48 | 873200  | 3.095 | 78   | 44.35 | 5328803 | 28.25 | 110  | 135.9 | 4453924 | 90.16 |
| 15   | 4.896 | 79539  | 0.179 | 47   | 15.00 | 926006  | 3.361 | 79   | 45.93 | 5450197 | 29.84 | 111  | 140.7 | 4043694 | 91.41 |
| 16   | 5.070 | 88584  | 0.204 | 48   | 15.53 | 947365  | 3.637 | 80   | 47.57 | 5829983 | 31.51 | 112  | 145.7 | 3809277 | 92.57 |
| 17   | 5.250 | 94087  | 0.231 | 49   | 16.08 | 995588  | 3.924 | 81   | 49.26 | 5964336 | 33.25 | 113  | 150.9 | 3399047 | 93.64 |
| 18   | 5.437 | 96646  | 0.259 | 50   | 16.65 | 1091418 | 4.232 | 82   | 51.01 | 6080354 | 35.02 | 114  | 156.3 | 3106026 | 94.60 |
| 19   | 5.631 | 108442 | 0.289 | 51   | 17.25 | 1240861 | 4.576 | 83   | 52.83 | 6243957 | 36.84 | 115  | 161.8 | 2813005 | 95.47 |
| 20   | 5.831 | 118723 | 0.323 | 52   | 17.86 | 1374492 | 4.961 | 84   | 54.71 | 6387865 | 38.71 | 116  | 167.6 | 2461379 | 96.25 |
| 21   | 6.039 | 129269 | 0.359 | 53   | 18.50 | 1346545 | 5.363 | 85   | 56.66 | 6622282 | 40.63 | 117  | 173.6 | 2109754 | 96.93 |
| 22   | 6.254 | 142971 | 0.399 | 54   | 19.16 | 1347837 | 5.760 | 86   | 58.68 | 6668542 | 42.59 | 118  | 179.7 | 1875336 | 97.51 |
| 23   | 6.477 | 145848 | 0.442 | 55   | 19.84 | 1477553 | 6.177 | 87   | 60.77 | 6798095 | 44.57 | 119  | 186.1 | 1699524 | 98.04 |
| 24   | 6.707 | 156017 | 0.486 | 56   | 20.54 | 1591053 | 6.630 | 88   | 62.93 | 6993492 | 46.61 | 120  | 192.8 | 1406502 | 98.50 |
| 25   | 6.946 | 168925 | 0.534 | 57   | 21.28 | 1669023 | 7.111 | 89   | 65.17 | 7032512 | 48.68 | 121  | 199.6 | 1172085 | 98.88 |
| 26   | 7.193 | 191070 | 0.587 | 58   | 22.03 | 1756976 | 7.616 | 90   | 67.49 | 7149720 | 50.77 | 122  | 206.7 | 996272  | 99.20 |
| 27   | 7.449 | 190484 | 0.644 | 59   | 22.82 | 1880114 | 8.153 | 91   | 69.89 | 7233434 | 52.89 | 123  | 214.1 | 861362  | 99.48 |
| 28   | 7.715 | 204454 | 0.702 | 60   | 23.63 | 2081197 | 8.737 | 92   | 72.38 | 7266929 | 55.03 | 124  | 221.7 | 637780  | 99.70 |
| 29   | 7.989 | 210363 | 0.763 | 61   | 24.47 | 2191831 | 9.367 | 93   | 74.96 | 7266929 | 57.18 | 125  | 229.6 | 354175  | 99.84 |
| 30   | 8.274 | 237137 | 0.829 | 62   | 25.34 | 2374818 | 10.04 | 94   | 77.63 | 7325533 | 59.33 | 126  | 237.8 | 234417  | 99.93 |
| 31   | 8.568 | 270389 | 0.904 | 63   | 26.24 | 2525970 | 10.76 | 95   | 80.39 | 7266929 | 61.48 | 127  | 246.2 | 117209  | 99.98 |
| 32   | 8.873 | 295114 | 0.987 | 64   | 27.18 | 2698535 | 11.53 | 96   | 83.25 | 7325533 | 63.63 | 128  | 255.0 | 0       | 100.0 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989  
 Time: 12:45:03 p.m.  
 Client: U.S. ARMY ENGINEERS.  
 Sample Number: RMA-2  
 Job No: ID-14966  
 Technician: L.W  
 Special Comments  
 SAMPLE SIVED AT 250 MICRONS.

Low at 1 3.000 0 High at 128 255.0 0 Top of scale is 9830400

Graph of DIAM Size vs. Differential Volume From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 12:45:03 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-2

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | below | 4.283 um |
| 1.00%  | Volm | below | 8.911 um |
| 6.00%  | Volm | below | 19.55 um |
| 22.00% | Volm | below | 38.19 um |
| 50.00% | Volm | below | 66.62 um |
| 78.00% | Volm | below | 105.5 um |
| 94.00% | Volm | below | 152.6 um |
| 99.00% | Volm | below | 201.8 um |
| 99.90% | Volm | below | 234.1 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 12:45:03 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-2

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 7.917  
 standard deviation = 12.01  
 median size = 6.598

arithmetic mean size = 10.80  
 coeff.of variation = 151.7  
 mode size = 3.497

Total = 4366752

Coincidence Corrected: No

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <    |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|--------|
| 1    | 3.000 | 0      | 0.000 | 31   | 8.568 | 65955  | 62.19 | 61   | 24.47 | 22976  | 91.31 | 91   | 69.89 | 3213   | 99.37  |
| 2    | 3.107 | 643    | 0.007 | 32   | 8.873 | 64830  | 63.69 | 62   | 25.34 | 22413  | 91.83 | 92   | 72.38 | 2972   | 99.45  |
| 3    | 3.217 | 2490   | 0.043 | 33   | 9.189 | 63705  | 65.16 | 63   | 26.24 | 21449  | 92.33 | 93   | 74.96 | 2651   | 99.51  |
| 4    | 3.332 | 80656  | 0.987 | 34   | 9.516 | 55672  | 66.53 | 64   | 27.18 | 20646  | 92.81 | 94   | 77.63 | 2410   | 99.57  |
| 5    | 3.451 | 153600 | 3.662 | 35   | 9.855 | 57439  | 67.82 | 65   | 28.15 | 20084  | 93.28 | 95   | 80.39 | 2169   | 99.62  |
| 6    | 3.573 | 135926 | 6.979 | 36   | 10.21 | 57439  | 69.14 | 66   | 29.15 | 18798  | 93.72 | 96   | 83.25 | 1928   | 99.67  |
| 7    | 3.701 | 128214 | 10.00 | 37   | 10.57 | 55672  | 70.43 | 67   | 30.19 | 17834  | 94.14 | 97   | 86.21 | 1767   | 99.71  |
| 8    | 3.832 | 129339 | 12.95 | 38   | 10.95 | 55993  | 71.71 | 68   | 31.26 | 17513  | 94.55 | 98   | 89.28 | 1607   | 99.75  |
| 9    | 3.969 | 126768 | 15.89 | 39   | 11.34 | 52459  | 72.95 | 69   | 32.37 | 16870  | 94.94 | 99   | 92.46 | 1446   | 99.78  |
| 10   | 4.110 | 120100 | 18.71 | 40   | 11.74 | 48362  | 74.11 | 70   | 33.53 | 15665  | 95.32 | 100  | 95.75 | 1285   | 99.81  |
| 11   | 4.256 | 118333 | 21.44 | 41   | 12.16 | 45710  | 75.19 | 71   | 34.72 | 15023  | 95.67 | 101  | 99.16 | 1125   | 99.84  |
| 12   | 4.408 | 115923 | 24.13 | 42   | 12.59 | 48362  | 76.26 | 72   | 35.96 | 14219  | 96.00 | 102  | 102.7 | 964    | 99.87  |
| 13   | 4.565 | 110621 | 26.72 | 43   | 13.04 | 42738  | 77.31 | 73   | 37.24 | 13175  | 96.32 | 103  | 106.3 | 884    | 99.89  |
| 14   | 4.727 | 111103 | 29.26 | 44   | 13.50 | 43140  | 78.29 | 74   | 38.56 | 12372  | 96.61 | 104  | 110.1 | 723    | 99.91  |
| 15   | 4.896 | 104033 | 31.72 | 45   | 13.98 | 43863  | 79.29 | 75   | 39.93 | 11408  | 96.88 | 105  | 114.1 | 643    | 99.92  |
| 16   | 5.070 | 104274 | 34.11 | 46   | 14.48 | 44104  | 80.29 | 76   | 41.36 | 10765  | 97.13 | 106  | 118.1 | 562    | 99.93  |
| 17   | 5.250 | 99695  | 36.44 | 47   | 15.00 | 42095  | 81.28 | 77   | 42.83 | 10283  | 97.38 | 107  | 122.3 | 482    | 99.95  |
| 18   | 5.437 | 92224  | 38.64 | 48   | 15.53 | 38802  | 82.21 | 78   | 44.35 | 9399   | 97.60 | 108  | 126.7 | 402    | 99.96  |
| 19   | 5.631 | 93188  | 40.77 | 49   | 16.08 | 36713  | 83.07 | 79   | 45.93 | 8596   | 97.81 | 109  | 131.2 | 321    | 99.97  |
| 20   | 5.831 | 91823  | 42.88 | 50   | 16.65 | 36231  | 83.91 | 80   | 47.57 | 8274   | 98.00 | 110  | 135.9 | 241    | 99.97  |
| 21   | 6.039 | 90055  | 44.97 | 51   | 17.25 | 37115  | 84.75 | 81   | 49.26 | 7632   | 98.18 | 111  | 140.7 | 241    | 99.98  |
| 22   | 6.254 | 89654  | 47.02 | 52   | 17.86 | 37034  | 85.60 | 82   | 51.01 | 6989   | 98.35 | 112  | 145.7 | 161    | 99.98  |
| 23   | 6.477 | 82343  | 48.99 | 53   | 18.50 | 32616  | 86.39 | 83   | 52.83 | 6507   | 98.50 | 113  | 150.9 | 161    | 99.99  |
| 24   | 6.707 | 79371  | 50.85 | 54   | 19.16 | 29403  | 87.10 | 84   | 54.71 | 5945   | 98.65 | 114  | 156.3 | 161    | 99.99  |
| 25   | 6.946 | 77362  | 52.64 | 55   | 19.84 | 29001  | 87.77 | 85   | 56.66 | 5623   | 98.78 | 115  | 161.8 | 80     | 99.99  |
| 26   | 7.193 | 78728  | 54.43 | 56   | 20.54 | 28117  | 88.43 | 86   | 58.68 | 5061   | 98.90 | 116  | 167.6 | 80     | 99.99  |
| 27   | 7.449 | 70695  | 56.14 | 57   | 21.28 | 26591  | 89.05 | 87   | 60.77 | 4659   | 99.01 | 117  | 173.6 | 80     | 100.00 |
| 28   | 7.715 | 68285  | 57.73 | 58   | 22.03 | 25225  | 89.65 | 88   | 62.93 | 4338   | 99.12 | 118  | 179.7 | 80     | 100.00 |
| 29   | 7.989 | 63304  | 59.24 | 59   | 22.82 | 24261  | 90.21 | 89   | 65.17 | 3936   | 99.21 | 119  | 186.1 | 80     | 100.00 |
| 30   | 8.274 | 64268  | 60.70 | 60   | 23.63 | 24181  | 90.77 | 90   | 67.49 | 3535   | 99.30 | 120  | 192.8 | 0      | 100.0  |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 12:45:03 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-2

Job No: ID-14966

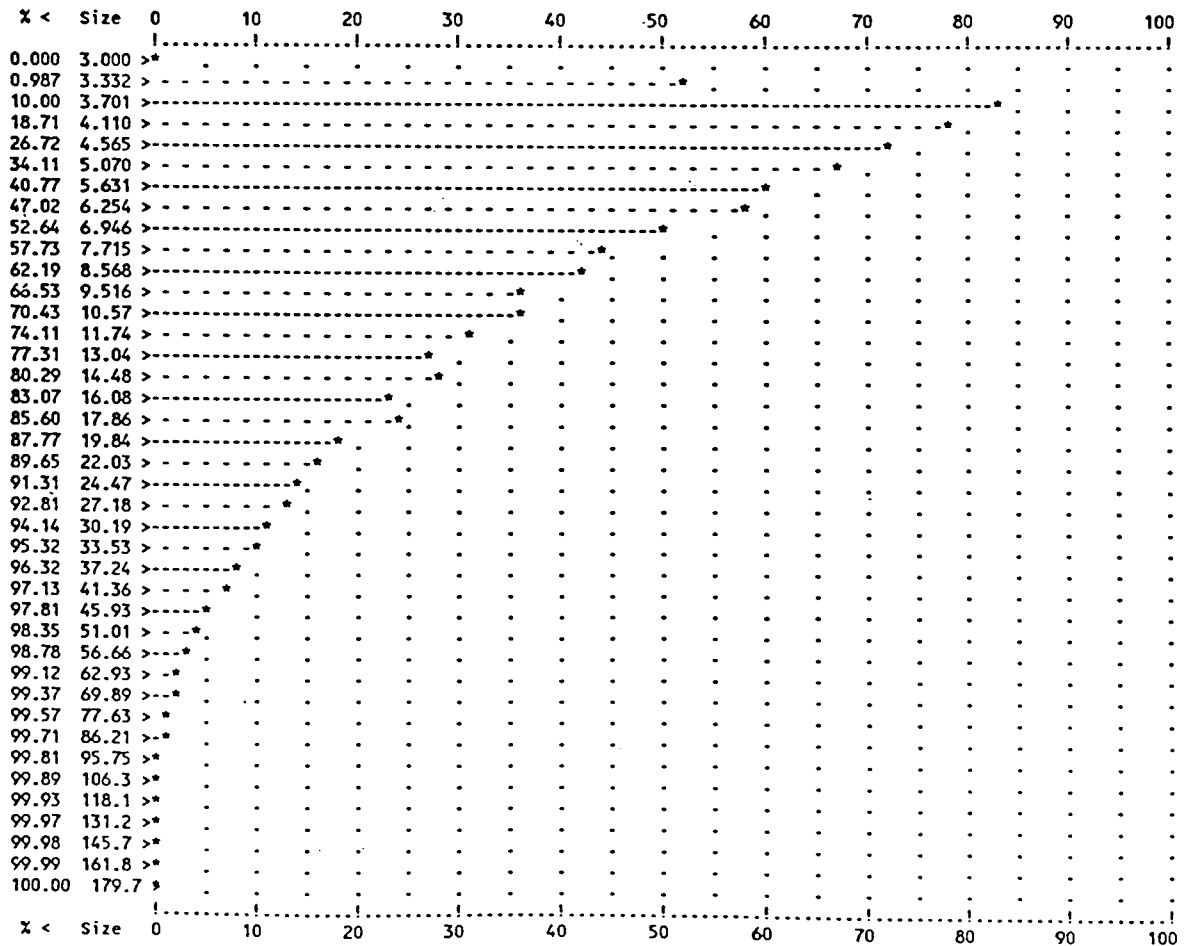
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 3.000 0 High at 120 192.8 0 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 118 skip: 2



PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Wed Mar 01 1989

Time: 12:45:03 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-2

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Popl | below | 3.276 um |
| 1.00%  | Popl | below | 3.331 um |
| 6.00%  | Popl | below | 3.533 um |
| 22.00% | Popl | below | 4.283 um |
| 50.00% | Popl | below | 6.598 um |
| 78.00% | Popl | below | 13.36 um |
| 94.00% | Popl | below | 29.81 um |
| 99.00% | Popl | below | 60.47 um |
| 99.90% | Popl | below | 108.9 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 57.58      arithmetic mean size = 77.99  
 standard deviation = 57.34      coeff.of variation = 99.58  
 median size = 66.39      mode size = 98.63

