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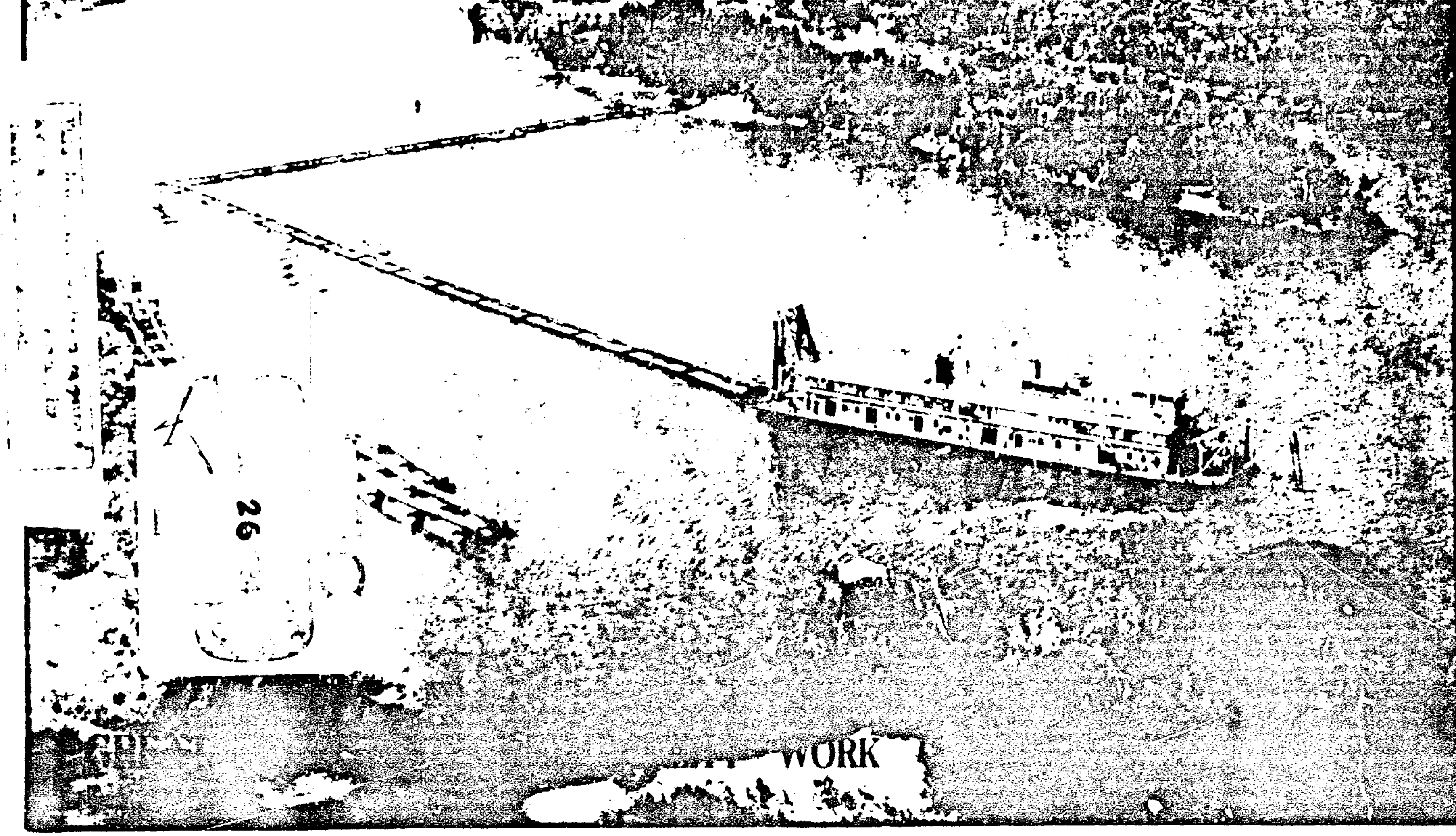
PILOT STUDY - JULY 1978
GREY CLOUD ISLAND
UPPER MISSISSIPPI RIVER



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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A143609
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) A PILOT STUDY ON EFFECTS OF HYDRAULIC DREDGING AND DISPOSAL ON WATER QUALITY OF THE UPPER MISSISSIPPI RIVER.	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS GREAT I Water Quality Work Group	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer Dist., St. Paul 1135 USPO & Custom House St. Paul, MN 55101	12. REPORT DATE July 1976
	13. NUMBER OF PAGES 129
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

DTIC ELECTE JUL [illegible] 1984 E

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

MISSISSIPPI RIVER
DREDGING
WATER QUALITY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A pilot study was designed and implemented to monitor the water quality impact of dredging and disposal using a variety of sampling techniques. The study took place at river mile 827 on the Upper Mississippi River immediately downsteam of the Minneapolis-St. Paul metropolitan area (Grey Cloud Island). Samples of undisturbed predredge bulk sediments and postdredge plume water were examined for physical, chemical and bacteriological parameters.

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A PILOT STUDY ON EFFECTS OF HYDRAULIC DREDGING AND DISPOSAL ON WATER QUALITY OF THE UPPER MISSISSIPPI RIVER (JULY 1976)

GREAT I

WATER QUALITY WORK GROUP

MARCH 1978

ABSTRACT

A pilot study was designed and implemented by the GREAT I Water Quality Work Group to monitor the water quality impacts of dredging and disposal using a variety of sampling techniques. The study took place at river mile 827 on the Upper Mississippi River immediately downstream of the Minneapolis-St. Paul metropolitan area. Samples of undisturbed predredge bulk sediments and postdredge disposal plume water were examined for physical, chemical, and bacteriological parameters during July 1976. Concentrations of contaminants in sediment samples were apparently influenced by seasonal fluctuations in flow, sediment deposition, and water quality. Bottom sediments revealed high concentrations of several contaminants in comparison to other sediment studies conducted at the same location, but this condition did not necessarily dictate corresponding concentrations within the disposal plume water. Most parameters exhibited an increase in concentration from above to below the dredging and disposal operation during the 2 days of monitoring. Ambient fluctuations in river water were, in many cases, greater than impacts caused by dredging and disposal. Physical and bacteriological parameters returned to background concentrations within 1.3 kilometers (0.8 mile) downstream of the disposal discharge. Chemical parameters normally returned to background within a much shorter distance. Impacts were generally localized due to the sorptive capacity of rapidly settling resuspended sediment particles and dilution. Most parameters, especially the suspended form of metals, showed a high positive correlation with suspended solids and other physical parameters. Proposed Minnesota water quality standards were exceeded by several parameters within the disposal plume but effects were generally restricted to the area adjacent to the disposal discharge.

ACKNOWLEDGMENTS

This report was prepared by the GREAT I Water Quality Work Group. The technical members of the Water Quality Work Group who provided input to this report are:

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Robert Whiting	U.S. Army Corps of Engineers
John Wolflin	U.S. Fish and Wildlife Service

Additional assistance was provided by the following organizations and agencies: GREAT River Environmental Action Team (GREAT I), U.S. Army Engineers Waterways Experiment Station, U.S. Environmental Protection Agency, U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Minnesota Pollution Control Agency, Wisconsin Department of Natural Resources, and River Studies Center, University of Wisconsin, La Crosse.

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CONCLUSIONS AND FINDINGS

I. Several physical, chemical, and bacteriological impacts due to dredging and disposal were readily discernible within the downstream water column.

A. Physical effects resulting from dredging and disposal returned to background levels within a short distance downstream of the discharge. Statistical analysis of the disposal plume at a 2.7- to 3.6-meter (9- to 12-foot) depth, using turbidity and suspended solids data, determined that physical effects disappear from 1.1 to 1.3 kilometers (0.7 to 0.8 mile) downstream. Other researchers associated with the study effort obtained values of 0.5 kilometer (0.3 mile) (Lee) and 1 kilometer (0.6 mile) (Grimes). Discrepancies were due to differences in determining return to background, use of different data, and depth of samples.

B. Several parameters revealed consistent trends from above to below the dredging operation during the 2 days of monitoring. Those which exhibited elevated concentrations below the operation included: total iron, total residue, total organic carbon, dissolved solids residue, suspended solids, total organic nitrogen, and biochemical oxygen demand. Only total and dissolved orthophosphorus and total sulfide showed consistent decreased concentrations from above to below the dredging and disposal operation.

C. Degradations in water quality resulting from hydraulic dredging and disposal of bottom sediments at the study site can be attributed largely to suspended solids and turbidity, heavy metals, and enteric bacteria. Chemical and biological impacts on water quality are closely correlated with physical effects and, like physical effects, their influence appears to be localized and short term.

D. Proposed Minnesota Pollution Control Agency standards for water quality were exceeded by a number of parameters within the disposal plume. However, where standards for arsenic, chromium, lead, mercury, manganese, PCB's (polychlorinated biphenyls), and suspended solids were exceeded, the area affected was limited to only a small portion of the disposal plume immediately below the disposal discharge pipe.

II. Release and resuspension of contaminants during dredging and disposal of sediments is a complex phenomenon governed by factors such as sorptive behavior, pH, reduction-oxidation reactions, settleability, and dilution.

A. Samples of bottom sediments at the Grey Cloud Slough dredging site revealed high concentrations of arsenic, lead, Kjeldahl nitrogen, phosphorus, oil and grease, and COD (chemical oxygen demand) in comparison to other sediment studies conducted in the same area. However, detection of high or low concentrations of a given component within the bulk sediment does not necessarily dictate that it will be found in corresponding concentrations in the water receiving the dredged material. This phenomenon can be exemplified by the fact that sediment oil and grease exceeded proposed State standards while oil and grease within the disposal discharge water was found in only minimal concentrations.

B. Although both bottom sediments and disposal plume samples were highly contaminated with enteric bacteria (coliforms), concentrations within the disposal plume returned to background within 1.6 kilometers (1 mile) downstream of the disposal discharge. Bacteria concentrations within this segment of the river were unusually high due to upstream influences from the Minneapolis-St. Paul metropolitan area.

C. Many chemical and bacteriological parameters correlate closely with the rise and fall of physical parameters (suspended solids, total residue, turbidity) below the disposal site, but few chemical compounds appear to go into the solution as a result of resuspension. Representative parameters which show a strong correlation (>0.74) with one another are: turbidity, suspended solids, total residue, total iron, chemical oxygen demand, dissolved manganese, suspended manganese, suspended nickel, suspended lead, total organic carbon, total organic nitrogen, and suspended cadmium. Suspended copper and suspended zinc also showed a correlation of 0.98 with suspended solids while BOD showed a correlation of 0.78 with suspended solids. This information suggests a strong sorptive tendency for these components, particularly metals, and is further supported by the fact that their concentrations decrease rapidly as particles settle out from the disposal plume and as dilution occurs. Phosphorus is the only parameter subjected to the correlation analysis which shows a noticeable negative correlation with almost all other parameters.

D. Contrary to much of the existing literature, the present study revealed no significant correlation of pH or dissolved oxygen with resuspended sediments.

E. Unusually low flows within the study segment contributed to lower dilution effects as well as increased settleability of resuspended sediments.

III. Influences from upstream point and nonpoint sources create an ever-changing gradient of conditions within the water column and bottom sediment over time as well as distance in the Upper Mississippi River. This dynamic nature of the riverine environment can mask specific impacts due to dredging and disposal, often making interpretation of data difficult.

A. In many instances fluctuations in ambient levels of a parameter within the water column were greater than differences observed between samples taken above the dredging operation and those taken below. Over half of the above (transect A) and below (transect B) samples were characterized by ambient fluctuations during the 2-day period greater than or equal to differences between above and below. However, over 80 percent of the parameters measured showed an increase from above to below on at least 1 day.

B. Comparison of bottom sediment data taken from the Grey Cloud Slough area (river mile 828) over a period of 1½ years revealed wide variations in concentrations of given components, thus suggesting the rather transient and seasonal nature of sediment composition within a particular area.

IV. Upon assessment of the study design and sampling techniques, it is evident that the phase involving correlation of physical-chemical parameters proved to be more effective than either the definition of the turbidity plume or the three-dimensional transverse segment phases. Improved application of these later two techniques may have yielded data of greater usefulness.

A. <u>Definition of turbidity plume</u>. - Methods used by the contractor in interpreting data and defining the turbidity plume were not accepted by the Water Quality Work Group. Instead, statistical analysis of turbidity and suspended solids values from the correlation of physical-chemical parameters phase produced an alternative means of defining the plume.

B. Monitoring of three-dimensional transverse segment of river. -

1. Attempts to identify a return to background or "no effect" zone downstream of the dredging and disposal operation were somewhat ineffective. Transect B (below) was inadvertently located in an area of minimal effects approximately 1.3 kilometers (0.8 mile) downstream of the discharge on the first day of sampling. By the second day, however, the discharge was relocated downstream and was within 0.6 kilometer (0.4 mile) of transect B. Sampling stations along transect B were also moved laterally toward the west shoreline on the second day.

2. Time of travel for river water passing from transect A (above) to transect B (below) turned out to be between 4 and 4.5 hours rather than 2.5 hours as predicted by previous velocity and dye study calculations. The amorphous nature of the river transverse segment, particularly at the prevailing low velocities, also contributed to difficulties in this technique.

3. Compositing of sample aliquots eliminated the possibility of examination of individual samples for extremes which might otherwise have yielded valuable information.

4. Use of depth-integrated samplers to collect water samples at transects A and B was not completely controlled and resulted in difficulties in maintaining uniform descent.

C. Correlation of physical-chemical parameters. - Simultaneous sampling of physical, chemical, and bacteriological parameters, and subsequent statistical analysis, was an effective technique in determining levels of contaminants as well as their decay rates within the plume. Suspended solids correlated more highly with chemical parameters than did turbidity or total residue. The correlation sampling technique proved to be a strong tool in evaluating effects of dredging and disposal.

RECOMMENDATIONS

I. Future studies - This pilot study has attempted to identify and define research needs and methodologies necessary to gain information on the effects of dredging and disposal on water quality within the Upper Mississippi River.

A. Further research into the effects of dredging and disposal on water quality is essential and should be encouraged in order to resolve problems inherent in these activities. Research should be conducted to determine the water quality effects related to:

1. Hydraulic-type dredging in other than "worst case" conditions (i.e., more typical river conditions).

2. The cutterhead on hydraulic-type dredges (not specifically addressed in the pilot study).

3. Clamshell-type dredging.

4. Confined disposal facility effluent.

5. Disposal plume mixing characteristics (e.g., stratification and dispersion).

6. Discharge into "static water" conditions.

7. Recovery period following dredging and disposal operations.

B. Studies should be done according to the following methods:

1. Prestudy evaluation of site sediment and water relationships should be incorporated into planning of future studies. Comparison of study results with prestudy

findings may lead to improvements in prestudy testing - including the elutriate test, liquid-phase procedure, and bulk sediment analysis.

2. Future study designs should emphasize "indicator" parameters (total suspended solids, manganese, iron, and reduction-oxidation potential, etc.), water quality standards parameters (fecal coliforms, dissolved oxygen, temperature, and pH, etc.), and toxic substance scans (metals and organics).

3. Use of discrete water sample collection techniques is recommended in evaluation of disposal plume characteristics.

4. Use of correlation analysis of selected parameters in discrete samples is recommended for future studies.

5. The pilot study technique involving monitoring of the three-dimensional transverse segment is not recommended for future studies as it yielded minimal information for effort expended.

6. Water quality monitoring of dredging and disposal impacts should be initiated only after mixing zones have become well established.

7. Reliable flow data should be collected as an integral aspect of future studies.

II. Water use classifications determine ambient water quality standards. Recommendations with respect to river use and/or discharge limitations as they relate to Minnesota water quality standards are as follows:

A. Development and application of discharge limitations (standards) for dredged material placement site runoff are necessary to protect water quality. (This recommendation may require channelization of the discharge flow.)

B. Suspended solids is a major water pollutant, notwithstanding its function as a substrate for sorption of contaminants. Arsenic, chromium, iron, lead, manganese, mercury, PCB's, fecal coliforms, dissolved oxygen, ammonia, and turbidity are other major contaminants which exceeded present and proposed Minnesota water quality standards in the pilot study. Consequently, in light of current and anticipated water quality standards, improved methodologies (e.g., land disposal, berming, and physical-chemical treatment) are needed to control and/or reduce levels of resuspended sediments during dredging and disposal. Open water disposal should not be allowed other than in emergency situations in lower pool 2, and in all other river segments where pollution characteristics of the sediments are unknown or are similar in quality to those found in lower pool 2.

C. Development and application of sediment criteria (i.e., pollution classification) are necessary to evaluate the potential impact of chemical and bacteriological contamination from dredged sediments.

D. If sediment samples are found to contain 100 or more fecal coliforms (mf) per gram (dry wt), every reasonable effort shall be made to alert downstream users for a distance of 2 miles of the intention to dredge. (This recommendation is based on applicable literature and sediment-water correlations identified by Grimes, appendix A.)

E. Known recreation areas (especially swimming areas) should be posted against primary contact recreation for a distance of 2 miles downstream both during dredging and for 24 hours after a dredging operation.

F. Water quality standards for dredged material disposal, or at least state-of-the-art information on dredging and disposal impacts, should be incorporated into State and Federal water quality standards.

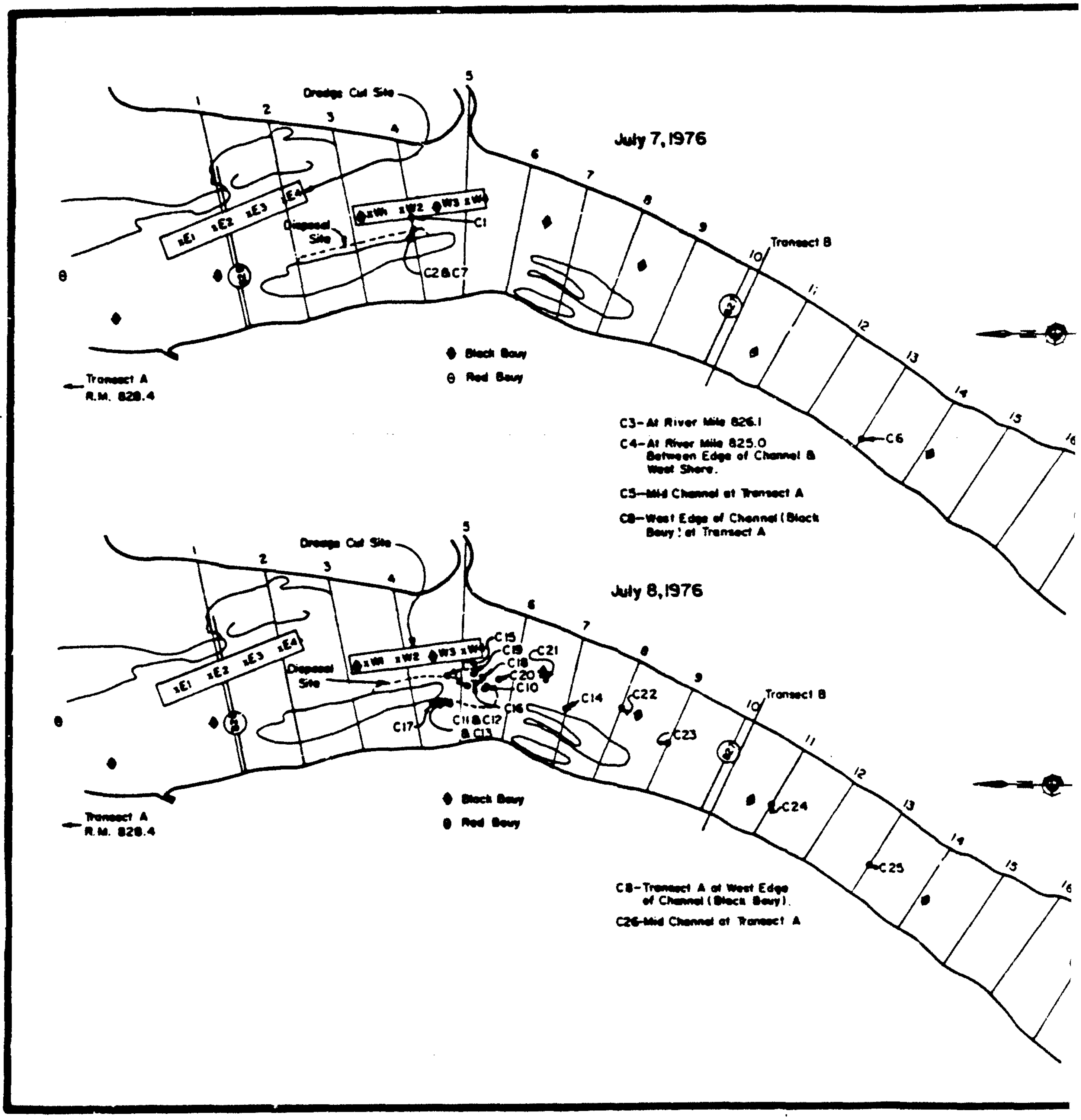
INTRODUCTION

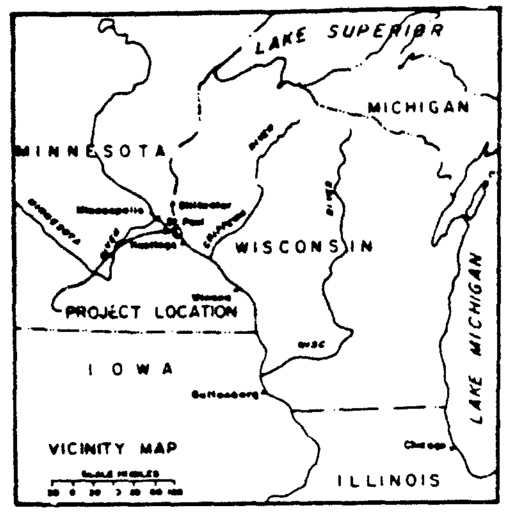
During 1974, GREAT (the Great River Environmental Action Team) was organized as an interagency mechanism to identify and address environmental problems associated with maintenance and operation of the Mississippi River 9-foot navigation channel. Subsequently, the Water Quality Work Group, under the direction of GREAT, was assigned the task of investigating water quality impacts resulting from these activities. Of major concern in this endeavor is the determination of short- and long-term effects of resuspended, dredged sediments on water quality during dredging and dredged material disposal.

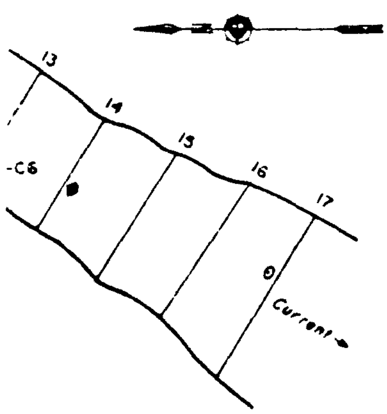
River sediments typically contain chemical and biological components, concentrations of which are determined by such factors as upstream influences, location within the sediment strata, and sediment particle size. Consequently, monitoring the resuspension and/or dissolution of these components during dredging and disposal is a complex undertaking. Moreover, as is evident in the literature, research to date has not adequately demonstrated the extent of effects resulting from these contaminants (Krenkel et al., 1976). Although the 5-year, $30 million Dredged Material Research Program sponsored by the U.S. Army Corps of Engineers Waterways Experiment Station has been a major effort toward determining such effects, most of this research has been concerned with marine effects. Much work remains to be done toward identifying impacts in freshwater systems as well.

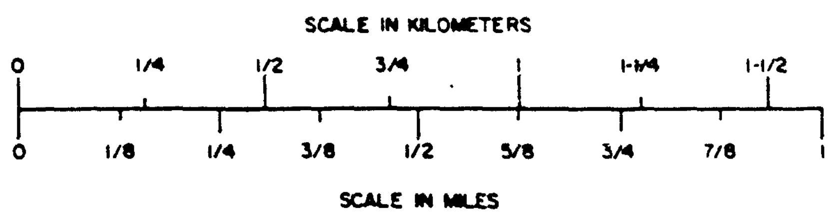
The scarcity of field data available on dredging effects is no less applicable to the GREAT I area (Minneapolis, Minnesota to Guttenberg, Iowa) of the Upper Mississippi River. Although surveys of sediments have been conducted in late 1974 and in early 1975 along the GREAT I reach (see appendix B), a concerted field effort to pursue water quality problems associated with dredging had not been attempted until the present study. Several relevant but abbreviated studies have been conducted by State and Federal agencies but these were of limited scope and information (Claflin, 1973; U.S. Army Corps of Engineers, 1974; Grimes, 1975; Minnesota Pollution Control Agency, 1975 (a) and (b)).

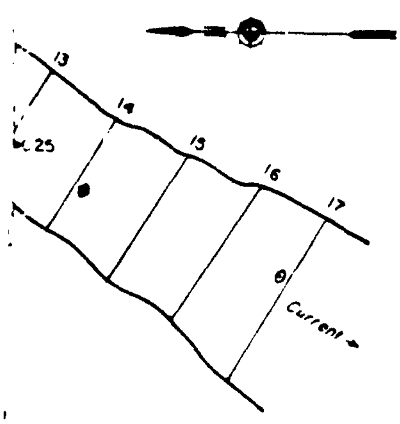
In an effort to gain information specific to GREAT I and the Upper Mississippi River, a pilot study was designed to monitor a hydraulic dredging operation. A scheduled dredging site near Grey Cloud Slough - Cairo river mile 827.7 - was selected for the water quality study since it represented one of the most contaminated bottom sediments and water quality reaches within the GREAT I river segment (figure 1). The study site was located approximately 15 miles downstream of the Minneapolis-St. Paul area and 8 miles downstream of the Metropolitan Wastewater Treatment Plant (Pigs Eye Plant). Dredging of the two adjacent dredge cuts was scheduled to a 13-foot water depth to maximize sediment-water column contact and to provide the best definition of any change in water quality (U.S. Army Corps of Engineers, 1977). Dredging was accomplished with the U.S. Army Corps of Engineers hydraulic dredge William A. Thompson with disposal of dredged material on an adjacent island located along the west riverbank.


July 7, 1976
Dredge Cut Site
Disposal Site
xE1 xE2 xE3 xE4
xW1 xW2 W3 xW4
C1
C2 & C7
Transect B
C6
Black Bouy
Red Bouy
Transect A
R.M. 828.4
C3–At River Mile 826.1
C4–At River Mile 825.0 Between Edge of Channel & West Shore.
C5–Mid Channel at Transect A
C8–West Edge of Channel (Black Bouy) at Transect A
July 8, 1976
Dredge Cut Site
Disposal Site
xE1 xE2 xE3 xE4
xW1 xW2 W3 xW4
C15
C19
C21
C18
C20
C10
C14
C22
C16
C11 & C12 & C13
C17
C23
Transect B
C24
C25
Black Bouy
Red Bouy
Transect A
R.M. 828.4
C8–Transect A at West Edge of Channel (Black Bouy).
C26–Mid Channel at Transect A









GREY CLOUD ISLAND
PILOT STUDY
MISSISSIPPI RIVER
DREDGE DISPOSAL SITE

OBJECTIVE

The primary objective of the pilot study was to evaluate experimental designs, including sampling equipment and procedures, in an attempt to assess the impacts of dredging and disposal of contaminated sediments on water quality. As such, it is intended that this study will not only add to the information available on dredging effects but will aid the work group in solidifying basic concepts and field techniques.

METHODS

SAMPLING PROCEDURES

Water quality monitoring of the dredging activities at Grey Cloud Slough (Cairo river mile 827.7) involved several different sampling crews and methods. Since this was a "pilot study," an attempt was made to test various sampling techniques and their relative effectiveness, as well as gather basic data on dredging and disposal impacts. Techniques were discussed and agreed to with the contractors involved. Sampling took place during a 3-day period (July 6, 7, 8, 1976) in which data were collected prior to and during the dredging operation. Background or control data for velocity, turbidity, and bottom sediments were collected on July 6. Monitoring of dredging and disposal impacts took place on July 7 and 8.

Site Characterization

Prior to dredging, 16 transects were established and marked across the navigation channel at 0.16 kilometer (0.1 mile) intervals. Velocity-depth measurements were taken each day of the study with a Standard AA Price Current Meter (Scientific Institute of Wisconsin, Milwaukee, Wisconsin) at three transects - A, B, and one immediately below the disposal site (see figure 1). Transect A was located 0.6 kilometer (0.4 mile) above the upstream dredge cut at river mile 828.4. Transect B was established at river mile 827, below the disposal discharge. Location of transect B was based on velocity measurements, where complete mixing of disposal water across the channel had been calculated to occur. Three stations were located along transect A, upstream, and three along transect B, downstream, and marked with anchored buoys. A dye study was also performed in May 1976 as an aid to determining time of travel of river water through the study site and to determine mixing patterns within the river.

Four bottom sediment samples were obtained from the center line of each of the two proposed dredge cuts using a petite ponar bottom sediment sampler. Samples were chilled and shipped promptly to the U.S. Geological Survey laboratory in Denver, Colorado. These samples provided a base line comparison against subsequent monitoring of water quality and resuspended sediments.

Predredging turbidity data were also collected along several of the 0.1-mile increment transects to obtain background data. The research vessel Izaak Walton (University of Wisconsin-La Crosse) equipped with a continuous-flow turbidimeter, depth-finder, and strip-chart recorder was used to make turbidity determinations. Samples were drawn through a swivel-mounted aluminum intake pipe mounted to the side railing of the boat. This allowed the pipe to pivot along a vertical arc, thus controlling the depth of the intake end of the pipe. Sampling depth could be varied from near surface to 12 feet through use of a calibrated line attached to the intake end of the pipe. The range of instream turbidity values was established by observing recorded readings on the on-line nephelometric turbidimeter (Hach Surface Scatter Model 2426, Hach Chemical Corp., Ames, Iowa) fed by the 2-inch diameter intake pipe and a 1-horsepower electric centrifugal pump (Red Jacket Pump, Davenport, Iowa).

Turbidity Plume Definition

The attempt in this phase of sampling was to define the physical boundaries of the dredge and disposal-generated plume. Markers located on the transects established during velocity-depth measurements were also used for this phase.

The Izaak Walton was used to monitor turbidity extremes identified by sampling along transects located upstream, adjacent to the disposal pile, and at various transects downstream of the dredging and disposal sites. Turbidity determinations were made along transects downstream to a point where dredging and disposal-generated turbidity could not be distinguished from background. This point was designated as the edge of the "no effect" zone.

Monitoring of Three-Dimensional Transverse Segment

Sampling activities were also initiated in an attempt to monitor overall changes in water quality from dredging and disposal. An effort was made to monitor a three-dimensional transverse segment of the river water at transect A and then again at transect B after it had passed through the dredging and disposal sites.

Water quality characterization of the transverse segment was performed according to the following scheme:

1. A boat equipped with two depth-integrating handline samplers Model DH-59 (St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota) collected 48 water samples or aliquots by making two round-trip passes over transect A. The passes required a total time of approximately one-half hour. These 48 aliquots were composited as they were collected and constituted one sample.

2. A boat equipped with two integrating samplers was also used to collect samples at transect B. Previous dye studies in May 1976 and velocity calculations had determined a travel time of approximately 2½ hours between transects A and B. Consequently, transect B sampling was initiated 2½ hours after transect A sampling.

3. After each composite sample was collected, a 10- to 30-minute period was allowed between experimental units before sampling for the next one was resumed. Thus, the sampling process was repeated at approximately 1-hour intervals during the day.

4. Sampling continued at the above rate until 12 composite samples had been collected both at transect A and at transect B on July 7. This procedure was repeated on July 8 until 13 composite samples had been collected from both transect A and transect B, thus yielding a total of 50 composite samples for the 2-day period.

5. Bacteriological samples were also obtained as subsamples from each of the composite samples.

Correlation of Physical-Chemical Parameters

The attempt in this phase was to relate values obtained for chemical parameters with observed turbidity fluctuations. Discrete water samples were collected representing the full range of turbidities observed upstream and at measured distances downstream within the disposal-generated plume. For this study, "physical parameters" will refer not only to turbidity but to suspended solids (defined as solids retained on a 0.45-micron membrane filter - Brown, Skougstad, and Fishman, 1970), total residue, specific conductivity, and temperature. All other parameters will be categorized as "chemical parameters," except coliforms and streptococci which are bacteriological parameters.

Water samples were collected from on board the Izaak Walton by means of a 3/8-inch diameter teflon vacuum tube attached to the turbidimeter intake pipe. This setup allowed turbidity samples and water chemistry samples to be drawn simultaneously. Samples were drawn through the teflon tube by applying a vacuum across two 45-liter (12-gallon) glass carboys connected in series to the teflon tube. The first carboy thus functioned as a sample container while the second served as a vacuum reservoir.

The sample was then transferred from the carboy to 30-liter (8-gallon) glass jars. These samples were then transported by shuttle boat to the shore station for further processing before shipment to the laboratory. After each sample transfer, the carboy was rinsed once with nitric acid and five times with deionized water to avoid contamination.

Twenty-six samples collected with the vacuum system were obtained at various intervals between the background and maximum turbidity levels observed during the 2 days of sampling. Two of these samples were obtained by hand near the mouth of the disposal discharge to represent peak levels of contaminants. The remaining 24 samples were drawn only when turbidity readings had stabilized as observed on the turbidimeter and strip-chart recorder (recorded values represented only the mean turbidity observed during the 45-second sampling period). Field data recorded with each sample collected included date, time, location, intake depth, stream dissolved oxygen, and temperature. Dissolved oxygen and temperature were obtained using a probe attached to the intake and a model 54A dissolved oxygen/temperature meter (Yellow Springs instruments, Yellow Springs, Ohio). Subsamples were also taken from each of the 26 samples for bacteriological analysis.

LABORATORY ANALYSIS

All 30-liter sample jars were rinsed once with hydrochloric acid and several times with deionized water. Those jars used for pesticide and PCB (polychlorinated biphenyls) samples were also rinsed with hexane and then deionized water.

Samples brought to the shore station for processing were placed on a magnetic stirrer for continuous mixing while the sample water was withdrawn into subsample bottles for subsequent laboratory analyses. Specific conductance and pH were determined at the shore station using portable instruments. Laboratory determinations were made for all other parameters.

Samples for dissolved constituents were pressure-filtered through a 0.45-micron membrane filter using a plexiglass filtering apparatus and compressed air. The metals samples were acidified with the nitric acid to a pH of less than 2. The cyanide samples were preserved with 2 milliliters of 10 N. sodium hydroxide per liter of sample.

Samples were chilled, except those for pesticides and PCBs which did not require chilling, and shipped to the laboratory. BOD (biochemical oxygen demand) determinations were made at the U.S. Geological Survey District Laboratory in St. Paul according to the method of the American Public Health Association and others (1971). The remaining chemical and physical analyses were performed at the U.S. Geological Survey laboratories in Albany, New York, and Denver, Colorado. Analyses were performed according to the methods of Brown, Skougstad, and Fishman (1970) approved by the U.S. Environmental Protection Agency. Water samples for bacteriological analysis were turned over to Dr. Jay Grimes, River Studies Center, University of Wisconsin-La Crosse for processing.

Phosphorus and nitrogen parameters were determined on an autoanalyzer. The digestion and distillation steps of the Kjeldahl method, described by Brown, Skougstad, and Fishman (1970), were used for determining organic nitrogen. The distillate was then analyzed on the autoanalyzer. Cyanide, along with the remaining inorganic parameters, was determined by the methods of Brown, Skougstad, and Fishman (1970) and updated revisions of these methods. Pesticides, PCB's, and TOC's (total organic carbon) were determined by the methods of Goerlitz and Brown (1972).

STATISTICAL ANALYSIS

Chemical, physical, and bottom sediment data were placed on STORET computer files (U.S. Environmental Protection Agency) and selected parameters were subjected to statistical analysis (Martin, appendix A). This process involved examination of the data through use of recognized statistical tests and computer programs and yielded a major portion of the information contained in the results section of this report.

RESULTS

SITE CHARACTERISTICS

River conditions during the sampling period were unusual as a result of extremely low flows. July averages at St. Paul, Minnesota, under normal flow conditions are 12,800 cfs (cubic feet per second); however, mean discharge for July 1976 was 2,564 cfs (U.S. Geological Survey, 1977). Average velocities measured in the Grey Cloud Slough segment during the study were only 0.15 meter per second (0.49 foot per second) or 0.54 kilometer per hour (0.34 mile per hour).

Hydraulic dredging of sediments commenced at approximately 12:15 a.m. on July 7, 1976. Removal of 36,414 cubic yards of material was accomplished during July 7 and 8. Material was dredged from two adjacent dredge "cuts", one on either side of the navigation channel, and transported as a slurry via pipeline to an island at river mile 827.7 for disposal (figure 1). The discharge pipe was moved during the study such that it was located near the head of the island at transect 2 when dredging began and near the downstream end of the island at transect 6 when dredging was terminated. Runoff from the disposal pile returned directly to the river.

SAMPLING TECHNIQUES

Definition of Turbidity Plume

Attempts to define the physical extent of the plume through turbidity measurements met with only limited success. It is evident that the most noticeable effects occurred immediately downstream of the disposal area with disposal material traveling largely through the bottom waters and behaving as a density current (Claflin, appendix A). However, the Water Quality Work Group did not agree with methods used to analyze the data, including vertical averaging of turbidity values, assumptions regarding settleability, extrapolation of turbidity decay curve, and numerical errors in statistical and typographical presentation. Consequently, results and conclusions put forth in the contractor's report were not incorporated into this report.

An alternative method was used to determine the extent of the plume by selecting data from discrete water samples taken during the correlation of the physical-chemical parameters phase (see figure 1 for location of discrete (C) samples). By applying a prediction equation to a selected set of discrete samples (C20 to C25), Martin (appendix A) determined that turbidity had returned to background or upstream concentrations within 1.1 kilometers (0.7 mile) downstream of the disposal discharge. The same equation applied to suspended solids concentrations yielded a value of 1.3 kilometers (0.8 mile). The measurements represent samples taken along the west side of the channel over a period of 2 hours on July 8. All samples were taken at a depth of 9 to 12 feet, except C20 which was obtained near the surface approximately 160 meters downstream of the discharge. Thus, the physical plume, reflected most noticeably in deeper waters, did not extend past transect 13 (1.3 kilometers or 0.8 mile downstream).

Monitoring of Three-Dimensional Transverse Segment of River Above and Below Study Site

Attempts to monitor the river as it passed from above to below the dredging and disposal operation met with several shortcomings. Estimations of travel time in this segment of the river were based on a dye study performed in May 1976 when flows were greater and on velocity measurements taken on July 6, 1976. After establishment of transect A as an upstream control and transect B downstream of the disposal site, it was predicted that travel time between the two transects would be approximately 2.5 hours. The intent, then, was to perform transect B sampling 2.5 hours after transect A sampling to monitor changes in the river segment after it had passed through the site. As it turned out, the prevailing low flows yielded a travel time of 4 to 4.5 hours between the two transects.

Establishment of transect B, downstream of the discharge, was also influenced by lack of information to make an effective prediction of location. As noted earlier, the physical plume disappeared after 1.1 to 1.3 kilometers (0.7 to 0.8 mile). Consequently, transect B, located adjacent to transect 10, was actually in a minimal effect zone on July 7.

However, from July 7 to July 8, the disposal discharge was moved closer to transect B so that it was approximately 0.6 kilometer (0.4 mile) upstream on July 8. Moreover, the three sampling stations along transect B were moved laterally to the west at 2:30 p.m. on July 8 upon observation that the plume was predominantly limited to the west side of the river.

Examination of water quality at transects A and B was carried out through compositing of individual sample aliquots. Analysis of the data confirmed that compositing prevented more detailed examination of the river water. The potential value of this method as a means of monitoring the horizontal river profile could perhaps be increased by analyzing the individual aliquots and avoiding compositing. Depth-integrating samplers used to collect the sample aliquots also proved difficult to use. The prevailing low velocities, along with problems in controlling descent and instream orientation of the sampler, were major obstacles in this regard.

Correlation of Physical-Chemical Parameters

The sampling approach used in correlating physical and chemical parameters was an effective method of monitoring effects from the dredging activity. Some improvement may have been made in location and timing of discrete samples but a relatively complete picture was obtained of the behavior of the plume, its attending contaminants, and their respective decay rates. Particularly effective in this regard were samples C20 through C25 which were taken over the length of the plume on July 8. Sample C17 was characterized by extreme values for most parameters as compared to other samples. This was due to the fact that disposal runoff water was being discharged into a shallow backwater in a direction opposite to that of the normal backwater flow. This resulted in extreme turbulence, thorough mixing, and elevated concentrations of material in the sampling area. Subsequently, after being subjected to preliminary statistical analysis, C17 was found to be an outlier and was treated separately in further analysis (Martin, appendix A). Samples C9 and C16 were taken near the disposal discharge and represented peak levels for most parameters.

ANALYSIS OF DATA

Sediment Analysis

Laboratory analysis of sediment samples reveals the nature of the bottom sediments within the study segment (table 1). The sediment appeared to be composed mainly of silty sand with very little clay. To gain a perspective on which parameters appeared in high concentrations, results of the present study were compared with those from other sediment studies conducted near the same location. Mean concentrations of arsenic, lead, Kjeldahl nitrogen, phosphorus, oil and grease, and chemical oxygen demand were comparatively high for samples collected in 1976 by the Water Quality Work Group. Oil and grease was detected in four of the eight samples with a mean of 1,900 mg/Kg, while PCBs showed a related spotty distribution and a mean of 7 ug/Kg. Arsenic concentrations were high, with a mean value of 77.5 ug/g, in comparison to 1974 and 1975 with mean concentrations of less than 1.0 ug/g. Analysis for pesticides revealed small quantities of only 3 of the 11 forms tested. Bacteria concentrations were also elevated and suggested human pollution (Grimes, appendix A). For a complete analysis of sediment data from 1974 to 1975, see appendix B.

Table 1. Bulk Sediment Analysis for Grey Cloud Slough Dredge Site - 1974, 1975, 1976

Parameter*	Pilot Study (WQWG) July 1976 R.M. 827.6/827.9 Avg (8 samples)	Lee (U of Texas) July 1976 R.M. 827.7 Avg (2 samples)	Corps of Engineers April 1975 R.M. 827.7 (1 sample)	Corps of Engineers Nov. 1974 R.M. 827.84 Avg (2 samples
Arsenic	77.5 µg/g	101 µg/g	0.45 µg/g	<0.85 µg/g
Cadmium	1.0 µg/g	0.4 µg/g	<0.1 µg/g	<1 µg/g
Chromium	3.8 µg/g	7.9 µg/g	16.5 µg/g	11 µg/g
Copper	3.6 µg/g	3.0 µg/g	7.9 µg/g	3.5 µg/g
Cyanide	0 µg/g	--	--	--
Iron	1346.3 µg/g	11,820 µg/g	--	--
Lead	4.3 µg/g	5.4 µg/g	<0.1 µg/g	<10 µg/g
Manganese	197.5 µg/g	348 µg/g	--	--
Mercury	0 µg/g	<0.005 µg/g	0.097 µg/g	0.55 µg/g
Nickel	3.8 µg/g	5.6 µg/g	--	8.5 µg/g
Zinc	14.4 µg/g	27 µg/g	29.7 µg/g	19.5 µg/g
Organic Carbon	1.9 mg/g	0.3%	--	--
C.O.D.	5957 mg/Kg	--	4850 mg/Kg	731 mg/Kg
Ammonia Nitrogen	27 mg/Kg	--	.20 mg/Kg	--
Kjeldahl Nitrogen	302.5 mg/Kg	--	5.74 mg/Kg	187 mg/Kg
Oil and Grease	1900 mg/Kg	60 mg/Kg	133 µg/g	70 µg/g
Phosphorus	232.5 mg/Kg	--	1.82 µg/g	218 µg/g
% Volatile Solids	0.17 (16875 mg/Kg)	--	1.8	0.4
% Total Solids	--	--	98.6	78.05
Chlordane	1.0 µg/Kg	--	--	<0.01 µg/g
DDD	.25 µg/Kg	<2.0 µg/Kg	--	--
DDE	0 µg/kg	1.6 µg/Kg	--	<0.01 µg/g
Lindane	0 µg/Kg	1.0 µg/Kg	--	<0.01 µg/g
Toxaphene	0 µg/Kg	--	--	<0.20 µg/g
PCB	7.0 µg/Kg	7 µg/Kg	--	--
Total Coliforms	3800 per gram			
Fecal Coliforms	820 per gram			
Fecal Streptococci	5 per gram			
FC/FS	164.0			

* Values represent "total" concentration for parameter.

Three-Dimensional Transverse Segment

Only a few of the parameters tested revealed consistent patterns during the 2 days of monitoring at transect A and B (table 2). While over 80 percent of the parameters showed an increase from transect A to transect B on at least 1 day, over half of these parameters were also characterized by ambient daily fluctuations during the 2-day period greater than or equal to differences between transect A and transect B. The fact that the disposal discharge was continually being moved during the study may have disguised patterns for many parameters.

le 2. Summary Data of Transect A and B Parameters for July 7 and 8, 1976 at Grey Cloud Slough, Mississippi River.

Parameter	TRANSECT A July 7 Mean	TRANSECT A July 7 Range	TRANSECT A July 8 Mean	TRANSECT A July 8 Range	TRANSECT B July 7 Mean	TRANSECT B July 7 Range	TRANSECT B July 8 Mean	TRANSECT B July 8 Range
Dissolved Arsenic	.40 µg/l[1]	0 -2.0	1.58 µg/l	0 -3.0	.36 µg/l	0 -3.0	1.85 µg/l	0 -3.0
Suspended Arsenic	1.2 µg/l	0 -2.0	.77 µg/l	0 -6.0	1.73 µg/l	0 -3.0	.69 µg/l	0 -3.0
Dissolved Cadmium	.40 µg/l	0 -1.0	.31 µg/l	0 -1.0	.50 µg/l	0 -2.0	.23 µg/l	0 -1.0
Suspended Cadmium	.70 µg/l	0 -1.0	1.08 µg/l	0 -2.0	1.27 µg/l	0 -2.0	1.08 µg/l	0 -3.0
Dissolved Chromium	<10 µg/l	<10-10	<10 µg/l	<10-10.0	10 µg/l	10	<10 µg/l	<10-10
Suspended Chromium	0 µg/l	0	1.54 µg/l	0-10.0	0 µg/l	0	6.92 µg/l	0-30.0
Dissolved Copper	0 µg/l	0	1.54 µg/l	0-10.0	0 µg/l	0	2.31 µg/l	0-10.0
Suspended Copper	.30 µg/l	0-10.0	7.69 µg/l	0-10.0	9.09 µg/l	0-10.0	7.69 µg/l	0-10.0
Dissolved Iron	1.40 µg/l	1.0- 2.0	.85 µg/l	0- 2.0	1.09 µg/l	0. 3.0	.62 µg/l	0- 2.0
Total Iron	653.0 µg/l	450-880	416.2 µg/l	310-790	1387.0 µg/l	460-1800	480.0 µg/l	330-2200
Dissolved Lead	5.3 µg/l	0-11.0	3.5 µg/l	0- 6.0	6.4 µg/l	4.0-11.0	3.5 µg/l	2.0- 7.0
Suspended Lead	1.4 µg/l	0- 6.0	5.2 µg/l	0-10.0	2.7 µg/l	0- 7.0	5.2 µg/l	0-12.0
Dissolved Manganese	17.00 µg/l	10.0-30.0	11.54 µg/l	10.0-20.0	19.09 µg/l	10.0-30.0	25.38 µg/l	10.0-60.0
Suspended Manganese	157.0 µg/l	120.0-170.0	117.7 µg/l	110.0-150.0	202.7 µg/l	180-220	136.9 µg/l	110-260
Dissolved Mercury	<.50 µg/l	<.50	<.50 µg/l	<.50- .50	<.50 µg/l	<.50 -.50	<.50 µg/l	<.50-.50
Suspended Mercury	0 µg/l	0	0 µg/l	0-.80	0 µg/l	0	0 µg/l	0
Dissolved Nickel	5.4 µg/l	4.0-9.0	10.3 µg/l	9.0-12.0	6.3 µg/l	4.0-10.0	10.1 µg/l	7.0 -14.0
Suspended Nickel	.05 µg/l	0- 2.0	2.77 µg/l	0-12.0	.82 µg/l	0- 5.0	2.85 µg/l	0-11.0
Dissolved Zinc	2.00 µg/l	0-10.0	6.92 µg/l	0-30.0	4.55 µg/l	0-10.0	4.62 µg/l	0-10.0
Suspended Zinc	18.0 µg/l	0-30.0	19.2 µg/l	0-150.0	25.5 µg/l	0-40.0	19.2 µg/l	0-70.0
Dissolved Chloride	25.30 mg/l[2]	24.0-27.0	26.54 mg/l	25.0-28.0	24.09 mg/l	22.0-28.0	26.62 mg/l	23.0-28.0
Total Cyanide	0 mg/l	0	0 mg/l	0	0 mg/l	0	.39 mg/l	0- 5.0
Total Sulfide	.58 mg/l	.20- 1.0	.43 mg/l	0- 1.0	.42 mg/l	0- .90	.23 mg/l	0- 1.1
BOD	6.25 mg/l	4.4- 8.8	6.01 mg/l	4.5- 7.2	6.76 mg/l	6.2- 7.5	6.30 mg/l	4.8- 8.0
COD	32.4 mg/l	24.0-40.0	34.2 mg/l	26.0-41.0	38.9 mg/l	36.0-42.0	36.0 mg/l	25.0-49.0
Total Organic Carbon	13.20 mg/l	12.0-15.0	12.92 mg/l	9.0-16.0	14.55 mg/l	10.0-18.0	16.00 mg/l	11.0-25.0
Dissolved Ammonia Nitrogen	1.04 mg/l	1.1- 1.4	1.13 mg/l	.05- 1.5	1.18 mg/l	1.1- 1.4	1.04 mg/l	0- 1.4
Total Ammonia Nitrogen	1.38 mg/l	1.3- 1.6	1.22 mg/l	.05- 1.7	1.43 mg/l	1.2- 1.5	1.04 mg/l	.01- 1.6
Dissolved Organic Nitrogen	.70 mg/l	.50- .90	.79 mg/l	0- 1.2	.75 mg/l	.5- 1.0	.73 mg/l	0- 2.0
Total Organic Nitrogen	1.2. mg/l	1.10- 1.40	1.19 mg/l	1.00- 1.60	1.39 mg/l	1.20- 1.60	1.10 mg/l	0- 2.5
Dissolved Nitrite & Nitrate	0.25 mg/l	.21- .38	0.22 mg/l	.21- .24	0.32 mg/l	.20- .67	0.25 mg/l	.20- .67
Total Nitrite & Nitrate	0.28 mg/l	.23- .43	0.54 mg/l	.21- 1.70	0.40 mg/l	.23- .72	0.84 mg/l	.22- 2.0
Oil & Grease	.64 mg/l	0- 3.0	1.08 mg/l	0- 4.0	.36 mg/l	0- 1.0	.77 mg/l	0- 3.0
Total Ortho Phosphorus	0.31 mg/l	.27- .39	0.39 mg/l	.33- .44	0.25 mg/l	.20- .28	0.37 mg/l	.29- .42
Dissolved Ortho Phosphorus	0.29 mg/l	.25- .35	0.36 mg/l	.31- .41	0.24 mg/l	.19- .27	0.35 mg/l	.27- .40
Dissolved Solids Residue	271.90 mg/l	260.0-279.0	272.30 mg/l	264.0-282.0	274.2 mg/l	256.0-303.0	275.3 mg/l	265.0-300.0
Total Residue	322.4 mg/l	311.0-338.0	323.3 mg/l	314.0-344.0	348.5 mg/l	321.0-381.0	347.4 mg/l	322.0-386.0
pH	8.2	8.1- 8.2	8.0	7.9- 8.1	8.1	7.6- 8.2	8.0	7.9- 8.2
Suspended Solids	21.80 mg/l	14.0- 31.0	14.85 mg/l	4.0- 37.0	41.00 mg/l	26.0- 55.0	33.85 mg/l	6.0- 80.0
Conductance	516.0 µmhos	500.0-525.0	511.9 µmhos	495.0-525.0	512.7 µmhos	500.0-530.0	517.7 µmhos	495.0-535.0
Total Coliform	1979/100ml	610-2800	6363/100ml	260-30,000	4117/100ml	260-30,000	6508/100ml	1200-29,000
Fecal Coliform	511/100ml	400-710	4112/100ml	350-44,000	632/100ml	400-750	551/100ml	220-2500
Fecal Streptococci	14/100ml	0-40	62/100ml	0-160	53/100ml	0-160	75/100ml	10-520
FC/FS	30.4	13.5-45.0	140.0	2.3-1466.7	47.7	4.7-108.0	21.7	0.6 -7.4

[1] µg/l = ppb (parts per billion)

[2] mg/l = ppm (parts per million)

Ambient fluctuations at transect A from July 7 to July 8 were generally greater than differences between transect A and B concentrations. Those which experienced greater than ambient fluctuations attributable to dredging effects include: total iron, total residue, total sulfide, total organic carbon, dissolved solids residue, suspended solids, total organic nitrogen, and biochemical oxygen demand.

Total sulfide and phosphorus were the only parameters of the group above which showed a distinct decrease from above to below during both days. Total and dissolved orthophosphorus revealed decreases from above to below but ambient increases from July 7 to July 8 were greater. Statistical analysis revealed that ambient concentrations of phosphorus went up during July 7, peaked out overnight, and declined on July 8, thus suggesting an upstream discharge (Martin, appendix A). Iron was by far the most abundant metal detected at both transect A and B and, although ambient concentrations decreased by almost 40 percent from July 7 to July 8, concentrations doubled from above to below on both days. Day to day fluctuations in the second most abundant metal, manganese (suspended), were considerably larger than differences from above to below. Ambient concentrations of dissolved manganese decreased from July 7 to July 8, while concentrations below were greater than concentrations above the dredging and disposal operation on both days.

Most metals at transect B showed a higher concentration of the suspended form than the dissolved form. Nickel is the most notable exception to this trend with dissolved concentrations almost eight times greater than suspended concentrations on July 7, but only three times greater on July 8 when the discharge was closer to transect B.

Correlation of Physical-Chemical Parameters

Simultaneous sampling of physical and chemical parameters in the discrete samples revealed consistent patterns. Correlation coefficients (r) were calculated and a correlation matrix was established showing relationships between selected parameters (Martin, appendix A). Interrelated parameters with r values greater than 0.74 were: turbidity, suspended solids, total residue, total iron, chemical oxygen demand, dissolved manganese, suspended manganese, suspended nickel, suspended lead, total organic carbon, total organic nitrogen, and suspended cadmium. Suspended copper and suspended zinc also showed a correlation of approximately 0.98 with suspended solids while BOD showed a correlation of 0.78 with suspended solids.

The analysis revealed that suspended solids as well as total residue actually showed higher correlations with other parameters than did turbidity. A substantial explanation lies in the fact that turbidity is a measure of optical density characterized by a greater lack of precision than is suspended solids which is a gravimetric measure of weight per volume. Moreover, turbidity is influenced by a greater number of variables including temperature, color, and dissolved constituents. Perhaps a more precise method of measuring turbidity would increase its value as a correlative parameter. It is also evident that the suspended form of metals correlates more highly with physical parameters than does the dissolved form.

The only parameter showing a significant negative correlation with most other parameters is phosphorus. Additionally, total ammonia nitrogen exhibited strong negative correlations of -0.84 and -0.82 with dissolved organic nitrogen and total nitrite and nitrate, respectively.

In discrete samples C20 through C25, most chemical and biological parameters correlated closely with the decay phenomenon seen in physical parameters as the disposal water was carried downstream and mixed with ambient river water (table 3). Exceptions to this phenomenon were pH, dissolved solids residue, dissolved iron, phosphorus, and nitrite + nitrate which all experienced depressed concentrations in samples near the discharge pipe but returned to background concentrations in downstream samples. The remaining parameters showed fluctuating patterns. Figures 2 and 3 provide graphic examples for many of the patterns observed between suspended solids and other parameters.

Table 3 . Trends Shown for Selected Discrete Samples Taken During the Correlation of Physical-Chemical Parameters Phase of the Grey Cloud Slough Study.

Parameter	Background C-[illegible]	Discharge C-[illegible] (Avg.)	.01 Km Down C-[illegible]	.16 Km Down C-[illegible]	.48 Km Down C-22	.64 Km Down C-23	.97 Km Down C-24	1.29 Km Down C-25
Dis. Arsenic	3 µg/l[1]	2 µg/l	4 µg/l	2 µg/l	2 µg/l	1 µg/l	3 µg/l	2 µg/l
Sus. Arsenic	0	10	6	2	0	2	0	3
Dis. Cadmium	0	1	1	0	0	1	1	0
Sus. Cadmium	1	8	3	2	1	0	0	1
Dis. Chromium	<10	10	20	<10	<10	10	<10	<10
Sus. Chromium	0	65	10	10	20	0	0	10
Dis. Copper	0	0	0	0	0	0	0	0
Sus. Copper	10	45	30	20	10	10	10	10
Dis. Iron	10	5	0	0	0	0	10	0
Total Iron	310	16700	9200	4100	1400	1400	800	780
Dis. Lead	5	3	6	3	2	4	3	4
Sus. Lead	1	66	26	11	7	2	2	3
Dis. Manganese	10	500	220	140	50	50	60	40
Sus. Manganese	110	1120	560	290	140	180	120	130
Dis. Mercury	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sus. Mercury	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dis. Nickel	7	9	9	9	9	9	10	11
Sus. Nickel	0	35	15	8	0	3	1	0
Dis. Zinc	10	0	10	10	0	0	10	10
Sus. Zinc	0	145	80	30	20	20	0	0
Dis. Chloride	24 mg/l[2]	26 mg/l	27 mg/l	27 mg/l	27 mg/l	27 mg/l	28 mg/l	25 mg/l
Total Cyanide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Sulfide	0.0	1.1	0.1	0.1	0.2	0.0	0.0	0.5
BOD	4.8	12.9	11.8	7.5	6.3	6.4	4.8	--
COD	31	117	81	53	41	40	37	38
Total Org. Carbon	13	42	24	19	14	15	13	13
Dis. Ammonia Nitrogen	0.68	1.13	0.58	1.0	0.01*	0.82	1.0	0.64
Total Ammonia Nitrogen	0.68	1.13	0.58	1.0	0.01*	0.82	1.0	0.64
Dis. Organic Nitrogen	1.1	1.5	1.8	1.2	1.7	1.3	1.1	1.2
Total Organic Nitrogen	1.1	2.9	2.0	1.7	1.7	1.3	1.1	1.2
Dis. Nitrite and Nitrate	3.4	0.26	1.0	1.4	1.7	1.2	0.49	0.20
Total Nitrite and Nitrate	4.1	1.14	2.3	2.2	3.7	2.0	1.1	1.2
Oil and Grease	0	1	--	1	0	1	1	2
Dis. Ortho Phosphorus	0.30	0.17	0.21	0.29	0.36	0.34	0.37	0.33
Total Ortho Phosphorus	0.30	0.19	0.22	0.29	0.40	0.39	0.38	0.35
Dis. Solids Residue	257	232	280	280	273	287	281	278
Total Residue	335	897	654	467	379	384	348	356
Pesticides	--	.00 µg/l	--	--	--	--	--	--
PCB's	--	.05	--	--	--	--	--	--
pH	7.9	7.7	7.9	7.9	8.1	8.0	8.0	8.0
Suspended Solids	12 mg/l	503 mg/l	321	152	45	59	35	44
Turbidity	12.3 NTU[3]	--	143.9 NTU	58 NTU	29 NTU	31 NTU	23.0 NTU	18.6 NTU
Dissolved Oxygen	2.4	--	3.0	2.8	2.6	2.2-2.5	2.0-2.1	1.8
Temperature	25.9°C.	--	25.8°C.	25.8°C.	26.1°C.	25.5°C.	25.5-25.8°C.	25.5°C.
Specific Conductance	500 µmhos	563 µmhos[5]	525 µmhos	520 µmhos	520 µmhos	515 µmhos	515 µmhos	505 µmhos
Total Coliforms	5600 cfu/100ml[4]	21000 cfu/100ml	4100 cfu/100ml	4200 cfu/100ml	4800 cfu/100ml	5800 cfu/100ml	3200 cfu/100ml	2700 cfu/100ml
Fecal Coliforms	750	12000	1200	460	620	630	530	370
Fecal Streptococcus	20	4000	45	35	30	30	15	0
FC/FS	37.5	3.0	26.7	13.1	20.7	21.0	35.3	--

[1] µg/l = ppb (parts per billion)
[2] mg/l = ppm (parts per million)
[3] NTU = Nephelometric Turbidity Unit
[4] Colony forming units per 100ml
[5] Sample C-[illegible] only

* Probable error in tabulation.

Figure 2. Relationship Between Suspended Solids and Selected Parameters for Discrete Samples (C-26, 9 and 16, 20-25) Taken at [illegible] Grey Cloud Slough Dredge Site, July 8, 1976.

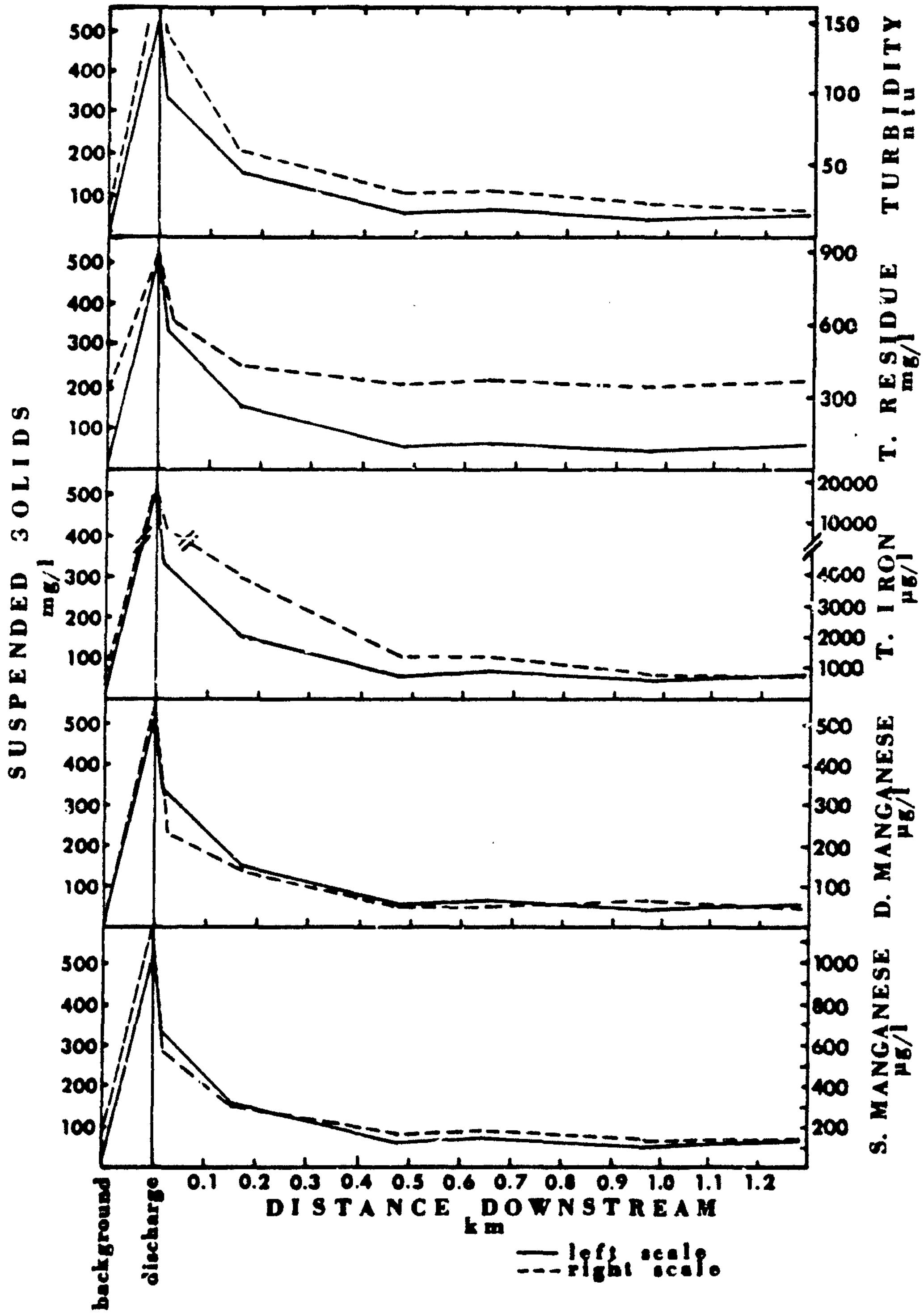
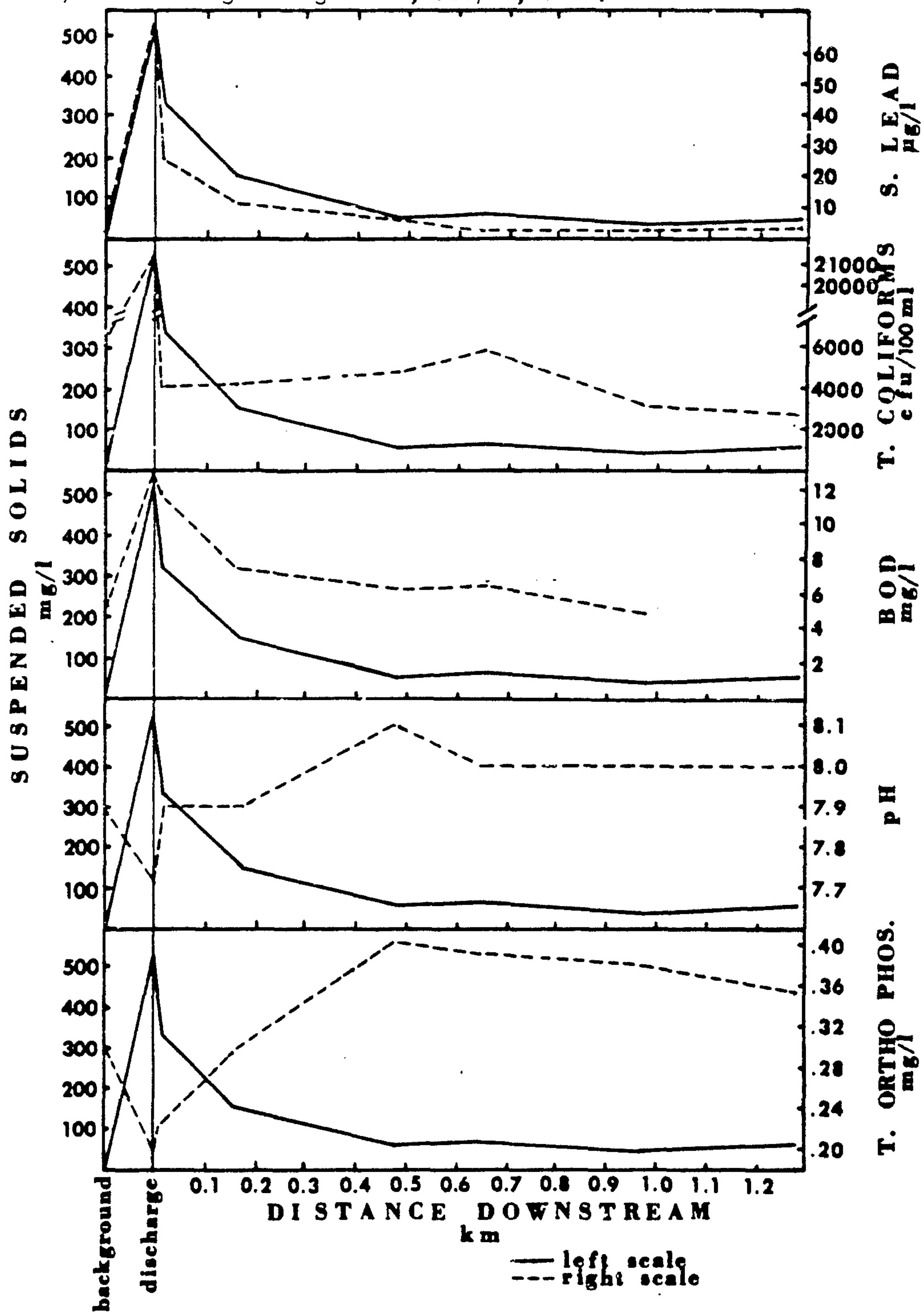


Figure 3. Relationship Between Suspended Solids and Selected Parameters for Discrete Samples (C-26, 9 and 16, 20-25) Taken at the Grey Cloud Slough Dredge Site, July 8, 1976.



Almost all suspended metals, along with suspended solids, were increased by 10 times or more in discharge samples (C9 and C16) but had returned to background concentrations, or nearly so, by 1.3 kilometers downstream. Dissolved manganese showed an 80-fold increase in discharge samples, and concentrations 1.3 kilometers downstream were still four times higher than background concentrations. Although concentrations of suspended nickel were greater than dissolved concentrations in discharge samples, dissolved nickel was higher than suspended nickel in background samples as well as 1.3 kilometers downstream. Pesticides were not detected in any of the discrete water samples. Oil and grease was detected in discrete samples in only small amounts while PCBs were found in only one sample at the discharge. Biochemical oxygen demand at the discharge was more than double that of background levels but had returned again to background after 1 kilometer (0.6 mile). Chemical oxygen demand at the discharge was more than triple that of background levels but was near background again after 1.3 kilometers. Concentrations of bacteria at the discharge pipe were four times higher than background concentrations but returned to background within 1 kilometer.

The remainder of the discrete water samples (figure 1) revealed identifiable patterns in which concentrations of a given parameter correlated roughly with distance from the discharge. Generally, samples which showed the greatest concentrations of suspended solids also showed the greatest concentrations of chemical parameters and bacteria. Samples C10 and C14 were characterized by the highest levels for most parameters except C9 and C16 taken at the discharge. Both C10 and C14 were taken immediately downstream of the discharge in 2.5 feet of water on the west side of the channel. Samples C11, C12, and C13 were taken in shallow water immediately west of the disposal island and represent effects from a back eddy which was moving upstream along the west side of the island. Concentrations of some contaminants in these samples were greater than in discharge samples. Discrete sample C4, taken approximately 4.3 kilometers (2.7 miles) downstream of the discharge at river mile 825.0, shows values comparable to background concentrations for almost all parameters except turbidity and suspended solids which were slightly higher than background.

DISCUSSION

There is no historical evidence available on the Upper Mississippi River which shows that dredging and disposal activities create gross water quality degradation. However, sufficient information is available documenting the fact that these activities can cause significant localized impacts on water quality, not only in the Upper Mississippi River (Claflin, 1973; U.S. Army Corps of Engineers, 1974; Grimes, 1975; Minnesota Pollution Control Agency, 1975 (a) and (b)) but also in other aquatic environments (O'Neil and Sceva 1971, Lee and Plumb 1974, Sly 1977).

In general, most studies have concluded that increases in turbidity as well as resuspension of chemical contaminants and decreases in dissolved oxygen are the major adverse effects associated with dredging and disposal. Under certain conditions these effects may, in turn, hold important consequences for the integrity of the aquatic environment. Increased turbidities and suspended solids can reduce light penetration and algal growth and create physiological stress on aquatic organisms. Sedimentation can smother aquatic organisms and alter habitat. Organisms exposed to resuspended toxicants may be debilitated or destroyed while resuspended nutrients may increase eutrophication and demand on oxygen levels within the aquatic environment. Resuspended pathogens can result in health hazards downstream.

The Mississippi River immediately below the Minneapolis-St. Paul metropolitan area and extending down to lock and dam 2 at Hastings, Minnesota, is, overall, the most contaminated segment of the GREAT I portion of the Mississippi River. The Minnesota Pollution Control Agency has indicated that this segment is in noncompliance with Federal and State water quality goals established for July 1, 1983 (Minnesota Pollution Control Agency, 1977b); that is, proposed "fishable, swimmable" standards (Minnesota Pollution Control Agency, Class C) are not being met.

Factors which contribute to this degraded condition include high turbidities, ammonia, bacteria, and low dissolved oxygen levels. PCB's have also been identified as a major problem in this segment (Minnesota-Wisconsin PCB Interagency Task Force, 1976).

In many cases, the source of these contaminants can be identified. During late June and early July 1976, the Minnesota River was contributing increased loads of nutrients and turbidity and depressed concentrations of dissolved oxygen to the Mississippi River at river mile 844 (Metropolitan Waste Control Commission, 1977). Combined sewer and stormwater overflows, urban runoff, erosion, and other nonpoint sources are additional causes of contamination. A major point source of contamination is the Metropolitan Wastewater Treatment Plant at river mile 835.2. Industries within the metropolitan area contribute a wide variety of chronic and incidental waste products to the river system.

In light of this information it became evident to the Water Quality Work Group that dredging and disposal activities immediately downstream of the metropolitan area had the potential for aggravating the existing degraded water quality conditions. Consequently, the opportunity to monitor impacts from dredging at Grey Cloud Slough provided a "worst case" situation with regard to water quality and sediments. A prime example lies in analysis of dissolved oxygen data during the summer of 1976 which shows that the dredging and disposal sites were located near the bottom of the dissolved oxygen sag caused by the Metropolitan Wastewater Treatment Plant (Minnesota Pollution Control Agency, 1977a). Moreover, low flows during the study period further aggravated this condition by reducing the dilution and assimilation capacity of the river. Caution should be exercised in applying results of this study to periods of normal flow or flood conditions as well as to other segments of the river.

In the hydraulic dredging process, virtually all studies have shown that the major share of adverse water quality effects occurs at the disposal end of the operation as well as immediately downstream from the disposal site. Lee (1977) concluded that there were no discernible turbidity effects from the actual dredging act (i.e., cutterhead effects) at the Grey Cloud Slough study site. Although no specific effort was directed toward identifying cutterhead effects in the present study, analysis of discrete sample C1, located downstream of the cutterhead, reaffirms this conclusion. Most of the sediment is drawn into the cutterhead as a slurry and then deposited at the disposal site where it is dispersed within the disposal-generated plume.

Table 1 points out the dynamic nature of the river environment. The composition of bottom sediments within a particular area is determined by a combination of seasonal fluctuations of contaminants within the water column along with seasonal fluctuations in the deposition of these components during sedimentation. Thus, to a limited degree, the researcher may obtain a historical record of upstream influences and river conditions within a broadly defined area through examination of these sediment "sinks." Some variation among the studies presented in the table can be attributed to subtle differences in locale, methods of collection, and analysis, but seasonal flow factors may have played an even greater role in these differences. Concentrations of many parameters are similar between the present study and Lee (1977) who took his samples at the same time and location as the present study.

Due to the absence of established guidelines or limits for bottom sediment contaminants in the Upper Mississippi River, it is difficult to classify the sediments at Grey Cloud Slough as "polluted." The only exception to this situation is the Minnesota Pollution Control Agency's proposed standard for sediment oil and grease (Minnesota Pollution Control Agency, 1977a). Individual sediment samples, along with the average of 1,900 mg/Kg, exceeded the proposed standard of 1,000 mg/Kg. For the remaining parameters, comparisons with data from other studies must be used, as was done in table 1.

Past investigations have shown that a high concentration of a particular contaminant in the bulk sediment analysis does not dictate that it will be found in correspondingly high levels in the disposal water, and vice versa (Lee and Plumb, 1974). This phenomenon can be attributed to dilution and the fact that potential for release and/or resuspension is unique for any given component within the sediment. To use a simple analogy, it would be difficult to correlate the color of a given sediment with the color of water serving as a disposal medium for that sediment. The Standard Elutriate Test was designed as an alternative approach to this dilemma but examination of this method was not within the scope of this study (see Lee, 1977, for an analysis of this approach at Grey Cloud Slough).

The most important concerns regarding the effects of dredging and disposal are turbidity, chemical contaminants, and dissolved oxygen. Results of this study support most of these concerns; however, significant decreases in dissolved oxygen were not observed. The fact that dissolved oxygen concentrations were already extremely low as a result of the Metropolitan Wastewater Treatment Plant upstream makes conclusions difficult. Even if some observable depressive effects on dissolved oxygen levels occurred, this may have been offset by the aeration effect of the dredging process. Lee (1977) concluded that depressed dissolved oxygen levels were due to the upstream wastewater discharge and that dredging and disposal had no effect on dissolved oxygen.

The most easily observable effect of dredging and disposal is the increase in turbidity. In addition to the effects of the dredged material disposal observed visually, quantitative effects were measured as well. Statistical analysis revealed that suspended solids and turbidity effects had disappeared within 1.3 kilometers of the discharge. Nonstatistical analysis of the same data by Grimes (appendix A) was in close agreement with this value. He concluded that turbidity was approaching background levels 0.97 kilometer (0.6 mile) downstream. He went on to postulate that record low current velocities failed to keep significant amounts of sediment in suspension for longer than 2 hours or 0.97 kilometer. In a separate set of samples obtained at the site, Lee (1977) observed that increased turbidities in the surface water were restricted to a few meters from the discharge, while deeper waters contained a density current of turbid material extending downstream for several hundred meters. Again, however, definition of the plume was not done statistically. It seems reasonable to expect that the sediment, composed mainly of sand and some silt, would settle rapidly and create elevated turbidities mainly in the deeper downstream waters as supported by these findings. Finer sediments can be expected to create longer plumes and decay curves in both surface and bottom waters.