Total = 337169208

Coincidence Corrected: No

VOLUME DISTRIBUTION DATA

| Chnl | Size  | Volume | % >    | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   | Chnl | Size  | Volume  | % >   |
|------|-------|--------|--------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|-------|
| 1    | 0.900 | 0      | 100.0  | 33   | 3.734 | 209832  | 99.16 | 65   | 15.49 | 1917287 | 91.31 | 97   | 64.25 | 6788260 | 51.51 |
| 2    | 0.941 | 59     | 100.00 | 34   | 3.903 | 217502  | 99.10 | 66   | 16.19 | 2057730 | 90.72 | 98   | 67.17 | 6996397 | 49.47 |
| 3    | 0.984 | 12503  | 100.00 | 35   | 4.081 | 239793  | 99.03 | 67   | 16.93 | 2148099 | 90.09 | 99   | 70.23 | 7125720 | 47.37 |
| 4    | 1.028 | 25007  | 99.99  | 36   | 4.266 | 258700  | 98.96 | 68   | 17.70 | 2237659 | 89.44 | 100  | 73.42 | 7050202 | 45.27 |
| 5    | 1.075 | 37511  | 99.98  | 37   | 4.460 | 271576  | 98.88 | 69   | 18.50 | 2313809 | 88.77 | 101  | 76.76 | 7148452 | 43.17 |
| 6    | 1.124 | 50014  | 99.97  | 38   | 4.663 | 285073  | 98.79 | 70   | 19.34 | 2407897 | 88.07 | 102  | 80.25 | 7131197 | 41.05 |
| 7    | 1.175 | 62518  | 99.95  | 39   | 4.875 | 308168  | 98.71 | 71   | 20.22 | 2479652 | 87.34 | 103  | 83.90 | 7259791 | 38.91 |
| 8    | 1.229 | 63741  | 99.94  | 40   | 5.097 | 332813  | 98.61 | 72   | 21.14 | 2610588 | 86.59 | 104  | 87.71 | 7279890 | 36.76 |
| 9    | 1.284 | 67042  | 99.92  | 41   | 5.328 | 366907  | 98.51 | 73   | 22.10 | 2760918 | 85.79 | 105  | 91.70 | 7157912 | 34.62 |
| 10   | 1.343 | 67139  | 99.90  | 42   | 5.571 | 390815  | 98.40 | 74   | 23.11 | 2882420 | 84.96 | 106  | 95.87 | 7295026 | 32.47 |
| 11   | 1.404 | 70481  | 99.88  | 43   | 5.824 | 422203  | 98.27 | 75   | 24.16 | 2947005 | 84.09 | 107  | 100.2 | 7325533 | 30.31 |
| 12   | 1.468 | 68952  | 99.85  | 44   | 6.089 | 464046  | 98.14 | 76   | 25.26 | 3064315 | 83.20 | 108  | 104.8 | 7216216 | 28.15 |
| 13   | 1.534 | 64279  | 99.83  | 45   | 6.365 | 497265  | 98.00 | 77   | 26.41 | 3229012 | 82.27 | 109  | 109.5 | 7156999 | 26.02 |
| 14   | 1.604 | 62517  | 99.82  | 46   | 6.655 | 518686  | 97.85 | 78   | 27.61 | 3404713 | 81.28 | 110  | 114.5 | 7094218 | 23.90 |
| 15   | 1.677 | 62517  | 99.80  | 47   | 6.957 | 579603  | 97.69 | 79   | 28.86 | 3582907 | 80.25 | 111  | 119.7 | 6968657 | 21.82 |
| 16   | 1.753 | 65333  | 99.78  | 48   | 7.274 | 605643  | 97.51 | 80   | 30.17 | 3797773 | 79.15 | 112  | 125.2 | 6889865 | 19.76 |
| 17   | 1.833 | 68054  | 99.76  | 49   | 7.604 | 681252  | 97.32 | 81   | 31.55 | 3969503 | 78.00 | 113  | 130.9 | 6748266 | 17.74 |
| 18   | 1.916 | 75021  | 99.74  | 50   | 7.950 | 702327  | 97.12 | 82   | 32.98 | 4175918 | 76.80 | 114  | 136.8 | 6529192 | 15.77 |
| 19   | 2.004 | 62517  | 99.72  | 51   | 8.312 | 798365  | 96.89 | 83   | 34.48 | 4350134 | 75.53 | 115  | 143.0 | 6278069 | 13.87 |
| 20   | 2.095 | 86456  | 99.70  | 52   | 8.689 | 850072  | 96.65 | 84   | 36.05 | 4606558 | 74.20 | 116  | 149.5 | 5964166 | 12.06 |
| 21   | 2.190 | 90244  | 99.67  | 53   | 9.085 | 900279  | 96.39 | 85   | 37.69 | 4887876 | 72.80 | 117  | 156.3 | 5752749 | 10.32 |
| 22   | 2.289 | 101899 | 99.64  | 54   | 9.498 | 1000372 | 96.11 | 86   | 39.40 | 5078963 | 71.32 | 118  | 163.4 | 5336359 | 8.672 |
| 23   | 2.394 | 108219 | 99.61  | 55   | 9.929 | 1050290 | 95.80 | 87   | 41.19 | 5260132 | 69.79 | 119  | 170.9 | 5007728 | 7.138 |
| 24   | 2.502 | 121453 | 99.58  | 56   | 10.38 | 1150208 | 95.48 | 88   | 43.06 | 5369557 | 68.21 | 120  | 178.6 | 4331868 | 5.751 |
| 25   | 2.616 | 121116 | 99.54  | 57   | 10.85 | 1250201 | 95.12 | 89   | 45.02 | 5609163 | 66.58 | 121  | 186.8 | 3955184 | 4.522 |
| 26   | 2.735 | 125585 | 99.50  | 58   | 11.35 | 1350182 | 94.74 | 90   | 47.07 | 5886306 | 64.88 | 122  | 195.3 | 3515719 | 3.413 |
| 27   | 2.859 | 133935 | 99.46  | 59   | 11.86 | 1450311 | 94.32 | 91   | 49.21 | 6098439 | 63.10 | 123  | 204.1 | 3076254 | 2.435 |
| 28   | 2.989 | 142124 | 99.42  | 60   | 12.40 | 1500811 | 93.88 | 92   | 51.45 | 6285426 | 61.26 | 124  | 213.4 | 2574008 | 1.596 |
| 29   | 3.125 | 162419 | 99.38  | 61   | 12.96 | 1600157 | 93.42 | 93   | 53.78 | 6362573 | 59.39 | 125  | 223.1 | 2008982 | 0.916 |
| 30   | 3.267 | 162540 | 99.33  | 62   | 13.55 | 1740401 | 92.93 | 94   | 56.23 | 6556782 | 57.47 | 126  | 233.3 | 1443956 | 0.403 |
| 31   | 3.416 | 186853 | 99.28  | 63   | 14.17 | 1790293 | 92.41 | 95   | 58.79 | 6676872 | 55.51 | 127  | 243.9 | 627807  | 0.094 |
| 32   | 3.571 | 199612 | 99.22  | 64   | 14.81 | 1850799 | 91.87 | 96   | 61.46 | 6755975 | 53.52 | 128  | 255.0 | 0       | 0.000 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: 1D-14966

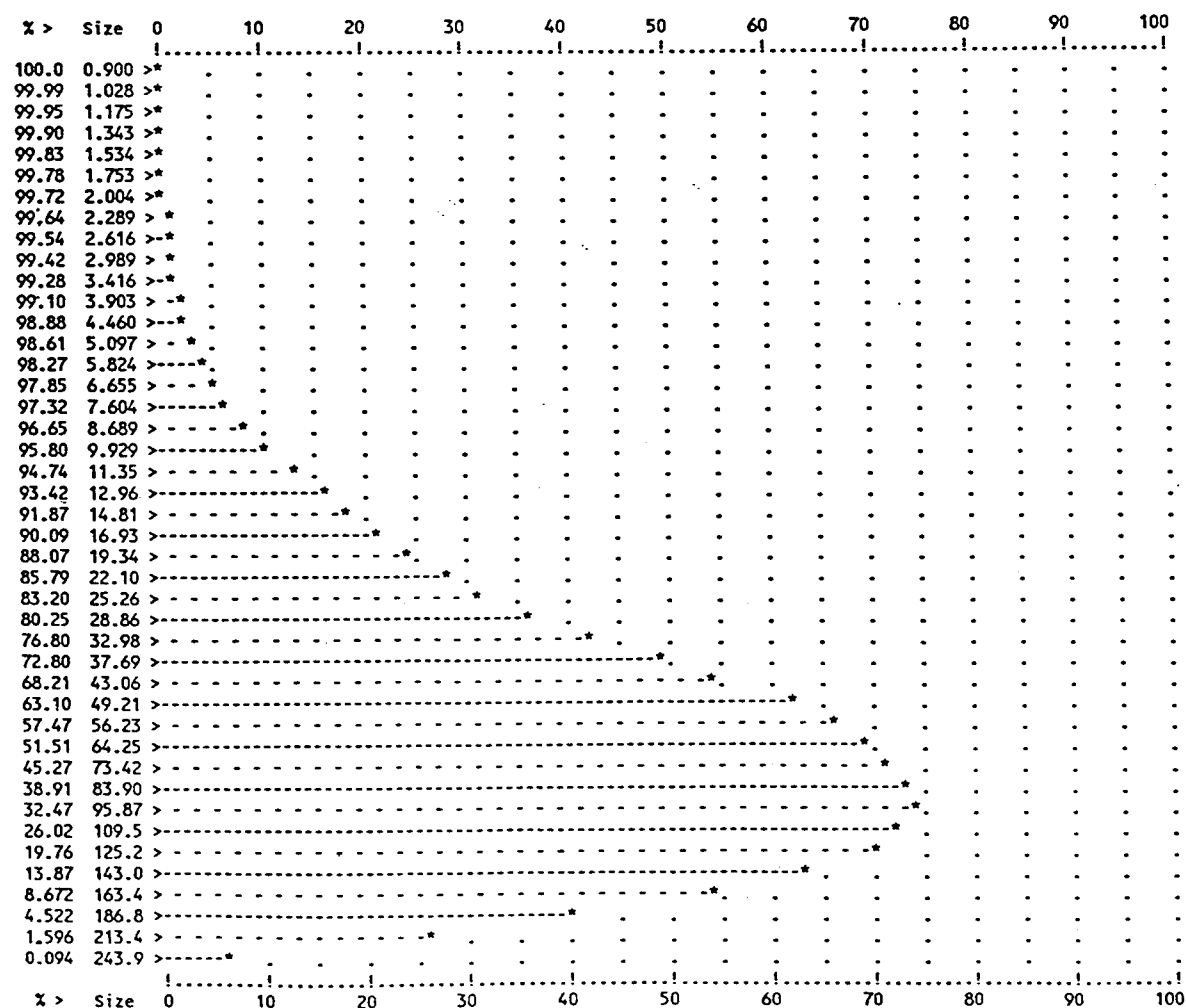
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 0.900 0 High at 128 255.0 0 Top of scale is 9830400

Graph of DIAM Size vs. Differential Volume From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | above | 243.3 um |
| 1.00%  | Volm | above | 221.6 um |
| 6.00%  | Volm | above | 177.0 um |
| 22.00% | Volm | above | 119.2 um |
| 50.00% | Volm | above | 66.38 um |
| 78.00% | Volm | above | 31.52 um |
| 94.00% | Volm | above | 12.25 um |
| 99.00% | Volm | above | 4.148 um |
| 99.90% | Volm | above | 1.329 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 1.803      arithmetic mean size = 2.419  
 standard deviation = 3.667      coeff.of variation = 203.4  
 median size = 1.434      mode size = 1.170

Total = 2064477

Coincidence Corrected: No

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   | Chnl | Size  | Counts | % >   |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|
| 1    | 0.900 | 0      | 100.0 | 33   | 3.734 | 16075  | 11.92 | 65   | 15.49 | 2058   | 1.101 | 97   | 64.25 | 102    | 0.037 |
| 2    | 0.941 | 282    | 99.99 | 34   | 3.903 | 14583  | 11.18 | 66   | 16.19 | 1933   | 1.005 | 98   | 67.17 | 92     | 0.032 |
| 3    | 0.984 | 52373  | 98.73 | 35   | 4.081 | 14069  | 10.48 | 67   | 16.93 | 1766   | 0.915 | 99   | 70.23 | 81     | 0.028 |
| 4    | 1.028 | 91670  | 95.25 | 36   | 4.266 | 13284  | 9.819 | 68   | 17.70 | 1610   | 0.833 | 100  | 73.42 | 71     | 0.024 |
| 5    | 1.075 | 120336 | 90.13 | 37   | 4.460 | 12203  | 9.202 | 69   | 18.50 | 1457   | 0.759 | 101  | 76.76 | 63     | 0.021 |
| 6    | 1.124 | 140412 | 83.82 | 38   | 4.663 | 11211  | 8.634 | 70   | 19.34 | 1326   | 0.691 | 102  | 80.25 | 54     | 0.018 |
| 7    | 1.175 | 153600 | 76.70 | 39   | 4.875 | 10606  | 8.106 | 71   | 20.22 | 1196   | 0.630 | 103  | 83.90 | 48     | 0.016 |
| 8    | 1.229 | 137051 | 69.66 | 40   | 5.097 | 10023  | 7.606 | 72   | 21.14 | 1102   | 0.575 | 104  | 87.71 | 44     | 0.014 |
| 9    | 1.284 | 126149 | 63.28 | 41   | 5.328 | 9670   | 7.129 | 73   | 22.10 | 1019   | 0.523 | 105  | 91.70 | 38     | 0.012 |
| 10   | 1.343 | 110557 | 57.54 | 42   | 5.571 | 9015   | 6.676 | 74   | 23.11 | 931    | 0.476 | 106  | 95.87 | 33     | 0.010 |
| 11   | 1.404 | 101568 | 52.40 | 43   | 5.824 | 8522   | 6.252 | 75   | 24.16 | 833    | 0.433 | 107  | 100.2 | 29     | 0.008 |
| 12   | 1.468 | 86956  | 47.83 | 44   | 6.089 | 8196   | 5.847 | 76   | 25.26 | 758    | 0.395 | 108  | 104.8 | 25     | 0.007 |
| 13   | 1.534 | 70941  | 44.00 | 45   | 6.365 | 7687   | 5.462 | 77   | 26.41 | 699    | 0.359 | 109  | 109.5 | 21     | 0.006 |
| 14   | 1.604 | 60381  | 40.82 | 46   | 6.655 | 7017   | 5.105 | 78   | 27.61 | 645    | 0.327 | 110  | 114.5 | 19     | 0.005 |
| 15   | 1.677 | 52842  | 38.08 | 47   | 6.957 | 6862   | 4.769 | 79   | 28.86 | 595    | 0.297 | 111  | 119.7 | 17     | 0.004 |
| 16   | 1.753 | 48327  | 35.62 | 48   | 7.274 | 6276   | 4.451 | 80   | 30.17 | 551    | 0.269 | 112  | 125.2 | 15     | 0.003 |
| 17   | 1.833 | 44053  | 33.39 | 49   | 7.604 | 6178   | 4.149 | 81   | 31.55 | 503    | 0.243 | 113  | 130.9 | 13     | 0.003 |
| 18   | 1.916 | 42500  | 31.29 | 50   | 7.950 | 5572   | 3.865 | 82   | 32.98 | 463    | 0.220 | 114  | 136.8 | 10     | 0.002 |
| 19   | 2.004 | 30994  | 29.51 | 51   | 8.312 | 5545   | 3.595 | 83   | 34.48 | 424    | 0.199 | 115  | 143.0 | 8      | 0.002 |
| 20   | 2.095 | 37510  | 27.85 | 52   | 8.689 | 5165   | 3.336 | 84   | 36.05 | 392    | 0.179 | 116  | 149.5 | 6      | 0.001 |
| 21   | 2.190 | 34264  | 26.11 | 53   | 9.085 | 4787   | 3.095 | 85   | 37.69 | 363    | 0.160 | 117  | 156.3 | 6      | 0.001 |
| 22   | 2.289 | 33859  | 24.46 | 54   | 9.498 | 4656   | 2.866 | 86   | 39.40 | 332    | 0.144 | 118  | 163.4 | 4      | 0.001 |
| 23   | 2.394 | 31468  | 22.88 | 55   | 9.929 | 4278   | 2.649 | 87   | 41.19 | 301    | 0.128 | 119  | 170.9 | 4      | 0.001 |
| 24   | 2.502 | 30907  | 21.37 | 56   | 10.38 | 4100   | 2.446 | 88   | 43.06 | 267    | 0.115 | 120  | 178.6 | 2      | 0.000 |
| 25   | 2.616 | 26971  | 19.96 | 57   | 10.85 | 3900   | 2.253 | 89   | 45.02 | 244    | 0.102 | 121  | 186.8 | 2      | 0.000 |
| 26   | 2.735 | 24474  | 18.72 | 58   | 11.35 | 3685   | 2.069 | 90   | 47.07 | 225    | 0.091 | 122  | 195.3 | 2      | 0.000 |
| 27   | 2.859 | 22844  | 17.57 | 59   | 11.86 | 3466   | 1.896 | 91   | 49.21 | 205    | 0.080 | 123  | 204.1 | 2      | 0.000 |
| 28   | 2.989 | 21213  | 16.50 | 60   | 12.40 | 3138   | 1.736 | 92   | 51.45 | 184    | 0.071 | 124  | 213.4 | 2      | 0.000 |
| 29   | 3.125 | 21215  | 15.48 | 61   | 12.96 | 2927   | 1.589 | 93   | 53.78 | 163    | 0.063 | 125  | 223.1 | 0      | 0.000 |
| 30   | 3.267 | 18581  | 14.51 | 62   | 13.55 | 2787   | 1.450 | 94   | 56.23 | 146    | 0.055 |      |       |        |       |
| 31   | 3.416 | 18691  | 13.61 | 63   | 14.17 | 2509   | 1.322 | 95   | 58.79 | 132    | 0.048 |      |       |        |       |
| 32   | 3.571 | 17474  | 12.73 | 64   | 14.81 | 2269   | 1.206 | 96   | 61.46 | 117    | 0.042 |      |       |        |       |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 MAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: ID-14966

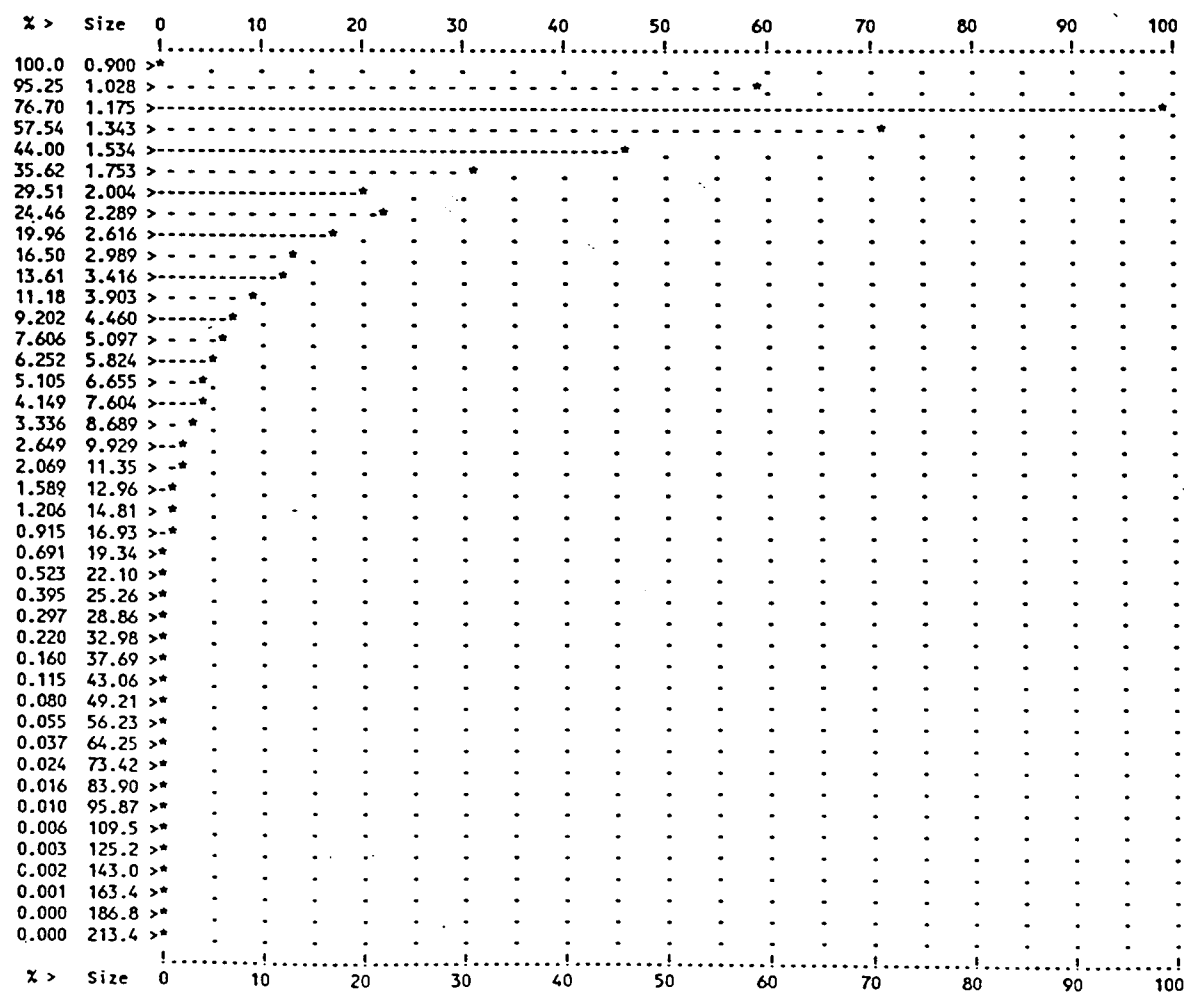
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICROWS.

Low at 1 0.900 0 High at 125 223.1 0 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 124 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Fri Mar 01 1989

Time: 11:50:12 a.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-3

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Popl | above | 45.33 um |
| 1.00%  | Popl | above | 16.21 um |
| 6.00%  | Popl | above | 5.983 um |
| 22.00% | Popl | above | 2.455 um |
| 50.00% | Popl | above | 1.432 um |
| 78.00% | Popl | above | 1.165 um |
| 94.00% | Popl | above | 1.040 um |
| 99.00% | Popl | above | 0.978 um |
| 99.90% | Popl | above | 0.963 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 MAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 47.35      arithmetic mean size = 64.66  
 standard deviation = 50.94      coeff.of variation = 107.6  
 median size = 51.75      mode size = 56.73

Total = 412905380

Coincidence Corrected: No

Extrapolated below: 3.415

VOLUME DISTRIBUTION DATA

| Chnl | Size  | Volume | % <   | Chnl | Size  | Volume  | % <   | Chnl | Size  | Volume  | % <   | Chnl | Size  | Volume  | % <    |
|------|-------|--------|-------|------|-------|---------|-------|------|-------|---------|-------|------|-------|---------|--------|
| 1    | 2.000 | 25439  | 0.003 | 33   | 6.792 | 888817  | 2.338 | 65   | 23.06 | 4211798 | 19.46 | 97   | 78.32 | 6831788 | 68.91  |
| 2    | 2.078 | 29390  | 0.010 | 34   | 7.056 | 990156  | 2.565 | 66   | 23.96 | 4467470 | 20.51 | 98   | 81.37 | 6787895 | 70.56  |
| 3    | 2.159 | 33892  | 0.017 | 35   | 7.331 | 1026124 | 2.809 | 67   | 24.89 | 4659944 | 21.62 | 99   | 84.54 | 6672659 | 72.19  |
| 4    | 2.243 | 39011  | 0.026 | 36   | 7.616 | 1101370 | 3.067 | 68   | 25.86 | 4789846 | 22.76 | 100  | 87.83 | 6674434 | 73.81  |
| 5    | 2.330 | 44820  | 0.036 | 37   | 7.913 | 1158289 | 3.340 | 69   | 26.87 | 4926498 | 23.94 | 101  | 91.25 | 6589775 | 75.41  |
| 6    | 2.421 | 51397  | 0.048 | 38   | 8.221 | 1275467 | 3.635 | 70   | 27.92 | 5108942 | 25.15 | 102  | 94.80 | 6465069 | 76.99  |
| 7    | 2.515 | 58830  | 0.061 | 39   | 8.541 | 1320236 | 3.949 | 71   | 29.01 | 5299800 | 26.41 | 103  | 98.50 | 6264684 | 78.54  |
| 8    | 2.613 | 67212  | 0.077 | 40   | 8.874 | 1348106 | 4.272 | 72   | 30.13 | 5523270 | 27.72 | 104  | 102.3 | 6010556 | 80.02  |
| 9    | 2.715 | 76645  | 0.094 | 41   | 9.220 | 1537468 | 4.621 | 73   | 31.31 | 5630896 | 29.07 | 105  | 106.3 | 5677103 | 81.44  |
| 10   | 2.821 | 87239  | 0.114 | 42   | 9.579 | 1618461 | 5.003 | 74   | 32.53 | 5799673 | 30.46 | 106  | 110.5 | 5842513 | 82.83  |
| 11   | 2.931 | 99113  | 0.136 | 43   | 9.952 | 1686211 | 5.403 | 75   | 33.79 | 5863831 | 31.87 | 107  | 114.8 | 5591192 | 84.22  |
| 12   | 3.045 | 112394 | 0.162 | 44   | 10.34 | 1796881 | 5.825 | 76   | 35.11 | 6060522 | 33.31 | 108  | 119.2 | 5416556 | 85.55  |
| 13   | 3.163 | 127216 | 0.191 | 45   | 10.74 | 1823832 | 6.263 | 77   | 36.48 | 6335984 | 34.81 | 109  | 123.9 | 5231019 | 86.84  |
| 14   | 3.286 | 143724 | 0.224 | 46   | 11.16 | 1919160 | 6.717 | 78   | 37.90 | 6366516 | 36.35 | 110  | 128.7 | 5125372 | 88.09  |
| 15   | 3.414 | 162073 | 0.261 | 47   | 11.59 | 2055316 | 7.198 | 79   | 39.37 | 6510759 | 37.91 | 111  | 133.7 | 4985622 | 89.32  |
| 16   | 3.547 | 219067 | 0.307 | 48   | 12.05 | 2088458 | 7.700 | 80   | 40.91 | 6636345 | 39.50 | 112  | 138.9 | 4650596 | 90.49  |
| 17   | 3.686 | 229763 | 0.361 | 49   | 12.52 | 2139100 | 8.211 | 81   | 42.50 | 6815479 | 41.13 | 113  | 144.3 | 4575512 | 91.60  |
| 18   | 3.829 | 257804 | 0.420 | 50   | 13.00 | 2193642 | 8.736 | 82   | 44.16 | 6906219 | 42.79 | 114  | 149.9 | 4337451 | 92.68  |
| 19   | 3.978 | 279499 | 0.485 | 51   | 13.51 | 2231645 | 9.272 | 83   | 45.88 | 7066206 | 44.48 | 115  | 155.8 | 4235890 | 93.72  |
| 20   | 4.133 | 328673 | 0.559 | 52   | 14.04 | 2276582 | 9.818 | 84   | 47.66 | 7164618 | 46.21 | 116  | 161.9 | 3735103 | 94.69  |
| 21   | 4.294 | 348064 | 0.641 | 53   | 14.58 | 2302318 | 10.37 | 85   | 49.52 | 7245624 | 47.95 | 117  | 168.2 | 3656186 | 95.58  |
| 22   | 4.461 | 368741 | 0.727 | 54   | 15.15 | 2433740 | 10.95 | 86   | 51.45 | 7319708 | 49.72 | 118  | 174.7 | 3203367 | 96.41  |
| 23   | 4.635 | 411603 | 0.822 | 55   | 15.74 | 2531782 | 11.55 | 87   | 53.45 | 7321644 | 51.49 | 119  | 181.5 | 3006721 | 97.17  |
| 24   | 4.816 | 449521 | 0.926 | 56   | 16.35 | 2640063 | 12.17 | 88   | 55.53 | 7323585 | 53.26 | 120  | 188.6 | 2542108 | 97.84  |
| 25   | 5.003 | 486358 | 1.039 | 57   | 16.99 | 2728981 | 12.82 | 89   | 57.69 | 7325533 | 55.04 | 121  | 195.9 | 2161122 | 98.41  |
| 26   | 5.198 | 526108 | 1.162 | 58   | 17.65 | 2867105 | 13.50 | 90   | 59.94 | 7308408 | 56.81 | 122  | 203.5 | 1810368 | 98.89  |
| 27   | 5.400 | 560203 | 1.294 | 59   | 18.34 | 3044468 | 14.22 | 91   | 62.28 | 7265593 | 58.57 | 123  | 211.5 | 1497347 | 99.29  |
| 28   | 5.611 | 603970 | 1.434 | 60   | 19.05 | 3221965 | 14.97 | 92   | 64.70 | 7249953 | 60.33 | 124  | 219.7 | 1081793 | 99.60  |
| 29   | 5.829 | 665768 | 1.588 | 61   | 19.79 | 3426551 | 15.78 | 93   | 67.22 | 7124793 | 62.07 | 125  | 228.3 | 615917  | 99.81  |
| 30   | 6.056 | 721100 | 1.756 | 62   | 20.57 | 3610718 | 16.63 | 94   | 69.84 | 7161307 | 63.80 | 126  | 237.2 | 298118  | 99.92  |
| 31   | 6.292 | 767400 | 1.936 | 63   | 21.37 | 3790277 | 17.53 | 95   | 72.56 | 7119730 | 65.53 | 127  | 246.4 | 173372  | 99.98  |
| 32   | 6.537 | 829486 | 2.129 | 64   | 22.20 | 3982098 | 18.47 | 96   | 75.38 | 6973851 | 67.24 | 128  | 256.0 | 6917    | 100.00 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

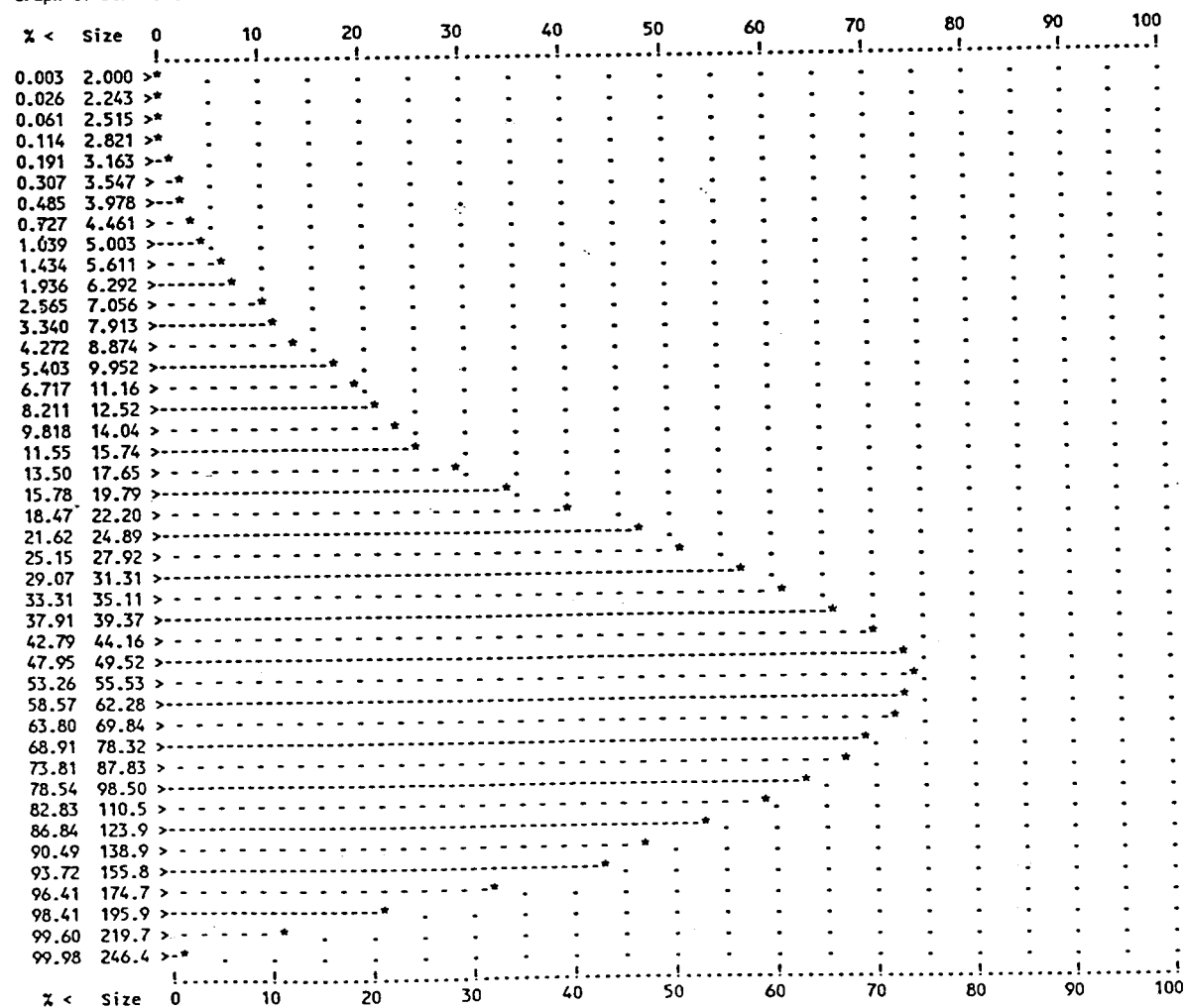
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 2.000 25439 High at 128 256.0 6917 Top of scale is 9830400