Grimes (appendix A) also documented another extremely important concern for the Grey Cloud Slough area. Coliform and streptococcus levels in the bottom sediment were indicative of gross human pollution and Grimes states that the most probable source is the Metropolitan Wastewater Treatment Plant. Total and fecal coliform densities were approximately four times greater immediately below the dredged disposal discharge than corresponding upstream values, but levels had returned to background within 1 kilometer downstream of the discharge. Again, the rather rapid decrease in bacteria levels was attributed to the settling of resuspended particles upon which the bacteria were adsorbed.

It can be emphasized immediately in the discussion of chemical contaminants that the suspended form of metals was predominant in the disposal plume and that these suspended metals correlate closely with the physical parameters - turbidity, suspended solids, and total residue.

Several organic and bacterial parameters correlate closely with physical parameters as well. Both the correlation matrix established by Martin (appendix A) and table 3 confirm this finding. Chemical contaminants do not appear to go into solution but, instead, exhibit a strong sorptive tendency. Their concentrations decrease rapidly as particles settle to the bottom and dilution occurs. This phenomenon has been well documented by past studies (Lee and Plumb, 1974; Gambrell, et al., 1977). The major exception to this situation in the present study is dissolved manganese which increased from a background level of 7 ug/l to 560 ug/l immediately below the discharge and continued to show elevated levels as far downstream as 1.3 kilometers. This condition is in keeping with results presented by Lee (1977) who found that manganese was readily released (or dissolved) in 5 percent oxic and 20 percent oxic elutriate tests, more so than the other metals.

Iron, which was even more abundant than manganese in sediment and disposal samples, does not reveal the same pattern of dissolution as manganese. Dissolved iron in the discharge samples was only 0.03 percent of the total iron while dissolved manganese at the discharge represents 33 percent of the total. These two elements are closely related in their chemical properties (Ruttner, 1973), yet they appear to exhibit widely different behavior as affected by dredging. Dissolved iron concentrations actually show a decrease in disposal water over background while dissolved manganese shows a marked increase. This behavior may be explained, in part, by the fact that manganese tends to dissolve more readily than iron at low concentrations of oxygen (Hem, 1959). Both metals are known to be effective scavengers of trace metals, thus suggesting that they may inhibit dissolution of other metals in the disposal water (Khalid, et al., 1977). Iron, manganese, and nickel have been categorized as the most readily released metals during resuspension of bottom sediments (Chen, et al., 1976), but only manganese showed a noticeable release in the present study. Manganese was the only metal which showed substantial release in a study by Blom, et al., (1976), but this study was conducted in salt water.

Decreases from background concentrations were observed for phosphorus in both transect B and downstream discrete samples, but no immediate reason for this decrease is apparent. Similar to metals, however, phosphorus is thought to be closely associated with sediment iron and through sorption reactions may form iron phosphates (Sly, 1977). Reducing (anaerobic) conditions favor phosphorus release, while oxidizing (aerobic) conditions favor phosphorus adsorption. Increases in the redox potential of interstitial water containing elevated phosphorus concentrations would tend to counter the possible release of phosphorus caused by dredging and dredged material disposal (Gambrell, et al., 1977). The redox potential must have been high enough in the disposal water at Grey Cloud Slough to inhibit the release and to promote the adsorption of phosphorus, which was already predominantly in the dissolved form in the ambient river water.

Important mechanisms governing resuspended sediments and attending chemical reactions include adsorption by cation exchange reactions; metal precipitation as insoluble sulfides encounter strongly reducing conditions; formation of discrete metal oxides and hydroxides of low solubility or metal adsorption to colloidal iron and manganese oxides in aerobic, neutral, or alkaline environments; and complexation with soluble and insoluble organic matter at all levels of pH and redox potential (Gambrell, et al., 1976).

Table 4 presents a list of standards both established and proposed by the Minnesota Pollution Control Agency to protect "fishable, swimmable" waters. Public Law 92-500 dictates that these standards shall be met for the Mississippi River segment below Minneapolis-St. Paul by 1983. A mandate for determining acceptable mixing zones below dredging and disposal sites has also been established (Environmental Protection Agency, 1975) but, to date, little has been done in this regard. As a means of providing impetus and information toward this end, concentrations of contaminants found in samples in the present study have been compared with Minnesota standards in table 4. The proposed Minnesota Pollution Control Agency standards are based largely on "Quality Criteria for Water" (Environmental Protection Agency, 1976), and these criteria in turn are based largely on bioassays. Bioassays measure toxicity of available (e.g., dissolved) forms of a contaminant during continuous exposure. Thus, although a contaminant may be detected in its "total" concentration, all of it may not be available to an organism occupying a space within the disposal plume.

Table 4. Minnesota Pollution Control Agency Standards to Protect Fishable, Swimmable Waters

Substance or Characteristic (Total, unless indicated)	Present Criteria (Class 2B)	Proposed Criteria
Arsenic		10 µg/l[1]
Cadmium		10 µg/l[1]
Chromium	50 µg/l	50 µg/l[1]
Copper	10 µg/l or 0.1 x 96-hr TLM	1.0 mg/l[1] or 0.1 x 96-hr LC_{50}[2]
Iron		1 mg/l[2]
- Soluble		0.3 mg/l[1]
Lead		50 µg/l[1]
- Soluble		0.01 x 96-hr LC_{50}[2]
Manganese		50 µg/l[1]
Mercury		0.05 µg/l[2]
Nickel		0.01 x 96-hr LC_{50}[2]
Zinc		5 mg/l[1] or 0.01 x 96-hr LC_{50}[2]
Dissolved Chlorides		250 mg/l[1]
Ammonia (Un-ionized)	1 mg/l	20 µg/l[2]
Nitrate and Nitrite		100 mg/l[3]
Oil and Grease	0.5 mg/l	
- Emulsified		0.01 x 96-hr LC_{50}[2]
- Floating		Virtually free from floating oil[2]
- Sediment		1,000 mg/Kg (dry wt.) hexane extractable[2]
pH	6.5 - 9.0	6.5-9.0[2]
Suspended and Settleable Solids		Reduction of "compensation point" depth not more than 10% of seasonal norm.[2]
Turbidity	25 NTU	25 NTU[2]
Dissolved Oxygen	5 mg/l (6 mg/l April-May)	Not less than 5 mg/l[2] (Class C)
PCB's		0.001 µg/l[2]
Fecal Coliforms	200 MPN/100 ml	200 organisms/100 ml[4] †

Use Category
[1]Water Supply and Food Processing
[2]Freshwater Aquatic Life and Wildlife
[3]Agricultural Water Supply
[4]Primary Body Contact

† Log mean; not less than 5 samples taken over 30-day period, nor more than 10% of total samples during 30-day period greater than 400 organisms/100 ml.

Parameters identified by the Minnesota Pollution Control Agency as being in frequent violation in this segment are dissolved oxygen, ammonia, fecal coliforms, and turbidity (Minnesota Pollution Control Agency, 1977a). Dissolved oxygen and ammonia data did not demonstrate statistical differences resulting from dredging activities according to the present study. Such effects may have been masked by influences from the metropolitan area. Although ambient fecal coliform concentrations within the water column at Grey Cloud Slough greatly exceed Minnesota Pollution Control Agency standards, effects from dredging and disposal aggravate this condition by resuspending previously sediment-bound coliforms. However, effects from dredging and disposal had disappeared within 1 kilometer downstream. Ambient turbidity levels were within established standards above the dredging operation but levels exceeded Minnesota Pollution Control Agency standards for a distance of over 0.6 kilometer (0.4 mile) downstream of the discharge.

Numerous other parameters exceeded proposed Minnesota Pollution Control Agency standards for at least a portion of the disposal plume. Those which exceeded proposed standards immediately below the discharge included: arsenic, chromium, iron, lead, mercury, manganese, PCB's, and suspended solids. Iron continued to exceed standards for more than 0.6 kilometer but returned to acceptable concentrations thereafter. Levels of mercury were too low for detection by methods used; hence, it was difficult to determine the extent to which standards were exceeded. The manner of measuring suspended solids was not conducive to determination of the degree to which proposed standards were exceeded. Manganese exhibited ambient concentrations which were already in excess of standards above the dredging operation and, with increased loading evident immediately below the disposal discharge, concentrations continued to exceed standards as far as 4.3 kilometers (2.6 miles) downstream at sample C4.

In conclusion, despite the "worst case" conditions within which the dredging and disposal process was monitored, impacts from these activities ap[illegible] to be localized and short term. The chemistry of release and resuspension of contaminants during the dredging process is seen as a complex phenomenon which is not easily understood. Furthermore, methods and criteria used to categorize these effects are merely in their initial stages and more information is needed for these problems to be resolved.

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APPENDIX A

THREE CONTRACTOR REPORTS

FINAL DRAFT

MICROBIOLOGICAL WATER QUALITY EFFECTS OF HYDRAULICALLY DREDGING POLLUTED BOTTOM SEDIMENTS IN THE UPPER MISSISSIPPI RIVER. I. RESUSPENSION OF BACTERIA.

A report to the Water Quality Work Group of the Great River Environmental Action Team in partial fulfillment of U. S. Army Corps of Engineers purchase order DACW376M-2345

by

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March 1977

ABSTRACT

The microbiological effects of hydraulically dredging polluted bottom sediments in the navigation channel of the Mississippi River were investigated. Bottom sediments in the dredge cut area contained high densities of total coliforms (ca. 6800 MPN total coliform index per gram dry wt. and 3800 membrane filter total coliforms per gram dry wt.) and fecal coliforms comprised an average 32% of each total coliform count. Total coliform and fecal coliform densities in river samples taken immediately below the dredge discharge pipe were each approximately 4 times corresponding upstream values. Linear regression analyses indicated that mean turbidity values downstream to the dredging operation were directly and significantly ($r > 0.94$) related to corresponding total coliform, fecal coliform, and fecal streptococcus densities. Salmonellae and shigellae were not recovered from either upstream water samples or from downstream water samples. Within less than 1 mi below the dredge spoil discharge area at the prevailing current velocity of ca. 0.15 m/sec, turbidity and indicator bacteria levels had returned to pre-dredge levels. Recommendations were made that would protect downstream water users from the temporary health hazard associated with dredging polluted sediments.

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The effects of dredging and of dredged material disposal on Mississippi River water quality have been investigated to a limited extent. Claflin, in 1973, reported that dredging and concomittant dredge spoil deposition caused a significant increase in turbidity, nitrate nitrogen, and nitrite nitrogen levels of water samples taken downstream to the dredging operation. He did not detect elevations in orthophosphate or in conductivity (8). Durant and Reimold had previously observed similar turbidity increases as a result of dredging a creek in Georgia (12). Grimes, during the same maintenance dredging operation studied by Claflin (8), found significant numbers of sediment-bound fecal coliforms were released to the overlying water column and to downstream areas (20).

Indicators of fecal pollution (fecal coliforms, fecal streptococci, Clostridium perfringens) and enteric pathogens (salmonellae, shigellae, enteroviruses, infectious hepatitus agent) have been shown to persist in bottom sediments (22,37) and in filter-feeding benthic invertebrates (10,11,29). Presumably, these organisms and particles behave like fecal coliforms and re-enter the water column during dredging. There is little doubt that these pathogens are entering the Mississippi River, as evidenced by data reported to the Center for Disease Control in 1975 (6). Table 1 shows that enteric disease is prevalent in states riparian to the Upper Mississippi River; certainly, some of the agents responsible for these and other enteric diseases enter the Mississippi River. This statement is given support by data from an epidemiological investigation which strongly suggested that 39 cases of shigellosis resulted from swimming in a stretch of the Mississippi River that was polluted with Shigella sonnei (5,32).

TABLE 1. Incidence of selected enteric diseases during 1975 in states riparian to the Upper Mississippi River.[a]

States[b]	Salmonellosis[c]		Shigellosis		Infectious hepatitis	
	Reported Cases	Rank[d]	Reported Cases	Rank	Reported Cases	Rank
Illinois	1,536	2	969	3	1,667	5
Missouri	434	20	172	27	542	17
Wisconsin	900	7	253	21	393	28
Minnesota	358	22	310	17	418	23
Iowa	206	32	60	38	202	39

[a]Data taken from "Reported Morbidity and Mortality in the United States 1975" (6).

[b]States listed in decreasing order according to population.

[c]Salmonellosis excluding typhoid fever.

[d]Rank, in decreasing order of cases reported, among 50 states.

With the knowledge that dredging has the potential to degrade chemical, physical, and biological water quality and that enteric pathogens can remain viable in contaminated bottom sediments and resident benthos, came the necessity to clarify the microbial effects of dredging polluted sediments. Therefore, the following microbiological study was undertaken during the summer of 1976 and was part of a large pilot study to determine the significant effects on water quality from dredging in the Upper Mississippi River.

OBJECTIVES

The objective of the microbiology portion of the pilot study was to investigate the microbiobogical effects of hydraulically dredging bottom sediments suspected of being heavily polluted with metropolitan sewage effluent. Specific goals were to determine the effects of maintenance dredging on:

(i) total coliform, fecal coliform, and fecal streptococcus densities in the navigation channel of Navigation Pool No. 2,

(ii) the recovery of salmonellae and shigellae from water samples processed for indicator bacteria,

(iii) the recovery of poliovirus from the same water samples.

These determinations were to be made in such a manner that the extent of any observed microbial changes in both time and space could be elucidated. This required analysis of sediment from the proposed dredge cut area prior to dredging.

MATERIALS AND METHODS

Sample site. The dredging operation was conducted in the Grey Cloud Slough area of Navigation Pool No. 2 of the Mississippi River. Dredged material came from bottom sediments in that stretch of river extending from river mile 828.1 downstream to mile 827.5 (Fig. 1). Specifically, the dredge cut on 7 July 1976 extended from mile 828.1 downstream to mile 827.9 and the dredge cut on 8 July 1976 extended from 827.8 to 827.6 (Fig. 1). The dredged material disposal sites on 7 and 8 July 1976 were at miles 827.8 and 827.6, respectively (Fig. 1). Transsects were established by the U. S. Army Corps of Engineers above and below the operation at mile 828.4 (Transect A) and at mile 826.95 (Transect B), respectively (Fig. 1). The location of Transect B was established by Phase 2 turbidity values. These preliminary turbidity data were used to position Transect B within a zone of downstream dredging effect. Transect B was sampled 2.5 hr (± 35 min) after each sampling of Transect A. The rationale for this sampling schedule was that an aliquot of water being sampled at Transect B had been previously sampled at Transect A 2.5 hr earlier. This rationale was later shown to be erroneous. Current velocity data collected by the U. S. Geological Survey (USGS) showed that current velocities averaged 0.15 m/sec (0.5 ft/sec). This placed Transect B 4.3 hr downstream to Transect A.

Sampling techniques. Water samples were collected using two different sampling techniques. Samples taken from the two transects were collected by others with a 1-pt USGS integrated water sampling device (21). Eight 1-pt samples were obtained from each of 3 stations on each transect, and the 3 8-pt volumes were pooled and mixed in an

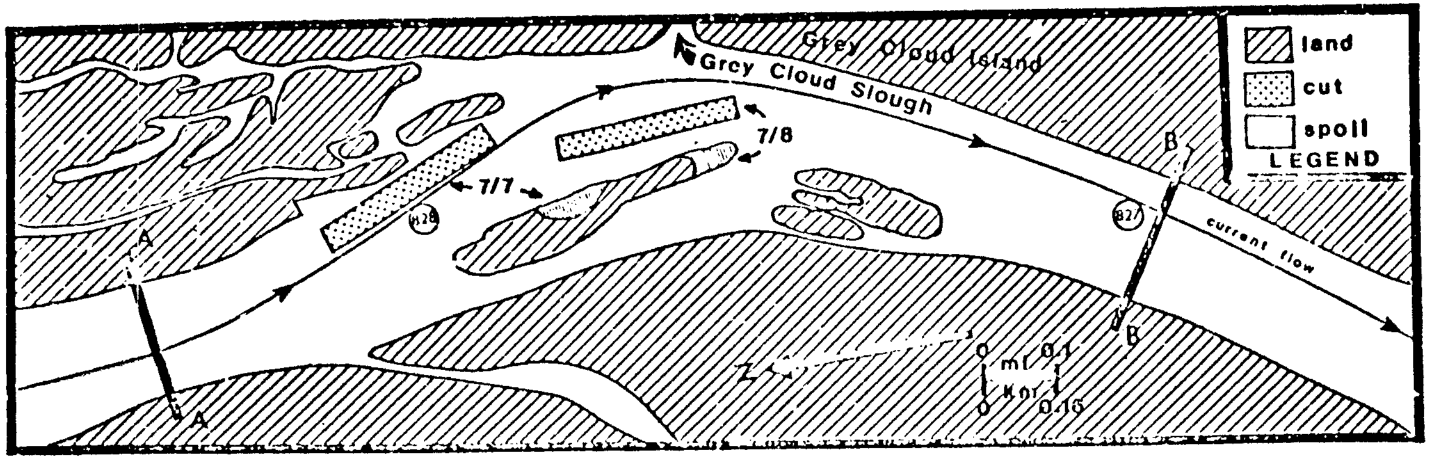

FIG. 1. Map showing the navigation channel of the Upper Mississippi River in the vicinity of Grey Cloud Slough. River miles 828 and 827 are shown in circles. The dates of each dredge cut and associated spoil site are indicated.

8-gal glass bottle containing a Teflon-coated magnetic stir bar. Approximately 2.5 l of each pooled transect sample were poured into a sterile 1-gal polypropylene milk bottle and returned to the laboratory for microbiological analysis. The 1-pt glass milk bottle in the integrated sampler and the 8-gal glass bottle and Teflon stir bar used for mixing were chemically cleaned on site (1N nitric acid rinse followed by 3 deionized water rinses followed by a hexane rinse followed by thorough drying) but were not sterile. Aseptic technique was employed only after the samples were collected in the sterile 1-gal polypropylene milk bottles.

Discrete water samples were obtained from the overflow line of an on-line nephelometric turbidimeter (Hach Surface Scatter Model 2426, Hach Chemical Co., Ames, IA 50010). The turbidimeter was fed by a 2-in intake, 1-hp electric centrifugal pump (Red Jacket Pump, Davenport, IA) and it was connected to a strip chart recorder (Model L1101S, Esterline Angus, Indianapolis, IN 45224). The discrete water samples were collected in sterile 1-gal polypropylene milk bottles and were taken so as to be representative of the entire range of turbidities observed during the study.

The integrated transect samples were taken by untrained volunteers from various state and federal agencies and were refrigerated (4 C) upon receipt by us. Unfortunately, time lapses of up to 2 hr occurred between transect sampling and refrigeration. Discrete samples were collected by us onboard the R/V Izaak Walton, and discrete samples were immediately refrigerated (4 C) until they could be processed. Processing was carried out onboard the R/V Izaak Walton and, except for poliovirus concentration, always occurred within 4 hr of sampling.

Sediment samples were obtained on 6 July 1976 (prior to dredging) with the use of a petite Ponar grab dredge (Wildlife Supply Co., Saginaw, MI 48602). The samples were obtained from 4 different sites within each of the 2 proposed dredge cut areas (Fig. 1). Three Ponar grab samples were collected at each site, and were pooled and thoroughly mixed in a sterile aluminum foil baking pan. All eight sediment samples were immediately refrigerated (4 C) and were processed within 2 hr onboard the R/V Izaak Walton.

Indicator bacteria. All water samples were examined for the presence of membrane filter total coliforms, fecal coliforms, and fecal streptococci by filtering appropriate decimal volumes (0.1, 1.0, and 10.0 ml) through type HC membranes (HCWG 047 S1, Millipore Corp., Bedford, MA 01730). Total coliforms were detected with mEndo agar MF (Difco), fecal coliforms with mFC agar (Difco), and fecal streptococci with KF-Streptococcus agar (Difco); mFC agar plates were immediately incubated in a 44.5-C waterbath (Coliform Incubator/Bath, GCA/PRECISION Scientific, Chicago). Standard materials and methods were employed (1) and all indicator determinations were performed in duplicate.

Sediment samples were also examined for total and fecal coliforms and for fecal streptococci. Standard MPN procedures (1) were run on the eight samples and were paralleled with membrane filter tests of sediment elutriates. The sediment elutriates were obtained by a modification of the USGS procedure (36), the modification consisting of using sterile phosphate buffer (1) for the eluting medium. Elutriates were processed using the media and membranes already described for water samples.

Enteric bacteria. Salmonellae and shigellae were isolated by broth enrichment of filtrates collected on absorbent pad pre-filters (AP10 047 S1, Millipore Corp., Bedford, MA 01730) and type HC membrane filters. Filtrates were collected by filtering 100-ml volumes of water and 10-ml volumes of sediment elutriates. Salmonellae enrichment was accomplished by placing one-half of the pad-membrane combination into tetrathionate broth containing 10 mg/l brilliant green and incubating at 41 C. Each broth was streaked onto bismuth sulfite agar (Difco) and XLD agar (Difco) at both 24 and 48 hr. The other half of each pad-membrane pair was placed into GN broth (Difco) and incubated at 35 C for shigellae enrichment. GN broths were streaked onto XLD agar at 24 hr.

Typical colonies were transferred to triple sugar iron (TSI) agar slants (Difco) and all alkaline/acid cultures were checked for urease activity in urea agar (Difco). Urease negative cultures were streaked onto MacConkey agar to ensure purity and typical isolated oxidase-negative colonies were transferred to tryptic soy agar (TSA) slants (Difco). These TSA cultures were then gram-stained and characterized using SIM medium, Simmon's citrate agar, MRVP broth, phenylalanine malonate broth, and lysine decarboxylase medium (all Difco). Cultures giving reactions consistent with salmonellae and shigellae (13) were then grown on veal infusion agar (Difco) and serotyped with a MinESS Antisera Set II (Difco).

Poliovirus concentration. Poliovirus was concentrated from each water sample by filtering 1 l of water through a sterile Whatman #1 filter that had been soaked in sterile 1% aqueous Tween 80 for 1 hr and rinsed with sterile distilled water (25,39). The Whatman # 1 filtrate was then adjusted by (i) acidification to pH 3.5 with sterile 1N HCl and

(ii) the addition of sterile 0.1 M $AlCl_3$ to give a final concentration of 0.0005 M $AlCl_3$ in the filtrate (25,34). The adjusted filtrate was then filtered through a type HA membrane filter (HAWG 047 S1, Millipore Corp., Bedford, MA 01730). Both filters were placed in sterile Whirlpak bags (NASCO, Fort Atkinson, WI 53538), moistened with 1 ml of sterile distilled water, and frozen and stored at -58 C.

Poliovirus was concentrated from sediment elutriates in a similar manner, except that only 60 to 70 ml of elutriate was filtered through the Whatman #1 filter and 0.1 N HCl was used for filtrate acidification to pH 3.5. Sediment elutriate filtrates were also frozen and stored in Whirlpak bags at -58 C.

Poliovirus isolation. Poliovirus will be eluted from the Whatman #1 and type HA filters and detected with Buffalo green monkey kidney tissue cultures. The exact procedures will be described in a supplement to this report that will describe the results of the poliovirus concentration and isolation and summarize the entire microbiological study.

RESULTS

Indicator bacteria. All sediment samples, except E-2, contained large amounts of silt and organic material. Sample E-2 was predominantly medium sand. The sediment samples contained high densities of the two coliform groups, but relatively low numbers of fecal streptococci. Table 2 lists the MPN indices and membrane filter (mf) counts for each of the three indicators in sediment, as well as fecal coliform: fecal streptococcus (FC/FS), ratios. Fecal coliforms comprised an average 32% of each total coliform count (Table 2), and FC/FS ratios were strongly suggestive of human fecal pollution (18). The mf elutriate counts averaged 55% of the MPN indices.

Indicator bacteria densities and FC/FS ratios for composite water samples from Transects A and B are shown in Tables 3 and 4. The concentrations measured at Transect B on Wednesday (Table 3) averaged twice the corresponding concentrations at Transect A. Fecal coliforms accounted for an average 23% of each total coliform enumeration performed on Wednesday (Table 3). With one exception (Sample No. 10, Transect B), FC/FS ratios at both transects were indicative of human fecal pollution (Table 3). Results expressed in Table 4 are inconclusive; indicator densities at Transect A were often greater than those at Transect B. Fecal coliform densities observed on Thursday averaged 29% of the total coliforms (Table 4).

Results for the discrete water samples are listed in Table 5. The position of each sample relative to the dredge effluent pipe is shown and each position has been corrected for the location of the two dredged material disposal sites (Fig. 1). FC/FS ratios are all high (all but 3 are indicative of human pollution) and fecal coliform counts averaged 43% of each total coliform count (Table 5). Samples below the effluent pipe showed higher turbidities and indicator bacteria concentrations than upstream or far downstream samples. Because of this, the data shown in Table 5 were averaged according to sample position (Table 6). Data presented in Table 6 were then graphed on an arithmetic plot which is presented in Fig. 2. Examination of Fig. 2 immediately reveals a close, direct relationship between the four curves. For this reason, linear

TABLE 2. Number of indicator bacteria per gram (dry wt.) of sediment[a]

Sample No.	Total Coliforms		Fecal coliforms		Fecal Streptococci		FC/FS[d]
	MPN[b]	mf[c]	MPN	mf	MPN	mf	
E-1	11000	3400	2600	830	< 24	2	415.0
E-2	390	330	82	26	< 23	1	26.0
E-3	19000	4800	4100	1100	23	11	100.0
E-4	4100	2600	930	630	24	6	105.0
W-1	2600	5300	2600	880	< 23	5	176.0
W-2	6500	3900	4200	1100	24	5	220.0
W-3	6400	6300	2900	1200	< 24	10	120.0
W-4	4200	3400	2000	790	< 24	2	395.0
$\bar{X}$	6800	3800	2400	820	< 24	5	164.0

[a]Conversion of the numbers to a wet-wt. basis can be accomplished by dividing each by 1.18.

[b]MPN index based on 3 decimal dilutions of the sediment with 5 tubes per dilution.

[c]Membrane filter (mf) colony forming units on Type HC membranes as determined by the elutriate test; arithmetic mean of 2 replicate determinations.

[d]Fecal coliform:fecal streptococcus ratio calculated from membrane filter densities.

TABLE 3. Total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) densities in water samples collected at Transects A and B on Wednesday[a]

Sample Number	Time[b]		TC per 100 ml		FC per 100 ml		FS per 100 ml		FC/FS	
	A	B	A	B	A	B	A	B	A	B
1	0720	0915	2800	5300	540	570	40	10	13.5	57.0
2	0800	1010	610	2100	560	750	40	160	14.0	4.7
3	0845	1115	2100	3800	560	550	15	20	37.3	27.5
4		1200		3600		660		15		44.0
5		1300		3600		480		5		96.0
6	1130	1400	2700	4200	470	400	0	10	UD[c]	40.0
7		1500		5300		740		15		49.3
8	1320	1600	2300	3800	400	570	10	0	40.0	UD
9	1430	1700	2000	3100	450	550	10	0	45.0	UD
10	1545	1800	1100	5700	490	1100	15	400	32.7	2.8
11	1605	1845	2200	4600	710	670	0	0	UD	UD
12	1705	2000	2000	4300	420	540	0	5	UD	108.0
Mean			1979	4117	511	632	14	53	30.4	47.7
Stand. Dev.			668	976	89	172	15	113		

[a]All values are the arithmetic average of 2 replicate determinations.

[b]Time of sampling at Transects A and B.

[c]UD=undefined

TABLE 4. Total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) densities in water samples collected at Transects A and B on Thursday[a]

Sample Number	Time[b]		TC per 100 ml		FC per 100 ml		FS per 100 ml		FC/FS	
	A	B	A	B	A	B	A	B	A	B
13	0645	0900	260	2700	870	2500	110	35	7.9	71.4
14	0745	1000	1300	5200	3000		35	100	85.7	
15	0815	1100	860	15000	350	350	70	45	5.0	7.8
16	0915	1200	30000	1200	590	330	20	520	29.5	0.6
17	1020	1300	2800	3000	44000	440	30	15	1466.7	29.3
18	1115	1433	2000	2500	1100	350	85	10	12.9	35.0
19	1215	1500	2700	1500	620	310	35	75	17.7	4.1
20	1345	1545	5000	6900	410	270	0	15	UD[c]	18.0
21	1410	1705	13000	29000	360	440	120	30	3.0	14.7
22	1505	1745	1700	3000	370	630	160	25	2.3	25.2
23	1610	1845	15000	2600	590	220	25	20	23.6	11.0
24	1715	1945	5000	5500	560	220	30	10	18.7	22.0
25	1840		3100		640		90		7.1	
Mean			6363	6508	4112	551	62	75	140.0	21.7
Stand. Dev.			8095	7663	11534	626	46	137		

[a]All values are the arithmetic average of 2 replicate determinations.

[b]Time of sampling at Transects A and B.

[c]UD=undefined.

TABLE 5. Turbidity and indicator bacteria densities in discrete water samples.

Sample Number	Sample Position[a]	Turbidity (NTU)	CFU per 100 ml[b] TC	FC	FS	FC/FS
C1	0.16 km down	42.3	730	720	290	2.5
C2	0.16 km down	61.4	600	550	45	12.2
C3	2.58 km down	26.2	690	640	10	64.0
C4	4.51 km down	18.9	470	380	15	25.3
C5	upstream	17.7	1000	670	25	26.8
C6	1.61 km down	26.6	2200	570	10	57.0
C7	0.16 km down	40.8	3200	460	15	30.7
C8	upstream	13.6	1400	630	50	12.6
C9	pipe effluent	300.0	21000	12000	4000	3.0
C10	river @ pipe	151.4	8500	3000	1500	2.0
C11	0.01 km down	52.0	2800	2200	25	88.0
C12	0.01 km down	73.0	8100	3700	35	105.7
C13	0.01 km down	98.0	5100	6600	30	220.0
C14	0.32 km down	25.0	2600	1400	10	140.0
C15	0.01 km down	53.3	4000	950	10	95.0
C17	0.01 km down	52.0	26000	840	40	21.0
C18	0.01 km down	28.0	2900	580	50	11.6
C20	0.01 km down	143.0	4100	1200	45	26.7
C21	0.16 km down	58.0	4200	460	35	13.1
C22	0.48 km down	29.0	4800	620	30	20.7
C23	0.64 km down	31.0	5800	630	30	21.0
C24	0.97 km down	23.0	3200	530	15	35.3
C25	1.29 km down	18.5	2700	370	0	UD[c]
C26	upstream	12.3	6600	750	20	37.5

[a]Sample position relative to dredge effluent pipe.

[b]Average of 2 replicate determinations.

[c]UD=undefined

TABLE 6. Turbidity and indicator bacteria densities in discrete water samples averaged according to distance from the dredge discharge pipe.

Sample Position[a]	Mean turbidity (NTU)	Mean CFU per 100 ml		
		TC	FC	FS
upstream	14.5	3000	680	32
pipe effluent	300.0	21000	12000	4000
river @ pipe	151.4	8500	3000	1500
0.01 km down	71.3	7600	2300	34
0.16 km down	50.6	2200	550	96
0.32 km down	25.0	2600	1400	10
0.48 km down	29.0	4800	620	30
0.64 km down	31.0	5800	630	30
0.97 km down	23.0	3200	530	15
1.29 km down	18.5	2700	370	0
1.61 km down	26.6	2200	570	10
2.58 km down	26.2	690	640	10
4.51 km down	18.9	470	380	15

[a]Sample position relative to dredge effluent pipe.

regression analyses were performed using turbidity (average values in Table 6) as the independent variable and indicator bacteria (average values in Table 6) as dependent variables. The regression analysis indicated that turbidity was directly and significantly related to total coliform, fecal coliform, and fecal streptococcus concentrations as evidenced by correlation coefficients of 0.949, 0.964, and 0.982, respectively.

Enteric bacteria. A total of 78 isolates out of 380 typical colonies picked from bismuth sulfite and XLD agars were found to be biochemically presumptive *Salmonella* or *Shigella* isolates, based on their reactions in TSI and urea agars. Three of the isolates were from sediment and the remaining 75 were isolated from water. Distribution of the water isolates was as follows: (i) 21 were from Transect A samples, (ii) 26 were from Transect B samples, and (iii) 28 were from the discrete, or C, samples. For reasons unknown, 28 of the 78 isolates, before they could be further classified, died within 4 weeks after transfer from TSI slants to stock culture TSA slants. Another 34 isolates were found not to be *Salmonella* or *Shigella* species, based on their reactions in the previously described differential media and tests. The remaining 16 isolates gave biochemical reactions indicative of *Salmonella* species, but none could be serologically confirmed as *Salmonella* based on their inability to agglutinate in the presence of Salmonella O antisera poly A-I.

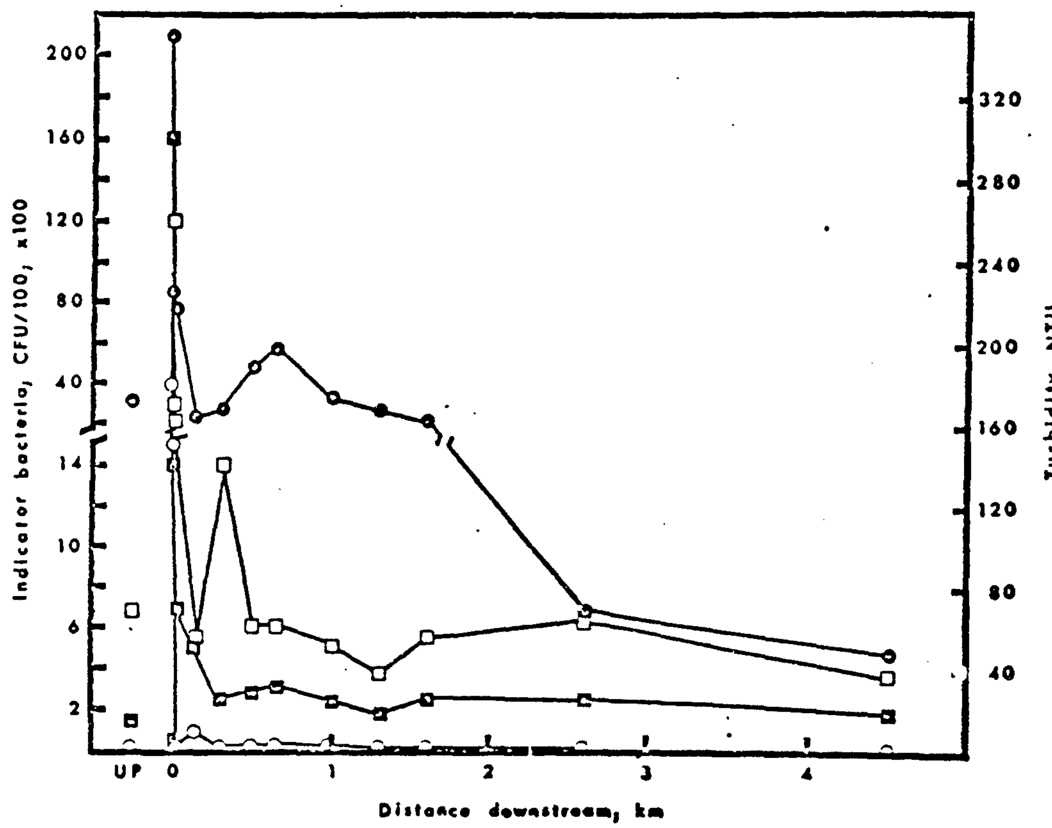

FIG. 2 Mean turbidity (■), total coliform (●), fecal coliform (□), and fecal streptococcus (○) values in discrete water samples, distributed according to distance downstream from the point of discharge of dredged material.

DISCUSSION

The bacteriological water quality of the Mississippi River in the vicinity of Grey Cloud Slough (Fig. 1) was very poor and suggestive of gross human pollution. Every water sample (Tables 3, 4, and 5) surpassed the average fecal coliform concentration of 200/100 ml recommended by U. S. EPA (then the F.W.P.C.A.) in 1968 as a maximum for safe primary contact recreation (14). Furthermore, 8 of the water samples exceeded the average recommended for all waters, 2000 fecal coliforms per 100 ml (14). These recommended standards have since been adopted for eventual implementation by several states, including Wisconsin (35).

The observations that sediment fecal coliforms comprised an average 32% of each sediment total coliform count and that fecal coliform densities in water averaged 23, 29, and 43% of the total coliform densities measured on Wednesday (Table 3), Thursday (Table 4), and in discrete samples (Table 5), respectively, further supports the contention that the river was heavily polluted with domestic sewage. Geldreich, in 1966, found that 93 to 96% of all coliforms in feces are of the fecal type, and that fecal coliforms constitute approximately 33% of the total coliforms present in raw sewage (15). The fecal coliform to total coliform ratios observed for the Grey Cloud Slough area were very similar to that of raw sewage. It is of interest to note that other workers have suggested that high fecal coliform to total coliform ratios are suggestive of inefficient wastewater treatment plants and conditions that require plants to by-pass large volumes of untreated wastewater (27).

The FC/FS ratios are another definitive line of evidence supportive of the statement that gross human pollution was responsible for the poor water quality observed in this study. Ratios greater than 4.0 are significant because they indicate human fecal pollution (18). Animal fecal pollution is suspected if ratios are less than 0.7; if ratios fall between 0.7 and 4.0, a mixture of human and animal pollution is suspected (18). In order to be valid, interpretations based on these ratios must be applied to streams that have received fecal pollution within 24 hr prior to sampling (18). The Grey Cloud Slough Area was receiving approximately 200 million gal/da of treated sewage effluent from the Metropolitan Wastewater Treatment Plant located on Pigs Eye Island at mile 836 (30). At prevailing current velocities (up to 0.15 m/sec), this effluent required 22 hr to reach Transect A. A dye study conducted by USGS on 12 July 1976 revealed that it would take 30 hr for effluent to reach Transect A and 36.5 hr to reach Transect B. Examination of Tables 3, 4, and 5 reveal that 70 of 77 FC/FS ratios are above 4.0 and are therefore indicative of human fecal pollution. The most probable point source for this human pollution was obviously the Pigs Eye effluent which entered the river within the required 24 hr prior to sampling.

Sediment samples were also suggestive of human fecal pollution, based on the extremely high FC/FS ratios (Table 2). While FC/FS ratios have been applied to sediments (33), their exact meaning and validity for this use are unclear, because fecal coliforms and fecal streptococci have different survival characteristics. Several workers have shown that fecal streptococci remain viable longer than coliforms in estuarine sediment (33), sterile well water (28), chlorinated secondary sewage effluent (26), stormwater (18), filter-sterilized seawater (38), sterile, artificial seawater pressuraized at 1000 atm (3), and under natural conditions at 0 C in an ice-covered river (9). In addition, it has been demonstrated that coliforms can grow in water and sediment if sufficient nutrients are available (19,23,24), but Geldreich feels that the natural occurrence of this phenomenon is rare (17). Fecal streptococci, while exhibiting better survival than coliforms, apparently do not multiply in natural water (26). Thus, the very high FC/FS ratios in sediment may reflect both a prolonged survival of the low numbers of fecal streptococci entering the river and an aftergrowth of sedimented fecal coliforms.