Graph of DIAM Size vs. Differential Volume From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELETROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Volm | below | 2.746 um |
| 1.00%  | Volm | below | 4.938 um |
| 6.00%  | Volm | below | 10.48 um |
| 22.00% | Volm | below | 25.19 um |
| 50.00% | Volm | below | 51.71 um |
| 78.00% | Volm | below | 97.15 um |
| 94.00% | Volm | below | 157.2 um |
| 99.00% | Volm | below | 205.3 um |
| 99.90% | Volm | below | 234.6 um |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

geometric mean size = 5.338  
 standard deviation = 36.84  
 median size = 4.427

arithmetic mean size = 11.48  
 coeff.of variation = 690.2  
 mode size = 3.590

Total = 5403924

Coincidence Corrected: No

Extrapolated below: 3.415

FREQUENCY DISTRIBUTION DATA

| Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <   | Chnl | Size  | Counts | % <   |
|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|------|-------|--------|-------|
| 1    | 2.000 | 99532  | 0.912 | 33   | 6.792 | 88813  | 71.97 | 65   | 23.06 | 10751  | 95.64 | 97   | 78.32 | 443    | 97.84 |
| 2    | 2.078 | 102548 | 2.782 | 34   | 7.056 | 88223  | 73.61 | 66   | 23.96 | 10161  | 95.83 | 98   | 81.37 | 393    | 97.85 |
| 3    | 2.159 | 105448 | 4.706 | 35   | 7.331 | 81520  | 75.18 | 67   | 24.89 | 9457   | 96.01 | 99   | 84.54 | 344    | 97.86 |
| 4    | 2.243 | 108218 | 6.683 | 36   | 7.616 | 78029  | 76.65 | 68   | 25.86 | 8670   | 96.18 | 100  | 87.83 | 311    | 97.86 |
| 5    | 2.330 | 110873 | 8.709 | 37   | 7.913 | 73178  | 78.05 | 69   | 26.87 | 7949   | 96.33 | 101  | 91.25 | 279    | 97.87 |
| 6    | 2.421 | 113381 | 10.78 | 38   | 8.221 | 71850  | 79.39 | 70   | 27.92 | 7342   | 96.48 | 102  | 94.80 | 229    | 97.87 |
| 7    | 2.515 | 115724 | 12.90 | 39   | 8.541 | 66311  | 80.67 | 71   | 29.01 | 6802   | 96.61 | 103  | 98.50 | 213    | 97.88 |
| 8    | 2.613 | 117888 | 15.07 | 40   | 8.874 | 60378  | 81.85 | 72   | 30.13 | 6310   | 96.73 | 104  | 102.3 | 180    | 97.88 |
| 9    | 2.715 | 119887 | 17.26 | 41   | 9.220 | 61410  | 82.97 | 73   | 31.31 | 5736   | 96.84 | 105  | 106.3 | 148    | 97.89 |
| 10   | 2.821 | 121674 | 19.50 | 42   | 9.579 | 57641  | 84.08 | 74   | 32.53 | 5277   | 96.94 | 106  | 110.5 | 131    | 97.89 |
| 11   | 2.931 | 123264 | 21.77 | 43   | 9.952 | 53560  | 85.10 | 75   | 33.79 | 4753   | 97.04 | 107  | 114.8 | 115    | 97.89 |
| 12   | 3.045 | 124640 | 24.06 | 44   | 10.34 | 50889  | 86.07 | 76   | 35.11 | 4376   | 97.12 | 108  | 119.2 | 98     | 97.89 |
| 13   | 3.163 | 125804 | 26.38 | 45   | 10.74 | 46054  | 86.97 | 77   | 36.48 | 4081   | 97.20 | 109  | 123.9 | 82     | 97.89 |
| 14   | 3.286 | 126738 | 28.71 | 46   | 11.16 | 43218  | 87.79 | 78   | 37.90 | 3655   | 97.27 | 110  | 128.7 | 82     | 97.90 |
| 15   | 3.414 | 127443 | 31.07 | 47   | 11.59 | 41268  | 88.58 | 79   | 39.37 | 3343   | 97.33 | 111  | 133.7 | 66     | 97.90 |
| 16   | 3.547 | 153600 | 33.66 | 48   | 12.05 | 37400  | 89.30 | 80   | 40.91 | 3032   | 97.39 | 112  | 138.9 | 49     | 97.90 |
| 17   | 3.686 | 143652 | 36.41 | 49   | 12.52 | 34155  | 89.97 | 81   | 42.50 | 2786   | 97.45 | 113  | 144.3 | 49     | 97.90 |
| 18   | 3.829 | 143734 | 39.07 | 50   | 13.00 | 31238  | 90.57 | 82   | 44.16 | 2508   | 97.50 | 114  | 149.9 | 33     | 97.90 |
| 19   | 3.978 | 138964 | 41.69 | 51   | 13.51 | 28337  | 91.12 | 83   | 45.88 | 2294   | 97.54 | 115  | 155.8 | 33     | 97.90 |
| 20   | 4.133 | 145717 | 44.32 | 52   | 14.04 | 25780  | 91.62 | 84   | 47.66 | 2065   | 97.58 | 116  | 161.9 | 33     | 97.90 |
| 21   | 4.294 | 137604 | 46.95 | 53   | 14.58 | 23240  | 92.08 | 85   | 49.52 | 1868   | 97.62 | 117  | 168.2 | 16     | 97.90 |
| 22   | 4.461 | 129983 | 49.42 | 54   | 15.15 | 21912  | 92.50 | 86   | 51.45 | 1688   | 97.65 | 118  | 174.7 | 16     | 97.90 |
| 23   | 4.635 | 129377 | 51.82 | 55   | 15.74 | 20323  | 92.89 | 87   | 53.45 | 1508   | 97.68 | 119  | 181.5 | 16     | 97.90 |
| 24   | 4.816 | 126001 | 54.18 | 56   | 16.35 | 18897  | 93.25 | 88   | 55.53 | 1344   | 97.71 | 120  | 188.6 | 16     | 97.90 |
| 25   | 5.003 | 121559 | 56.48 | 57   | 16.99 | 17422  | 93.59 | 89   | 57.69 | 1196   | 97.73 | 121  | 195.9 | 16     | 97.90 |
| 26   | 5.198 | 117265 | 58.69 | 58   | 17.65 | 16324  | 93.90 | 90   | 59.94 | 1065   | 97.75 | 122  | 203.5 | 0      | 97.90 |
| 27   | 5.400 | 111332 | 60.80 | 59   | 18.34 | 15455  | 94.19 | 91   | 62.28 | 934    | 97.77 | 123  | 211.5 | 0      | 97.90 |
| 28   | 5.611 | 107038 | 62.82 | 60   | 19.05 | 14586  | 94.47 | 92   | 64.70 | 836    | 97.79 | 124  | 219.7 | 0      | 97.90 |
| 29   | 5.829 | 105219 | 64.79 | 61   | 19.79 | 13833  | 94.73 | 93   | 67.22 | 738    | 97.80 | 125  | 228.3 | 0      | 97.90 |
| 30   | 6.056 | 101613 | 66.70 | 62   | 20.57 | 12997  | 94.98 | 94   | 69.84 | 656    | 97.81 | 126  | 237.2 | 0      | 97.90 |
| 31   | 6.292 | 96434  | 68.53 | 63   | 21.37 | 12161  | 95.22 | 95   | 72.56 | 590    | 97.82 | 127  | 246.4 | 0      | 97.90 |
| 32   | 6.537 | 92943  | 70.29 | 64   | 22.20 | 11391  | 95.43 | 96   | 75.38 | 508    | 97.83 | 128  | 256.0 | 113364 | 98.94 |

PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
 PARTICLE DATA, INC  
 111 HAHN ST., ELMHURST, IL 60126  
 TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

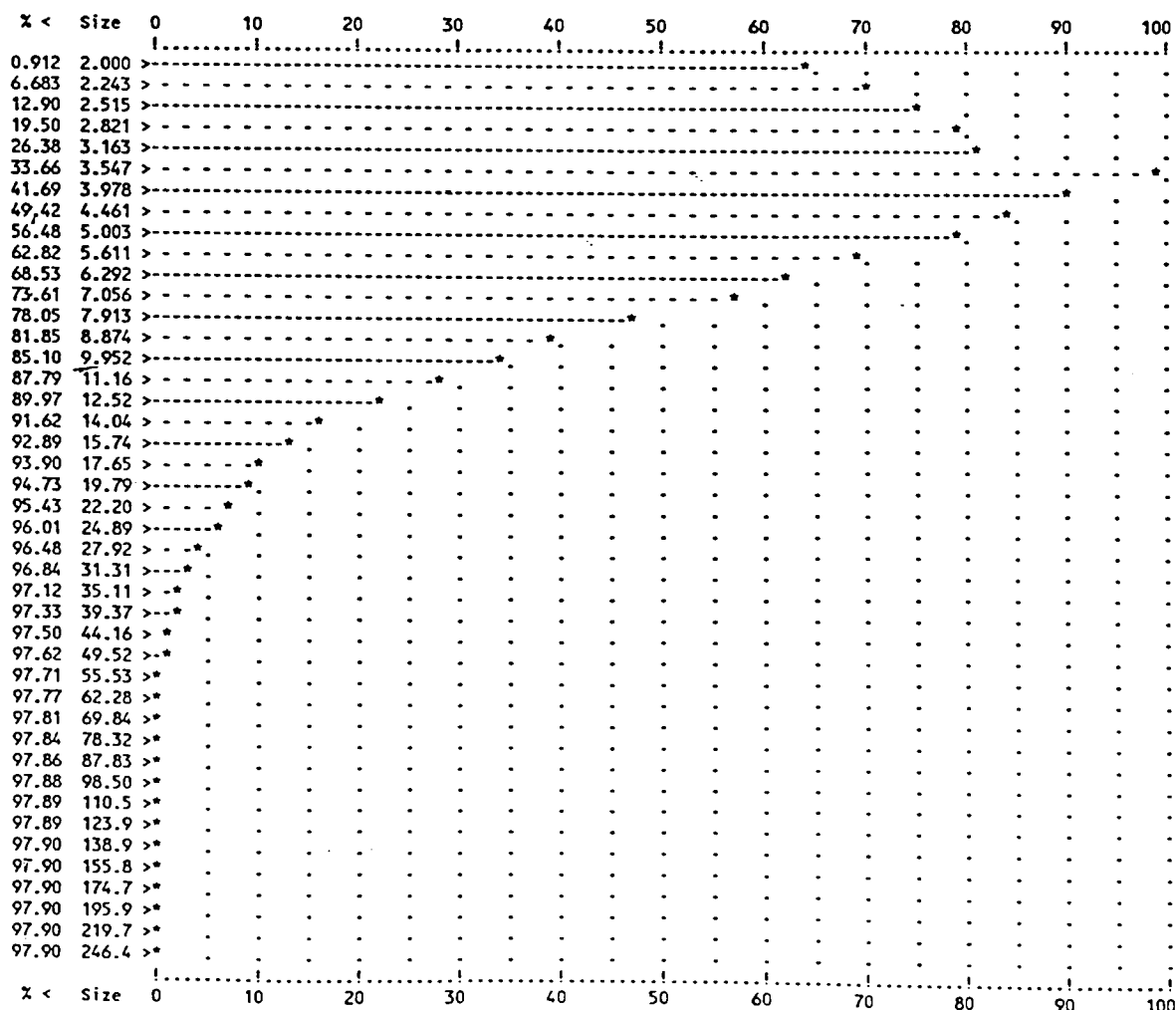
Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

Low at 1 2.000 99532 High at 128 256.0 113364 Top of scale is 153600

Graph of DIAM Size vs. Differential Counts From channel 1 to 127 skip: 2



PARTICLE SIZE ANALYSIS BY ELEKTROZONE METHOD  
PARTICLE DATA, INC  
111 HAHN ST., ELMHURST, IL 60126  
TEL: 312 832 5653 FAX: 312 832 5686

Date: Thu Feb 28 1989

Time: 3:51:23 p.m.

Client: U.S. ARMY ENGINEERS.

Sample Number: RMA-1

Job No: ID-14966

Technician: L.W

Special Comments

SAMPLE SIVED AT 250 MICRONS.

PERCENTILES

|        |      |       |          |
|--------|------|-------|----------|
| 0.10%  | Popl | below | 1.964 um |
| 1.00%  | Popl | below | 1.982 um |
| 6.00%  | Popl | below | 2.213 um |
| 22.00% | Popl | below | 2.940 um |
| 50.00% | Popl | below | 4.498 um |
| 78.00% | Popl | below | 7.896 um |
| 94.00% | Popl | below | 17.86 um |
| 99.00% | Popl | below | 256.1 um |
| 99.90% | Popl | below | 260.1 um |

## APPENDIX B: MICROBIOLOGICAL METHODS



## Materials and Methods

### Media composition

Fermenter medium: Trypticase soy 2 g/l, glucose 3 g/l, mineral salts 100 ml/l, phenol red 10 mg/l, pH to 7.2.

Sulfate reducer/facultative: Trypticase soy 3 g/l, Na lactate 10 mM, HEPES buffer 10 mM, FeSO<sub>4</sub> 100 µl of 2.5 percent stock solution/l, resazurin add stock till faint blue, mineral salts 100 ml/l, Hutner's mineral base 10 ml/l, pH to 7.2, reduce with sulfide free cysteine HCl and oxygen free nitrogen.

Heterotrophic aerotolerant medium: Trypticase soy 500 mg/l, Na succinate 300 mg/l, 150 mg/l filter sterilized yeast extract, mineral salts 100 ml/l, Hutner's mineral base 10 ml/l.

Mineral salts: NH<sub>4</sub>Cl 20 mM, Na<sub>2</sub>PO<sub>4</sub> 2 mM.

Hutner's mineral base: As formulated in Manual of Methods for General Bacteriology.

### MPN procedure

The 5 tube Most Probable number method was used to evaluate numbers of Heterotrophic Aerotolerant bacteria, Facultative bacteria, Sulfate Reducing bacteria and Fermenting bacteria. This method is outlined in Standard Methods for the Examination of Water and Waste Water, 14th edition. The formula for calculation used is found in the Manual of Methods for General Bacteriology. A basic program was developed by Heather Allison to run on an IBM PC computer in this laboratory.

### Membrane filtration method

The membrane filtration method was used to enumerate fungi, as published in Manual of Methods for General Bacteriology. Gelman GA filters, 0.2 µm porosity, were used for these evaluations.

### Epifluorescence acridine orange photomicroscopy

Samples were fixed on collection with the addition of formalin (1 percent v/v). Samples were stained for 5 min with acridine orange (final concentration 10 mg/ml) prior to filtration onto Nuclepore filters (Irgalan black stained, 0.2 µm porosity). A Nikon epifluorescent microscope was used for photomicroscopy.