Comparison of the MPN indices with mf densities (Table 2) revealed nothing conclusive, other than the fact that MPN values were higher than corresponding mf numbers. This observation has been made by almost every laboratory that has ever compared MPN values with those obtained using mf. The MPN index overestimates true incidence and mf values are more accurate and precise. The accuracy of using mf on a sediment elutriate (15) can not be evaluated on the basis of the few tests performed in this study (Table 2). However, the precision obtained between mf replicates was excellent.

Two points of clarification must be made concerning Table 2. First, it should be emphasized that the data in Table 2 are values per 1 g dry weight, rather than per 100 g (or 100 cm^3) wet wt as some workers prefer to use (19,33,37). If however, the mean fecal coliform values in Table 2 are corrected to 100 g wet wt, they exhibit the same relationship to fecal coliform densities in overlying water that was observed by VanDonsel and Geldreich (37). There were 100 to 1000 times as many fecal coliforms in mud as in overlying water. Secondly, the low values observed for sample E-2 are probably due to its sandy composition. Sand sediments contain smaller numbers of bacteria per unit weight than do mud (muck) samples.

Although there were no confirmed salmonellae or shigellae isolations, it is highly improbable that they were absent from the bottom sediments and water of the study area. Both salmonellosis and shigellosis are endemic to the Minneapolis-St. Paul area, and the agents of these diseases would be expected to enter the Mississippi River from this large point source. This statement can be made because, as with fecal coliforms, small numbers of salmonellae and shigellae can survive secondary sewage treatment and subsequent chlorination (4,17). Also the Pigs Eye plant must by-pass large volumes of raw sewage to the Mississippi River during periods of heavy rainfall (30), and this would introduce pathogens from both the raw sewage and the urban stormwater (17). Another source of salmonellae, but not shigellae, would be from feces of wild and domestic animals in the watershed. Survival of salmonellae in mud closely parallels that of fecal coliforms (37), and in water salmonellae and shigellae persist for at least as long as fecal coliforms (18), if not longer (28,38). In fact, some studies have shown that salmonellae, like coliforms, can grow in surface water (7,23,24). VanDonsel and Geldreich found that when fecal coliform densities in water ranged from 200 to 2000 per 100 ml, 50% of the bottom sediment samples from such areas were positive for salmonellae; they obtained a median of 1 MPN Salmonella organism in mud per 150 fecal coliforms in overlying water (37). In another study, Geldreich reported that a similar relationship existed for fecal coliforms and salmonellae in water. He found that when fecal coliform densities in water ranged from 200 to 2000 (per 100 ml), 70.3% of the water samples were positive for Salmonella (16). In the present study, mention has already been made of the fact that all water samples contained more than 200 fecal coliforms per 100 ml of water (Tables 3, 4, and 5). Furthermore, 37.5% of the mud samples and 73% of the water samples yielded biochemically presumptive salmonellae or shigellae. These per cent recoveries are in close agreement with those reported by Geldreich's laboratory and suggest that some of the isolates would have been confirmed as Salmonella or Shigella species had they not died before being serotyped. The lack of confirmed salmonella and shigella isolations could also be, in part, due to the fact that only typical colonies were picked for characterization from the primary isolation media. Andre, Weiser, and Maloney demonstrated that prolonged exposure (ca. greater than 3 to 4 da) of salmonellae and shigellae to farm pond water changed their colonial morphology on differential, selective media (2). The large number of samples processed in this study made it impossible to pick atypical colonies from the 2 primary isolation media. Finally, the volume of water filtered (100 ml) may have been too small to ensure isolation of salmonellae and shigellae. This is especially true when it is remembered that each pad-membrane pair was cut in half for processing. In effect, enrichment for salmonellae was carried out on the filtrate from only 50 ml of sample, as was enrichment for shigella. The use of such a small volume was unavoidable however, because of experimental design. We were limited in the amount of sample that we received (ca. 2.5 l). Also, because of a mixup in sampling (C samples being processed simultaneously with A and B samples), we did not have sufficient time to filter volumes of water larger than 100 ml.

Transect B samples did not always contain larger volumes of indicator organisms than Transect A samples. In fact, several Transect A samples contained significantly larger densities of the 3 indicators than did corresponding B samples (Tables 3 and 4). There are at least 6 possible reasons for these unexpected results. The first possibility is that Transect A and B samples were contaminated during their collection and compositing. This investigator found the USGS integrated water sampler very difficult to use at best, and we chose not to use it in a later study of sediment resuspension by commercial barge traffic. One of the difficulties we encountered with the device was in controlling its descent, and sampling personnel at Transect A admitted to dropping the integrated sampler into the sediments during several sample collections. This probably contaminated each of these water samples and caused them to have significantly higher bacterial densities. Another disadvantage with the integrated sampler was a significant carry-over from one sample to the next of bacteria adsorbed to the Teflon nozzle through which sample water entered the 1-pt bottle. Studies conducted in our laboratory revealed that after swab-coating the lumen of a sterile Teflon nozzle with a broth culture of chromogenic Serratia marcescens, 13% of the standard plate count colonies isolated from well water samples obtained with the integrated sampler were S. marcescens. The nozzle had been rinsed 3 times with sample water prior to sampling, and previous standard plate counts performed on the well water had failed to detect any red-pigmented colonies. Another potential source of contamination occurred during the mixing of composite samples; for example, it was reported that the Teflon-coated magnet stir bar was added to the 8-gal mixing bottle by hand (John Helvig, personal communication).

A second possible explanation for any lack of correlation between the Transect A and B samples was the premature sampling of Transect B following each Transect A sampling. The decision to sample Transect B 2.5 hr after each Transect A sampling was based on the incorrect assumption that it required 2.5 hr for a block of water to traverse the distance between Transects A and B. Unfortunately, at the prevailing record low current velocities (ca. 0.15 m/sec and lower), water passing Transect A required at least 4.3 hr to pass through Transect B.

A third possible reason for the unexplained results (Tables 3 and 4) was the fact that Transect B was inadvertently located out of the zone of dredge disturbance, even after laterally moving the 3 Transect B sampling sites to the west at 1430 hr on 8 July in an attempt to correct this situation. Transect B was, then, actually located in a "no or minimal effect zone", and this statement is supported by data presented in Tables 5 and 6 and in Fig. 2. Transect B was located approximately 1.29 km (0.8 mi) downstream from the dredge spoil deposition area (Fig. 1). Turbidity values (Table 5) and indicator bacteria densities (Table 5) obtained for discrete samples taken from as little as 0.97 km (0.6 mi) downstream from the spoil area were either approaching or had already reached background (upstream) values (Table 5). This rapid settling was presumably due to the inability of the record low current velocities to keep significant amounts of sediment in suspension for longer than 2 hr (i.e., 0.6 mi).

A fourth possible contributing factor could be fluctuations in the quality or quantity of effluent discharged from the Metropolitan Wastewater Treatment Plant on Pigs Eye Island. All wastewater treatment facilities have fairly well identified peak loading times during each 24-hr period, and this, combined with the fact that Transect B samples were obtained 2.5 hr instead of 4.3 hr after a given sampling at Transect A, could explain some of the lack of correlation.

A fifth possible contributing factor, which is related to the one just discussed, is the effect that different rates of sewage effluent chlorination could have had. The chlorine residuals reported for effluents on 6 and 7 July were 2.4 and 1.8 mg/l, respectively (30); these effluents would have passed through the study area during the following days, respectively.

The sixth possible reason for the apparent lack of correlation between Transect A and B values, especially between those values listed in Table 4, is that the dredge effluent, instead of moving downstream from the deposition area, moved upstream behind the island used for dredge spoil deposition (Fig. 1). This effectively prevented these re-suspended materials from being detected at Transect B. It is very possible that all of these factors were responsible for the unexpected results obtained at Transect B (Tables 3 and 4). However, the most significant factors would appear to be the first three: (i) water sample contamination with bottom sediment, (ii) premature sampling of Transect B, and (iii) location of Transect B in the zone of no effect.

The data obtained for the discrete (or C) samples (Tables 5 and 6) were most illustrative of the microbiological effect of dredging contaminated bottom sediments. These samples were obtained from several locations above and below the dredging area, they were obtained by our experienced personnel using our own pumping system, and they were collected directly into sterile polypropylene containers. Turbity values were allowed to stabilize prior to each discrete sample collection, and this, as far as was practicable, ensured minimal carry-over from one sample to the next. Turbidity values in the water immediately below the dredge effluent discharge pipe were 10 times those recorded for upstream water samples (Fig. 2), and this turbidity increase was presumably due to dredge-associated resuspension of bottom sediment (T. O. Claflin, unpublished data). Total coliform and fecal coliform densities immediately below the discharge pipe were each approximately 4 times corresponding upstream densities, and fecal streptococci exhibited a 46-fold increase over upstream concentrations (Fig. 2).. There were significant correlations ($r > 0.94$) between mean turbidity values and each of the indicator bacteria mean densities (Table 6), and this same relationship has been observed under other circumstances by other investigators. Saylor et al. suggested that total coliforms, fecal coliforms, and fecal streptococci are associated with suspended sediment (i.e., total suspended solids), based on very high correlation coefficients ($r = 0.99$) obtained between suspended solids and each indicator organism for 102 water samples (33). Rheinheimer, in at least 2 different studies of

German rivers and the Baltic Sea, found a significant relationship between turbidity and total bacterial content (31). Wuhrmann, in a review of the literature concerning river bacteriology, reported that the majority of riverine bacteria in free-flowing water were associated with suspended solids (40).

In conclusion, it should again be pointed out that neither turbidity effects nor bacteriological effects extended far downstream, based on the discrete water sample results (Table 5 and Fig. 2). Within less than 1 mi below the dredge spoil discharge area, the river had recovered from the effects of dredging. In fact, data in Table 5 suggest that water quality 1 mi downstream and beyond became progressively better than upstream water quality. This was probably due to natural sedimentation of suspended materials. However, it is possible that dredge-suspended particles could have increased the rate of adsorption or flocculation (with subsequent sedimentation) of normal suspended, planktonic (unattached or epipsommic) indicator bacteria by serving as new adsorptive surfaces in the water column.

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THE EFFECTS OF HYDRAULIC DREDGING ON THE RESUSPENSION AND TRANSPORT OF SEDIMENT MATERIAL

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April, 1977

ABSTRACT

The downstream effects of hydraulic dredging were investigated in Navigation Pool No. 2 in the vicinity of Grey Cloud Slough, on the Upper Mississippi River during July, 1976. The general shape of the turbidity plume was determined, as was the approximate distance downstream that the sediments were transported.

The turbidity (NTU) was converted to dry-weight of suspended sediment (mg/l.). The most noticable effects of the dredging activity were noted immediately downstream from the disposal site. The plume was carried into the main channel and was transported in deep water in the channel for a distance of approximately 0.5 miles. Water currents then redistributed the sediment somewhat uniformly through the cross-section of the river in areas further downstream (0.5 mi. to 1.2 mi.). The suspended solids in the water were significantly higher at least 1.4 miles downstream from the spoil site during the dredging period. An extrapolation of the suspended solid curve indicated that suspended solids remained in the water for a distance of ca. three miles downstream.

INTRODUCTION

The resuspension of sediment materials due to hydraulic dredging has been noted in several instances in highly varied environments (Durant and Riemold, 1972) (Claflin, 1973). In most of the studies of these effects on the Upper Mississippi River, the primary effect was determined to be from runoff from the deposition area, and not from the disturbances caused by the cutter head, (Claflin, 1973, Held, 1975). The distances that the materials are transported downstream is a function of the size of the sediment particles and of the hydrological features of the downstream channel. In the vast majority of the reaches of the Mississippi River channel, the sediments consist of medium sand. Dredging of this material results in a brief suspension of the material followed by rapid settling (Held, 1975). However, where fine particulate sediments occur, the transport distances of resuspended sediments to downstream areas are usually greater. The transport of these sediments into productive backwater areas has been noted at several locations on the Upper Mississippi River, either as a result of mass-wasting from the spoil piles during normal flow and by erosion of the unstabilized material during periods of high discharge. However, few quantitative data are available on the resuspension and subsequent transport of fine sediments on the Upper Mississippi River. This report describes the rates of resuspension and the transport of the resuspended materials downstream from a spoil site in Navigation Pool No. 2 in the area of Grey Cloud Slough. The turbidity study is a single phase of a larger study that was constructed to determine the total effects of dredging on the resuspension of etiological agents as well as the effects on water quality due to leaching from sediments. The study was considered to be a "worst-case" situation due to the location of the dredge cuts downstream from the outfall of the Metropolitan Waste treatment facility. It was designed by and conducted by the Water Quality work group of GREAT, during July, 1977.

Objectives

The objective of the turbidity portion of the total water quality study was to:

1. Determine background turbidity in the river prior to the initiation of dredging.
2. Determine the increases in turbidity in the area downstream from the spoil site, and;
3. Delineate the size and shape of the turbidity plume.

Description of the Study Site

Figure 1 depicts the location of the dredge cuts and the disposal areas as well as the locations of the transects. The points that are located on the transects and numbered right to left, describe the specific locations of the sampling sites along each transect and correspond to the location data on Table 1.

The channel downstream from the disposal area between transects 4 and 10 is quite deep (maximum depth = ca. 24 feet, average depth = ca. 15 feet). However, the bottom slopes upward in the area west of the channel and a bench is formed along the western shore. Transects 9 and 10, for example terminated some distance from the western shoreline because of the inaccessibility due to shallow water. Transect 6 terminated off-shore on the western end of the transect since it was behind the disposal island.

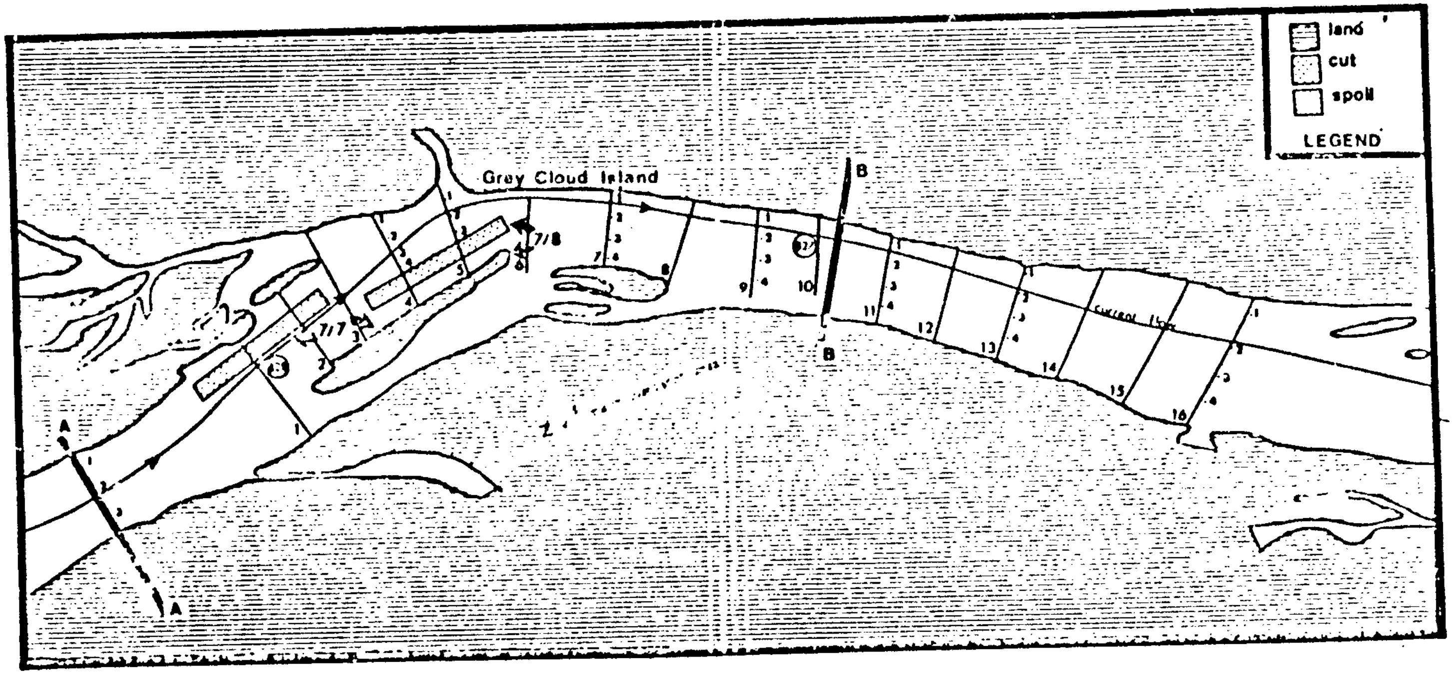

Figure 1. Map, Grey Cloud Slough Area, Navigation Pool No. 2, Upper Mississippi River, depicting dredge cuts, disposal areas, upstream and downstream transects, and station locations on the transects, July, 1976

METHODS AND MATERIALS

Location

The hydraulic dredging was conducted in Navigation Pool No. 2 at Rivers Miles 827.8 and 828 (Figure 1) on July 8 and July 7, 1976, respectively (Figure 1). The material was disposed of on a small island located between river miles 827.6 and 828.0, at two locations (Figure 1). For purposes of monitoring the turbidity, sixteen transects were established at 0.1 mile intervals, perpendicular to the main channel, from mile 826.4 to 828 (Figure 1). An upstream control transect (Transect A) was located approximately 0.3 miles upstream from the dredge cut. Whereas this transect was established for the collection of samples for chemical analyses, it was also used as a control for the turbidity portion of the study.

Sampling Procedures

On July 6, prior to the initiation of dredging, turbidity data were collected from Transects A, 4, 5, 7, 9, 11, 13, and 16 to determine the background turbidity levels in the reach of the river supposed to be affected. On July 7, turbidity determinations were made on water collected from the surface, and from 5, 8, 10, and 12 foot depths from all transects noted above.

The Research Vessel Izaak Walton was employed in this study and was equipped with a continuous turbidity monitoring system consisting of:

1. A 1 hp shallow well pump (1100 gal./hour capacity) provided with a two-inch intake pipe.

2. A device to lower the end of the intake pipe to the desired sampling depth.

3. A Surface Scatter-4 Turbidimeter[R1].

4. A strip-chart recorder.

Water was retrieved from the desired depth and was delivered to the turbidimeter. The flow of water through the turbidimeter was adjusted by a valve located in the discharge line between the pump and the turbidimeter and was adjusted to the maximum possible level without introducing bubbles into the system. The pump, intake and discharge lines were periodically purged of air to eliminate error introduced by presence of bubbles. The turbidimeter output was recorded with a 12-inch stripchart recorder (Esterline-Angus Speed-Servo II)[R2]. The depth, transect number, and horizontal location of the vessel were manually recorded on the stripchart. Average discharge of water through the turbidimeter was approximately 140-160 gallons per hour during the experiment. From three to five locations on each transect (dependent upon river width) were sampled at the depths noted above. Where the depth was less than 12 feet, the appropriate sampling depths were eliminated to insure that sediment materials from the bottom were not retrieved and delivered to the turbidimeter. When this occassionally happened, the system was dismantled and purged of sediments.

R_1. Hach Chem. Corp., Ames, Iowa.

R_2. Esterline Angus, Indianapolis, Indiana.

Calibration

The turbidimeter was periodically recalibrated with a standard opaque glass with a known reflective value. The standardization plate was provided with the instrument by the manufacturer.

Sampling

The vessel was maneuvered along the transects and held on station during the sampling periods. The flow-through time of the piping system was measured, and an appropriate time interval was allowed to lapse before the turbidity values were recorded. This insured that water from that specific site was passing through the turbidimeter. Turbidity measurements were made at the stations noted above on July 6 (control) and July 7 (experimental, upstream cut). Readings were also recorded on July 8, (downstream cut, Figure 1). These data are not included, however, on Table 1. Discrete samples were also collected (C-series), at various upstream and downstream locations, on July 8 for chemical analyses. The samples were collected such that the widest possible range of turbidity conditions were encountered.

Turbidity-Suspended Solids

The relationship between turbidity ([illegible]) and sediment mass (mg./L. dry weight) was determined by collecting 21 discrete samples and by filtering them with pre-weighed glass fiber filters. The filter pads were dried and re-weighed, and a linear correlation was calculated for the data. The results are shown in Figure 2. Conversion values from NTU to dry-weight suspended solids are shown on Table 1.

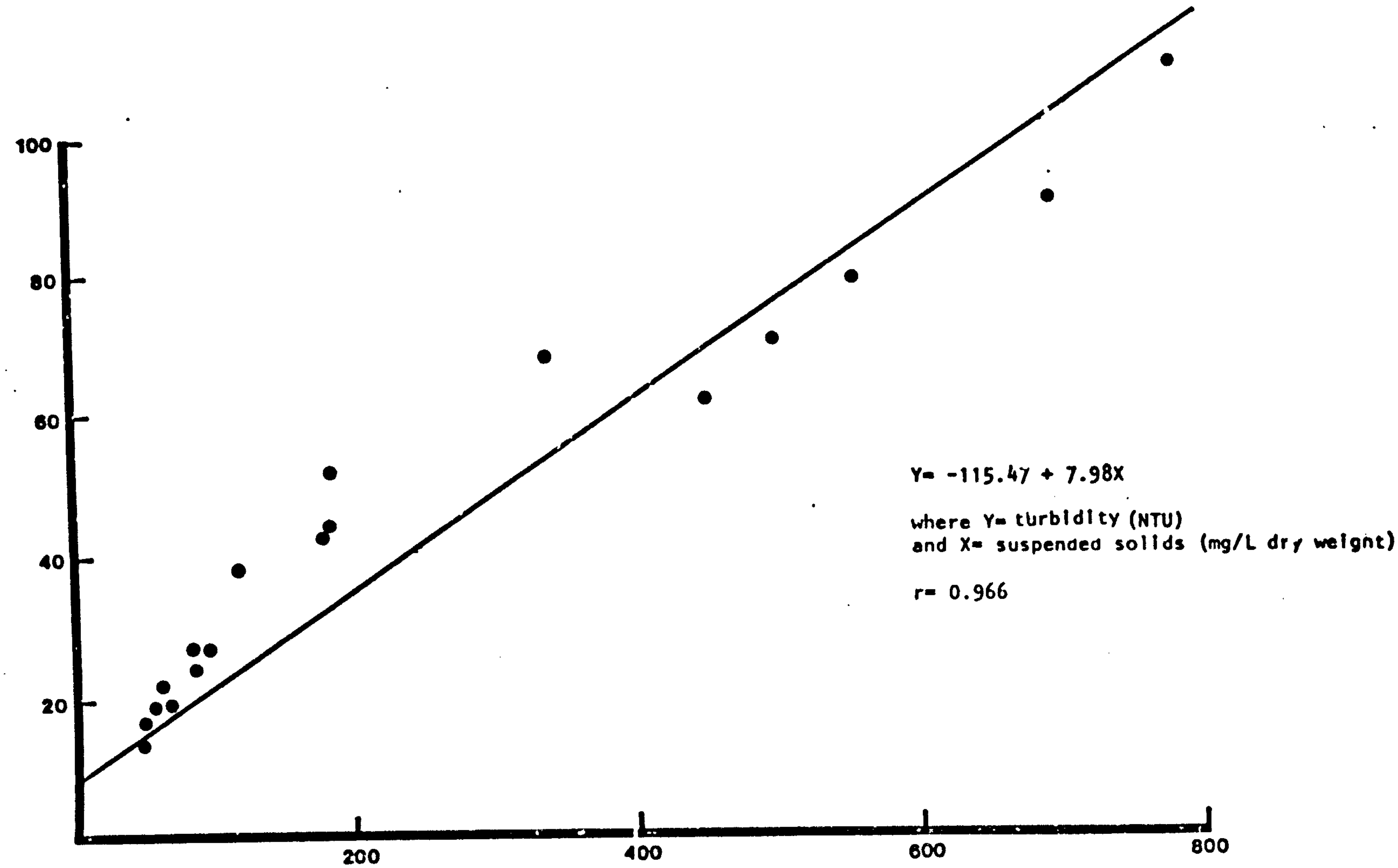

FIGURE 2 REGRESSION ANALYSIS BETWEEN TURBIDITY (NTU) AND SUSPENDED SOLIDS (MG/L DRY WEIGHT). POOL 2, UPPER MISSISSIPPI RIVER, SUMMER 1976

RESULTS

The paired observations at each location (7/6/76 control and 7/7/76 experimental) were compared and the pre-dredge values were subtracted from the during-dredging values. The differences are expressed in Table 1. In addition to this, each datum was corrected for differences between the mean values in the upstream control transect (Transect A) on the two days that were sampled (average value 1.3 NTU higher on 7/7/76). The reason for this elevation is not known, but it was possibly due to boat activity in the upstream area. It was assumed that this increase in turbidity found at the control transect was also reflected in the downstream transects.

Definition of Plume Size

The plume that was generated from the dredging operation on July 7 is defined as that area where the turbidity levels are significantly higher at the 99% confidence level. The data on Table 1 and Figure 3 indicate that the plume extended to transect 16, 1.4 miles downstream from the cut and 1.2 miles downstream from the disposal site. Samples were not collected further downstream because of time constraints.

The greatest differences between pre- and post-dredging values were noted on transect 5, where the turbidity almost doubled at stations 1 and 2 and more than doubled at location 3, on the west shore (Table 1, Figure 3). The highest value that was encountered was at the 8 foot depth at location #2 on this transect (52 NTU). Large fluctuations were noted at this transect during the dredging operation.

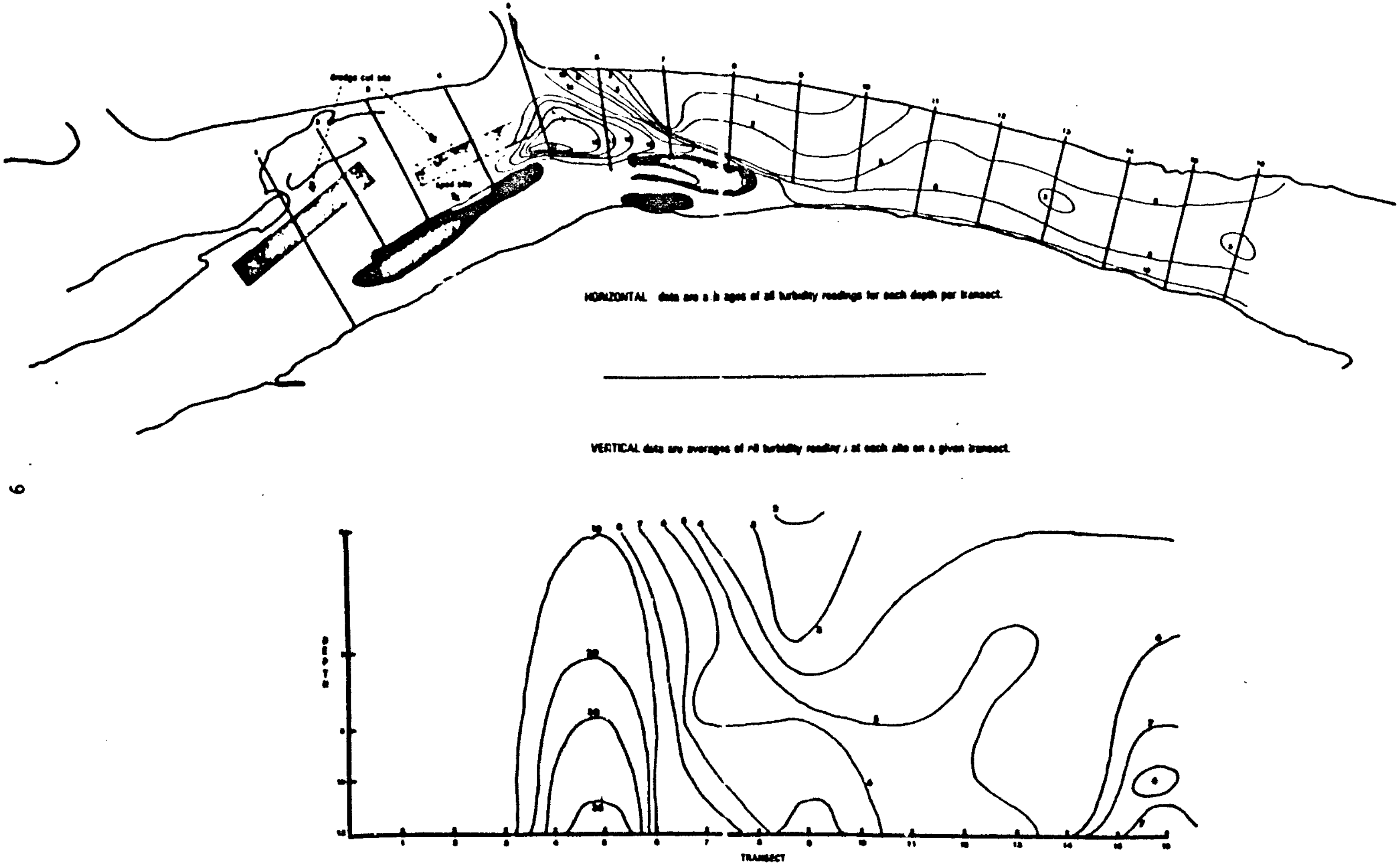

Figure 3.

Horizontal and Vertical Distribution of Turbidity (NTU) Downstream from the Spoil Site of Hydraulically Dredged Material, Navigation Pool No. 2, Upper Mississippi River

All isopleths indicate the difference between paired observations before and after dredging for five depths at four locations on each transect.

Table 1. Turbidity (NTU) determined along transects located upstream and downstream from the Dredge Thompson, prior to and during dredging, Grey Cloud Slough area, Navigation Pool No. 2, Upper Mississippi River, July 6-7, 1976.

LOCATION	Surface		5 feet		8 feet		10 feet		12 feet		AVERAGE		DIFFERENCE	SIGNIFICANCE LEVEL	AVERAGE DIFFERENCES (mg/L dry weight)
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre-Dredge	Post Dredge			
*Transect-A															
T	19	21	20	21	18	21	18	21	18	20	18.6	20.8	2.2	**	30.5
2	21	21	22	23	23	24	22	24	22	25	22.0	23.4	1.4		19.5
3	19	20	20	23	20	23	23	23	24	25	21.8	22.8	1.0		13.0
Transect-4															
1		24.5		27		23		25		25		24.8			
2		22		22		23		20		20		21.8			
3		14		18		18		22		23		19.0			
4		23		52								37.5			
Transect-5															
1	19	25	20	22	21	33	21	47	21	54	20.4	36.2	15.8	99%	219.0
2	19	22	17	36	21	52	20		20		19.4	36.6	17.2	99%	239.0
3	16	38	19	39							17.5	38.5	21.0	99%	291.0
Transect-7															
1	19	18	18	18	20	20	23	22	18	21	19.6	19.8	0.2	95%	2.78
2	22	22	21	28	31	26	21	27	22	27	21.6	26.0	4.4	99%	61.6
3	16	27	15	29	18	31	19	36	20	36	17.6	31.8	14.2	99%	197.4
4		23		23											
Transect-9															
1	20	23	21	18	22	19	22	18	21	19	21.0	17.0	-4.0		16.7
2	18	21	18	22	18	19	19	19	19	19	19.0	19.2	0.2	99%	
3	16	19	17	26	19	23	21	20	20	23	23.0	21.0	-2.0	99%	33.4
4	17	23	20	30							18.5	26.5	8.0	99%	111.2
Transect-11															
1	16	20	19	20	20	22	19	22	19	23	18.6	21.4	2.8	99%	38.9
2	16	20	17	20	17	20	17	25	18	27	17.0	22.4	5.4	99%	7.5
3	15	18	16	20	16	20	17	22	18	25	16.2	21.0	5.8	99%	80.6
4	17	20	17	28	18	28					17.3	25.3	8.0	99%	111.2
Transect-13															
1	15	18	15	20	17	22	17	20	19	22	16.6	20.2	3.6	99%	200.0
2	15	20	15	20	16	20	17	23	17	26	16.0	21.6	5.6	99%	77.8
3	15	18	15	19	17	20	19	21	19	24	17.0	20.2	3.2	99%	44.5
4	15	20	16	25	18	28	17	20			16.5	25.7	9.2	99%	127.9
Transect-16															
1	15	19	15	23	20	28					16.6	23.3	6.7	99%	93.1
2	15	18	15	20	20	26					16.6	21.3	4.7	99%	65.3
3	14	18	15	21	15	22	15	22	17	22	15.8	21.0	5.2	99%	72.3
4	15	20	15	22	15	23	17	23	18	27	16.0	23.0	7.0	99%	97.3

*Transects are in numerical sequence from the right to the left side of the river, facing upstream.

**Not Tested: Both samples were upstream controls. An average value of 1.53 was subtracted from all post dredge values to affect the increase in the transect A values on the second day.

On transect 7, there was little difference between the control and experimental values at location #1 near the eastern shore. However, as one proceeds toward the western shore, the differences increase significantly to 4.4 NTU average difference and 14.2 NTU at locations 2 and 3 respectively, indicating that the plume is proceeding downstream closer to the west shore.

On transect 9, the average values were lower after dredging at stations 1 and 3 and were approximately equal at station 2. At station 4, a difference of 8 NTU was noted.

DISSCUSSION

Whereas the data depicted in Figure 3, are horizontal and vertical averages, they generally depict the size and shape of the sediment plume. Since the plume is three-dimensional and the depiction must be two-dimensional, one must compare the horizontal and vertical displays to visualize the shape and extent of the plume.

It is granted however, that extremely high and low values are lost in this type of visualization. The reader is directed to Table 1 for these data.

If the plume is defined as occupying that area where the difference between the control and the during-dredging data are significantly different at the 99% confidence limit, then the plume occupies virtually all of the river volume to mile 826.4 (transect 16).

The data in Figure 1 indicate that the resuspended sediments were transported downstream as they were detected at transect #9. The turbidity levels between transects 10 and 14 however, were low. The intake pipe for the sampler was limited to a depth of 12 feet from the surface. Consequently, if the suspended material was transported below that depth it would not be detected. This was apparently the case, since the suspended solids re-appeared at transect 14 and were noticable in areas further downstream. An examination of the vertical distribution of the same reach of river indicates the same; that the suspended solids were carried in deeper waters and were re-distributed upward with water currents of transect 14. An examination of the depth profiles indicate that a very deep channel is located between transects 9 and 13 and lies adjacent to the east shore. Presumably a majority of

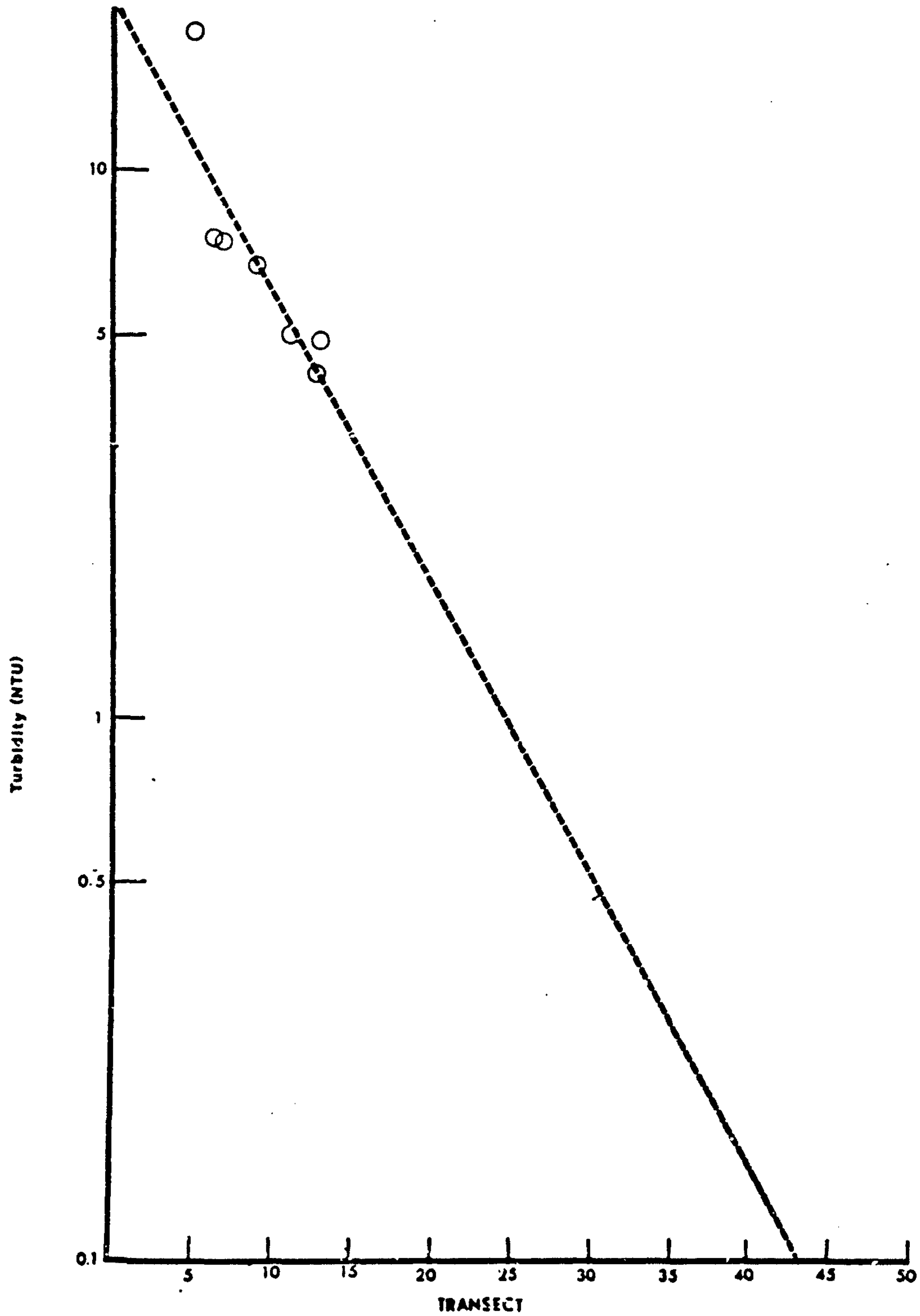

Figure 4. Average turbidity differences between control and experimental values for all transects, extrapolated to downstream areas, (line), Navigation Pool No. 2, Upper Mississippi River, 1976.

the water discharges through this channel, emerges at the downstream end and becomes redistributed into the shallow areas carrying with it, the suspended materials.

An examination of the average turbidities of all transects that were sampled, indicate that the sediment material probably remained in suspension for a considerable distance downstream from transect 16.

The average total turbidities were plotted (semi-log) to extrapolate the distances downstream that the effect could be seen (Figure 4). It should be noted that confidence limits cannot be applied to the line of extrapolation. However, differences in turbidity of 3 to 4 NTU were well within the limits for the actual data. If one assumes that the hydrologic properties of the reach of river downstream from transect 16 were similar to those above, and that the settling is somewhat uniform in both of these areas, then Figure 4 may approximate the NTU values in downstream areas.

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STATISTICAL ANALYSIS
OF
SELECTED DATA
FROM
THE 1976 MISSISSIPPI RIVER DREDGE STUDY
NEAR GRAY CLOUD ISLAND

Prepared for the W.Q.W.G.

Frank B. Martin 9/1/77

Frank B. Martin

CONTENTS

I

INTRODUCTION

This report is intended to reveal the information contained in a considerable mass of data, in a way which is complete and immediately accessable to any reader regardless of their lack of involvement with the project. It has been said many times and quite truly that a picture is worth a thousand words and it might also be added that a picture will reveal information that a few summary statistics cannot possibly convey. Thus the reader will find that the great bulk of the report is a collection of data plots. They may be scanned quickly so that an apology for length might hopefully be unnecessary.

Explanation of Report

The data reported herein were collected on July 7 and again on July 8, and at two positions on the river above A, and below B, the dredge activity and also in a second phase throughout the dredge plume. We will maintain a distinction within days according to the time at which the sample was drawn. All samples are numbered serially for the purpose of identifying these distinctions. In the ABOVE and BELOW transect data a three digit number identifies and locates each sample and its time of collection. The first digit is a 7 or an 8 for the day of the month and the last two digits record the order in which the samples were drawn from the river with the A samples beginning serially at 701 through approximately 713 and the B samples beginning serially at 720 through approximately 732. Thus, sample 727 was the <u>seventh</u> sample drawn down stream on July 7 while 811 would be the eleventh sample drawn up stream on July 8. In the dredge plume phase of this report, the data are simply numbered 01 through 26 which conforms to the field numbers given to the samples, also referred to as C samples.

In several places throughout the report computer files of the data are printed out. The immediately noticeable features of these files are the blanks for missing data and the lack of decimal points to conserve space. The actual data are contained in the appendicies in their correct decimal units. On the computer files in the body of the report the reader will note multipliers on some of the many variable names. This is the factor by which the original data was multiplied for computer analysis and represents the scale in which the analysis was done. For instance ph appears in this report as a set of numbers clustered about 81 rather than 8.1. When studying the analysis of such rescaled numbers the reader will find it necessary to convert back to the scales in the appendix.

II

DREDGING EFFECTS MEASURED AT A AND B TRANSECTS

1. Description of sampling

Composite samples were drawn across each transect using depth integrated techniques. Using this technique it would be inadvertently possible to pick up some bottom material by allowing the sampler to settle on the bottom. An examination of the total set of July 7 and July 8 samples turned up one such incident, namely sample 729. Outlier values for certain variables in this sample are marked by a small arrow in several July 7 scatter plots. The data for the many variables measured are contained in Appendix 1. Samples were taken at nearly equally spaced time intervals of approximately 1 hr. The below transect, B, was sampled approximately 2 hrs. after sampling was begun at the above transect. The sampling model was directed toward measuring a block of water before entering the dredge zone and then resampling that same block of water when it passed transect B. The extremely low flow in the river caused the lag time to be in the neighborhood of 4.5 hours. The low current made the block of water concept some what hazy but noticeable effects due to water changes will be noted in Section 5 of this part of the report.

2. Selection of data for analysis

The data recorded in the July 7 and July 8 files were selected for statistical analysis here because they required more than a quick glance examination to be understood. The following list of variables was given quick look examination and found to be uneffected by dredging in terms of above versus below differences: dissolved arsenic, suspended arsenic, dissolved and suspended cadmium, dissolved and suspended chrominum, dissolved and suspended copper, cyanide, dissolved mercury, dissolved zinc, suspended mercury, ammonia nitrogen, and oil and grease. In most cases the concentration seen both above and below are quite low and the detection of differences may be limited by the lack of more refined analysis techniques. That is to say, whatever differences do exist, above to below, are not detectable using the chemical analysis done in this study.

It can be noted, however, that there was a detectable but slight elevation from July 7 to July 8 in the readings on dissolved arsenic, suspended nickel, and oil and grease.

July 7 Transects File

SAMPLE SERIAL NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residues	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
701			31		068					82		27		030	320	495				12		025
702	12	25	29	1	072	05	00	02	16	82	25	27	273	020	319	505	02	05	05	11	21	028
703	13	26	24	1	064	06	00	02	16	81	26	28	267	028	316	520	02	05	06	11	25	026
704	13		35		069					81		28		030	325	510	00			12		030
705	12	24	40	1	068	11	00	02	16	82	26	29	274	030	324	520	02	05	09	12	22	032
706	13	24	35	1	066	00	06	01	17	81	28	30	267	025	331	515	01	04	09	11	23	028
707	14	24	33	2	064	05	02	01	16	82	26	28	260	019	323	515	01	05	07	14	22	023
708	15	24	32	2	063	06	00	01	16	81	28	28	271	031	313	520	02	06	08	13	38	043
709	13	26	31	1	060	05	00	01	16	81	32	32	278	014	332	520	03	05	05	12	29	029
710	12	26		1	063	03	03	02	15	82	31	33	273	018	317	520	02	05	06	12	22	024
711	15	27	37	2	088	06	02	03	17	82	32	33	277	019	338	525	03	05	08	13	22	025
712	13	27	30	2	045	06	01	02	12	82	35	39	279	014	311	500	00	09	07	12	21	024
720	10	23	40	0	130	08	00	01	21	82	23	24	267	026	355	515	03	06	08	12	20	037
721	12	22	36	1	120	04	04	03	18	76	23	25	303	031	381	530	02	06	10	16	67	068
722	15	23	37	0	140	07	03	02	21	81	19	20	256	055	321	505	00	06	05	12	55	056
723	14	23	37	2	120	08	00	01	20	82	23	23	272	033	335	515	04	06	07	14	36	039
724	13	23	36	1	120	07	00	01	19	82	24	25	267	033	324	510	02	08	06	13	25	030
725	17	24	38	1	130	08	00	01	20	82	25	26	270	030	349	515	03	04	06	13	24	035
726	17	23	42	1	160	11	00	02	22	82	26	27	285	049	352	515	02	10	07	14	29	072
727	13	26	42	1	160	04	06	02	22	82	23	25	270	051	363	510	03	05	09	15	23	025
728	14	24	37	1	096	04	04	02	19	82	26	27	270	035	339	500	02	05	09	14	24	028
729	25	26	58	3	450	07	15	15	31	82	33	34	276	154	452	520	04	09	08	20	88	110
730	17	28	42	3	180	04	07	03	21	82	27	28	269	053	360	515	03	07	08	16	23	023
731	18	26	41	1	170	05	06	03	20	82	27	27	287	055	355	510	04	06	07	14	23	026

July 8 Transects File

SAMPLE SERIAL NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residues	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
[illegible]	09	27	28	2	060	06	10	01	13	80	39	42	282	010	314	515	15	09	09	10	24	[illegible]
801	14	27	35	1	033	03	09	01	11	79	41	44	274	004	324	525	00	09	08	10	21	023
802	13	28	35	2	033	03	10	01	11	79	39	43	280	010	324	510	01	10	08	12	21	022
803	13	26	34	1	046	00	07	01	12	79	38	39	279	013	325	520	02	09	08	11	22	[illegible]
804	13	28	39	1	038	05	04	01	11	79	36	41	280	010	321	525	01	09	07	10	21	021
805	16	27	34	1	031	05	02	01	11	79	38	40	270	012	327	520	01	12	06	13	23	036
[illegible]	13	26	26	0	036	05	02	01	11	80	40	41	270	010	317	525	02	12	00	13	21	099
807	14	27	33	0	034	01	06	01	11	81	37	38	265	013	323	515	00	11	09	13	21	043
808	12	26	32	0	031	03	04	01	11	80	35	37	268	014	320	505	01	11	07	12	22	028
809	13	25	36	0	038	03	05	01	11	81	32	38	264	015	315	505	01	11	08	11	21	046
810	13	26	33	0	041	05	00	01	13	81	35	35	265	023	325	495	01	12	09	16	22	061
812	13	26	41	2	079	02	08	02	15	81	31	34	270	037	344	500	00	09	12	12	24	140
813	12	26	38	1	041	04	00	02	12	81	33	33	273	022	324	495	00	10	12	12	22	[illegible]
820	22	24	49	1	220	04	08	03	26	79	27	29	293	080	381	520	04	07	09	16	22	[illegible]
821	15	27	31	2	033	03	04	01	11	79	40	40	300	006	322	525	01	10	04	11	21	[illegible]
822	18	28	25	1	045	02	03	01	12	80	33	38	274	016	333	520	02	11	08	12	22	041
823	15	26	34	1	045	07	06	01	11	79	38	40	267	015	331	525	01	10	00	00	23	068
824	14	27	34	0	066	03	06	02	13	80	37	38	270	025	339	530	01	11	10	13	21	060
825	14	28	32	1	065	04	03	01	13	81	37	39	273	027	343	535	01	11	08	14	22	036
826	13	27	38	0	086	02	12	03	14	81	37	37	266	053	373	525	00	11	07	13	22	042
827	11	28	39	0	083	03	05	02	13	81	36	42	275	032	367	515	02	10	20	25	20	200
828	25	28	34	0	056	04	01	03	12	82	35	38	281	025	337	520	00	14	10	10	67	[illegible]
829	13	27	39	0	081	05	05	03	14	81	35	36	275	034	344	505	02	09	02	06	20	110
830	12	27	34	1	053	04	00	03	11	81	33	33	273	030	326	505	01	10	09	09	20	170
831	17	26	34	0	089	02	05	04	11	81	32	32	265	025	334	495	07	07	00	01	21	098
832	19	23	45	1	170	03	10	06	17	80	30	33	267	072	386	510	03	10	08	13	22	056

READY.

3.
The July 7 Observations

Tables of means and standard deviations are presented for the above and separately for the below dredge transect samples immediately following this discussion. Following these tables is a set of scatter plots of each variable studied against the sample serial numbers. Since the sample serial numbers reflect exactly the order and location of the samples, these plots convey to the reader the desired picture of what occured. They are the most informative aspects of this analysis and are recommended for careful study. As mentioned earlier the 729 sample is an outlier and will not be utilized in the statistical analysis described below. Sample 729 readings are flaged in the scatter plots.

A common aspect of statistical analysis is the test of significance or the hypothesis test. The testable or null hypothesis for this data is the concept that the above samples and the below samples are each drawn from the same population of water or in other words, there is no effect due to dredging on the variables being studied. When this null hypothesis is rejected by the nature of the data statistically significant differences are often said to exist. The most common statistical test for comparing the means of two samples is the t test. This report employs the Mann-Whitney test for differences which is for all practical purposes equivalent to the t test and reaches the same conclusions as the t test. The Mann-Whitney test is based on ranks and is nonparametric in the sense that it makes no distributional assumptions for the water samples.

A statistically significant difference is an identifiable difference in this data set and is not presumed to be large or important. It will be noticed that many significant differences noted below are quite small. Variables for which no significant differences are noted are of such a nature that the fluctuation from above to below is no greater than that which might be reasonably asscribed to the random variation inherent in river sampling. The relative importance of significant differences noted in the following table is left to the reader to decide.

Statistically significant increases from above to below

Variable	Above Mean	Below Mean	
Organic Carbon	13.20	14.55	MG/L
Chemical Oxygen Demand	32.40	38.91	MG/L
Total Iron	653.0	1387.	UG/L
Suspended Manganese	157.0	202.7	UG/L
Suspended Solids	21.80	41.00	MG/L
Total Residues	322.40	348.5	MG/L
Suspended Zinc	18.00	25.45	UG/L
Total Organic Nitrogen	1.21	1.39	MG/L
Total Nitrite + Nitrate	.28	.40	MG/L

Statistically significant decreases from above to below

Variable	Above Mean	Below Mean	
Dissolved Ortho Phosphorus	.299	.242	MG/L
Total Phosphorus	.307	.252	MG/L

July 7 Transect A Means

SAMPLE SERIAL NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residue	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
702	12	25	29	1	072	05	00	02	16	82	25	27	273	020	319	505	02	05	05	11	21	028
703	13	26	24	1	064	06	00	02	16	81	26	28	267	028	316	520	02	05	06	11	25	026
705	12	24	40	1	068	11	00	02	16	82	26	29	274	030	324	520	02	05	09	12	22	032
706	13	24	35	1	066	00	06	01	17	81	28	30	267	025	331	515	01	04	09	11	23	028
707	14	24	33	2	064	05	02	01	16	82	26	28	260	019	323	515	01	05	07	14	22	023
708	15	24	32	2	063	06	00	01	16	81	28	28	271	031	313	520	02	06	08	13	38	043
709	13	26	31	1	060	05	00	01	16	81	32	32	278	014	332	520	03	05	05	12	29	029
710	12	26	33	1	063	03	03	02	15	82	31	33	273	018	317	520	02	05	06	12	22	024
711	15	27	37	2	088	06	02	03	17	82	32	33	277	019	338	525	03	05	08	13	22	025
712	13	27	30	2	045	06	01	02	12	82	35	39	279	014	311	500	00	09	07	12	21	024

VARIABLE	N	MEAN	VARIANCE	ST.DEV.	MIN	MAX
V1	10	707.3	11.12	3.335	702.0	712.0
V2	10	13.20	1.289	1.135	12.00	15.00
V3	10	25.30	1.567	1.252	24.00	27.00
V4	10	32.40	19.60	4.427	24.00	40.00
V5	10	1.400	.2667	.5164	1.000	2.000
V6	10	65.30	113.6	10.66	45.00	88.00
V7	10	5.300	7.567	2.751	0	11.00
V8	10	1.400	3.822	1.955	0	6.000
V9	10	1.700	.4556	.6749	1.000	3.000
V10	10	15.70	2.011	1.418	12.00	17.00
V11	10	81.60	.2667	.5164	81.00	82.00
V12	10	28.90	11.43	3.381	25.00	35.00
V13	10	30.70	13.34	3.653	27.00	39.00
V14	10	271.9	34.54	5.877	260.0	279.0
V15	10	21.80	39.51	6.286	14.00	31.00
V16	10	322.4	79.16	8.897	311.0	338.0
V17	10	516.0	60.00	7.746	500.0	525.0
V18	10	1.800	.8444	.9189	0	3.000
V19	10	5.400	1.822	1.350	4.000	9.000
V20	10	7.000	2.222	1.491	5.000	9.000
V21	10	12.10	.9689	.9944	11.00	14.00
V22	10	24.50	28.28	5.318	21.00	38.00
V23	10	28.20	34.62	5.884	23.00	43.00

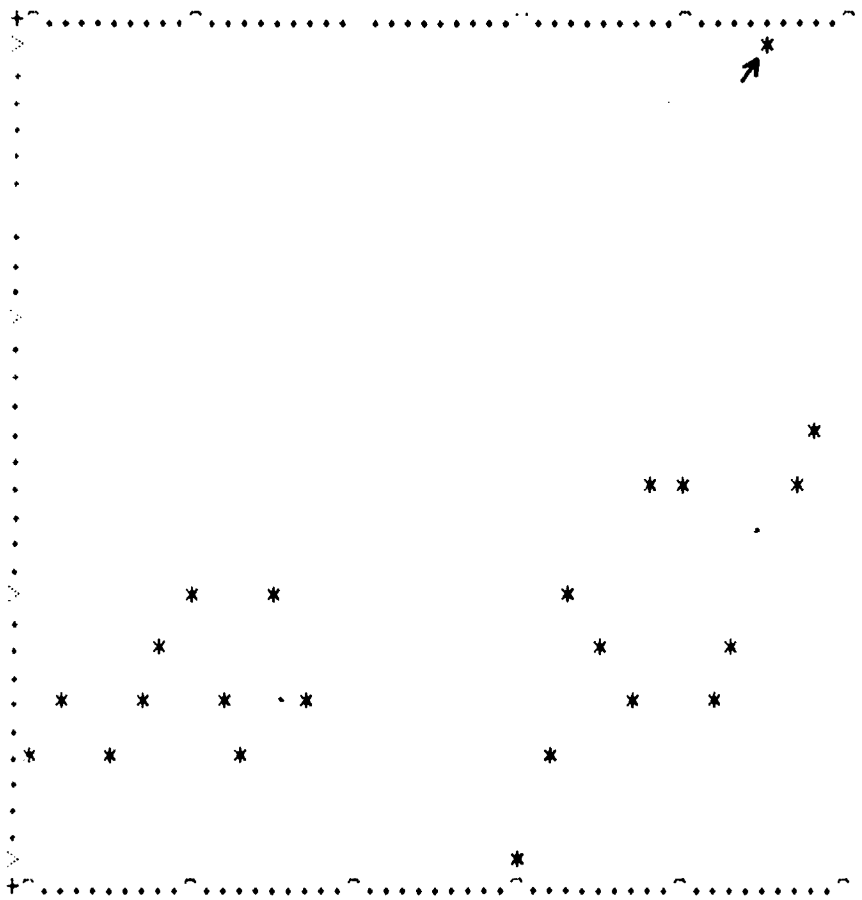
July 7? Transect B means

SAMPLE SERIAL NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residues	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
720	10	23	40	0	130	08	00	01	21	82.	23	24	267	026	355	515	03	06	08	12	20	037
721	12	22	36	1	120	04	04	03	18	76	23	25	303	031	381	530	02	06	10	16	67	068
722	15	23	37	0	140	07	03	02	21	81	19	20	256	055	321	505	00	06	05	12	55	056
723	14	23	37	2	120	08	00	01	20	82	23	23	272	033	335	515	04	06	07	14	36	039
724	13	23	36	1	120	07	00	01	19	82	24	25	267	033	324	510	02	08	06	13	25	030
725	17	24	38	1	130	08	00	01	20	82	25	26	270	030	349	515	03	04	06	13	24	035
726	17	23	42	1	160	11	00	02	22	82	26	27	285	049	352	515	02	10	07	14	29	072
727	13	26	42	1	160	04	06	02	22	82	23	25	270	051	363	510	03	05	09	15	23	025
728	14	24	37	1	096	04	04	02	19	82	26	27	270	035	339	500	02	05	09	14	24	028
[729	25	26	58	3	450	07	15	15	31	82	33	34	276	154	452	520	04	09	08	20	88	110]
730	17	28	42	3	180	04	07	03	21	82	27	28	269	053	360	515	03	07	08	16	23	023
731	18	26	41	1	170	05	06	03	20	82	27	27	287	055	355	510	04	06	07	14	23	026

VARIABLE	N	MEAN	VARIANCE	ST.DEV.	MIN	MAX
V1	11	725.2	12.96	3.601	720.0	731.0
V2	11	14.55	6.273	2.505	10.00	18.00
V3	11	24.09	3.291	1.814	22.00	28.00
V4	11	38.91	6.291	2.508	36.00	42.00
V5	11	1.091	.6909	.8312	0	3.000
V6	11	138.7	661.8	25.73	96.00	180.0
V7	11	6.364	5.455	2.335	4.000	11.00
V8	11	2.727	8.018	2.832	0	7.000
V9	11	1.909	.6909	.8312	1.000	3.000
V10	11	20.27	1.618	1.272	18.00	22.00
V11	11	81.36	3.255	1.804	76.00	82.00
V12	11	24.18	5.564	2.359	19.00	27.00
V13	11	25.18	5.164	2.272	20.00	28.00
V14	11	274.2	163.0	12.77	256.0	303.0
V15	11	41.00	131.0	11.45	26.00	55.00
V16	11	348.5	312.5	17.68	321.0	381.0
V17	11	512.7	56.82	7.538	500.0	530.0
V18	11	2.545	1.273	1.128	0	4.000
V19	11	6.273	2.618	1.618	4.000	10.00
V20	11	7.455	2.273	1.508	5.000	10.00
V21	11	13.91	1.891	1.375	12.00	16.00
V22	11	31.73	234.2	15.30	20.00	67.00
V23	11	39.91	305.3	17.47	23.00	72.00

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **ORGANIC CARBON**

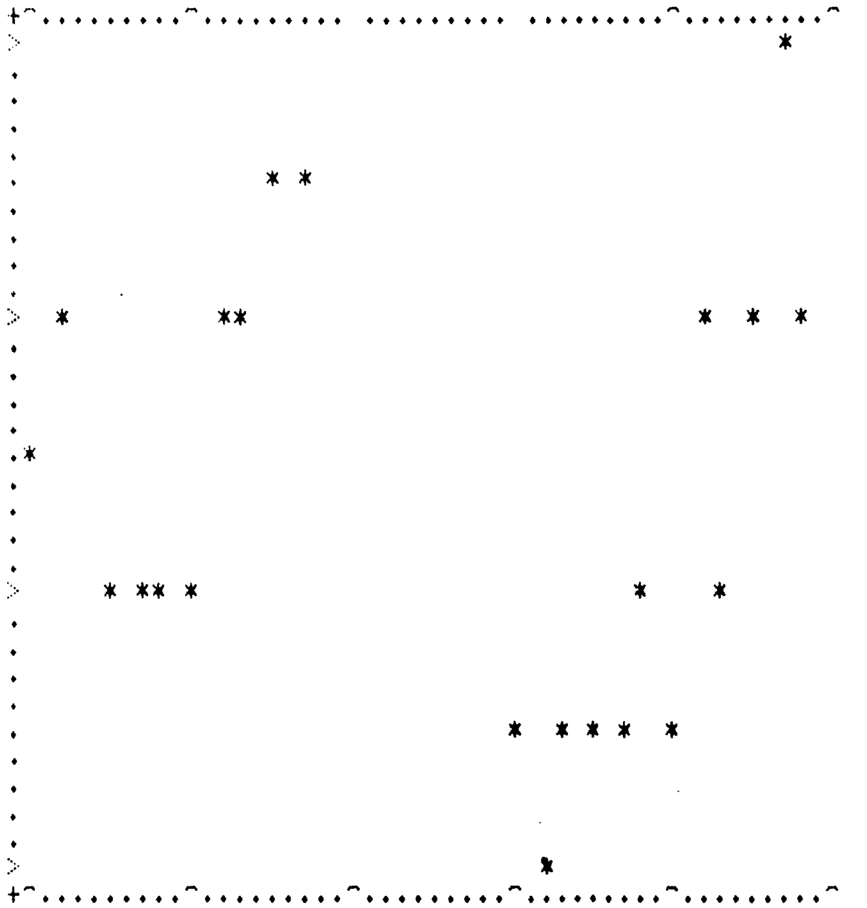


X AXIS: 1-ST TICK	= 702.0	/INCREMENT	=	6.000
DATA: MINIMUM	= 702.0	/MAXIMUM	=	731.0
Y AXIS: 1-ST TICK	= 10.00	/INCREMENT	=	5.000
DATA: MINIMUM	= 10.00	/MAXIMUM	=	25.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = DISSOLVED CHLORIDE

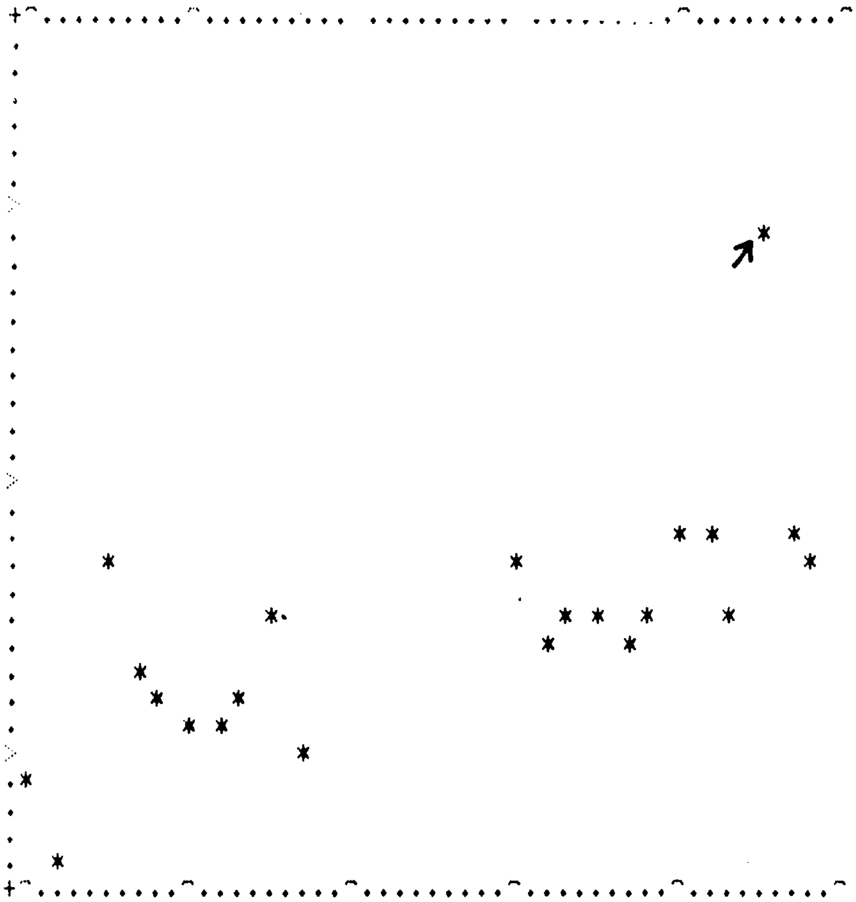


X AXIS:	1-ST TICK =	702.0	/INCREMENT =	6.000
DATA:	MINIMUM =	702.0	/MAXIMUM =	731.0
Y AXIS:	1-ST TICK =	22.00	/INCREMENT =	2.000
DATA:	MINIMUM =	22.00	/MAXIMUM =	28.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
        Y-AXIS = **CHEMICAL OXYGEN DEMAND**



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X AXIS: 1-ST TICK =      702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =      702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =      30.00    /INCREMENT =     15.00
  DATA. MINIMUM   =      24.00    /MAXIMUM   =     58.00
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NEXT?

SCPLOT

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SCPLOT: X-AXIS = July 7 serial number
        Y-AXIS = DISSOLVED IRON
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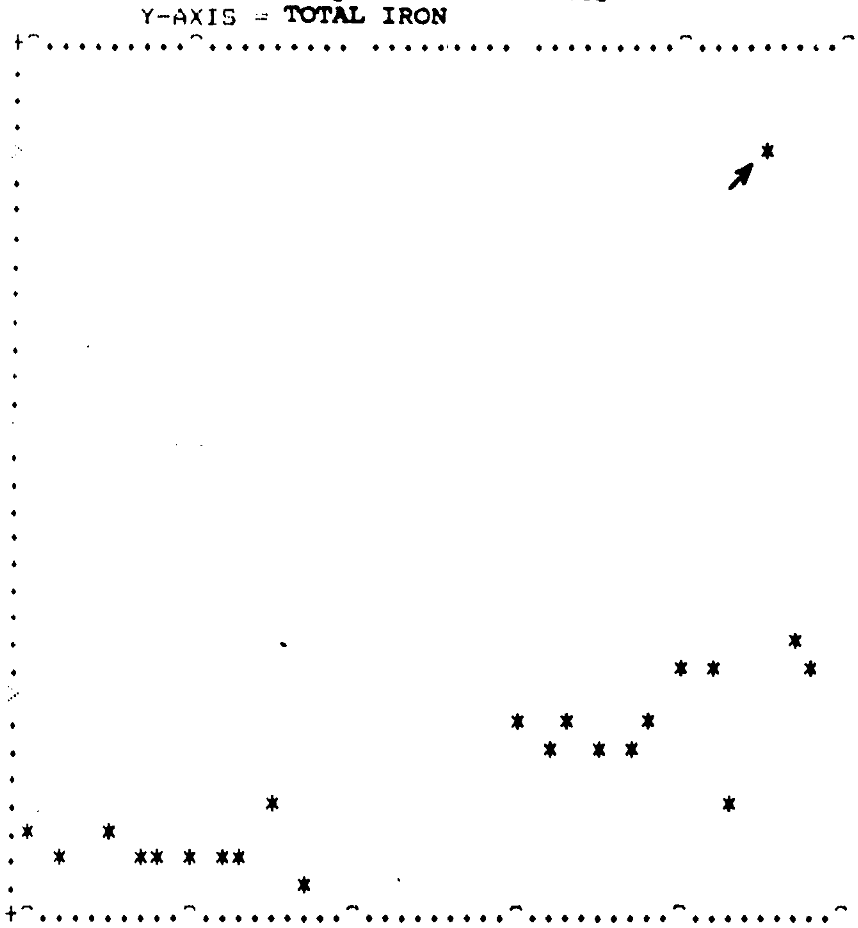
+^.........^.........^.........^.........^.........^

X AXIS: 1-ST TICK =     702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     1.000
  DATA: MINIMUM   =             0/MAXIMUM   =     3.000

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **TOTAL IRON**

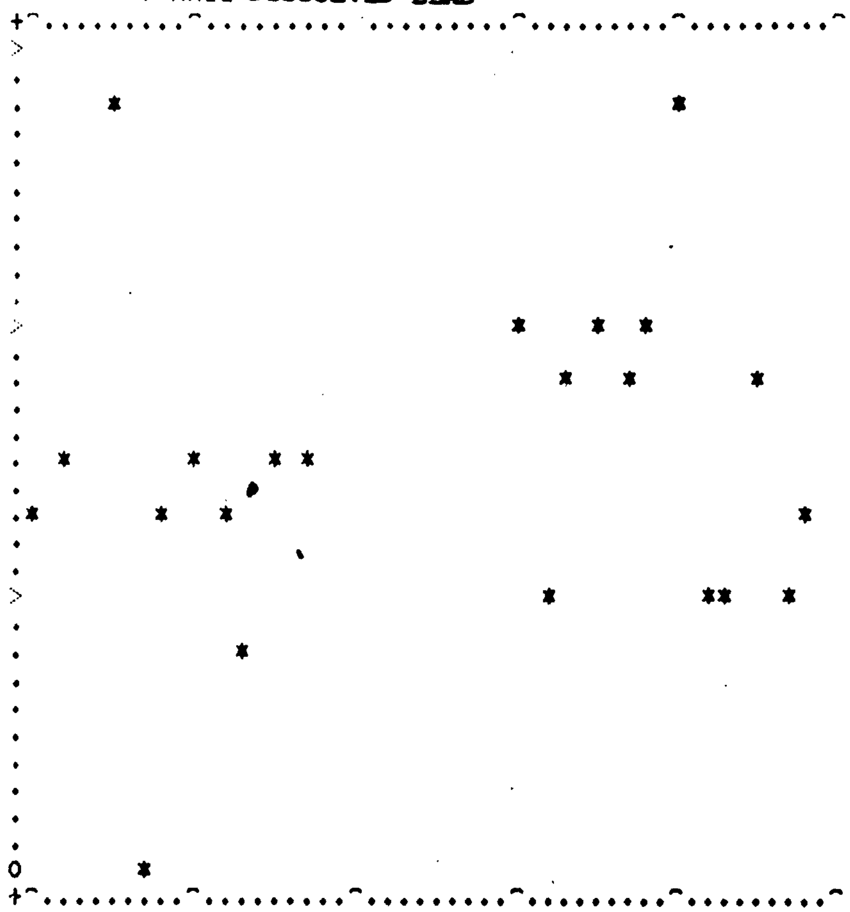


X AXIS:	1-ST TICK =	702.0	/INCREMENT =	6.000
DATA:	MINIMUM =	702.0	/MAXIMUM =	731.0
Y AXIS:	1-ST TICK =	150.0	/INCREMENT =	150.0
DATA:	MINIMUM =	45.00	/MAXIMUM =	450.0

NEXT?

SCPLOT

```
SCPLOT: X-AXIS July 7 serial number
        Y-AXIS DISSOLVED LEAD
```

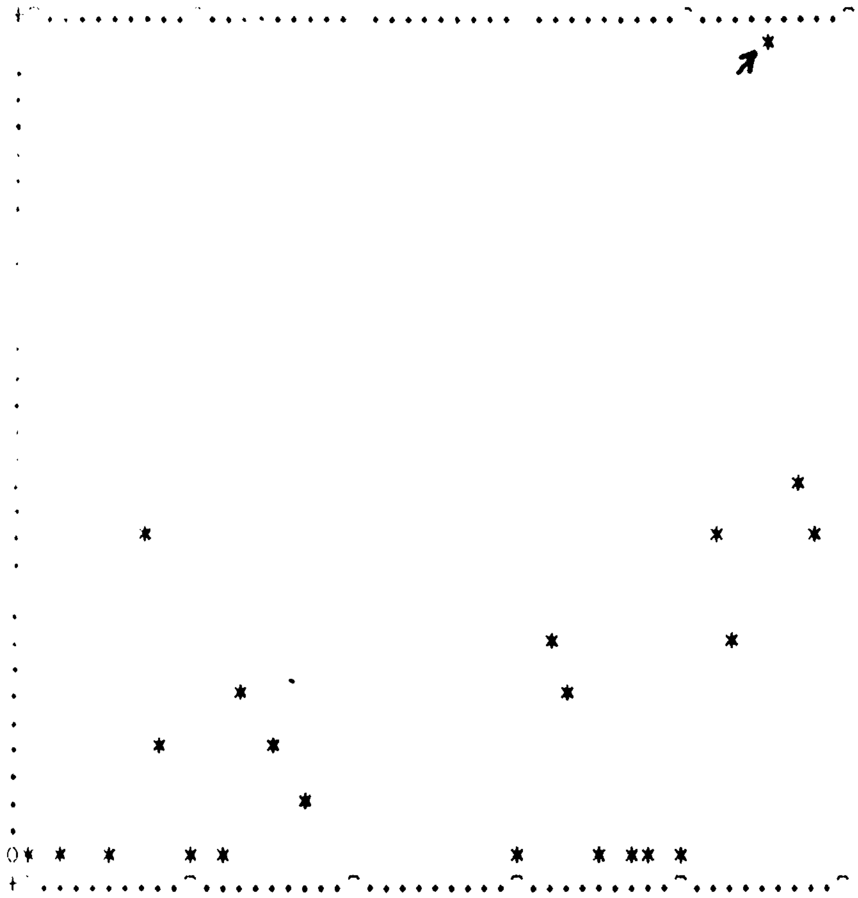


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    4.000
  DATA: MINIMUM   =             0/MAXIMUM   =    11.00

      NEXT?
```

SCPLOT

SCPLOT: X AXIS = **July 7 serial number**
Y-AXIS = **SUSPENDED LEAD**

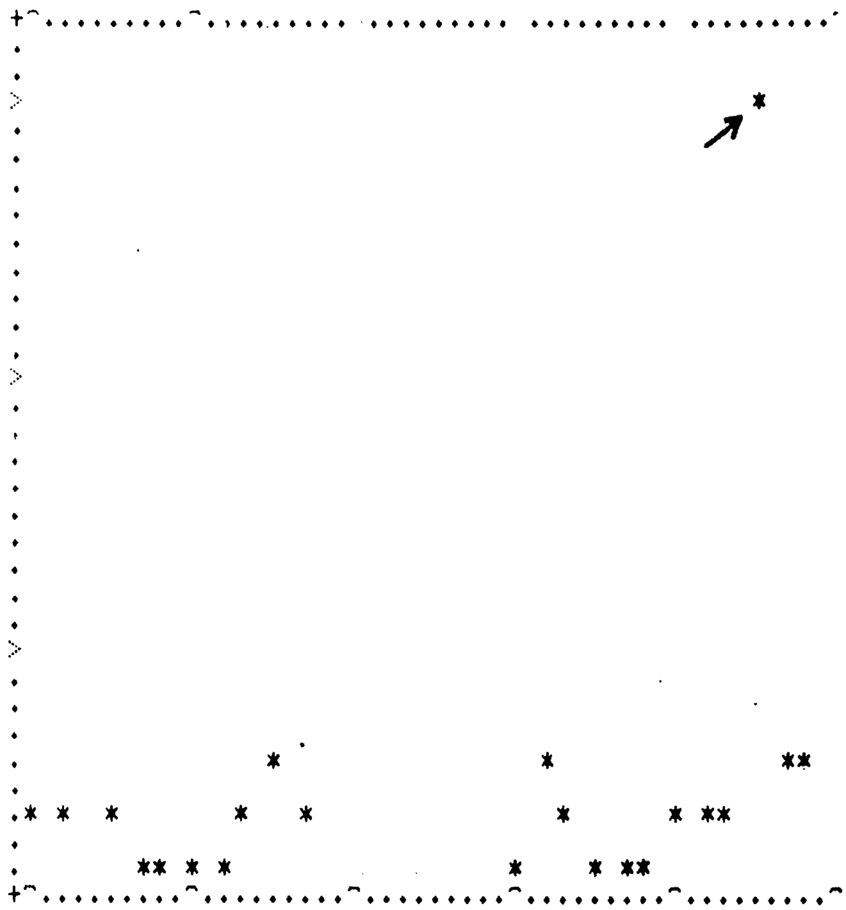


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    5.000
  DATA: MINIMUM   =             0/MAXIMUM   =    15.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **DISSOLVED MANGANESE**

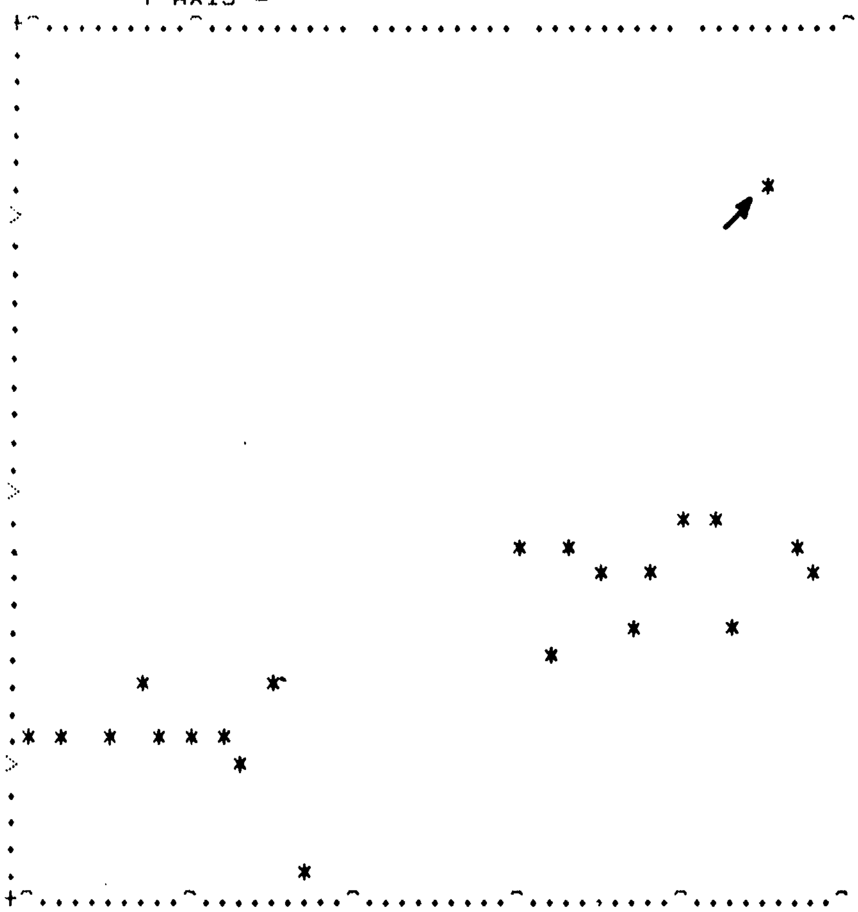