APPENDIX C: UNREDUCED SUSPENDED SOLIDS DATA

Table C1

## North Boundary Treatment System Solids Mass Balance Analysis RMA

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 1A            | Well No. 19        | 9-21-88 | 1532 | 1.47011          | 300                   | 1.47013         | 0.07                     |
| B             |                    |         |      | 1.47255          | 300                   | 1.47262         | 0.23                     |
| C             |                    |         |      | 1.47648          | 300                   | 1.47652         | 0.13                     |
| 2A            | Well No. 19        | 9-22-88 | 1533 | 1.46836          | 300                   | 1.46820         | -0.53                    |
| B             |                    |         |      | 1.47372          | 300                   | 1.47350         | -0.73                    |
| C             |                    |         |      | 1.47629          | 300                   | 1.47623         | -0.20                    |
| 3A            | Well No. 19        | 9-23-88 | 1435 | 1.47270          | 200                   | 1.47250         | -1.00                    |
| B             |                    |         |      | 1.47540          | 200                   | 1.47530         | -0.50                    |
| C             |                    |         |      | 1.47648          | 200                   | 1.47630         | -0.90                    |
| 4A            | Well No. 19        | 9-20-88 | 1643 | 1.47362          | 300                   | 1.47360         | -0.07                    |
| B             |                    |         |      | 1.47481          | 300                   | 1.47485         | 0.13                     |
| C             |                    |         |      | 1.47831          | 300                   | 1.47825         | -0.20                    |
| 5A            | Well No. 19        | 9-19-88 | 1700 | 1.47720          | 100                   | 1.47707         | -1.30                    |
| B             |                    |         |      | 1.47507          | 100                   | 1.47486         | -2.10                    |
| C             |                    |         |      | 1.47378          | 100                   | 1.47353         | -2.50                    |
| 6A            | Well No. 21        | 9-20-88 | 1650 | 1.47707          | 300                   | 1.47700         | -0.23                    |
| B             |                    |         |      | 1.48099          | 300                   | 1.48096         | -0.10                    |
| C             |                    |         |      | 1.47944          | 300                   | 1.47945         | 0.03                     |
| 7A            | Well No. 21        | 9-23-88 | 1439 | 1.47548          | 200                   | 1.47540         | -0.40                    |
| B             |                    |         |      | 1.47994          | 200                   | 1.47972         | -1.10                    |
| C             |                    |         |      | 1.47592          | 200                   | 1.47597         | 0.25                     |

(Continued)

(Sheet 1 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time       | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------------|------------------|-----------------------|-----------------|--------------------------|
| 8A            | Well No. 21        | 9-19-88 | 1705       | 1.48046          | 300                   | 1.48043         | -0.10                    |
| B             |                    |         |            | 1.47929          | 300                   | 1.47920         | -0.30                    |
| C             |                    |         |            | 1.47693          | 300                   | 1.47681         | -0.40                    |
| 9A            | Well No. 21        | 9-22-88 | 1538       | 1.47053          | 300                   | 1.47042         | -0.37                    |
| B             |                    |         |            | 1.47428          | 300                   | 1.47426         | -0.08                    |
| C             |                    |         |            | 1.47497          | 300                   | 1.47486         | -0.37                    |
| 10A           | Well No. 21        | 9-21-88 | 1538       | 1.47966          | 300                   | 1.47960         | -0.20                    |
| B             |                    |         |            | 1.47729          | 300                   | 1.47724         | -0.17                    |
| C             |                    |         |            | 1.47976          | 300                   | 1.47974         | 0.07                     |
| 11A           | Well No. 24        | 9-22-88 | 1542       | 1.48107          | 300                   | 1.48108         | 0.03                     |
| B             |                    |         |            | 1.47781          | 300                   | 1.47777         | -0.13                    |
| C             |                    |         |            | 1.47853          | 300                   | 1.47846         | -0.23                    |
| 12A           | Well No. 24        | 9-19-88 | 1630, 1711 | 1.47814          | 300                   | 1.47825         | 0.37                     |
| B             |                    |         |            | 1.48514          | 300                   | 1.48513         | -0.03                    |
| C             |                    |         |            | 1.48203          | 300                   | 1.48237         | 1.13                     |
| 13A           | Well No. 24        | 9-23-88 | 1545       | 1.51001          | 300                   | 1.51098         | 3.23                     |
| B             |                    |         |            | 1.51118          | 300                   | 1.51139         | 0.70                     |
| C             |                    |         |            | 1.50968          | 300                   | 1.51056         | 2.93                     |
| 14A           | Well No. 24        | 9-23-88 | 1444       | 1.50652          | 300                   | 1.50662         | 0.33                     |
| B             |                    |         |            | 1.50026          | 300                   | 1.50038         | 0.40                     |
| C             |                    |         |            | 1.50005          | 300                   | 1.50015         | 0.33                     |

(Continued)

(Sheet 2 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 15A           | Well No. 24        | 9-20-88 | 1657 | 1.49829          | 300                   | 1.49837         | 0.27                     |
| B             |                    |         |      | 1.47564          | 300                   | 1.49567         | 0.10                     |
| C             |                    |         |      | 1.51174          | 300                   | 1.51179         | 0.17                     |
| 16A           | Carbon Wash        | 9-20-88 | 1125 | 1.50973          | 100                   | 1.51211         | 23.80                    |
| B             |                    |         |      | 1.51098          | 100                   | 1.51305         | 20.70                    |
| C             |                    |         |      | 1.49498          | 100                   | 1.49734         | 23.60                    |
| 17A           | Wash               | 9-16-88 | 1000 | 1.47315          | 300                   | 1.47359         | 1.47                     |
| B             |                    |         |      | 1.47433          | 300                   | 1.47483         | 1.67                     |
| C             |                    |         |      | 1.47245          | 300                   | 1.47293         | 1.60                     |
| 18A           | Wash               | 9-16-88 | 1000 | 1.47070          | 300                   | 1.47301         | 7.70                     |
| B             |                    |         |      | 1.46932          | 300                   | 1.47157         | 7.50                     |
| C             |                    |         |      | 1.46869          | 300                   | 1.47124         | 8.50                     |
| 19A           | A-Wash             | 9-16-88 | 1000 | 1.46455          | 300                   | 1.46671         | 7.20                     |
| B             |                    |         |      | 1.46712          | 300                   | 1.46927         | 7.17                     |
| C             |                    |         |      | 1.46755          | 300                   | 1.46943         | 6.27                     |
| 20A           | RC-25              | 9-16-88 | 1400 | 1.46700          | 300                   | 1.46701         | 0.03                     |
| B             |                    |         |      | 1.46888          | 300                   | 1.46888         | 0.00                     |
| C             |                    |         |      | 1.47288          | 300                   | 1.47297         | 0.30                     |
| 21A           | CW-13A             | 9-13-88 | 1140 | 1.47088          | 100                   | 1.52351         | 526.30                   |
| B             |                    |         |      | 1.46195          | 100                   | 1.51392         | 519.70                   |
| C             |                    |         |      | 1.46512          | 100                   | 1.51347         | 483.50                   |

(Continued)

(Sheet 3 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 22A           | CW-13B             | 9-13-88 | 1140 | 1.46566          | 100                   | 1.46804         | 23.80                    |
| B             |                    |         |      | 1.46779          | 100                   | 1.47004         | 22.50                    |
| C             |                    |         |      | 1.46294          | 100                   | 1.46528         | 23.40                    |
| 23A           | 13                 | --      | --   | 1.66388          | 600                   | 1.66514         | 2.10                     |
| B             |                    |         |      | 1.67037          | 600                   | 1.67175         | 2.30                     |
| C             |                    |         |      | 1.67300          | 600                   | 1.67461         | 2.68                     |
| 24A           | 18                 | 9-13-88 | 1550 | 1.46080          | 100                   | 1.46446         | 36.60                    |
| B             |                    |         |      | 1.46460          | 100                   | 1.46856         | 39.60                    |
| C             |                    |         |      | 1.47028          | 100                   | 1.47393         | 36.50                    |
| 25A           | 21                 | 9-16-88 | 1320 | 1.47012          | 300                   | 1.47042         | 1.00                     |
| B             |                    |         |      | 1.46774          | 300                   | 1.46794         | 0.67                     |
| C             |                    |         |      | 1.46425          | 300                   | 1.46450         | 0.83                     |
| 26A           | 21                 | 9-14-88 | 1450 | 1.46443          | 100                   | 1.46749         | 30.60                    |
| B             |                    |         |      | 1.47248          | 100                   | 1.47517         | 26.90                    |
| C             |                    |         |      | 1.47181          | 100                   | 1.47491         | 31.00                    |
| 27A           | 21                 | 9-15-88 | 1500 | 1.46486          | 300                   | 1.46512         | 0.87                     |
| B             |                    |         |      | 1.47088          | 300                   | 1.47112         | 0.80                     |
| C             |                    |         |      | 1.46456          | 300                   | 1.46476         | 0.67                     |
| 28A           | 22                 | 9-16-88 | 1320 | 1.47336          | 300                   | 1.47368         | 1.07                     |
| B             |                    |         |      | 1.46638          | 300                   | 1.46663         | 0.83                     |
| C             |                    |         |      | 1.46431          | 300                   | 1.46457         | 0.87                     |

(Continued)

(Sheet 4 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight g | Volume Filtered ml | Dry Weight g | Suspended Solids mg/l |
|---------------|--------------------|---------|------|---------------|--------------------|--------------|-----------------------|
| 29A           | 22                 | 9-15-88 | 1500 | 1.48259       | 300                | 1.48266      | 0.23                  |
| B             |                    |         |      | 1.46810       | 300                | 1.46848      | 1.27                  |
| C             |                    |         |      | 1.46904       | 300                | 1.46965      | 2.03                  |
| 30A           | 22                 | 9-14-88 | 1450 | 1.47363       | 300                | 1.47435      | 2.40                  |
| B             |                    |         |      | 1.46850       | 300                | 1.46954      | 3.47                  |
| C             |                    |         |      | 1.46795       | 300                | 1.46806      | 0.37                  |
| 31A           | 12                 | 9-13-88 | 1420 | 1.47234       | 300                | 1.47250      | 0.53                  |
| B             |                    |         |      | 1.47609       | 300                | 1.47616      | 0.23                  |
| C             |                    |         |      | 1.47293       | 300                | 1.47339      | 1.53                  |
| 32A           | 12                 | 9-14-88 | 1452 | 1.47104       | 300                | 1.47106      | 0.07                  |
| B             |                    |         |      | 1.47480       | 300                | 1.47482      | 0.07                  |
| C             |                    |         |      | 1.47786       | 300                | 1.47786      | 0.00                  |
| 33A           | 12                 | 9-15-88 | 1500 | 1.47356       | 300                | 1.47357      | 0.03                  |
| B             |                    |         |      | 1.47365       | 300                | 1.47365      | 0.00                  |
| C             |                    |         |      | 1.47436       | 300                | 1.47440      | 0.13                  |
| 34A           | 12                 | 9-16-88 | 1400 | 1.47596       | 300                | 1.47596      | 0.00                  |
| B             |                    |         |      | 1.47116       | 300                | 1.47117      | 0.03                  |
| C             |                    |         |      | 1.47442       | 300                | 1.47451      | 0.30                  |
| 35A           | 11                 | 9-22-88 | 1515 | 1.51337       | 900                | 1.51343      | 0.07                  |
| B             |                    |         |      | 1.51066       | 900                | 1.51067      | 0.01                  |
| C             |                    |         |      | 1.51000       | 900                | 1.51013      | 0.14                  |

(Continued)

(Sheet 5 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 36A           | 11                 | 9-23-88 | 1455 | 1.50764          | 900                   | 1.50770         | 0.07                     |
| B             |                    |         |      | 1.51221          | 900                   | 1.51226         | 0.06                     |
| C             |                    |         |      | 1.51490          | 900                   | 1.51498         | 0.09                     |
| 37A           | 11                 | 9-15-88 | 1500 | 1.51458          | 900                   | 1.51348         | -1.22                    |
| B             |                    |         |      | 1.51080          | 900                   | 1.51261         | 2.01                     |
| C             |                    |         |      | 1.51321          | 900                   | 1.51208         | -1.26                    |
| 38A           | 11                 | 9-21-88 | 0840 | 1.51669          | 900                   | 1.51756         | 0.97                     |
| B             |                    |         |      | 1.51385          | 900                   | 1.51516         | 1.46                     |
| C             |                    |         |      | 1.50743          | 900                   | 1.50882         | 1.54                     |
| 39A           | 11                 | 9-14-88 | 1450 | 1.50621          | 900                   | 1.50662         | 0.46                     |
| B             |                    |         |      | 1.51193          | 900                   | 1.51222         | 0.32                     |
| C             |                    |         |      | 1.50803          | 900                   | 1.50853         | 0.56                     |
| 40A           | 11                 | 9-21-88 | 1518 | 1.51639          | 600                   | 1.51700         | 1.02                     |
| B             |                    |         |      | 1.51603          | 600                   | 1.51677         | 1.07                     |
| C             |                    |         |      | 1.51737          | 600                   | 1.51806         | 1.15                     |
| 41A           | 11                 | 9-22-88 | 0850 | 1.51754          | 900                   | 1.51791         | 0.41                     |
| B             |                    |         |      | 1.51349          | 900                   | 1.51366         | 0.19                     |
| C             |                    |         |      | 1.51898          | 900                   | 1.51920         | 0.24                     |
| 42A           | 11                 | 9-16-88 | 0900 | 1.70220          | 600                   | 1.70252         | 0.53                     |
| B             |                    |         |      | 1.68226          | 600                   | 1.68310         | 1.40                     |
| C             |                    |         |      | 1.68361          | 600                   | 1.68418         | 0.95                     |

(Continued)

(Sheet 6 of 23)

Table C1 (Continued)

| Lab<br>ID<br>Number | Sample<br>Description | Date    | Time | Tare<br>Weight<br>g | Volume<br>Filtered<br>ml | Dry<br>Weight<br>g | Suspended<br>Solids<br>mg/l |
|---------------------|-----------------------|---------|------|---------------------|--------------------------|--------------------|-----------------------------|
| 43A                 | 11                    | 9-16-88 | 1618 | 1.65491             | 600                      | 1.65483            | -0.13                       |
| B                   |                       |         |      | 1.67442             | 600                      | 1.67440            | -0.03                       |
| C                   |                       |         |      | 1.67564             | 600                      | 1.67558            | -0.10                       |
| 44A                 | 11                    | 9-15-88 | 0920 | 1.67227             | 600                      | 1.67223            | -0.07                       |
| B                   |                       |         |      | 1.67883             | 600                      | 1.67883            | 0.00                        |
| C                   |                       |         |      | 1.66596             | 600                      | 1.66597            | 0.02                        |
| 45A                 | 11                    | 9-23-88 | 0905 | 1.68700             | 900                      | 1.68682            | -0.20                       |
| B                   |                       |         |      | 1.51193             | 900                      | 1.66380            | -0.14                       |
| C                   |                       |         |      | 1.67049             | 900                      | 1.67043            | -0.07                       |
| 46A                 | 11                    | 9-16-88 | 1320 | 1.66267             | 600                      | 1.66321            | 0.90                        |
| B                   |                       |         |      | 1.66265             | 600                      | 1.66308            | 0.72                        |
| C                   |                       |         |      | 1.65580             | 600                      | 1.65640            | 1.00                        |
| 47A                 | 11                    | 9-13-88 | 1000 | 1.68061             | 300                      | 1.68100            | 1.30                        |
| B                   |                       |         |      | 1.66282             | 300                      | 1.66332            | 1.67                        |
| C                   |                       |         |      | 1.67425             | 300                      | 1.67476            | 1.70                        |
| 48A                 | RC-10                 | 9-13-88 | 1000 | 1.66985             | 300                      | 1.67027            | 1.40                        |
| B                   |                       |         |      | 1.67185             | 300                      | 1.67232            | 1.57                        |
| C                   |                       |         |      | 1.66090             | 300                      | 1.66313            | 7.43                        |
| 49A                 | RC-10 IN              | 9-16-88 | 1400 | 1.66363             | 900                      | 1.66328            | -0.39                       |
| B                   |                       |         |      | 1.67337             | 900                      | 1.67308            | -0.32                       |
| C                   |                       |         |      | 1.67422             | 900                      | 1.67400            | -0.24                       |