```
X AXIS: 1-ST TICK =    702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =    5.000    /INCREMENT =    5.000
  DATA: MINIMUM   =    1.000    /MAXIMUM   =    15.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **SUSPENDED MANGANESE**

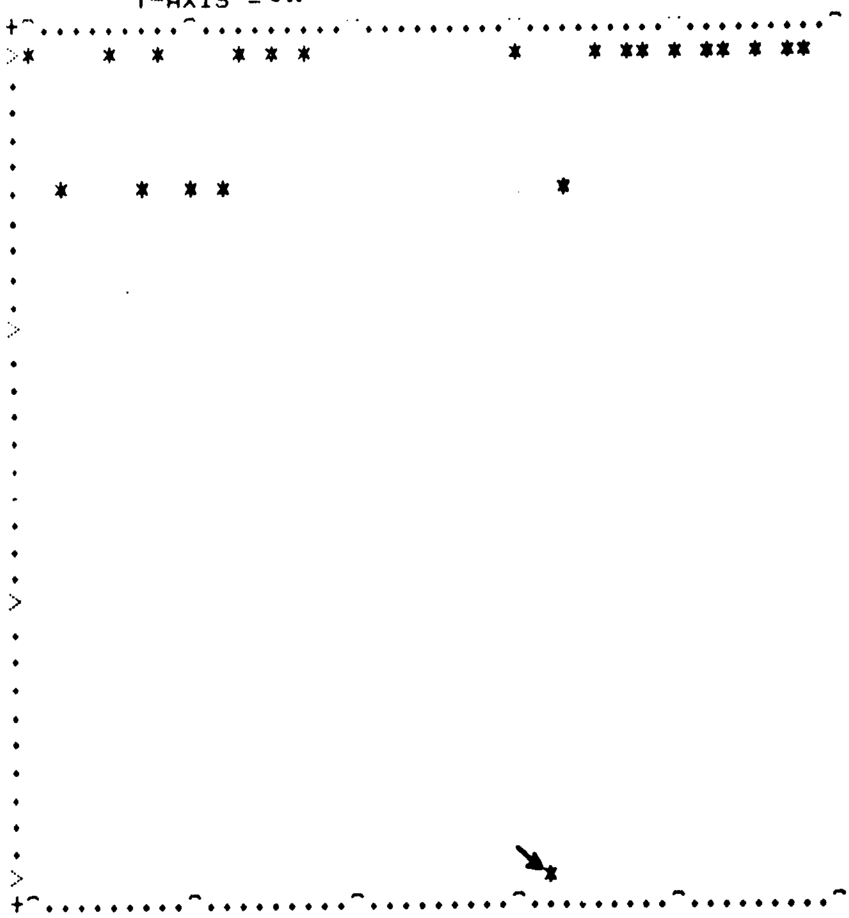


```
X AXIS: 1-ST TICK =    702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =    15.00    /INCREMENT =    7.500
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    31.00
```

NEXT? SCPLOT 12 *DEL*

SCPLOT

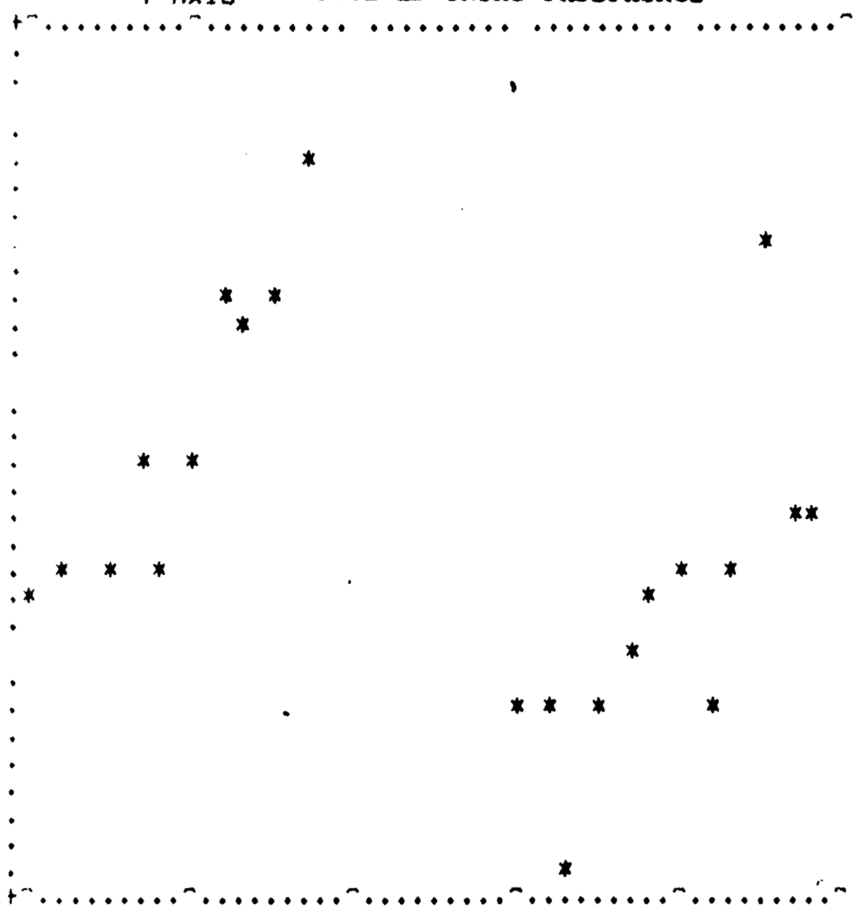
SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = Ph



```
X AXIS: 1-ST TICK =    702.0   /INCREMENT =    6.000
  DATA: MINIMUM   =    702.0   /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =    76.00   /INCREMENT =    2.000
  DATA: MINIMUM   =    76.00   /MAXIMUM   =    82.00
```

NEXT? SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **DISSOLVED ORTHO PHOSPHORUS**

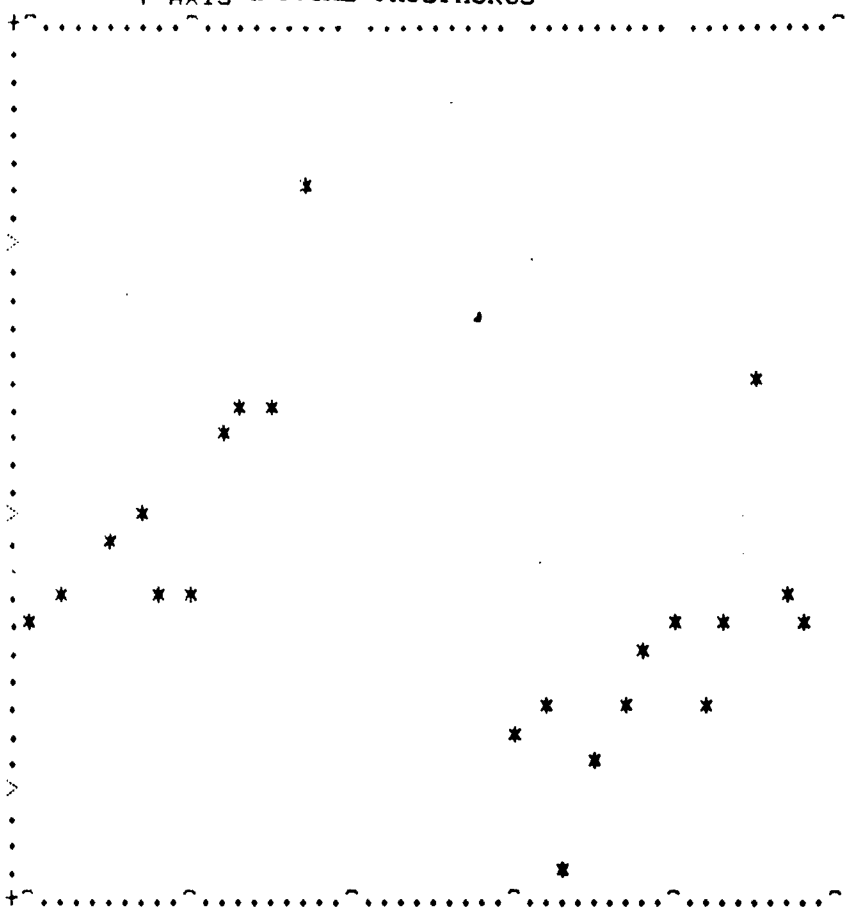


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =     24.00    /INCREMENT =     6.000
  DATA: MINIMUM   =     19.00    /MAXIMUM   =     35.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = TOTAL PHOSPHORUS

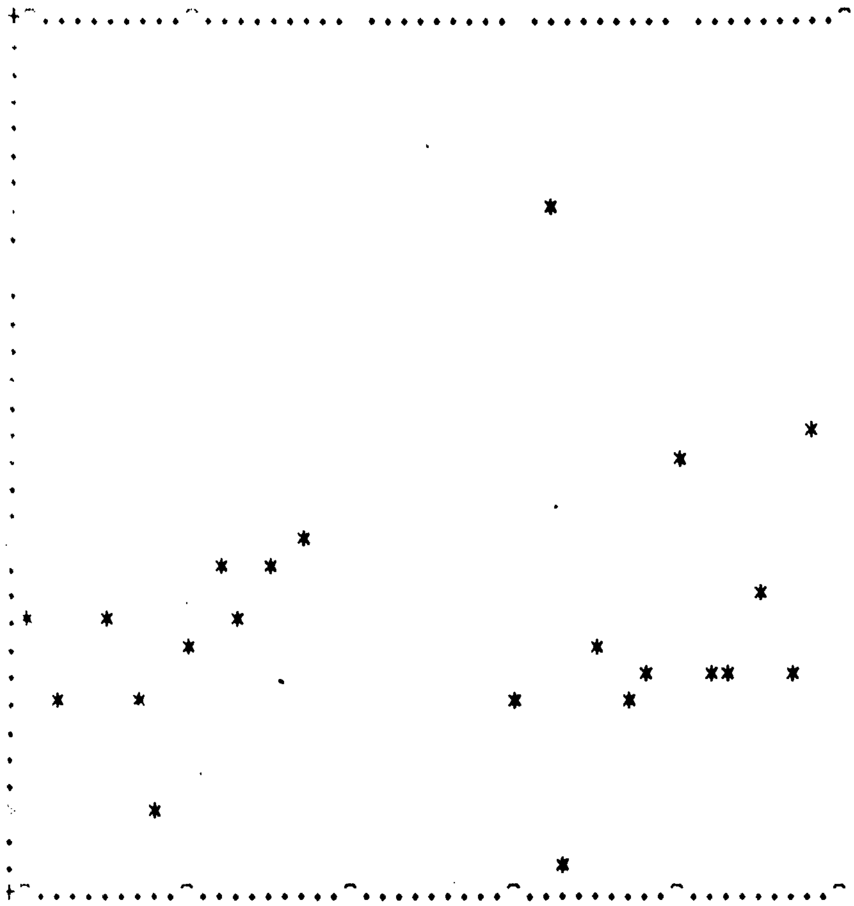


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =     22.50    /INCREMENT =     7.500
  DATA: MINIMUM   =     20.00    /MAXIMUM   =     39.00
```

NEXT?

SCPLOT 1

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **dissolved solids residues**

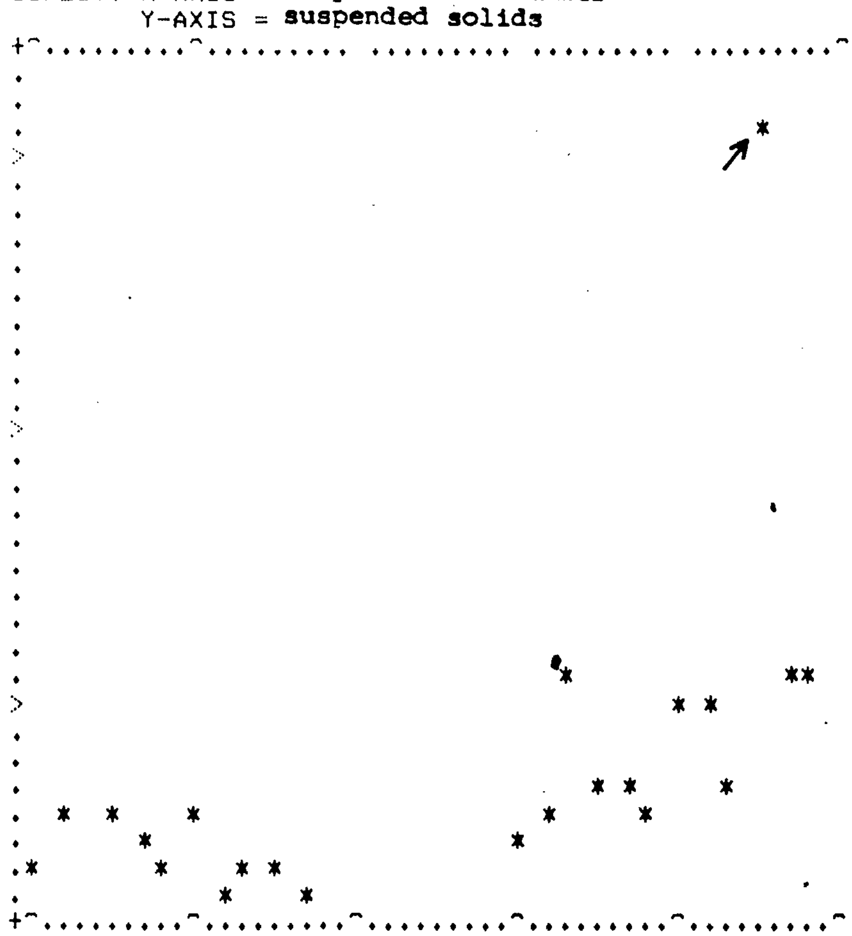


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =     260.0    /INCREMENT =     20.00
  DATA: MINIMUM   =     256.0    /MAXIMUM   =     303.0
```

NEXT?

SCPLOT :

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = suspended solids

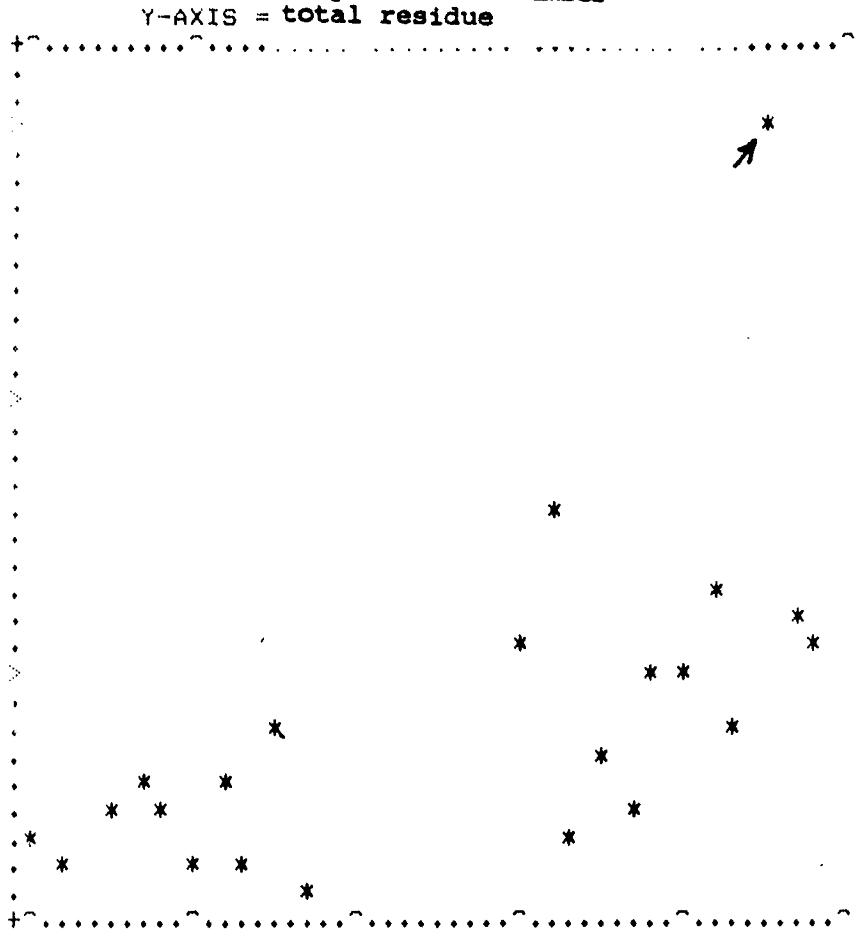


```
X AXIS: 1-ST TICK =    702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =    50.00    /INCREMENT =    50.00
  DATA: MINIMUM   =    14.00    /MAXIMUM   =    154.0
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = **total residue**



```
X AXIS: 1-ST TICK =     702.0     /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0     /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =     350.0     /INCREMENT =     50.00
  DATA: MINIMUM   =     311.0     /MAXIMUM   =     452.0
```

NEXT?

SCPLOT

```
SCPLOT: X-AXIS = July 7 serial number
        Y-AXIS = conductance
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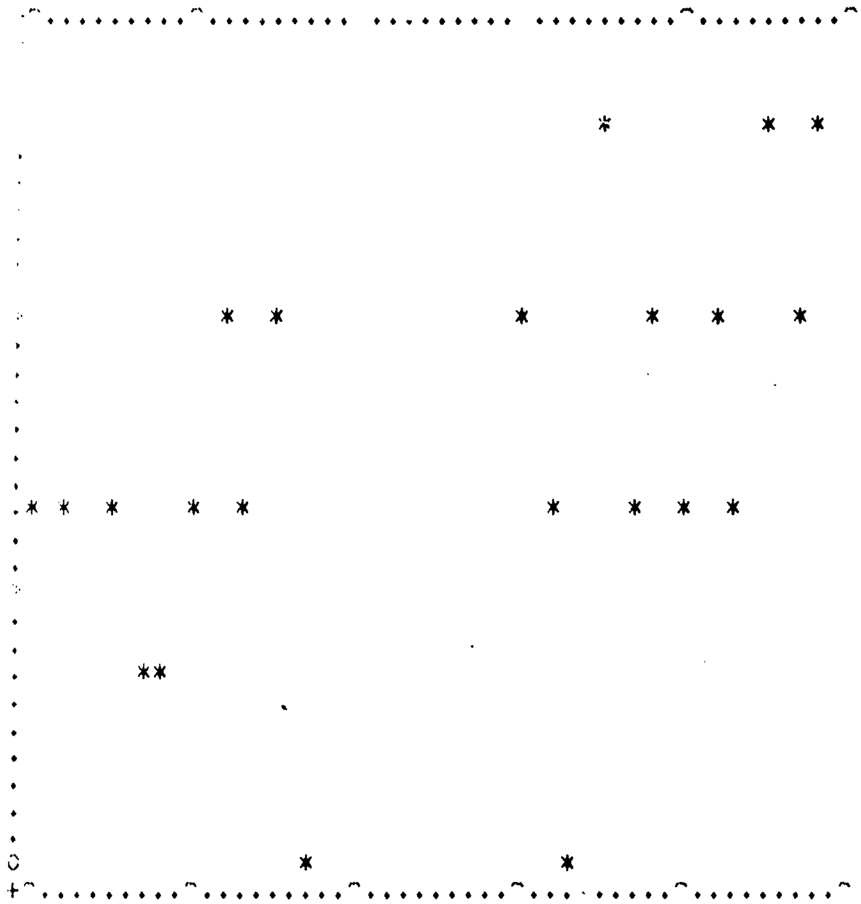
X AXIS: 1-ST TICK =     702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =     500.0    /INCREMENT =    10.00
  DATA: MINIMUM   =     500.0    /MAXIMUM   =    530.0

      NEXT?
```

SCPLOT

```
SCPLOT: X-AXIS = July 7 serial number
        Y-AXIS = Suspended Zinc
```

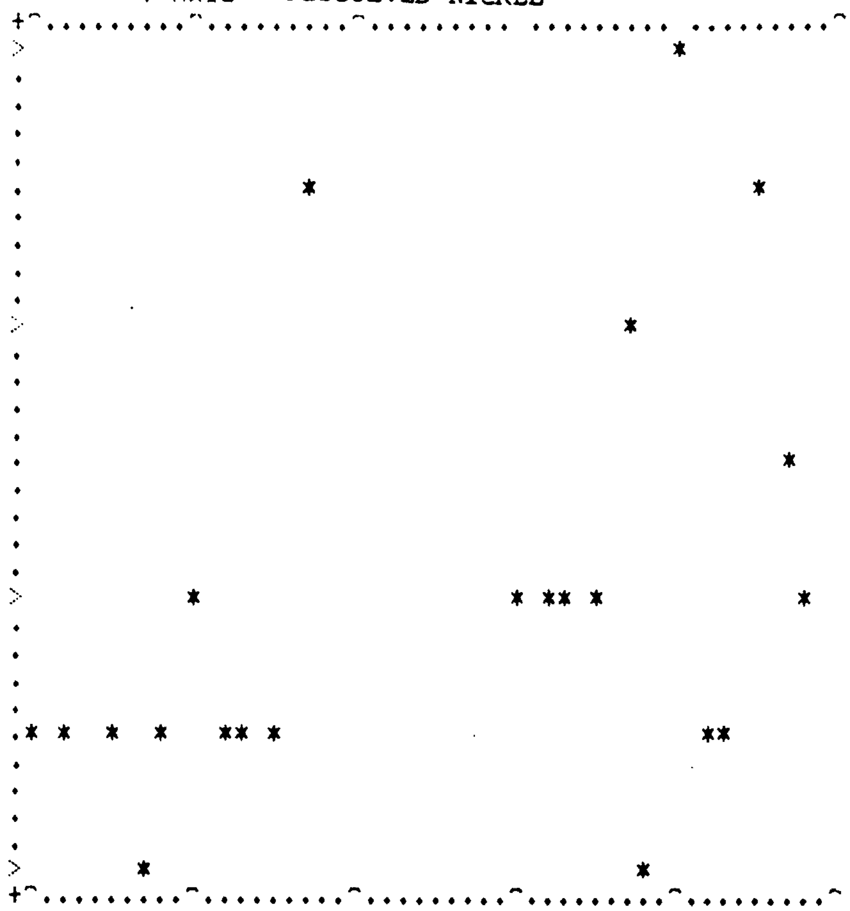


```
X AXIS: 1-ST TICK =    702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =    702.0    /MAXIMUM   =  731.0
Y AXIS: 1-ST TICK =            0/INCREMENT =    1.500
  DATA: MINIMUM   =            0/MAXIMUM   =    4.000

     NEXT?
```

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = DISSOLVED NICKEL

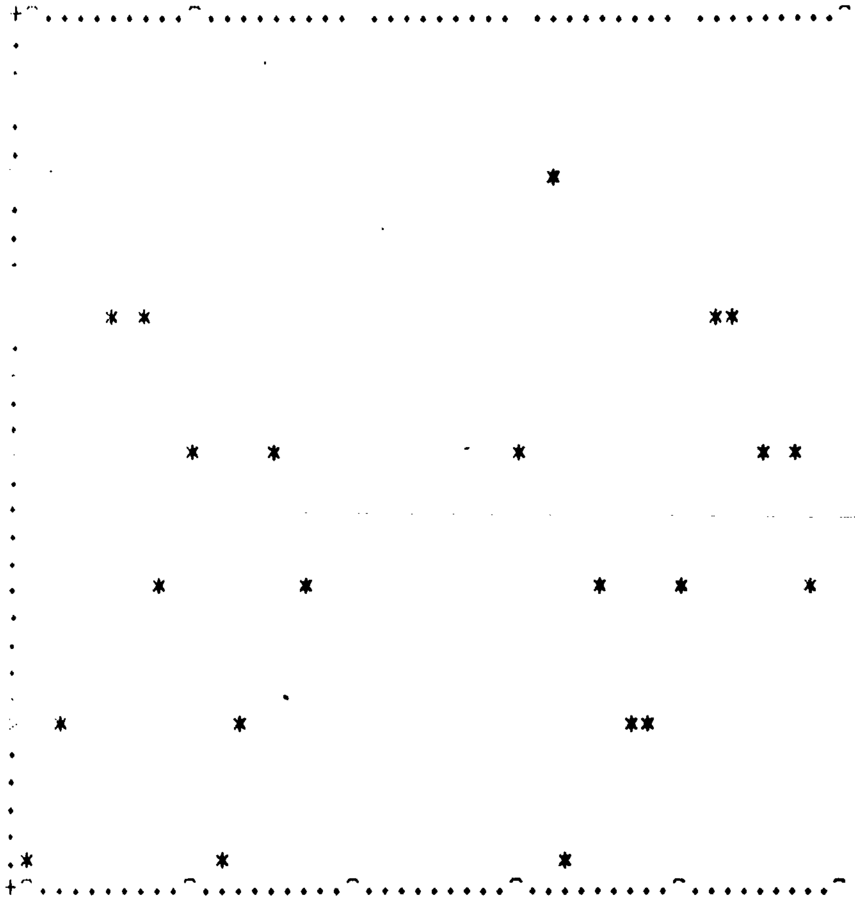


```
X AXIS: 1-ST TICK =   702.0   /INCREMENT =   6.000
  DATA: MINIMUM   =   702.0   /MAXIMUM   =   731.0
Y AXIS: 1-ST TICK =   4.000   /INCREMENT =   2.000
  DATA: MINIMUM   =   4.000   /MAXIMUM   =   10.00
```

NEXT?

SCPLO˜ .

SCPLOT: X-AXIS = **July 7 serial number**
Y-AXIS = DISSOLVED ORGANIC NITROGEN

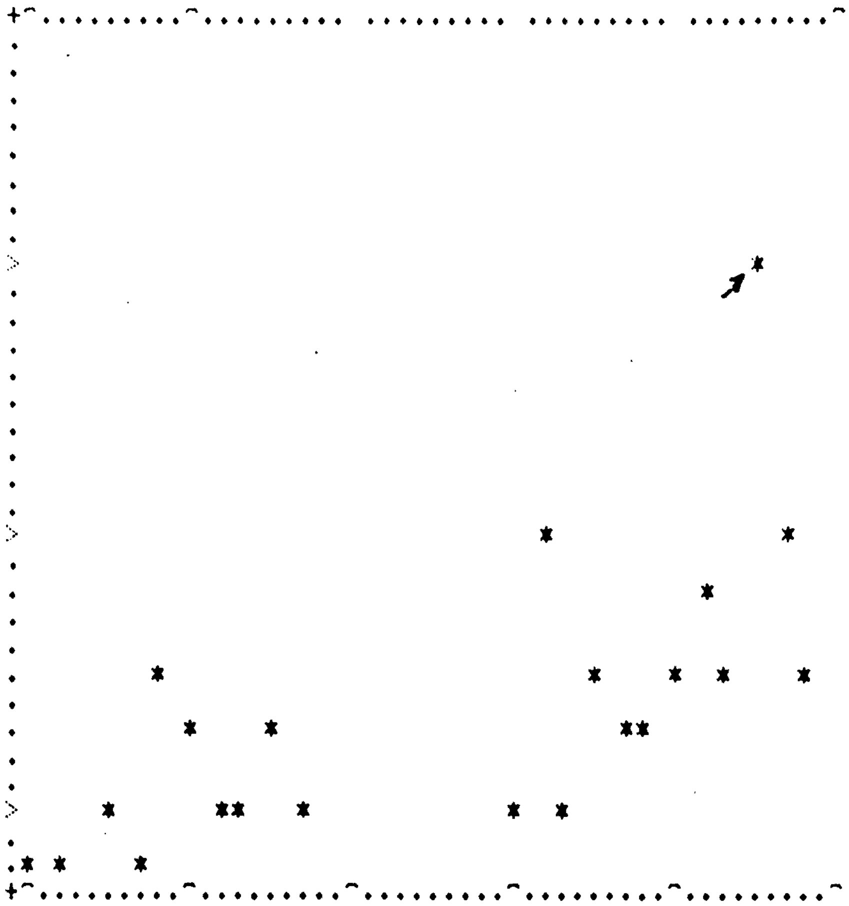


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =    6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    731.0
Y AXIS: 1-ST TICK =     6.000    /INCREMENT =    2.000
  DATA: MINIMUM   =     5.000    /MAXIMUM   =    10.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = TOTAL ORGANIC NITROGEN

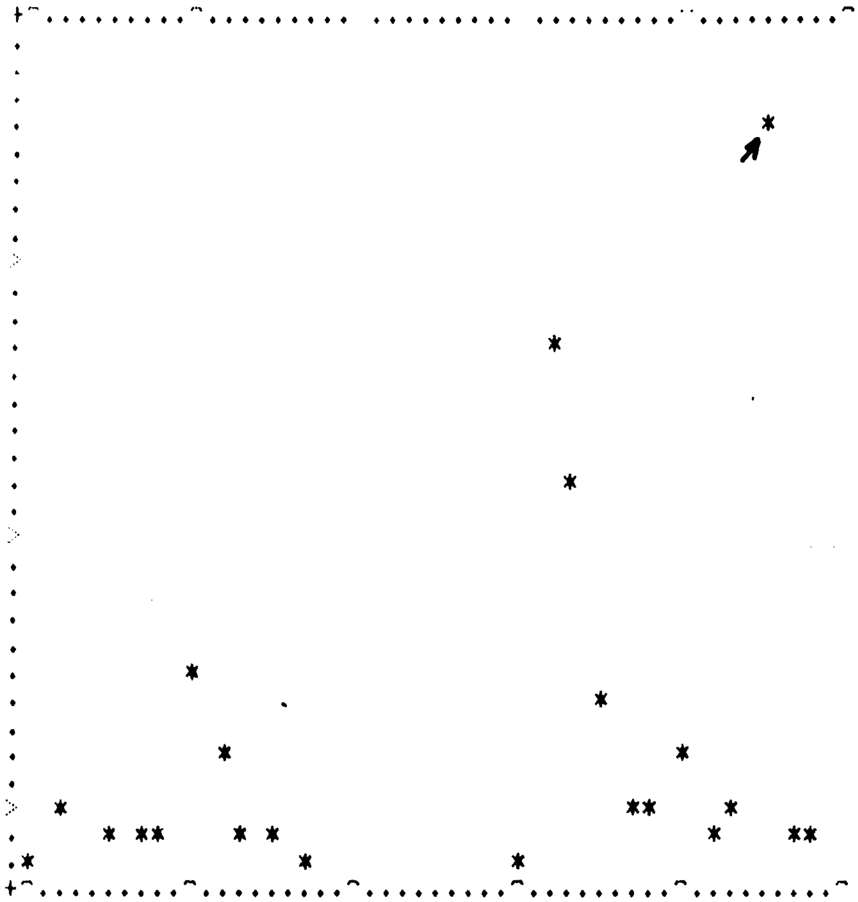


```
X AXIS: 1-ST TICK =     702.0    /INCREMENT =     6.000
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     731.0
Y AXIS: 1-ST TICK =     12.00    /INCREMENT =     4.000
  DATA: MINIMUM   =     11.00    /MAXIMUM   =     20.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = DISSOLVED NITRITE + NITRATE

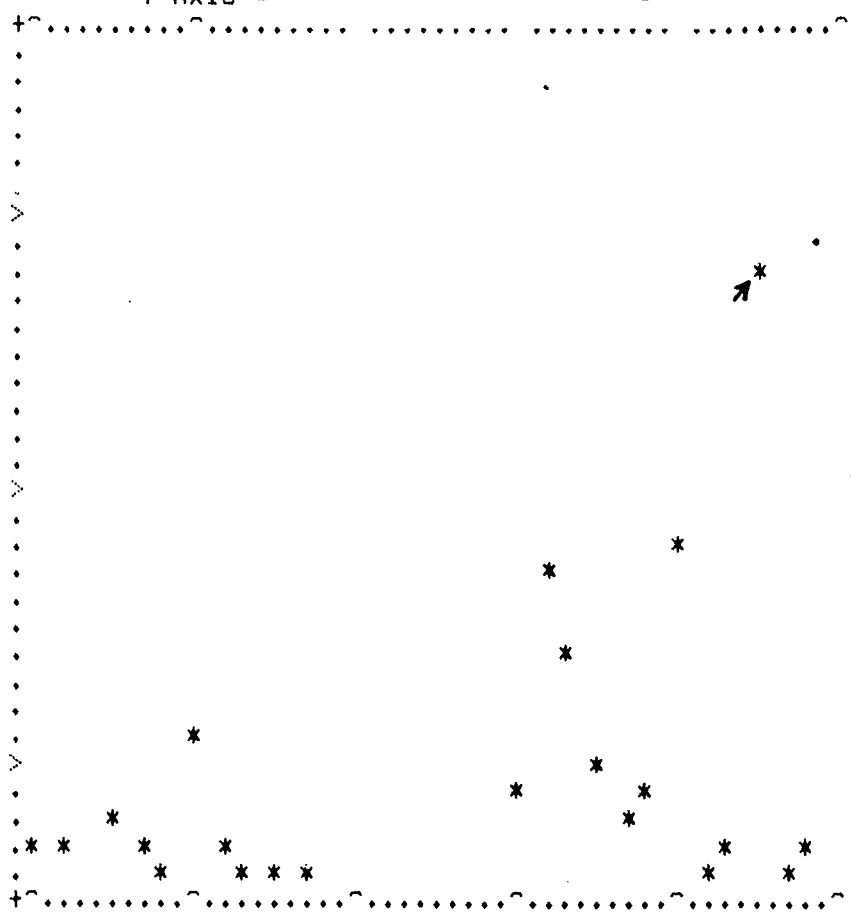


X AXIS:	1-ST TICK =	702.0	/INCREMENT	=	6.000
DATA:	MINIMUM =	702.0	/MAXIMUM	=	731.0
Y AXIS:	1-ST TICK =	25.00	/INCREMENT	=	25.00
DATA:	MINIMUM =	20.00	/MAXIMUM	=	88.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 7 serial number
Y-AXIS = TOTAL NITRITE + NITRATE



```
X AXIS: 1-ST TICK =    702.0   /INCREMENT =   6.000
  DATA: MINIMUM   =    702.0   /MAXIMUM   =   731.0
Y AXIS: 1-ST TICK =    40.00   /INCREMENT =   40.00
  DATA: MINIMUM   =    23.00   /MAXIMUM   =   110.0
```

NEXT?

4.
The July 8 Observations

Statistically significant increases from above to below

Variable	Above Mean	Below Mean	
Organic Carbon	12.92	16.00	MG/L
Total Iron	416.2	840.0	UG/L
Dissolved Manganese	11.54	25.38	UG/L
Suspended Manganese	117.7	136.9	UG/L
Suspended Solids	14.85	33.85	MG/L
Total Residue	323.3	347.4	MG/L
Dissolved Nitrite + Nitrate	.54	.84	MG/L

Statistically significant decreases from above to below

Variable	Above Mean	Below Mean	
Dissolved Ortho Phosphorus	.365	.345	MG/L
Total Ortho Phosphorus	.389	.365	MG/L

Examination of the data files for July 8 reveals that the suspended Manganese reading for sample 820 and the dissolved nitrite + nitrate reading for sample 828 are spurious or outliers. They were thus disregarded in the analysis and are flaged in the scatter plots for July 8.

Particular attention is directed to both the July 7 and the July 8 scatter plots for dissolved ortho-phosphorus and total phosphorus. On July 7, a striking upward trend in readings is evident at both the above and the below transects. Again, on July 8 and equally striking downward trend is evident at both the above and below transects. It is clear that the overall quality of the water body passing down the river was fluctuating to an extent which is noticeable in the data. In regard to phosphorus this fluctuation is considerably greater than the effect of dredging.

Section 5 of this transect analysis considers this issue in detail.

Those variables which showed statistically significant increases on both study days are: Organic Carbon, Total Iron, Suspended Manganese, Suspended Solids, and Total Residue.