(Continued)

(Sheet 7 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 50A           | No. 10             | 9-15-88 | 0920 | 1.68137          | 600                   | 1.68194         | 0.95                     |
| B             |                    |         |      | 1.67354          | 600                   | 1.67386         | 0.53                     |
| C             |                    |         |      | 1.66695          | 600                   | 1.66731         | 0.60                     |
| 51A           | No. 10             | 9-23-88 | 1421 | 1.64377          | 900                   | 1.64402         | 0.28                     |
| B             |                    |         |      | 1.67115          | 900                   | 1.67155         | 0.44                     |
| C             |                    |         |      | 1.68667          | 900                   | 1.68690         | 0.26                     |
| 52A           | No. 10             | 9-22-88 | 1510 | 1.67817          | 900                   | 1.67853         | 0.40                     |
| B             |                    |         |      | 1.68419          | 900                   | 1.68444         | 0.28                     |
| C             |                    |         |      | 1.66093          | 900                   | 1.66155         | 0.24                     |
| 53A           | No. 10             | 9-14-88 | 1450 | 1.67554          | 900                   | 1.67568         | 0.16                     |
| B             |                    |         |      | 1.65794          | 900                   | 1.65805         | 0.12                     |
| C             |                    |         |      | 1.67156          | 900                   | 1.67173         | 0.19                     |
| 54A           | No. 10             | 9-20-88 | 1505 | 1.66507          | 900                   | 1.66521         | 0.16                     |
| B             |                    |         |      | 1.68567          | 900                   | 1.68596         | 0.32                     |
| C             |                    |         |      | 1.69620          | 900                   | 1.69653         | 0.37                     |
| 55A           | No. 10             | 9-13-88 | 1000 | 1.67507          | 300                   | 1.67567         | 2.00                     |
| B             |                    |         |      | 1.68461          | 300                   | 1.68537         | 2.53                     |
| C             |                    |         |      | 1.66415          | 300                   | 1.66494         | 2.63                     |
| 55A           | No. 10             | 9-15-88 | 1500 | 1.65573          | 900                   | 1.65649         | 0.84                     |
| B             |                    |         |      | 1.70038          | 900                   | 1.70101         | 0.70                     |
| C             |                    |         |      | 1.64916          | 900                   | 1.64896         | 0.78                     |

(Continued)

(Sheet 8 of 23)

Table C1 (Continued)

| Lab<br>ID<br>Number | Sample<br>Description | Date    | Time | Tare<br>Weight<br>g | Volume<br>Filtered<br>ml | Dry<br>Weight<br>g | Suspended<br>Solids<br>mg/l |
|---------------------|-----------------------|---------|------|---------------------|--------------------------|--------------------|-----------------------------|
| 57A                 | No. 10                | 9-16-88 | 1320 | 1.66774             | 900                      | 1.66795            | 0.23                        |
| B                   |                       |         |      | 1.67181             | 900                      | 1.67194            | 0.14                        |
| C                   |                       |         |      | 1.66900             | 900                      | 1.66922            | 0.24                        |
| 58A                 | No. 9-C               | 9-19-88 | 0905 | 1.65477             | 600                      | 1.65505            | 0.47                        |
| B                   |                       |         |      | 1.68888             | 600                      | 1.68915            | 0.45                        |
| C                   |                       |         |      | 1.67686             | 600                      | 1.67725            | 0.65                        |
| 59A                 | No. 9-C               | 9-19-88 | 1615 | 1.66347             | 600                      | 1.66407            | 1.00                        |
| B                   |                       |         |      | 1.67015             | 600                      | 1.67075            | 1.00                        |
| C                   |                       |         |      | 1.66966             | 600                      | 1.67042            | 1.27                        |
| 60A                 | No. 9-C               | 9-21-88 | 0830 | 1.69925             | 600                      | 1.70053            | 2.13                        |
| B                   |                       |         |      | 1.67731             | 600                      | 1.67812            | 0.35                        |
| C                   |                       |         |      | 1.65617             | 600                      | 1.65687            | 1.17                        |
| 61A                 | No. 9-C               | 9-20-88 | 1510 | 1.66812             | 600                      | 1.66827            | 0.25                        |
| B                   |                       |         |      | 1.66360             | 600                      | 1.66366            | 0.10                        |
| C                   |                       |         |      | 1.69300             | 600                      | 1.69308            | 0.13                        |
| 62A                 | No. 9                 | 9-22-88 | 1525 | 1.66325             | 600                      | 1.66446            | 2.02                        |
| B                   |                       |         |      | 1.65104             | 600                      | 1.65235            | 2.18                        |
| C                   |                       |         |      | 1.70376             | 600                      | 1.70463            | 1.45                        |
| 63A                 | No. 9                 | 9-23-88 | 1500 | 1.68566             | 600                      | 1.68572            | 0.10                        |
| B                   |                       |         |      | 1.67656             | 600                      | 1.67657            | 0.02                        |
| C                   |                       |         |      | 1.69665             | 600                      | 1.69685            | 0.33                        |

(Continued)

(Sheet 9 of 23)

Table C1 (Continued)

| Lab<br>ID<br>Number | Sample<br>Description | Date    | Time | Tare<br>Weight<br>g | Volume<br>Filtered<br>ml | Dry<br>Weight<br>g | Suspended<br>Solids<br>mg/l |
|---------------------|-----------------------|---------|------|---------------------|--------------------------|--------------------|-----------------------------|
| 64A                 | No. 9                 | 9-22-88 | 0855 | 1.69783             | 600                      | 1.69754            | -0.48                       |
| B                   |                       |         |      | 1.66599             | 600                      | 1.66583            | -0.27                       |
| C                   |                       |         |      | 1.68428             | 600                      | 1.68400            | -0.47                       |
| 65A                 | No. 9                 | 9-14-88 | 1450 | 1.67461             | 600                      | 1.67442            | -0.32                       |
| B                   |                       |         |      | 1.65447             | 600                      | 1.65433            | -0.23                       |
| C                   |                       |         |      | 1.67155             | 600                      | 1.67144            | -0.18                       |
| 66A                 | No. 9                 | 9-23-88 | 0900 | 1.66865             | 900                      | 1.66832            | -0.37                       |
| B                   |                       |         |      | 1.68821             | 900                      | 1.68801            | -0.22                       |
| C                   |                       |         |      | 1.66731             | 900                      | 1.66707            | -0.27                       |
| 67A                 | No. 9                 | 9-13-88 | 1000 | 1.67674             | 300                      | 1.67714            | 1.33                        |
| B                   |                       |         |      | 1.68581             | 300                      | 1.68592            | 0.37                        |
| C                   |                       |         |      | 1.63905             | 300                      | 1.63919            | 0.47                        |
| 68A                 | No. 9                 | 9-15-88 | 1500 | 1.65965             | 600                      | 1.65966            | 0.02                        |
| B                   |                       |         |      | 1.68567             | 600                      | 1.68554            | -0.22                       |
| C                   |                       |         |      | 1.68913             | 600                      | 1.68899            | -0.23                       |
| 69A                 | No. 9                 | 9-16-88 | 1320 | 1.66557             | 600                      | 1.66543            | -0.23                       |
| B                   |                       |         |      | 1.66050             | 600                      | 1.66035            | -0.25                       |
| C                   |                       |         |      | 1.66740             | 600                      | 1.66728            | -0.20                       |
| 70A                 | No. 8-B               | 9-21-88 | 0830 | 1.68141             | 900                      | 1.68146            | 0.06                        |
| B                   |                       |         |      | 1.68702             | 900                      | 1.68705            | 0.03                        |
| C                   |                       |         |      | 1.66247             | 900                      | 1.66257            | 0.11                        |

(Continued)

(Sheet 10 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 71A           | No. 8-B            | 9-20-88 | 1510 | 1.67047          | 600                   | 1.67073         | 0.43                     |
| B             |                    |         |      | 1.69645          | 600                   | 1.69680         | 0.58                     |
| C             |                    |         |      | 1.67590          | 600                   | 1.67620         | 0.50                     |
| 72A           | No. 8-B            | 9-19-88 | --   | 1.67970          | 600                   | 1.68026         | 0.93                     |
| B             |                    |         |      | 1.68651          | 600                   | 1.65433         | 1.45                     |
| C             |                    |         |      | 1.65789          | 600                   | 1.67144         | 1.30                     |
| 73A           | No. 8-B            | 9-19-88 | 1615 | 1.67426          | 900                   | 1.67524         | 1.09                     |
| B             |                    |         |      | 1.68700          | 900                   | 1.68783         | 0.92                     |
| C             |                    |         |      | 1.67710          | 900                   | 1.67800         | 1.00                     |
| 74A           | Well No. 8         | 9-22-88 | 1530 | 1.68743          | 900                   | 1.68778         | 0.39                     |
| B             |                    |         |      | 1.67026          | 900                   | 1.67064         | 0.42                     |
| C             |                    |         |      | 1.65338          | 900                   | 1.65356         | 0.20                     |
| 75A           | Well No. 8         | 9-23-88 | 1430 | 1.68365          | 900                   | 1.68390         | 0.28                     |
| B             |                    |         |      | 1.66695          | 900                   | 1.66729         | 0.38                     |
| C             |                    |         |      | 1.68677          | 900                   | 1.68701         | 0.27                     |
| 76A           | Well No. 8         | 9-22-88 | 1525 | 1.67016          | 600                   | 1.67104         | 1.47                     |
| B             |                    |         |      | 1.66872          | 600                   | 1.66952         | 1.33                     |
| C             |                    |         |      | 1.69016          | 600                   | 1.69105         | 1.48                     |
| 77A           | Well No. 8         | 9-23-88 | 1455 | 1.68777          | 600                   | 1.68805         | 0.47                     |
| B             |                    |         |      | 1.68894          | 600                   | 1.68916         | 0.37                     |
| C             |                    |         |      | 1.67935          | 600                   | 1.67968         | 0.55                     |

(Continued)

(Sheet 11 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time       | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------------|------------------|-----------------------|-----------------|--------------------------|
| 78A           | No. 8              | 9-15-88 | 1500       | 1.67127          | 600                   | 1.67200         | 1.22                     |
| B             |                    |         |            | 1.67914          | 600                   | 1.67989         | 1.25                     |
| C             |                    |         |            | 1.68001          | 600                   | 1.68086         | 1.42                     |
| 79A           | No. 8              | 9-23-88 | 0900       | 1.66353          | 600                   | 1.66437         | 1.40                     |
| B             |                    |         |            | 1.67732          | 600                   | 1.67824         | 1.53                     |
| C             |                    |         |            | 1.67884          | 600                   | 1.67963         | 1.32                     |
| 80A           | 8                  | 9-13-88 | 1000       | 1.67937          | 300                   | 1.68077         | 4.67                     |
| B             |                    |         |            | 1.66367          | 300                   | 1.66597         | 7.67                     |
| C             |                    |         |            | 1.68556          | 300                   | 1.68699         | 4.77                     |
| 81A           | 8                  | 9-14-88 | 1450       | 1.68405          | 600                   | 1.68940         | 1.42                     |
| B             |                    |         |            | 1.67702          | 600                   | 1.67786         | 1.40                     |
| C             |                    |         |            | 1.63700          | 600                   | 1.63787         | 1.45                     |
| 82A           | 8                  | 9-22-88 | 0855       | 1.66630          | 900                   | 1.66663         | 0.37                     |
| B             |                    |         |            | 1.68732          | 900                   | 1.68757         | 0.28                     |
| C             |                    |         |            | 1.67141          | 900                   | 1.67166         | 0.28                     |
| 83A           | Well No. 8         | 9-21-88 | 1526       | 1.68030          | 600                   | 1.68053         | 0.38                     |
| B             |                    |         |            | 1.67612          | 600                   | 1.67653         | 0.68                     |
| C             |                    |         |            | 1.66586          | 600                   | 1.66612         | 0.43                     |
| 84A           | Well No. 8         | 9-19-88 | 1630, 1718 | 1.67944          | 600                   | 1.68000         | 0.93                     |
| B             |                    |         |            | 1.63891          | 600                   | 1.63937         | 0.77                     |
| C             |                    |         |            | 1.66094          | 600                   | 1.66167         | 1.22                     |

(Continued)

(Sheet 12 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 85A           | Well No. 8         | 9-20-88 | 1635 | 1.66700          | 600                   | 1.66836         | 1.10                     |
| B             |                    |         |      | 1.65977          | 600                   | 1.66053         | 1.27                     |
| C             |                    |         |      | 1.67030          | 600                   | 1.67099         | 1.15                     |
| 86A           | 8                  | 9-16-88 | 1320 | 1.68605          | 600                   | 1.68636         | 0.52                     |
| B             |                    |         |      | 1.68717          | 600                   | 1.68752         | 0.58                     |
| C             |                    |         |      | 1.65266          | 600                   | 1.65309         | 0.72                     |
| 87A           | 2                  | 9-19-88 | 1630 | 1.65998          | 900                   | 1.66020         | 0.24                     |
| B             |                    |         |      | 1.65886          | 900                   | 1.65907         | 0.23                     |
| C             |                    |         |      | 1.65811          | 900                   | 1.65840         | 0.32                     |
| 88A           | 2                  | 9-13-88 | 1000 | 1.66583          | 100                   | 1.71067         | 448.40                   |
| B             |                    |         |      | 1.65522          | 100                   | 1.69566         | 404.40                   |
| C             |                    |         |      | 1.66541          | 100                   | 1.70947         | 440.60                   |
| 89A           | 2                  | 9-21-88 | 1500 | 1.67477          | 600                   | 1.67569         | 1.53                     |
| B             |                    |         |      | 1.67856          | 600                   | 1.67759         | 1.58                     |
| C             |                    |         |      | 1.67828          | 600                   | 1.67953         | 2.08                     |
| 90A           | 2                  | 9-15-88 | 1500 | 1.67988          | 600                   | 1.68020         | 0.53                     |
| B             |                    |         |      | 1.67722          | 600                   | 1.67759         | 0.62                     |
| C             |                    |         |      | 1.67675          | 600                   | 1.67703         | 0.47                     |
| 91A           | No. 2              | 9-22-88 | 1520 | 1.65946          | 600                   | 1.65948         | 0.03                     |
| B             |                    |         |      | 1.65582          | 600                   | 1.65590         | 0.13                     |
| C             |                    |         |      | 1.65751          | 600                   | 1.65752         | 0.02                     |

(Continued)

(Sheet 13 of 23)

Table C1 (Continued)

| Lab<br>ID<br>Number | Sample<br>Description | Date    | Time | Tare<br>Weight<br>g | Volume<br>Filtered<br>ml | Dry<br>Weight<br>g | Suspended<br>Solids<br>mg/l |
|---------------------|-----------------------|---------|------|---------------------|--------------------------|--------------------|-----------------------------|
| 92A                 | No. 2                 | 9-14-88 | 1450 | 1.65800             | 600                      | 1.65812            | 0.20                        |
| B                   |                       |         |      | 1.68166             | 600                      | 1.68174            | 0.13                        |
| C                   |                       |         |      | 1.66492             | 600                      | 1.66504            | 0.20                        |
| 93A                 | No. 2                 | 9-23-88 | 1425 | 1.66535             | 600                      | 1.66555            | 0.33                        |
| B                   |                       |         |      | 1.67121             | 600                      | 1.67145            | 0.40                        |
| C                   |                       |         |      | 1.66931             | 600                      | 1.66959            | 0.47                        |
| 94A                 | No. 2                 | 9-16-88 | 1320 | 1.66420             | 600                      | 1.66436            | 0.27                        |
| B                   |                       |         |      | 1.66490             | 600                      | 1.66504            | 0.23                        |
| C                   |                       |         |      | 1.67124             | 600                      | 1.67143            | 0.32                        |
| 95A                 | No. 3                 | 9-23-88 | 1425 | 1.66962             | 600                      | 1.66967            | 0.08                        |
| B                   |                       |         |      | 1.66744             | 600                      | 1.66745            | 0.02                        |
| C                   |                       |         |      | 1.67081             | 600                      | 1.67086            | 0.08                        |
| 96A                 | No. 3                 | 9-14-88 | 1450 | 1.66086             | 300                      | 1.66210            | 4.13                        |
| B                   |                       |         |      | 1.68322             | 300                      | 1.68452            | 4.33                        |
| C                   |                       |         |      | 1.67542             | 300                      | 1.67665            | 4.10                        |
| 97A                 | No. 3                 | 9-21-88 | 1500 | 1.66896             | 900                      | 1.66755            | -1.57                       |
| B                   |                       |         |      | 1.68084             | 900                      | 1.68379            | 3.28                        |
| C                   |                       |         |      | 1.66808             | 900                      | 1.67022            | 2.38                        |
| 98A                 | No. 3                 | 9-19-88 | 1630 | 1.67084             | 600                      | 1.67165            | 1.35                        |
| B                   |                       |         |      | 1.66828             | 600                      | 1.66902            | 1.23                        |
| C                   |                       |         |      | 1.68820             | 600                      | 1.68891            | 1.18                        |

(Continued)

(Sheet 14 of 23)

Table C1 (Continued)

| Lab<br>ID<br>Number | Sample<br>Description | Date    | Time | Tare<br>Weight<br>g | Volume<br>Filtered<br>ml | Dry<br>Weight<br>g | Suspended<br>Solids<br>mg/l |
|---------------------|-----------------------|---------|------|---------------------|--------------------------|--------------------|-----------------------------|
| 99A                 | No. 3                 | 9-15-88 | 1500 | 1.68445             | 600                      | 1.68485            | 0.67                        |
| B                   |                       |         |      | 1.67039             | 600                      | 1.67096            | 0.95                        |
| C                   |                       |         |      | 1.66706             | 600                      | 1.66738            | 0.53                        |
| 100A                | No. 3                 | 9-16-88 | 1320 | 1.68212             | 600                      | 1.68261            | 0.82                        |
| B                   |                       |         |      | 1.67442             | 600                      | 1.67486            | 0.73                        |
| C                   |                       |         |      | 1.67622             | 600                      | 1.67654            | 0.53                        |
| 101A                | No. 3                 | 9-22-88 | 1520 | 1.67308             | 300                      | 1.67629            | 10.70                       |
| B                   |                       |         |      | 1.67943             | 300                      | 1.68235            | 9.73                        |
| C                   |                       |         |      | 1.67876             | 300                      | 1.68180            | 10.43                       |
| 102A                | No. 3                 | 9-13-88 | 1000 | 1.67399             | 100                      | 1.69275            | 187.60                      |
| B                   |                       |         |      | 1.66139             | 100                      | 1.67780            | 164.10                      |
| C                   |                       |         |      | 1.65534             | 100                      | 1.67688            | 215.40                      |
| 103A                | 5                     | 9-13-88 | 1000 | 1.66933             | 300                      | 1.67016            | 2.77                        |
| B                   |                       |         |      | 1.66102             | 300                      | 1.66175            | 2.43                        |
| C                   |                       |         |      | 1.66619             | 300                      | 1.66699            | 2.67                        |
| 104A                | 5                     | 9-15-88 | 1500 | 1.66575             | 600                      | 1.66642            | 1.12                        |
| B                   |                       |         |      | 1.67320             | 600                      | 1.67377            | 0.95                        |
| C                   |                       |         |      | 1.67947             | 600                      | 1.68115            | 2.80                        |
| 105A                | 5                     | 9-14-88 | 1450 | 1.68105             | 600                      | 1.68134            | 0.48                        |
| B                   |                       |         |      | 1.66828             | 600                      | 1.67482            | 0.87                        |
| C                   |                       |         |      | 1.68820             | 600                      | 1.66416            | 0.85                        |

(Continued)

(Sheet 15 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 106A          | 5                  | 9-15-88 | 1500 | 1.68266          | 900                   | 1.68296         | 0.33                     |
| B             |                    |         |      | 1.67523          | 900                   | 1.67551         | 0.31                     |
| C             |                    |         |      | 1.67560          | 900                   | 1.67584         | 0.27                     |
| 107A          | 5                  | 9-16-88 | 1320 | 1.68263          | 600                   | 1.68266         | 0.05                     |
| B             |                    |         |      | 1.66763          | 600                   | 1.66772         | 0.15                     |
| C             |                    |         |      | 1.66103          | 600                   | 1.66104         | 0.02                     |
| 108A          | 6                  | 9-13-88 | 1000 | 1.66794          | 600                   | 1.66926         | 2.20                     |
| B             |                    |         |      | 1.67375          | 600                   | 1.67534         | 2.65                     |
| C             |                    |         |      | 1.68593          | 600                   | 1.68780         | 3.12                     |
| 109A          | 6                  | 9-14-88 | 1450 | 1.68583          | 900                   | 1.68628         | 0.50                     |
| B             |                    |         |      | 1.68014          | 900                   | 1.68073         | 0.66                     |
| C             |                    |         |      | 1.67143          | 900                   | 1.67183         | 0.44                     |
| 110A          | 6                  | 9-16-88 | 1320 | 1.67650          | 900                   | 1.67684         | 0.38                     |
| B             |                    |         |      | 1.68600          | 900                   | 1.68619         | 0.21                     |
| C             |                    |         |      | 1.67051          | 900                   | 1.67075         | 0.27                     |
| 111A          | 7                  | 9-14-88 | 1450 | 1.66638          | 900                   | 1.66669         | 0.34                     |
| B             |                    |         |      | 1.66123          | 900                   | 1.66178         | 0.61                     |
| C             |                    |         |      | 1.67880          | 900                   | 1.67924         | 0.49                     |
| 112A          | 7                  | 9-23-88 | 1455 | 1.66972          | 900                   | 1.67026         | 0.60                     |
| B             |                    |         |      | 1.66399          | 900                   | 1.66438         | 0.43                     |
| C             |                    |         |      | 1.67101          | 900                   | 1.67149         | 0.53                     |

(Continued)

(Sheet 16 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 113A          | 7                  | 9-15-88 | 0900 | 1.66763          | 600                   | 1.66848         | 1.42                     |
| B             |                    |         |      | 1.67126          | 600                   | 1.67201         | 1.25                     |
| C             |                    |         |      | 1.67470          | 600                   | 1.67566         | 1.60                     |
| 114A          | 7                  | 9-22-88 | 1525 | 1.66640          | 600                   | 1.66693         | 0.88                     |
| B             |                    |         |      | 1.68110          | 600                   | 1.68156         | 0.77                     |
| C             |                    |         |      | 1.68033          | 600                   | 1.68065         | 0.53                     |
| 115A          | 7                  | 9-15-88 | 1500 | 1.67960          | 900                   | 1.68017         | 0.63                     |
| B             |                    |         |      | 1.66793          | 900                   | 1.66837         | 0.49                     |
| C             |                    |         |      | 1.66231          | 900                   | 1.66260         | 0.32                     |
| 116A          | 7                  | 9-16-88 | 1320 | 1.66539          | 900                   | 1.66569         | 0.33                     |
| B             |                    |         |      | 1.67316          | 900                   | 1.67354         | 0.42                     |
| C             |                    |         |      | 1.66614          | 900                   | 1.66650         | 0.40                     |
| 117A          | 7                  | 9-13-88 | 1000 | 1.66130          | 300                   | 1.66258         | 4.27                     |
| B             |                    |         |      | 1.64931          | 300                   | 1.65051         | 4.00                     |
| C             |                    |         |      | 1.67608          | 300                   | 1.67699         | 3.03                     |
| 118A          | 7                  | 9-23-88 | 0900 | 1.66171          | 900                   | 1.66223         | 0.58                     |
| B             |                    |         |      | 1.66286          | 900                   | 1.66353         | 0.74                     |
| C             |                    |         |      | 1.65374          | 900                   | 1.65434         | 0.67                     |
| 119A          | 7                  | 9-13-88 | 1410 | 1.66276          | 900                   | 1.66352         | 0.84                     |
| B             |                    |         |      | 1.66328          | 900                   | 1.66422         | 1.04                     |
| C             |                    |         |      | 1.65122          | 900                   | 1.65206         | 0.93                     |

(Continued)

(Sheet 17 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 120A          | 7                  | 9-22-88 | 0855 | 1.65284          | 900                   | 1.65347         | 0.70                     |
| B             |                    |         |      | 1.65947          | 900                   | 1.66012         | 0.72                     |
| C             |                    |         |      | 1.65866          | 900                   | 1.65953         | 0.97                     |
| 121A          | No. 7-A            | 9-21-88 | 0830 | 1.66194          | 900                   | 1.66238         | 0.49                     |
| B             |                    |         |      | 1.65878          | 900                   | 1.65956         | 0.87                     |
| C             |                    |         |      | 1.64898          | 900                   | 1.64949         | 0.57                     |
| 122A          | No. 7-A            | 9-19-88 | 1615 | 1.65606          | 900                   | 1.65683         | 0.86                     |
| B             |                    |         |      | 1.65968          | 900                   | 1.66042         | 0.82                     |
| C             |                    |         |      | 1.66623          | 900                   | 1.66700         | 0.86                     |
| 123A          | No. 7-A            | 9-20-88 | 1510 | 1.65946          | 600                   | 1.65968         | 0.37                     |
| B             |                    |         |      | 1.66490          | 600                   | 1.66558         | 1.13                     |
| C             |                    |         |      | 1.66902          | 600                   | 1.66974         | 1.20                     |
| 124A          | No. 7-A            | 9-19-88 | 0905 | 1.66844          | 600                   | 1.66918         | 1.23                     |
| B             |                    |         |      | 1.67062          | 600                   | 1.67127         | 1.08                     |
| C             |                    |         |      | 1.65633          | 600                   | 1.65714         | 1.35                     |
| 125A          | No. 1              | 9-23-88 | 1425 | 1.67285          | 300                   | 1.67330         | 1.50                     |
| B             |                    |         |      | 1.67602          | 300                   | 1.67668         | 2.20                     |
| C             |                    |         |      | 1.66349          | 300                   | 1.66384         | 1.17                     |
| 126A          | No. 1              | 9-16-88 | 1320 | 1.65879          | 300                   | 1.65906         | 0.90                     |
| B             |                    |         |      | 1.66432          | 300                   | 1.66442         | 0.33                     |
| C             |                    |         |      | 1.67216          | 300                   | 1.67238         | 0.73                     |

(Continued)

(Sheet 18 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 127A          | No. 1              | 9-15-88 | 1500 | 1.67185          | 300                   | 1.67520         | 11.17                    |
| B             |                    |         |      | 1.66391          | 300                   | 1.66443         | 1.73                     |
| C             |                    |         |      | 1.66925          | 300                   | 1.66989         | 2.13                     |
| 128A          | No. 1              | 9-21-88 | 1500 | 1.67277          | 300                   | 1.67447         | 5.67                     |
| B             |                    |         |      | 1.67106          | 300                   | 1.67284         | 5.93                     |
| C             |                    |         |      | 1.65927          | 300                   | 1.66155         | 7.60                     |
| 129A          | No. 1              | 9-19-88 | 1630 | 1.67422          | 300                   | 1.67443         | 0.70                     |
| B             |                    |         |      | 1.64898          | 300                   | 1.64900         | 0.07                     |
| C             |                    |         |      | 1.64405          | 300                   | 1.64418         | 0.43                     |
| 130A          | No. 1              | 9-16-88 | 0930 | 1.65126          | 300                   | 1.65164         | 1.27                     |
| B             |                    |         |      | 1.66446          | 300                   | 1.66499         | 1.77                     |
| C             |                    |         |      | 1.66087          | 300                   | 1.66113         | 0.87                     |
| 131A          | No. 1              | 9-13-88 | 1000 | 1.65838          | 100                   | 1.69121         | 328.30                   |
| B             |                    |         |      | 1.66461          | 100                   | 1.69859         | 339.80                   |
| C             |                    |         |      | 1.66503          | 100                   | 1.69720         | 321.70                   |
| 132A          | No. 1              | 9-22-88 | 1520 | 1.65430          | 200                   | 1.65463         | 1.65                     |
| B             |                    |         |      | 1.65396          | 200                   | 1.65440         | 2.20                     |
| C             |                    |         |      | 1.65458          | 200                   | 1.65520         | 3.10                     |
| 133A          | No. 4              | 9-16-88 | 1320 | 1.66182          | 300                   | 1.66225         | 1.43                     |
| B             |                    |         |      | 1.66583          | 300                   | 1.66632         | 1.63                     |
| C             |                    |         |      | 1.65738          | 300                   | 1.65776         | 1.27                     |

(Continued)

(Sheet 19 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g | Volume Filtered<br>ml | Dry Weight<br>g | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|------------------|-----------------------|-----------------|--------------------------|
| 134A          | No. 4              | 9-15-88 | 1500 | 1.66228          | 300                   | 1.66253         | 0.83                     |
| B             |                    |         |      | 1.65358          | 300                   | 1.65391         | 1.17                     |
| C             |                    |         |      | 1.66984          | 300                   | 1.67051         | 2.23                     |
| 135A          | No. 4              | 9-14-88 | 1450 | 1.65732          | 500                   | 1.65750         | 0.36                     |
| B             |                    |         |      | 1.66422          | 500                   | 1.66444         | 0.44                     |
| C             |                    |         |      | 1.65942          | 500                   | 1.65944         | 0.04                     |
| 136A          | No. 4              | 9-13-88 | 1000 | 1.67551          | 300                   | 1.67699         | 4.93                     |
| B             |                    |         |      | 1.65113          | 300                   | 1.65262         | 4.97                     |
| C             |                    |         |      | 1.66397          | 300                   | 1.66564         | 5.57                     |
| 137A          | 20                 | 9-16-88 | 1500 | 1.66408          | 300                   | 1.66476         | 2.27                     |
| B             |                    |         |      | 1.66100          | 300                   | 1.66150         | 1.67                     |
| C             |                    |         |      | 1.66414          | 300                   | 1.66470         | 1.87                     |
| 138A          | 20                 | 9-16-88 | 1320 | 1.67107          | 300                   | 1.67142         | 1.17                     |
| B             |                    |         |      | 1.66900          | 300                   | 1.66906         | 0.20                     |
| C             |                    |         |      | 1.66686          | 300                   | 1.66696         | 0.33                     |
| 139A          | 20                 | 9-16-88 | 0930 | 1.67518          | 200                   | 1.67571         | 2.65                     |
| B             |                    |         |      | 1.67054          | 200                   | 1.67100         | 2.30                     |
| C             |                    |         |      | 1.67003          | 200                   | 1.67078         | 3.75                     |
| 140A          | 20                 | 9-14-88 | 1450 | 1.68323          | 500                   | 1.69071         | 14.96                    |
| B             |                    |         |      | 1.66799          | 500                   | 1.67499         | 14.00                    |
| C             |                    |         |      | 1.65122          | 500                   | 1.66069         | 18.94                    |

(Continued)

(Sheet 20 of 23)

Table C1 (Continued)

| Lab ID Number                                                                          | Sample Description | Date    | Time | Tare Weight g | Volume Filtered ml | Dry Weight g | Suspended Solids mg/l |
|----------------------------------------------------------------------------------------|--------------------|---------|------|---------------|--------------------|--------------|-----------------------|
| 141A                                                                                   | No. 1              | 9-14-88 | 1450 | 1.68746       | 600                | 1.68795      | 0.82                  |
| B                                                                                      |                    |         |      | 1.65765       | 600                | 1.65812      | 0.78                  |
| C                                                                                      |                    |         |      | 1.67645       | 600                | 1.67683      | 0.63                  |
| Repeat of samples 11-7-88                                                              |                    |         |      |               |                    |              |                       |
| 3A                                                                                     | Well No. 19        | 9-13-88 | 1435 | 1.68917       | 400                | 1.68932      | 0.38                  |
| B                                                                                      |                    |         |      | 1.64320       | 400                | 1.64345      | 0.63                  |
| 5A                                                                                     | Well No. 19        | 9-19-88 | 1700 | 1.67427       | 500                | 1.67459      | 0.64                  |
| B                                                                                      |                    |         |      | 1.66479       | 500                | 1.66499      | 0.40                  |
| 10A                                                                                    | Well No. 21        | 9-21-88 | 1538 | 1.65741       | 600                | 1.65778      | 0.62                  |
| B                                                                                      |                    |         |      | 1.67465       | 600                | 1.67460      | -0.08                 |
| C                                                                                      |                    |         |      | 1.67395       | 600                | 1.67412      | 0.28                  |
| 37A                                                                                    | 11                 | 9-15-88 | 1500 | 1.66220       | 300                | 1.66209      | -0.37                 |
| B                                                                                      |                    |         |      | 1.68966       | 300                | 1.68971      | 0.17                  |
| 68A                                                                                    | 9                  | 9-15-88 | 1500 | 1.66538       | 800                | 1.66591      | 0.66                  |
| B                                                                                      |                    |         |      | 1.65583       | 800                | 1.65640      | 0.71                  |
| Repeat of Samples 11-9-88                                                              |                    |         |      |               |                    |              |                       |
| Samples were weighed, dried, and reweighed three times to determine a constant weight. |                    |         |      |               |                    |              |                       |
| 2A                                                                                     | Well No. 19        | 9-22-88 | 1533 | 1.67004       | 600                | 1.67137      | 2.22                  |
| B                                                                                      |                    |         |      | 1.65147       | 600                | 1.65174      | 0.45                  |