July 8 Transect A Means

SAMPLE SER L NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residues	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
800	09	27	28	2	060	06	10	01	13	80	39	42	282	010	314	515	15	09	09	10	24	026
801	14	27	35	1	033	03	09	01	11	79	41	44	274	004	324	525	00	09	08	10	21	023
802	13	28	35	2	033	03	10	01	11	79	39	43	280	010	324	510	01	10	08	12	21	022
803	13	26	34	1	046	00	07	01	12	79	38	39	279	013	325	520	02	09	08	11	22	023
804	13	28	39	1	038	05	04	01	11	79	36	41	280	010	321	525	01	09	07	10	21	021
805	16	27	34	1	031	05	02	01	11	79	38	40	270	012	327	520	01	12	06	13	23	036
806	13	26	26	0	036	05	02	01	11	80	40	41	270	010	317	525	02	12	00	13	21	099
807	14	27	33	0	034	01	06	01	11	81	37	38	265	013	323	515	00	11	09	13	21	043
808	12	26	32	0	031	03	04	01	11	80	35	37	268	014	320	505	01	11	07	12	22	028
809	13	25	36	0	038	03	05	01	11	81	32	38	264	015	315	505	01	11	08	11	21	046
810	13	26	33	0	041	05	00	01	13	81	35	35	265	023	325	495	01	12	09	16	22	031
812	13	26	41	2	079	02	08	02	15	81	31	34	270	037	344	500	00	09	12	12	24	140
813	12	26	38	1	041	04	00	02	12	81	33	33	273	022	324	495	00	10	12	12	22	170

VARIABLE	N	MEAN	VARIANCE	ST.DEV.	MIN	MAX
V1	13	806.2	17.14	4.140	800.0	813.0
V2	13	12.92	2.410	1.553	9.000	16.00
V3	13	26.54	.7692	.8771	25.00	28.00
V4	13	34.15	16.81	4.100	26.00	41.00
V5	13	.8462	.6410	.8006	0	2.000
V6	13	41.62	187.1	13.68	31.00	79.00
V7	13	3.462	3.103	1.761	0	6.000
V8	13	5.154	12.47	3.532	0	10.00
V9	13	1.154	.1410	.3755	1.000	2.000
V10	13	11.77	1.526	1.235	11.00	15.00
V11	13	80.00	.8333	.9129	79.00	81.00
V12	13	36.46	9.769	3.126	31.00	41.00
V13	13	38.85	11.81	3.436	33.00	44.00
V14	13	272.3	39.23	6.263	264.0	282.0
V15	13	14.85	69.64	8.345	4.000	37.00
V16	13	323.3	55.06	7.421	314.0	344.0
V17	13	511.9	123.1	11.09	495.0	525.0
V18	13	1.923	15.91	3.989	0	15.00
V19	13	10.31	1.564	1.251	9.000	12.00
V20	13	7.923	8.744	2.957	0	12.00
V21	13	11.92	2.744	1.656	10.00	16.00
V22	13	21.92	1.244	1.115	21.00	24.00
V23	13	54.46	2451.	49.50	21.00	170.0

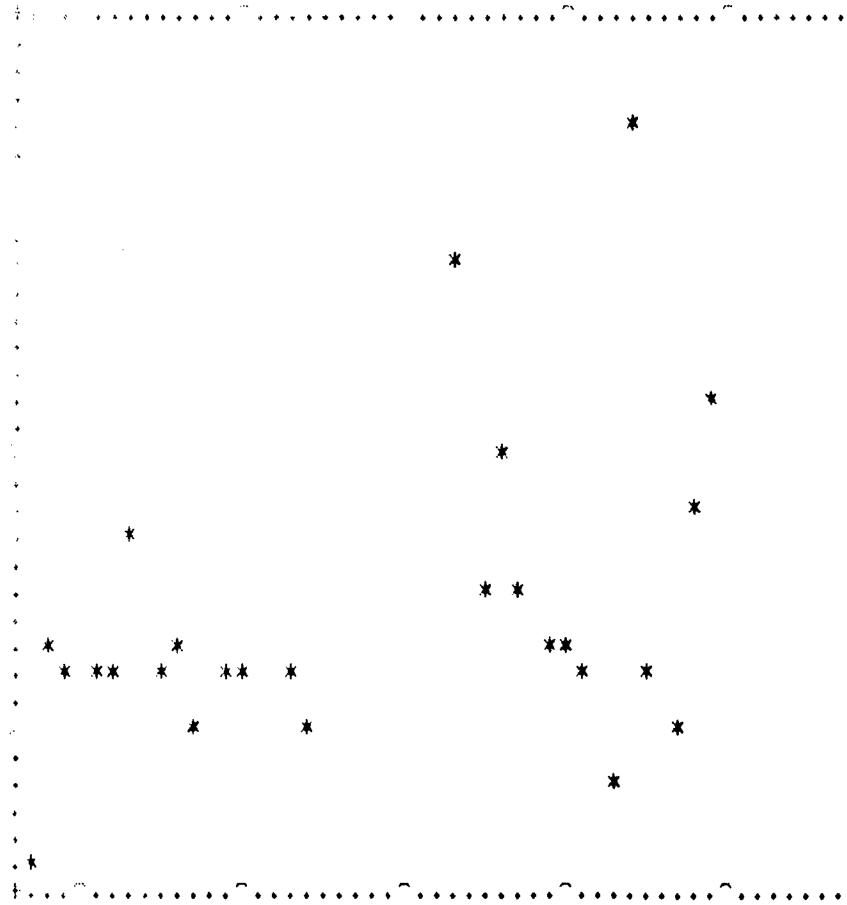
July 8 Transect B Means

SAMPLE SERIAL NUMBER	ORGANIC CARBON	DISSOLVED CHLORIDE	CHEMICAL OXYGEN DEMAND	DISSOLVED IRON x 1/10	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	Ph x 10	DISSOLVED ORTHO PHOSPHORUS x 100	TOTAL PHOSPHORUS x 100	dissolved solids residues	suspended solids	total residue	conductance	SUSPENDED ZINC x 1/10	DISSOLVED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	Dissolved Nitrite + Nitrate x 100	TOTAL NITRITE + NITRATE x 100
20	22	24	49	1	220	04	08	03	26	79	27	29	293	080	381	520	04	07	09	16	22	029
21	15	27	31	2	033	03	04	01	11	79	40	40	300	006	322	525	01	10	04	11	21	022
22	18	28	25	1	045	02	03	01	12	80	33	38	274	016	333	520	02	11	08	12	22	051
23	15	26	34	1	045	07	06	01	11	79	38	40	2[illegible]7	015	331	525	01	10	00	00	23	068
24	14	27	34	0	066	03	06	02	13	80	37	38	270	025	339	530	01	11	10	13	21	060
25	14	28	32	1	065	04	03	01	13	81	37	39	273	027	343	535	01	11	08	14	22	036
26	13	27	38	0	086	02	12	03	14	81	37	37	266	053	373	525	00	11	07	13	22	042
27	11	28	39	0	083	03	05	02	13	81	36	42	275	032	367	515	02	10	20	25	20	200
28	25	28	34	0	056	04	01	03	12	82	35	38	281	025	337	520	00	14	10	10	67	120
29	13	27	39	0	081	05	05	03	14	81	35	36	275	034	344	505	02	09	02	06	20	140
30	12	27	34	1	053	04	00	03	11	81	33	33	273	030	326	505	01	10	09	09	20	170
31	17	26	34	0	089	02	05	04	11	81	32	32	265	025	334	495	07	07	00	01	21	098
32	19	23	45	1	170	03	10	06	17	80	30	33	267	072	386	510	03	10	08	13	22	056

VARIABLE	N	MEAN	VARIANCE	ST.DEV.	MIN	MAX
V1	13	826.0	15.17	3.894	820.0	832.0
V2	13	16.00	16.67	4.082	11.00	25.00
V3	13	26.62	2.423	1.557	23.00	28.00
V4	13	36.00	37.83	6.151	25.00	49.00
V5	13	.6154	.4231	.6504	0	2.000
V6	13	84.00	2834.	53.23	33.00	220.0
V7	13	3.538	1.936	1.391	2.000	7.000
V8	13	5.231	11.19	3.345	0	12.00
V9	13	2.538	2.103	1.450	1.000	6.000
V10	13	13.69	16.56	4.070	11.00	26.00
V11	13	80.38	.9231	.9608	79.00	82.00
V12	13	34.62	12.59	3.548	27.00	40.00
V13	13	36.54	14.10	3.755	29.00	42.00
V14	13	275.3	110.6	10.51	265.0	300.0
V15	13	33.85	475.1	21.80	6.000	80.00
V16	13	347.4	468.9	21.65	322.0	386.0
V17	13	517.7	127.6	11.29	495.0	535.0
V18	13	1.923	3.577	1.891	0	7.000
V19	13	10.08	3.244	1.801	7.000	14.00
V20	13	7.308	27.40	5.234	0	20.00
V21	13	11.00	41.17	6.416	0	25.00
V22	13	24.85	161.3	12.70	20.00	67.00
V23	13	84.00	3260.	57.10	22.00	200.0

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = ORGANIC CARBON

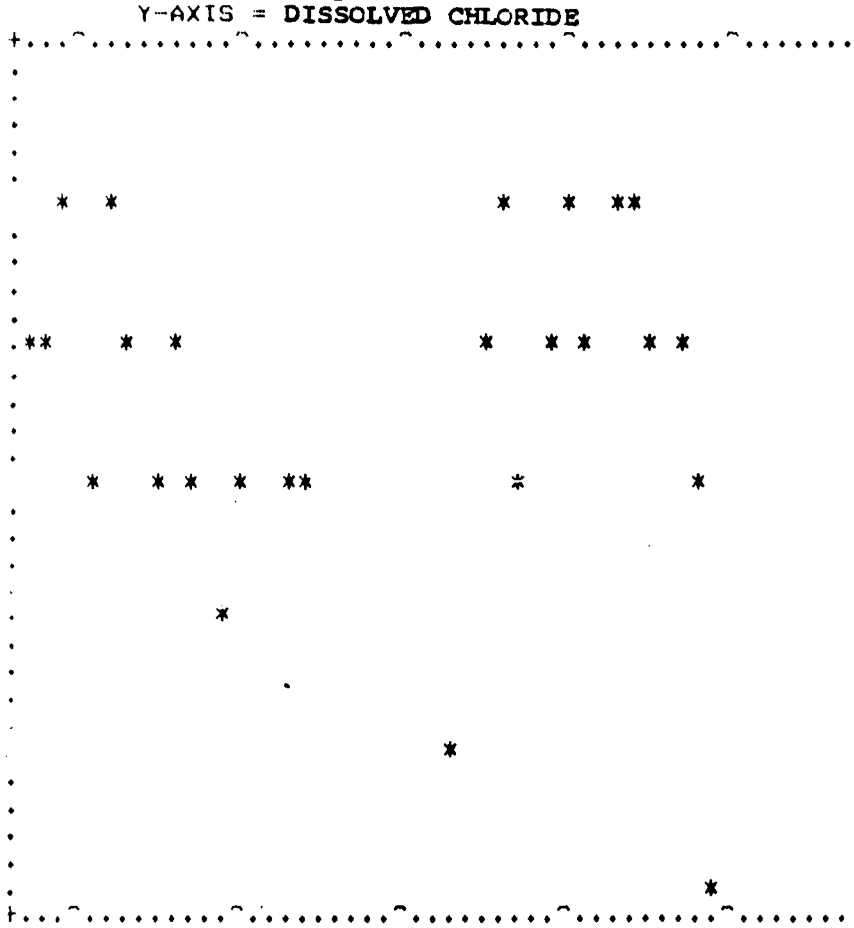


```
X AXIS: 1-ST TICK =    802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =    800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =    12.00    /INCREMENT =     6.000
  DATA: MINIMUM   =    9.000    /MAXIMUM   =     25.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **DISSOLVED CHLORIDE**

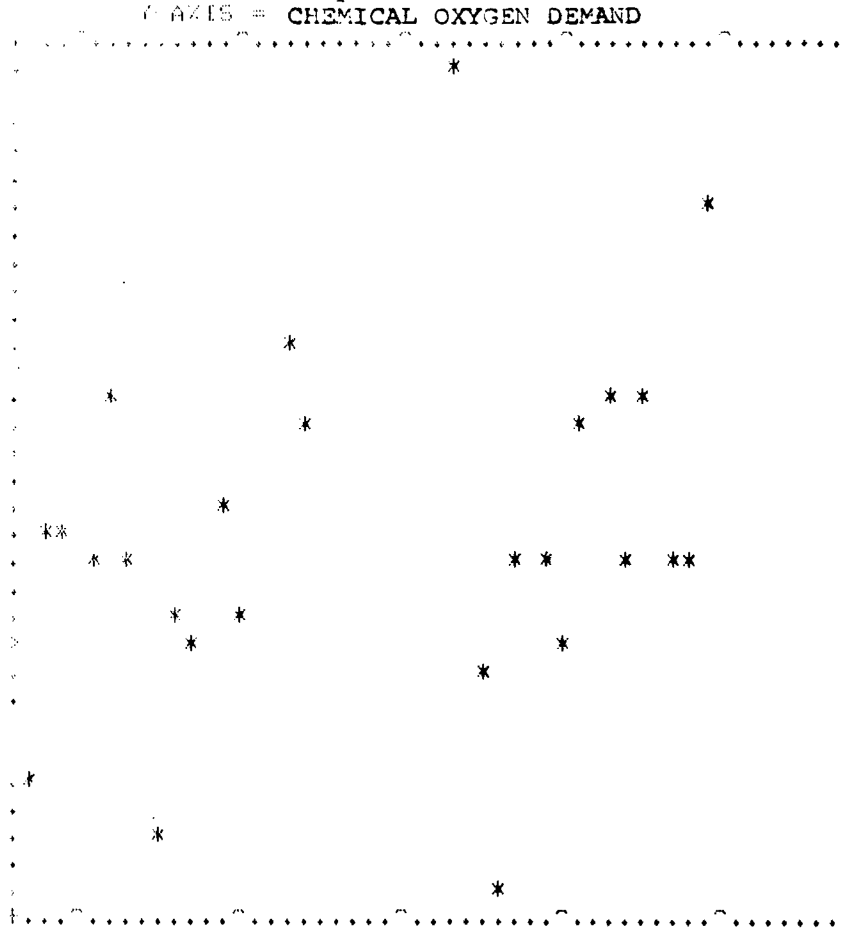


```
X AXIS: 1-ST TICK =     802.5     /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0     /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     24.00     /INCREMENT =     2.000
  DATA: MINIMUM   =     23.00     /MAXIMUM   =     28.00
```

NEXT?

SCPLOT

SCPLOT: X AXIS = July 8 serial number
Y AXIS = CHEMICAL OXYGEN DEMAND

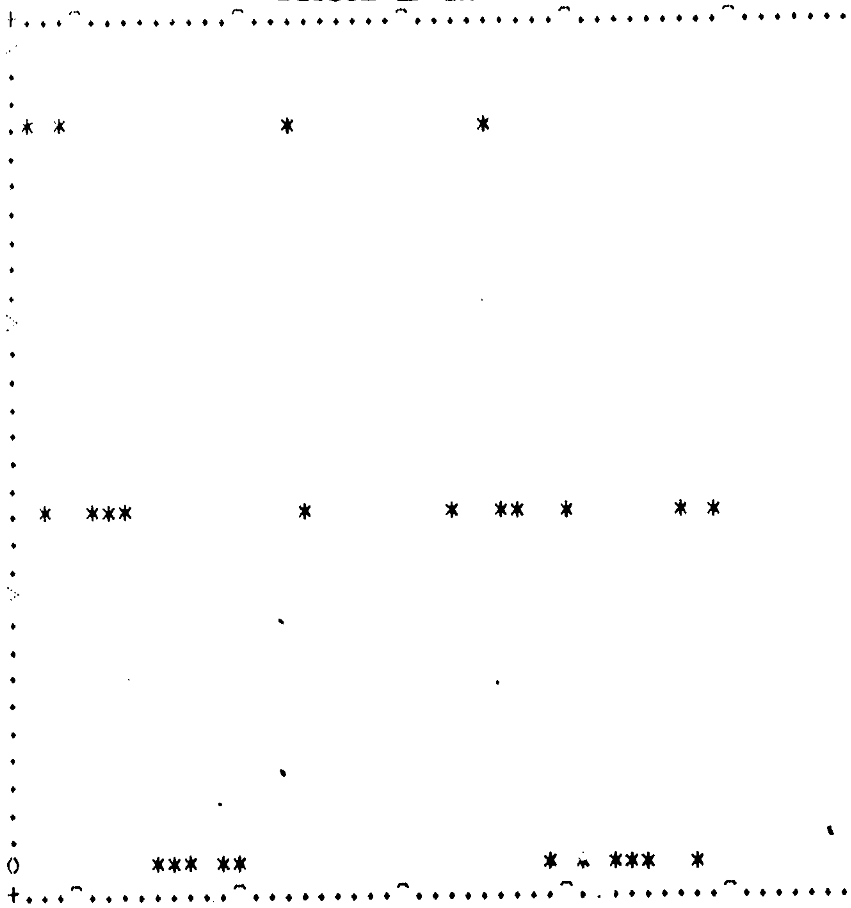


```
X AXIS: 1-ST TICK =    802.5   /INCREMENT =    7.500
  DATA: MINIMUM   =    800.0   /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =    32.00   /INCREMENT =    8.000
  DATA: MINIMUM   =    25.00   /MAXIMUM   =    49.00
```

NEXT?

SCPLOT

```
SCPLOT: X-AXIS = July 8 serial number
        Y-AXIS = DISSOLVED IRON
```

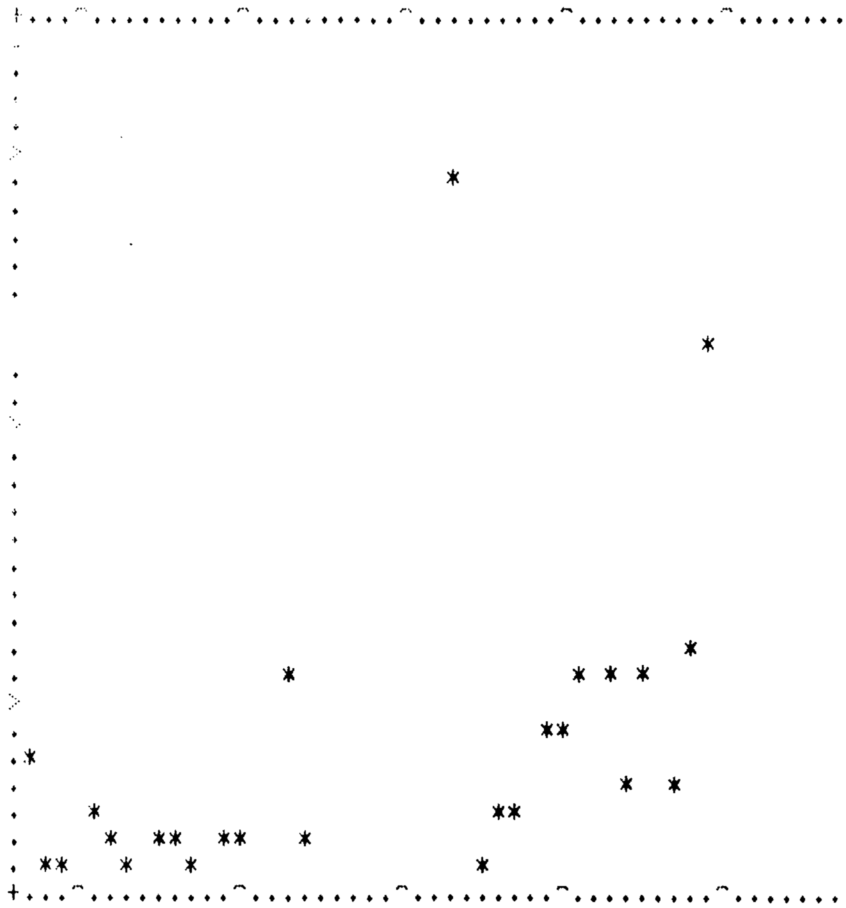



```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     .7500
  DATA: MINIMUM   =             0/MAXIMUM   =     2.000

     NEXT?
```

SCPLOT

SCPLOT: X-AXIS = July8 serial number
Y-AXIS = TOTAL IRON

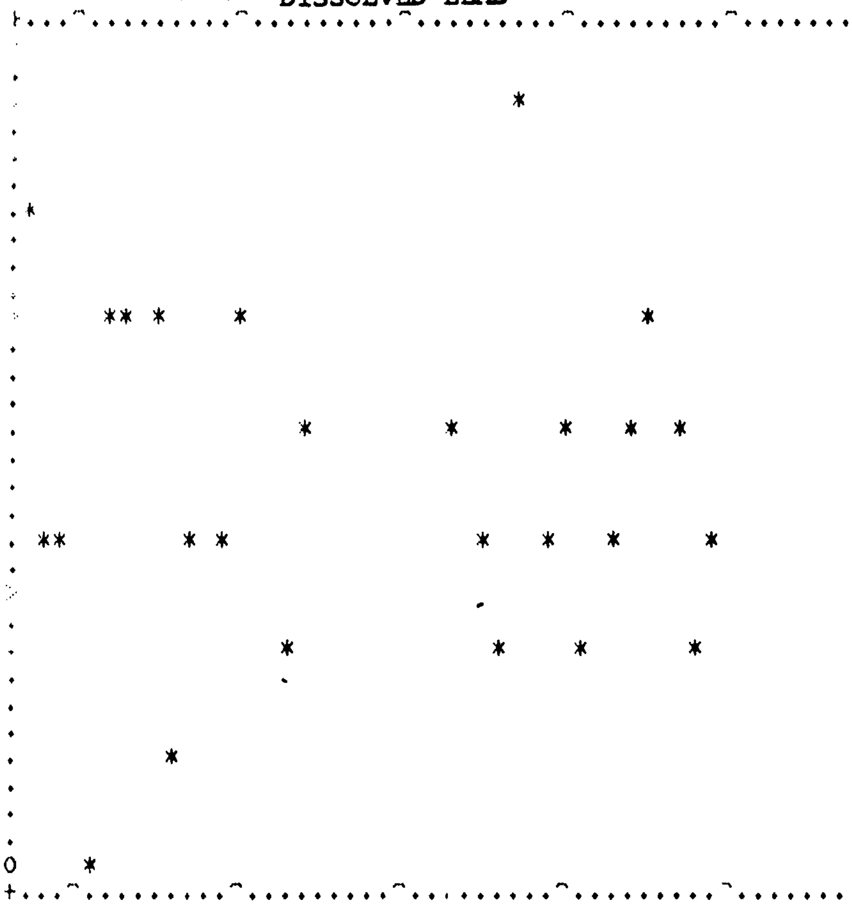


```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     75.00    /INCREMENT =     75.00
  DATA: MINIMUM   =     31.00    /MAXIMUM   =     220.0
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y-AXIS = DISSOLVED LEAD

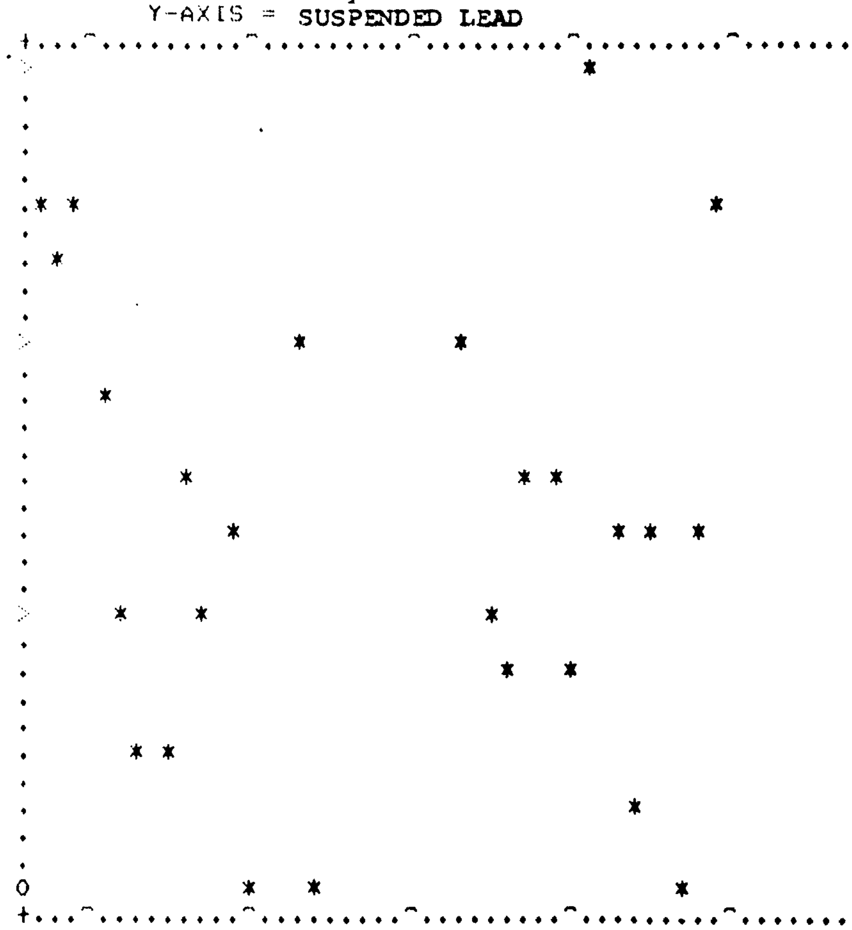



```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     2.500
  DATA: MINIMUM   =             0/MAXIMUM   =     7.000
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y-AXIS = SUSPENDED LEAD



```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =    7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    4.000
  DATA: MINIMUM   =             0/MAXIMUM   =    12.00
```

NEXT?

SCPLOT

```
SCPLOT: X-AXIS = July 8 serial number
        Y-AXIS = DISSOLVED MANGANESE
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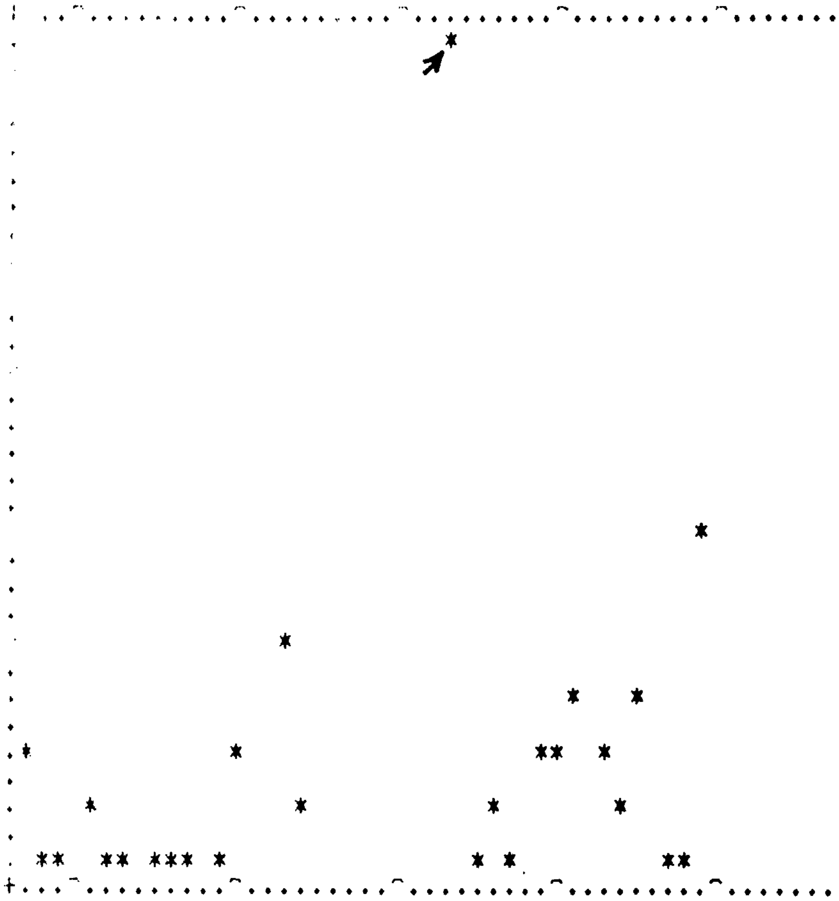
X AXIS: 1-ST TICK =     802.5     /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0     /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     2.000     /INCREMENT =     2.000
  DATA: MINIMUM   =     1.000     /MAXIMUM   =     6.000

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y AXIS = SUSPENDED MANGANESE

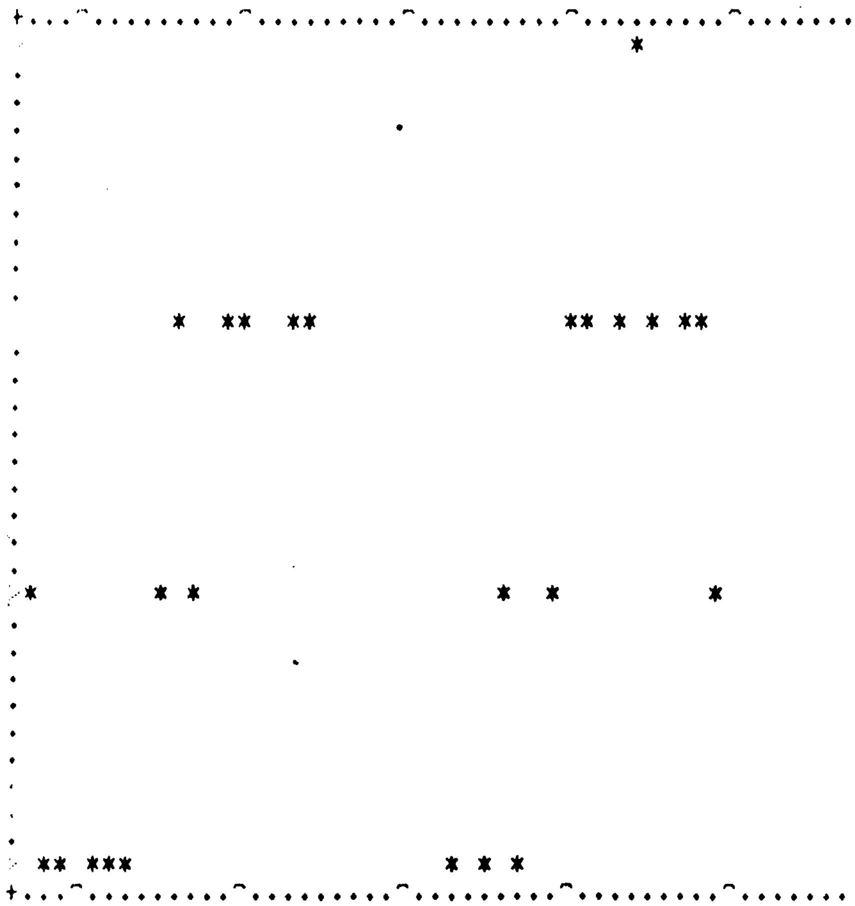


X AXIS: 1-ST TICK	=	802.5	/INCREMENT	=	7.500
DATA: MINIMUM	=	800.0	/MAXIMUM	=	832.0
Y AXIS: 1-ST TICK	=	15.00	/INCREMENT	=	5.000
DATA: MINIMUM	=	11.00	/MAXIMUM	=	26.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **Ph**

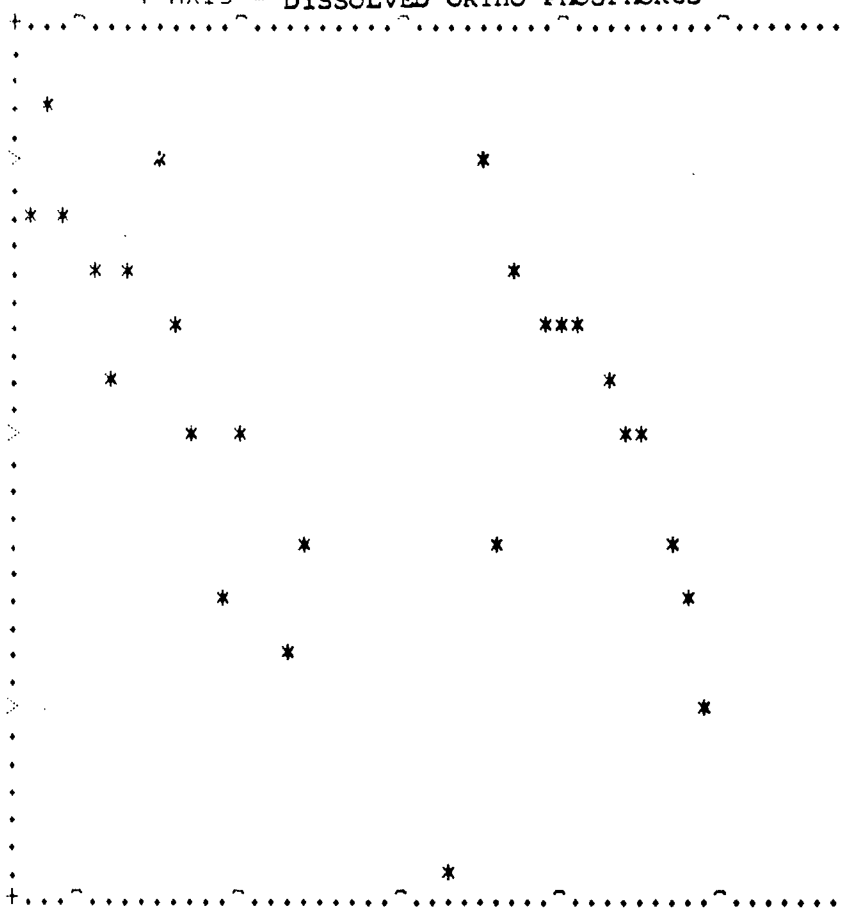


X AXIS: 1-ST TICK	= 802.5	/INCREMENT	=	7.500
DATA: MINIMUM	= 800.0	/MAXIMUM	=	832.0
Y AXIS: 1-ST TICK	= 79.00	/INCREMENT	=	1.000
DATA: MINIMUM	= 79.00	/MAXIMUM	=	82.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y-AXIS = DISSOLVED ORTHO PHOSPHORUS

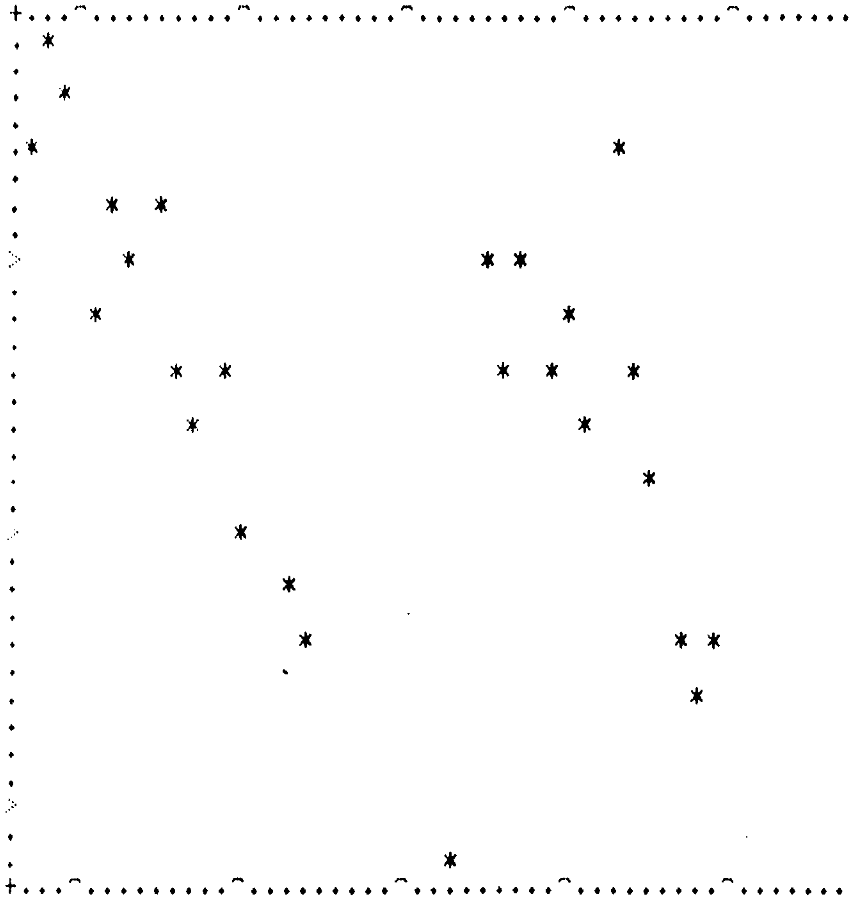


X AXIS: 1-ST TICK	=	802.5	/INCREMENT =	7.500
DATA: MINIMUM	=	800.0	/MAXIMUM =	832.0
Y AXIS: 1-ST TICK	=	30.00	/INCREMENT =	5.000
DATA: MINIMUM	=	27.00	/MAXIMUM =	41.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **TOTAL PHOSPHORUS**

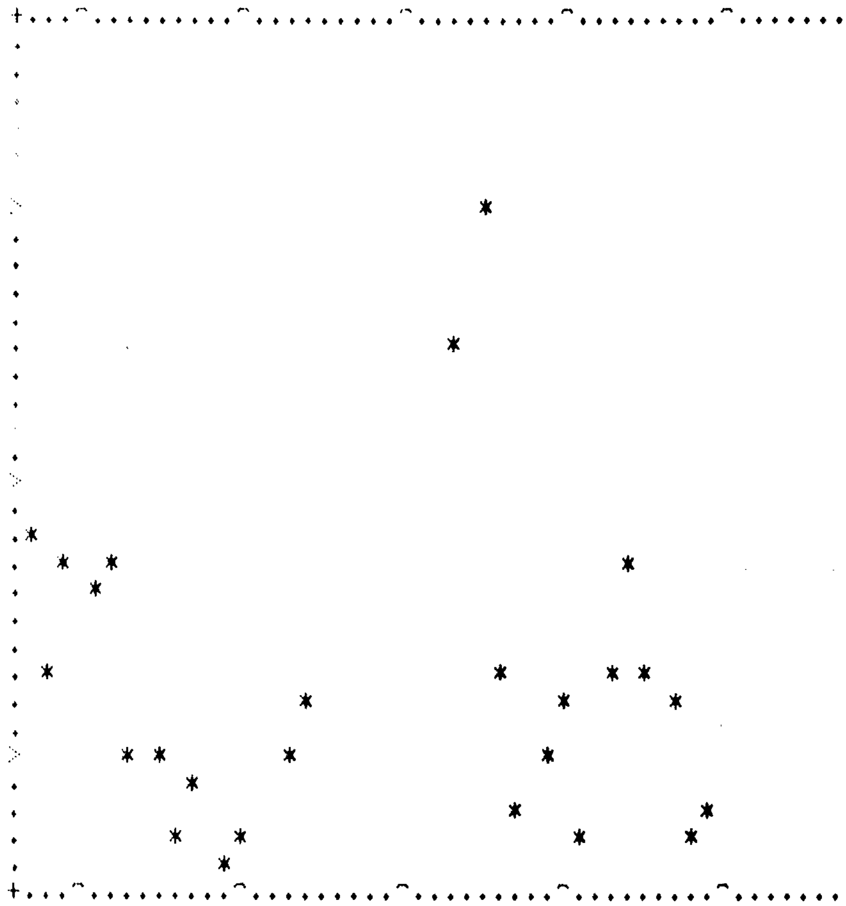


```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     30.00    /INCREMENT =     5.000
  DATA: MINIMUM   =     29.00    /MAXIMUM   =     44.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **dissolved solids residues**

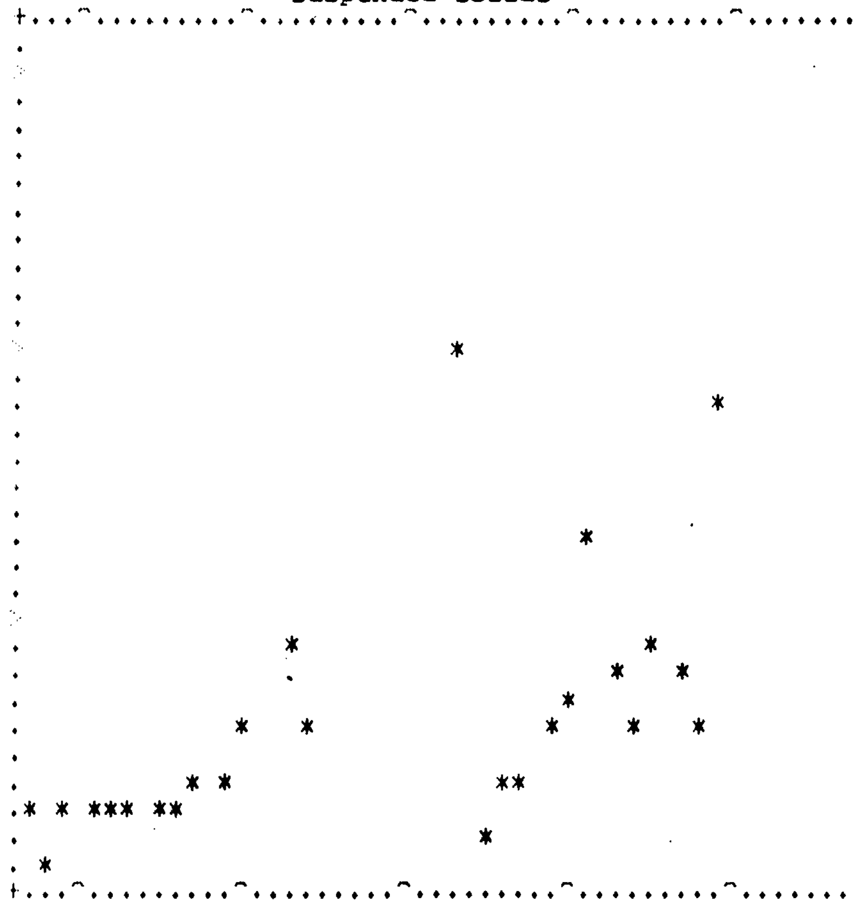