(Continued)

(Sheet 21 of 23)

Table C1 (Continued)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g   | Volume Filtered<br>ml | Dry Weight<br>g    | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|--------------------|-----------------------|--------------------|--------------------------|
| 4A<br>B       | Well No. 19        | 9-20-88 | 1643 | 1.68934<br>1.66662 | 600<br>600            | 1.69001<br>1.66713 | 1.12<br>0.85             |
| 7A<br>B       | Well No. 21        | 9-13-88 | 1439 | 1.67016<br>1.67341 | 400<br>400            | 1.67030<br>1.67344 | 0.35<br>0.08             |
| 9A<br>B       | Well No. 21        | 9-22-88 | 1538 | 1.69322<br>1.65379 | 400<br>400            | 1.69355<br>1.65356 | 0.83<br>-0.58            |
| 11A<br>B      | Well No. 24        | 9-22-88 | 1542 | 1.69127<br>1.65845 | 600<br>600            | 1.69200<br>1.65887 | 1.22<br>0.70             |
| 127A<br>B     | No. 1              | 9-15-88 | 1500 | 1.69028<br>1.67654 | 600<br>600            | 1.69134<br>1.67764 | 1.77<br>1.83             |
| 2A<br>B       | Well No. 19        | 9-22-88 | 1533 | 1.67004<br>1.65147 | 600<br>600            | 1.65173            | 0.43                     |
| 4A<br>B       | Well No. 19        | 9-20-88 | 1643 | 1.68934<br>1.66662 | 600<br>600            | 1.69011<br>1.67721 | 1.28<br>0.98             |
| 7A<br>B       | Well No. 21        | 9-13-88 | 1439 | 1.67016<br>1.67341 | 400<br>400            | 1.67035<br>1.67349 | 0.48<br>0.20             |
| 9A<br>B       | Well No. 21        | 9-22-88 | 1538 | 1.69322<br>1.65379 | 400<br>400            | 1.69360<br>1.65357 | 0.95<br>-0.55            |

(Continued)

(Sheet 22 of 23)

Table C1 (Concluded)

| Lab ID Number | Sample Description | Date    | Time | Tare Weight<br>g   | Volume Filtered<br>ml | Dry Weight<br>g    | Suspended Solids<br>mg/l |
|---------------|--------------------|---------|------|--------------------|-----------------------|--------------------|--------------------------|
| 11A B         | Well No. 24        | 9-22-88 | 1542 | 1.69127<br>1.65845 | 600<br>600            | 1.69196<br>1.65886 | 1.15<br>0.68             |
| 127A B        | No. 1              | 9-15-88 | 1500 | 1.69028<br>1.67654 | 600<br>600            | 1.69138<br>1.67766 | 1.83<br>1.87             |
| 2A B          | Well No. 19        | 9-13-88 | 1533 | 1.67004<br>1.65147 | 600<br>600            | 1.65162            | 0.25                     |
| 4A B          | Well No. 19        | 9-20-88 | 1643 | 1.68934<br>1.66662 | 600<br>600            | 1.69000<br>1.66707 | 1.10<br>0.75             |
| 7A B          | Well No. 21        | 9-13-88 | 1439 | 1.67016<br>1.67341 | 400<br>400            | 1.67027<br>1.67340 | 0.28<br>-0.03            |
| 9A B          | Well No. 21        | 9-22-88 | 1538 | 1.69322<br>1.65379 | 400<br>400            | 1.69353<br>1.65352 | 0.78<br>-0.68            |
| 11A B         | Well No. 24        | 9-22-88 | 1542 | 1.69127<br>1.65845 | 600<br>600            | 1.69180<br>1.65872 | 0.88<br>0.45             |
| 127A B        | No. 1              | 9-15-88 | 1500 | 1.69028<br>1.67654 | 600<br>600            | 1.69122<br>1.67765 | 1.57<br>1.85             |

C25

APPENDIX D: AVERAGE WEEKLY RECHARGE WELL WATER VOLUMES

Total Volume Recharged through North Boundary Recharge Wells (Gallons)

| Week<br>Well | 1<br>Aug 3 | 2<br>Aug 10 | 3<br>Aug 17 | 4<br>Aug 24 | 5<br>Aug 31 | 6<br>Sep 7 | 7<br>Sep 14 | 8<br>Sep 21 | 9<br>Sep 28 | 10<br>Oct 5 | 12<br>Oct 19 | 13<br>Oct 26 | 14<br>Nov 2 | Avg    |
|--------------|------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|-------------|--------------|--------------|-------------|--------|
| 1            | 21903      | 2983        | 2975        | 3059        | 3053        | 3079       | 3048        | 2973        | 2500        | 2345        | 2794         | 2979         | 2893        | 4353   |
| 2            | 27963      | 30934       | 32162       | 31652       | 24350       | 23033      | 25414       | 20040       | 15833       | 10411       | 32892        | 34333        | 33689       | 26362  |
| 3            | 10778      | 6281        | 8098        | 2259        | 2469        | 5299       | 4417        | 16430       | 1759        | 2411        | 1243         | 1426         | 1992        | 4989   |
| 4            | 5166       | 4249        | 3711        | 3347        | 3182        | 3876       | 3857        | 4775        | 4323        | 37198       | 5430         | 48826        | 5911        | 10296  |
| 5            | 14745      | 13490       | 12800       | 11059       | 11059       | 9619       | 8226        | 6693        | 4473        | 4514        | 4286         | 4325         | 3767        | 8389   |
| 6            | 3912       | 2609        | 2448        | 1883        | 1954        | 2369       | 1847        | 1921        | 1840        | 2082        | 1799         | 1829         | 1846        | 2180   |
| 7            | 10293      | 9256        | 8137        | 7355        | 6255        | 5728       | 4964        | 4442        | 3847        | 3836        | 4647         | 4681         | 4463        | 5993   |
| 8            | 13447      | 12663       | 11997       | 11356       | 10544       | 11767      | 970         | 9541        | 11794       | 9277        | 22166        | 22792        | 25119       | 13341  |
| 9            | 8064       | 9237        | 9042        | 8876        | 8161        | 10976      | 75254       | 14179       | 5300        | 8326        | 252          | 16           | 7           | 12130  |
| 10           | 9990       | 7695        | 5958        | 4599        | 3463        | 2949       | 2542        | 2011        | 1745        | 2505        | 1937         | 1893         | 1804        | 3776   |
| 11           | 69516      | 101107      | 128460      | 148498      | 188636      | 162096     | 156183      | 171965      | 121698      | 80331       | 43575        | 21936        | 3495        | 107500 |
| 12           | 33080      | 30065       | 27116       | 24935       | 22653       | 21129      | 19034       | 16289       | 14136       | 14111       | 10965        | 9836         | 8778        | 19394  |
| 13           | 25906      | 269491      | 22333       | 21532       | 18087       | 16777      | 13216       | 9950        | 9146        | 9869        | 6772         | 5887         | 5282        | 33404  |
| 14           | 23693      | 23646       | 22431       | 21246       | 19271       | 17939      | 15712       | 12519       | 10633       | 1586        | 15           | 37           | 6           | 12980  |
| 15           | 28175      | 29270       | 29560       | 29046       | 26957       | 27058      | 26151       | 22909       | 20089       | 22565       | 27234        | 22638        | 493         | 24011  |
| 16           | 43602      | 87638       | 142207      | 158315      | 142485      | 145359     | 159092      | 181235      | 231140      | 257505      | 378167       | 407841       | 4203        | 179907 |
| 17           | 45988      | 140921      | 339114      | 369072      | 381183      | 367129     | 381910      | 346493      | 344618      | 375127      | 434190       | 431515       | 428245      | 337347 |
| 18           | 177246     | 212181      | 193461      | 212276      | 215415      | 204506     | 213517      | 192687      | 194693      | 213432      | 246735       | 247721       | 251589      | 213535 |
| 19           | 254298     | 305149      | 278314      | 302226      | 309360      | 286929     | 294234      | 282614      | 279967      | 301689      | 358163       | 363465       | 361567      | 306006 |
| 20           | 249766     | 294591      | 256381      | 272839      | 310697      | 299965     | 311050      | 288243      | 272751      | 289795      | 360019       | 345739       | 335008      | 299680 |
| 21           | 234634     | 282093      | 255643      | 280536      | 277970      | 259019     | 261568      | 266468      | 268365      | 285960      | 282037       | 107627       | 95173       | 242853 |
| 22           | 7908       | 92231       | 97473       | 97139       | 89515       | 80799      | 74813       | 62865       | 56071       | 61418       | 70140        | 65179        | 58160       | 70285  |
| 23           | 65473      | 97120       | 67309       | 80703       | 85621       | 81908      | 67419       | 62549       | 90349       | 60126       | 101776       | 121599       | 104334      | 83560  |
| 24           | 785        | 46917       | 47963       | 47759       | 464604      | 46712      | 45715       | 34698       | 40385       | 27880       | 47629        | 46944        | 45917       | 72608  |
| 25           | 66783      | 65155       | 61511       | 58616       | 51355       | 50198      | 45802       | 41796       | 42055       | 45835       | 43278        | 40859        | 36549       | 49984  |
| 26           | 6507       | 64937       | 61499       | 58424       | 56623       | 56446      | 46615       | 44427       | 64081       | 67422       | 53636        | 49459        | 47634       | 52132  |
| 27           | 166203     | 200033      | 175317      | 177279      | 168692      | 150986     | 124836      | 109444      | 121401      | 10910       | 118663       | 109109       | 9522        | 126338 |
| 28           | 36352      | 43042       | 42186       | 39772       | 37962       | 35758      | 30710       | 4025        | 22218       | 26136       | 40804        | 43056        | 4066        | 31237  |
| 29           | 3103       | 21204       | 21790       | 21455       | 20493       | 20596      | 21168       | 17944       | 14964       | 18889       | 24720        | 23460        | 22924       | 19439  |
| 30           | 69244      | 86301       | 67891       | 69688       | 60925       | 58879      | 57792       | 25988       | 27711       | 24007       | 82733        | 39817        | 61757       | 56364  |
| 31           | 15193      | 43913       | 42527       | 39229       | 35459       | 34709      | 35134       | 20533       | 12297       | 4747        | 47122        | 52056        | 26048       | 31459  |
| 32           | 56227      | 59776       | 63523       | 55482       | 36668       | 52608      | 51602       | 52559       | 37564       | 29865       | 36768        | 18997        | 16779       | 43724  |
| 33           | 6802       | 5259        | 8069        | 5007        | 4382        | 4506       | 4315        | 3375        | 2334        | 1945        | 3053         | 1493         | 5224        | 4290   |
| 34           | 17051      | 16062       | 26554       | 13874       | 4385        | 2026       | 594         | 356         | 88          | 6945        | 24266        | 9403         | 125         | 9364   |
| 35           | 40279      | 40289       | 74030       | 40039       | 40775       | 41097      | 40904       | 33590       | 26782       | 18936       | 36630        | 37178        | 37468       | 39077  |
| 36           | 29744      | 28516       | 32529       | 28642       | 24760       | 20346      | 18615       | 14129       | 9094        | 4043        | 6842         | 4957         | 2947        | 17320  |
| 37           | 20699      | 16945       | 21880       | 17173       | 15248       | 13936      | 13359       | 10032       | 5741        | 4261        | 9100         | 7167         | 6658        | 12477  |
| 38           | 11499      | 12482       | 10073       | 12558       | 11040       | 11319      | 15600       | 8123        | 5603        | 6068        | 9598         | 8219         | 7360        | 9965   |

\* Note: The week of 10/28/88 was not used because of incomplete data.

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             |                                            | Form Approved<br>OMB No. 0704-0188                                              |                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.                                                                                                                                                                                                                                                                                 |                                                             |                                            |                                                                                 |                                                  |
| 1. AGENCY USE ONLY (Leave blank)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                             | 2. REPORT DATE<br>October 1994             |                                                                                 | 3. REPORT TYPE AND DATES COVERED<br>Final report |
| 4. TITLE AND SUBTITLE<br>Evaluation of Operational Factors Contributing to Reduced Recharge Capacity, North Boundary Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                            | 5. FUNDING NUMBERS<br><br>MIPR No. 0722                                         |                                                  |
| 6. AUTHOR(S)<br>Cynthia L. Teeter, Mark E. Zappi, Douglas Gunnison<br>Norman R. Francingues, Jr., David W. Strang<br>Thomas A. Brooks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                             |                                            |                                                                                 |                                                  |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>US Army Engineer Waterways Experiment Station<br>Environmental Laboratory, 3909 Halls Ferry Road<br>Vicksburg, MS 39180-6199<br>Rocky Mountain Arsenal, Commerce City, CO 80022-2180                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                                            | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br><br>Technical Report<br>EL-94-12 |                                                  |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>US Army Program Manager for Rocky Mountain Arsenal<br>Commerce City, CO 80022-2180                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                             |                                            | 10. SPONSORING/MONITORING<br>AGENCY REPORT NUMBER                               |                                                  |
| 11. SUPPLEMENTARY NOTES<br><br>Available from National Technical Information Service, 5285 Port Royal Road,<br>Springfield, VA 22161                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                                            |                                                                                 |                                                  |
| 12a. DISTRIBUTION / AVAILABILITY STATEMENT<br><br>Approved for public release; distribution is unlimited                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                                            | 12b. DISTRIBUTION CODE                                                          |                                                  |
| 13. ABSTRACT (Maximum 200 words)<br><br>The North Boundary treatment system at Rocky Mountain Arsenal, Commerce City, Colorado, involves the pumping of contaminated groundwater from an unconfined aquifer from one side of a soil bentonite slurry wall to three pulsed-bed activated carbon absorbers and prefilter and postfilter systems. The treated water is injected into the unconfined aquifer on the other side of the slurry wall via 38 recharge wells and 15 recharge trenches, collectively referred to as the recharge system. Over time, the dewatering and especially the recharge system have a tendency to become clogged, which limits their effectiveness. A number of factors have been attributed to the degradation in performance of dewatering and recharge systems. These are air binding, sodium adsorption, metal precipitation, deposition of cementing agents, straining of suspended solids, and microbial growths or biofouling. This report presents the<br>(Continued) |                                                             |                                            |                                                                                 |                                                  |
| 14. SUBJECT TERMS<br><br>Activated carbon      Microbial fouling      Recharge capacity<br>Carbon fines          Pump and treat                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                             |                                            | 15. NUMBER OF PAGES<br>137                                                      |                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                             |                                            | 16. PRICE CODE                                                                  |                                                  |
| 17. SECURITY CLASSIFICATION<br>OF REPORT<br>UNCLASSIFIED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 18. SECURITY CLASSIFICATION<br>OF THIS PAGE<br>UNCLASSIFIED | 19. SECURITY CLASSIFICATION<br>OF ABSTRACT | 20. LIMITATION OF ABSTRACT                                                      |                                                  |

13. (Concluded).

results of three separate assessments of reduced recharge capacity of a pump-and-treat system. The fate of carbon fines throughout the North Boundary system, clogging because of periodic losses of activated carbon fines, and growth of microorganisms in the recharge system are addressed.