```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     270.0    /INCREMENT =     15.00
  DATA: MINIMUM   =     264.0    /MAXIMUM   =     300.0
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **suspended solids**

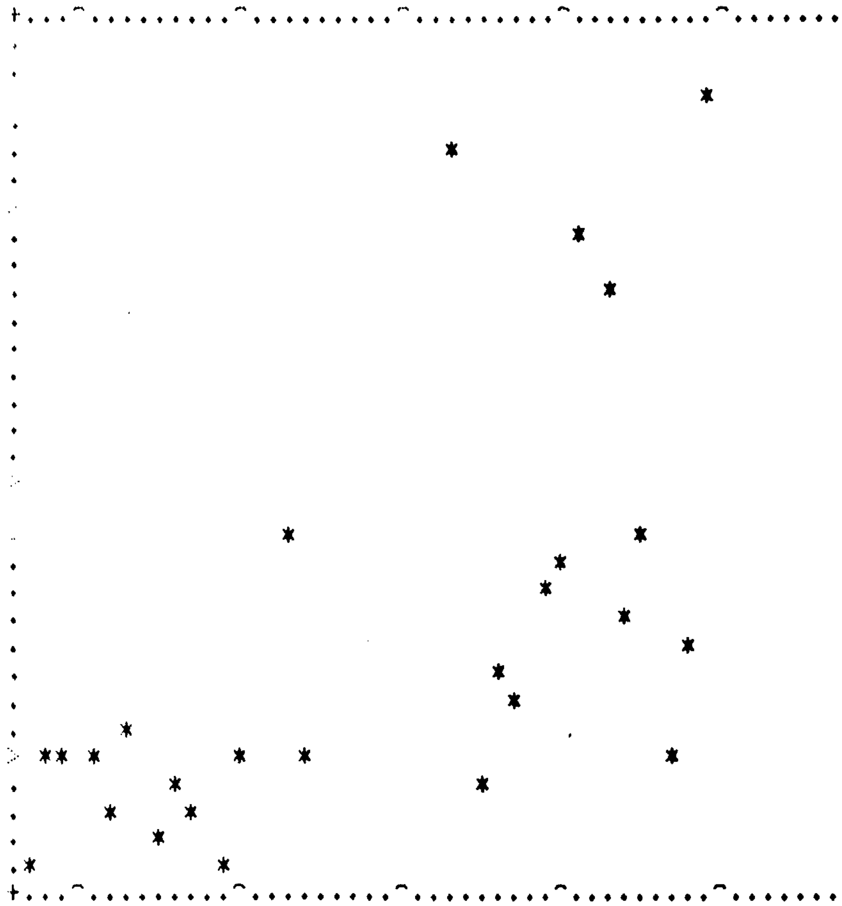


X AXIS:	1-ST TICK =	802.5	/INCREMENT	=	7.500
DATA:	MINIMUM =	800.0	/MAXIMUM	=	832.0
Y AXIS:	1-ST TICK =	40.00	/INCREMENT	=	40.00
DATA:	MINIMUM =	4.000	/MAXIMUM	=	80.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **total residue**

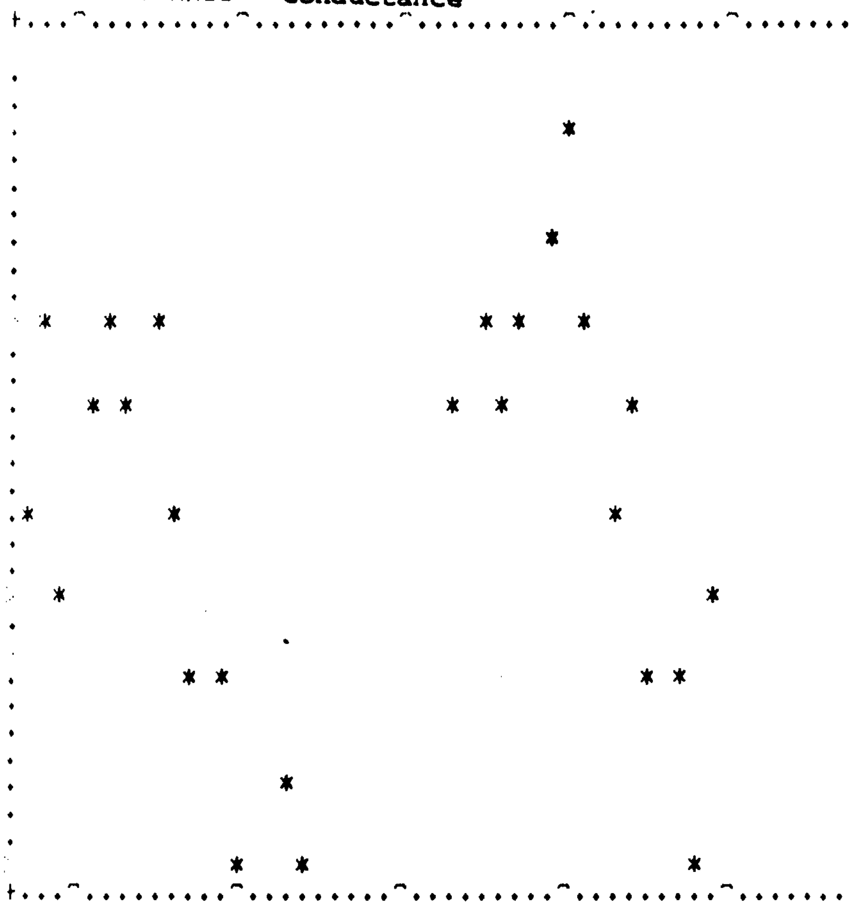


```
X AXIS: 1-ST TICK =     802.5     /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0     /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     325.0     /INCREMENT =     25.00
  DATA: MINIMUM   =     314.0     /MAXIMUM   =     386.0
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **conductance**

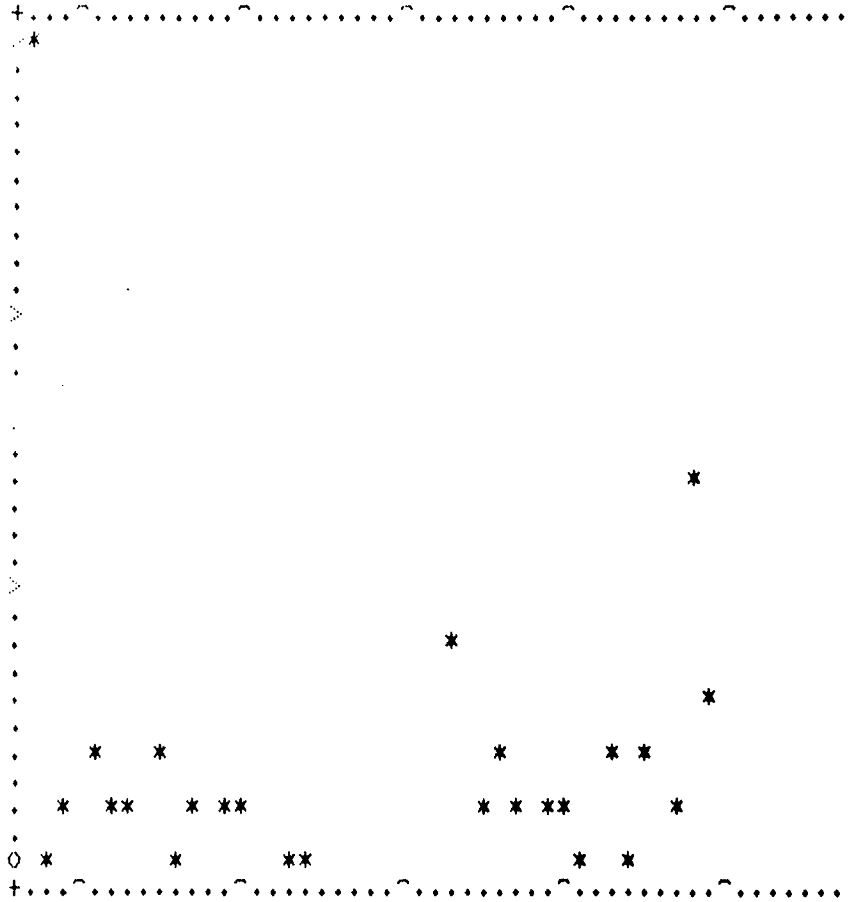


```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     495.0    /INCREMENT =     15.00
  DATA: MINIMUM   =     495.0    /MAXIMUM   =     535.0
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = SUSPENDED ZINC

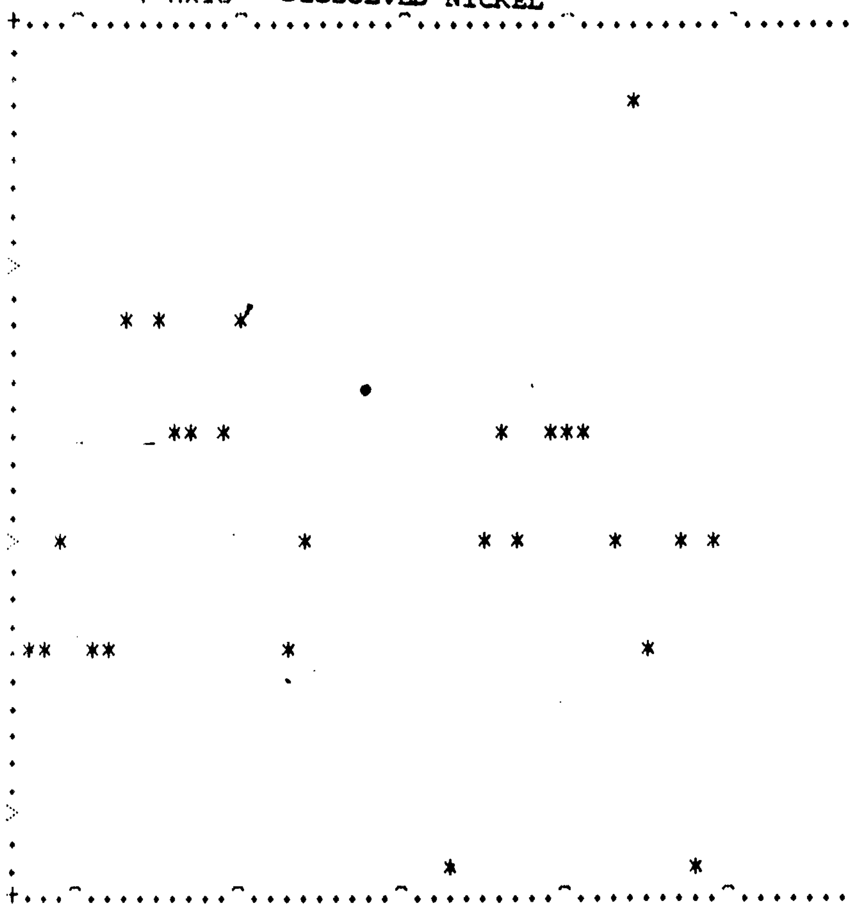


```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =    7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    5.000
  DATA: MINIMUM   =             0/MAXIMUM   =    15.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **DISSOLVED NICKEL**

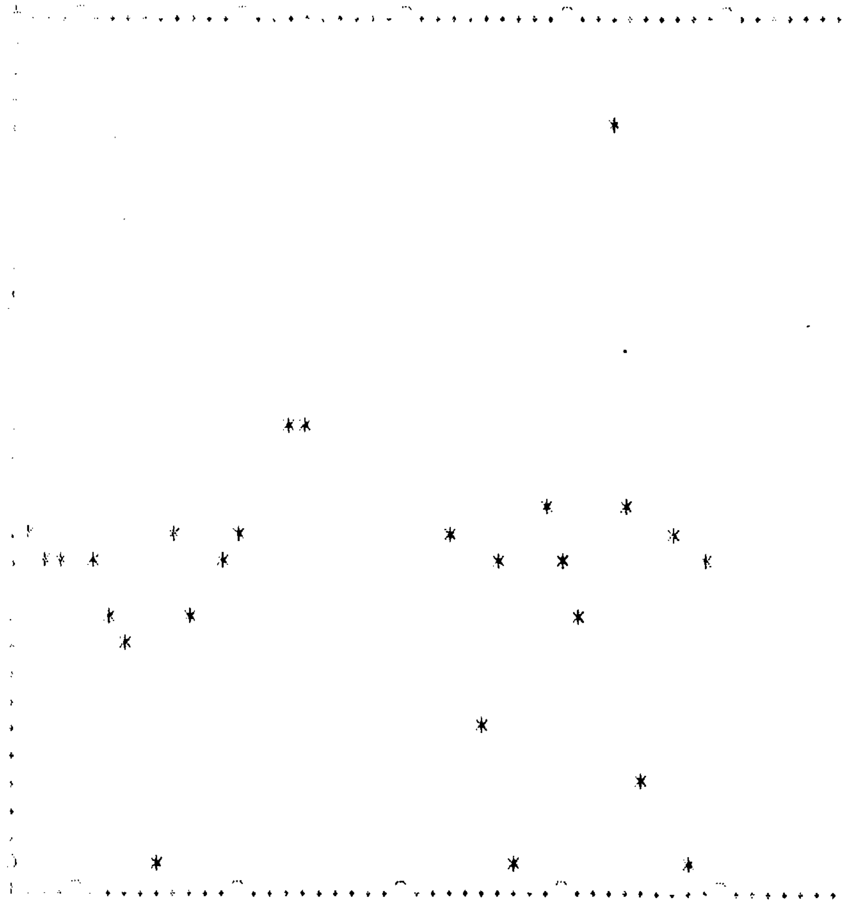


```
X AXIS: 1-ST TICK =    802.5    /INCREMENT =    7.500
  DATA: MINIMUM   =    800.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =    7.500    /INCREMENT =    2.500
  DATA: MINIMUM   =    7.000    /MAXIMUM   =    14.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y-AXIS = DISSOLVED ORGANIC NITROGEN

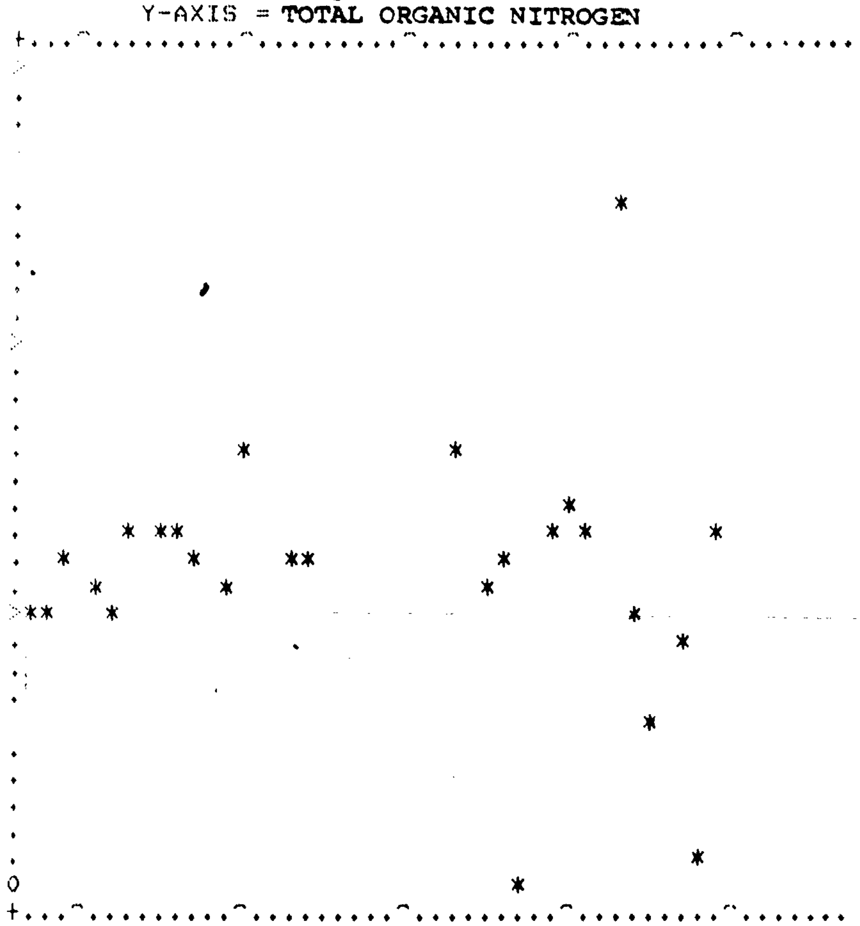


X AXIS: 1-ST TICK = 802.5 /INCREMENT = 7.500
DATA: MINIMUM = 800.0 /MAXIMUM = 832.0
Y AXIS: 1-ST TICK = 0/INCREMENT = 7.500
DATA: MINIMUM = 0/MAXIMUM = 20.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **TOTAL ORGANIC NITROGEN**

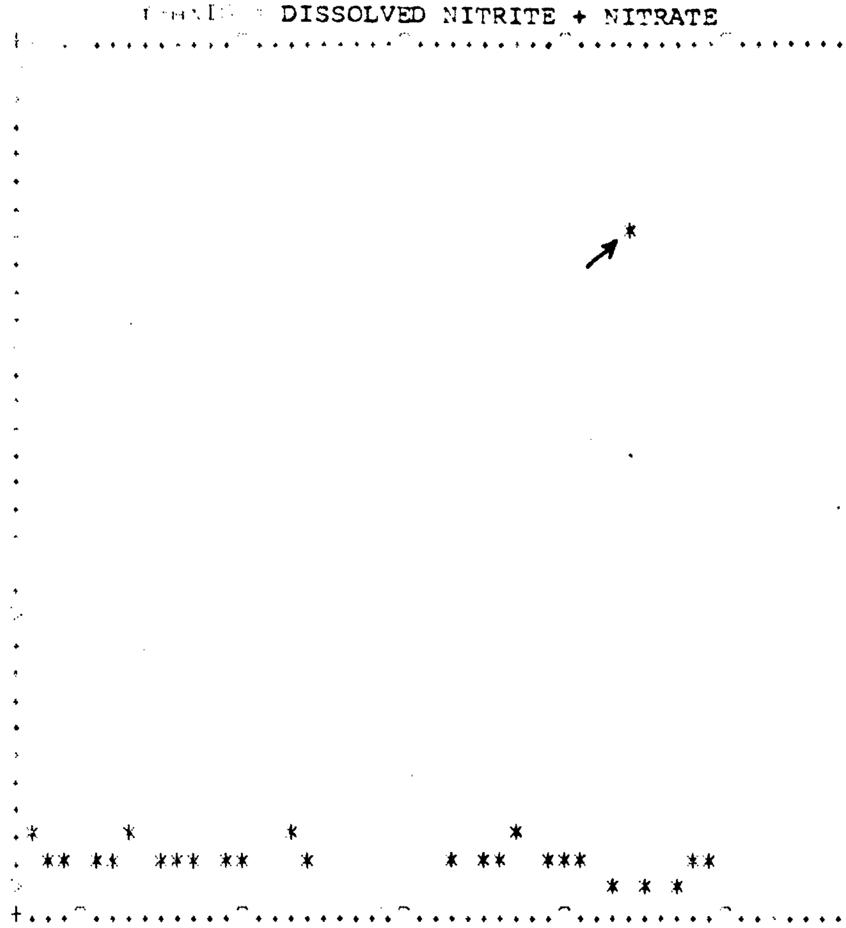


X AXIS: 1-ST TICK = 802.5 /INCREMENT = 7.500
DATA: MINIMUM = 800.0 /MAXIMUM = 832.0
Y AXIS: 1-ST TICK = 0/INCREMENT = 10.00
DATA: MINIMUM = 0/MAXIMUM = 25.00

NEXT?

SCPLOT

SCPLOT: X-AXIS = July 8 serial number
Y-AXIS = DISSOLVED NITRITE + NITRATE

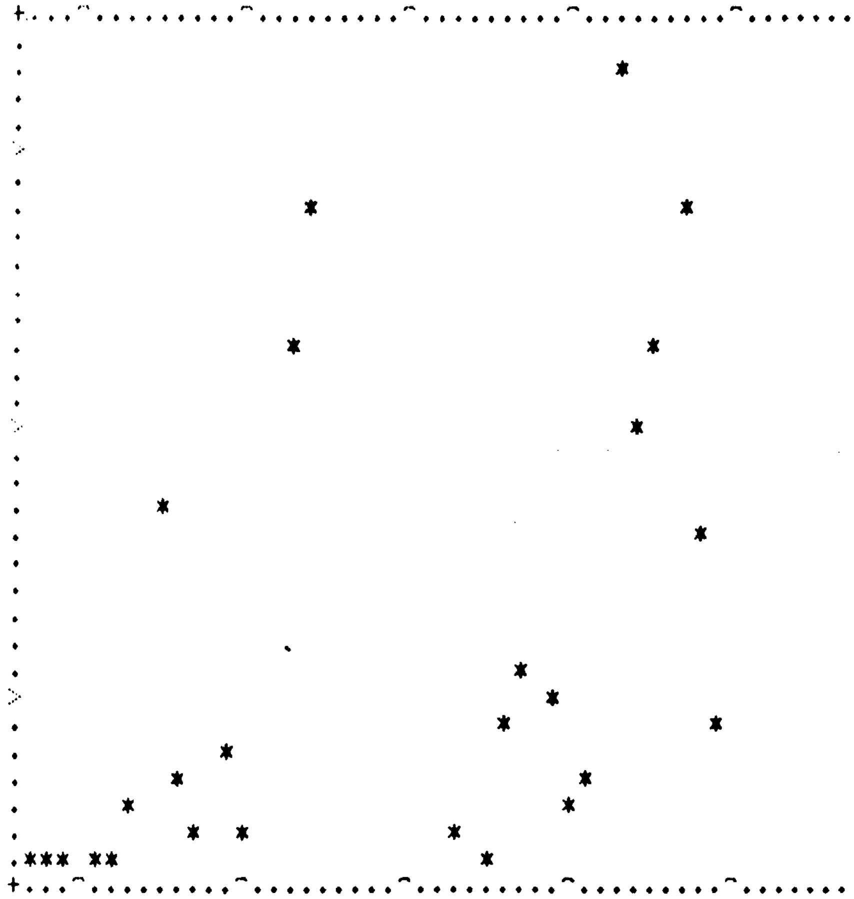


```
X AXIS: 1-ST TICK =     802.5     /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0     /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     20.00     /INCREMENT =     20.00
  DATA: MINIMUM   =     20.00     /MAXIMUM   =     67.00
```

NEXT?

SCPLOT

SCPLOT: X-AXIS = **July 8 serial number**
Y-AXIS = **TOTAL NITRITE + NITRATE**



```
X AXIS: 1-ST TICK =     802.5    /INCREMENT =     7.500
  DATA: MINIMUM   =     800.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     60.00    /INCREMENT =     60.00
  DATA: MINIMUM   =     21.00    /MAXIMUM   =     200.0
```

NEXT? EN

5.
Comparison of July 7 to July 8 transect observations

Data for each of the two days exhibits an overall level for each of the variables being studied at both transects. There are certain daily fluctuations in these variables and it may be assumed that this logic can be carried to hourly fluctuations, etc. However, the very low flows present made hourly flux difficult to observe except in the notable case of phosphorus. The question of daily differences in the variables is examined using the same statistical procedures employed for the comparison of the above to below differences of the separate days of the study. The results of this analysis are tabulated below.

Statistically significant increases from day 7 to day 8

Chemical Oxygen Demand
Suspended Lead
Dissolved Nickel
Total Nitrite + Nitrate
Dissolved Ortho Phosphorus
Total Phosphorus

Statistically significant decreases from day 7 to day 8

Total Iron
Dissolved Lead
Suspended Manganese
ph
Total residue
Suspended Zinc
Dissolved Nitrite + Nitrate

The following scatter plots present July 7 on the left and July 8 on the right by the serial sample numbering system, and constitute a merger of the two previous sets of scatter plots. The below transect data immediately follows the above transect data by a narrow space at the center of each daily batch.

The day to day variation in the phosphorus can be seen to be much larger than the above to below difference due to dredging. Examination of the phosphorus plots in this section clearly reveals that the level of phosphorus went up during the first day, peaked out over night, and began to recede the next day.

The day to day flux in suspended manganese was considerably larger than the statistically significant differences from above to below.

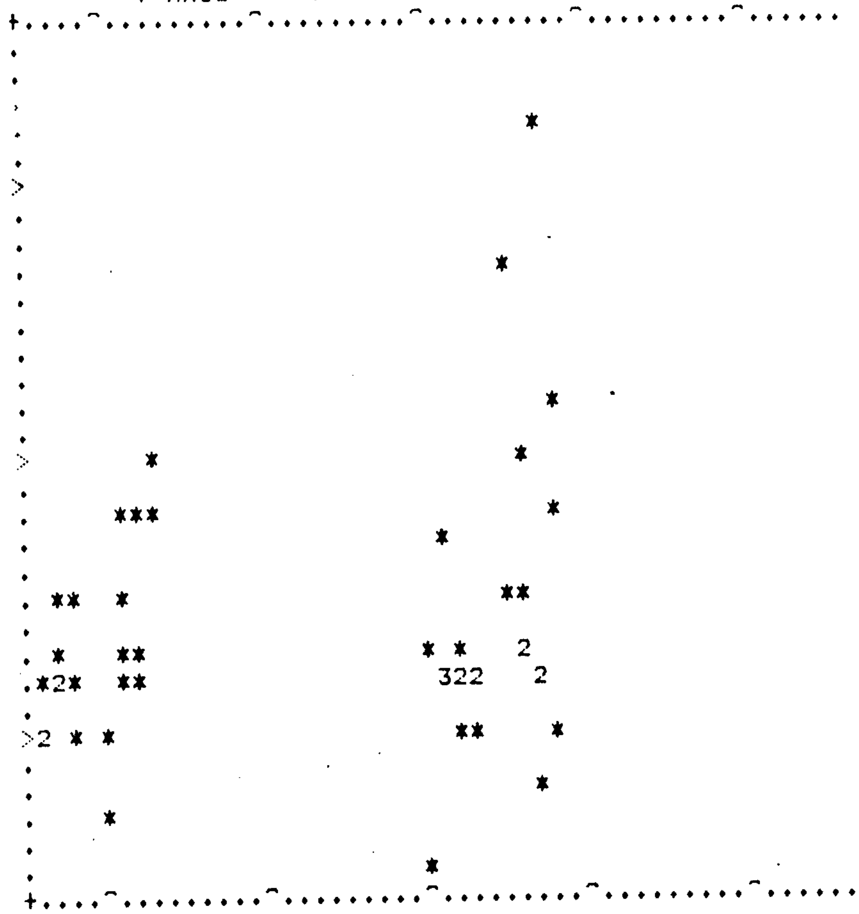
Organic carbon showed no fluctuation from day to day and was significantly higher on both days due to dredging.

The above to below differences in total iron were about the same size as the day to day fluctuation in total iron.

Suspended Solids and Total Residue were both significantly different from day 7 to day 8 but this difference was small compared to the above to below differences caused by dredging.

SCPLOT

SCPLOT: X-AXIS = sample serial number
Y-AXIS = organic carbon



```
X AXIS: 1-ST TICK =    720.0     /INCREMENT =     40.00
  DATA: MINIMUM   =    702.0     /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =    12.00     /INCREMENT =     6.000
  DATA: MINIMUM   =    9.000     /MAXIMUM   =     25.00
```

NEXT?

SCPLOT

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SCPLOT: X-AXIS =  sample serial number
        Y-AXIS =  dissolved chloride
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X AXIS: 1-ST TICK =    720.0    /INCREMENT =    40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =    22.00    /INCREMENT =    2.000
  DATA: MINIMUM   =    22.00    /MAXIMUM   =    28.00

      NEXT? SC
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          PLOT

SCPLOT: X-AXIS =  sample serial number
        Y-AXIS =  chemical oxygen demand
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     30.00    /INCREMENT =     10.00
  DATA: MINIMUM   =     24.00    /MAXIMUM   =     49.00

      NEXT?
```

SCPLOT

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SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved iron
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =    40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    1.000
  DATA: MINIMUM   =             0/MAXIMUM   =    3.000

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = sample serial number
Y-AXIS = total iron

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```

X AXIS: 1-ST TICK	=	720.0	/INCREMENT	=	40.00
DATA: MINIMUM	=	702.0	/MAXIMUM	=	832.0
Y AXIS: 1-ST TICK	=	75.00	/INCREMENT	=	75.00
DATA: MINIMUM	=	31.00	/MAXIMUM	=	220.0

NEXT?

SCPLOT

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SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved lead
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     4.000
  DATA: MINIMUM   =             0/MAXIMUM   =     11.00

      NEXT?
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            SCPLOT

SCPLOT: X-AXIS = sample serial number
        Y-AXIS = suspended lead
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     4.000
  DATA: MINIMUM   =             0/MAXIMUM   =     12.00

      NEXT?
```

SCPLOT

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SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved mamqanese
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X AXIS: 1-ST TICK =    720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =    2.000    /INCREMENT =     2.000
  DATA: MINIMUM   =    1.000    /MAXIMUM   =     6.000

    NEXT?
```

```
          SCPLOT

SCPLOT: X-AXIS = sample serial number
        Y-AXIS = suspended manganese
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     15.00    /INCREMENT =     5.000
  DATA: MINIMUM   =     11.00    /MAXIMUM   =     26.00

    NEXT?
```

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = Ph
+....^.........^.........^.........^.........^......
>2*3 *332                           *
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.*3   *                    23   *32
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     76.00    /INCREMENT =     2.000
  DATA: MINIMUM   =     76.00    /MAXIMUM   =     82.00

     NEXT?
```
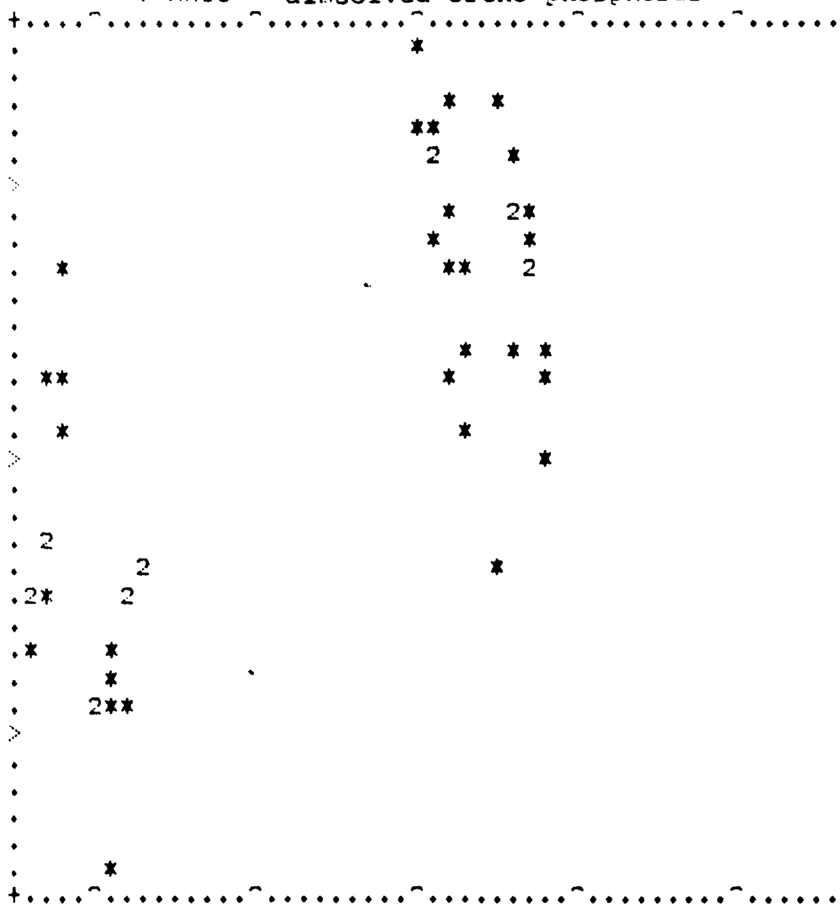
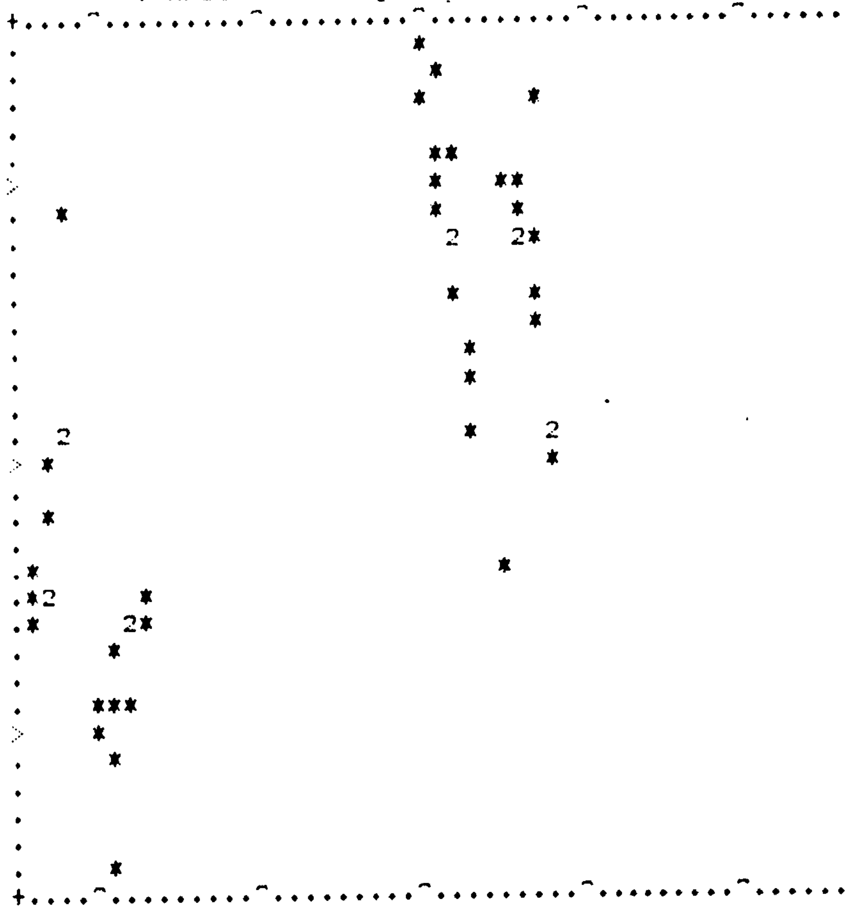

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved ortho phosphorus
```



```
X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     22.50    /INCREMENT =     7.500
  DATA: MINIMUM   =     19.00    /MAXIMUM   =     41.00

      NEXT? SCPLOT 14 VS 2
*INTERRU
```

SCPLOT: X-AXIS = sample serial number
Y-AXIS = total phosphorus



X AXIS:	1-ST TICK =	720.0	/INCREMENT =	40.00
DATA:	MINIMUM =	702.0	/MAXIMUM =	832.0
Y AXIS:	1-ST TICK =	24.00	/INCREMENT =	8.000
DATA:	MINIMUM =	20.00	/MAXIMUM =	44.00

NEXT?

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            SCPLOT

SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved solids residues
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X AXIS: 1-ST TICK =    720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =    260.0    /INCREMENT =     20.00
  DATA: MINIMUM   =    256.0    /MAXIMUM   =     303.0

      NEXT?
```

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = suspended solids
+....^.........^.........^.........^.........^......
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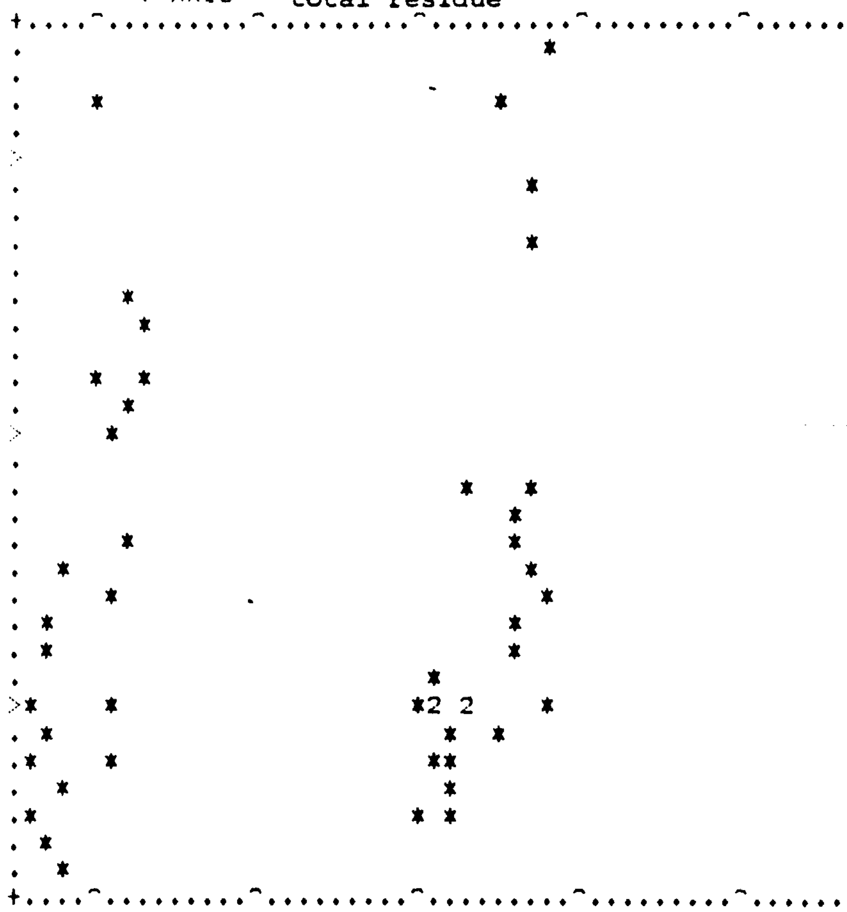
X AXIS: 1-ST TICK =    720.0    /INCREMENT =    40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =    40.00    /INCREMENT =    40.00
  DATA: MINIMUM   =    4.000    /MAXIMUM   =    80.00

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = sample serial number
        Y-AXIS = total residue



```
X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     325.0    /INCREMENT =     25.00
  DATA: MINIMUM   =     311.0    /MAXIMUM   =     386.0
```

NEXT?

SCPLOT

```
SCPLOT: X-AXIS =  sample serial number
        Y-AXIS =  conductance
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     495.0    /INCREMENT =     15.00
  DATA: MINIMUM   =     495.0    /MAXIMUM   =     535.0

      NEXT?
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            SCPLOT

SCPLOT: X-AXIS = samole serial number
        Y-AXIS = suspended zinc
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. 2                       32* *3 *
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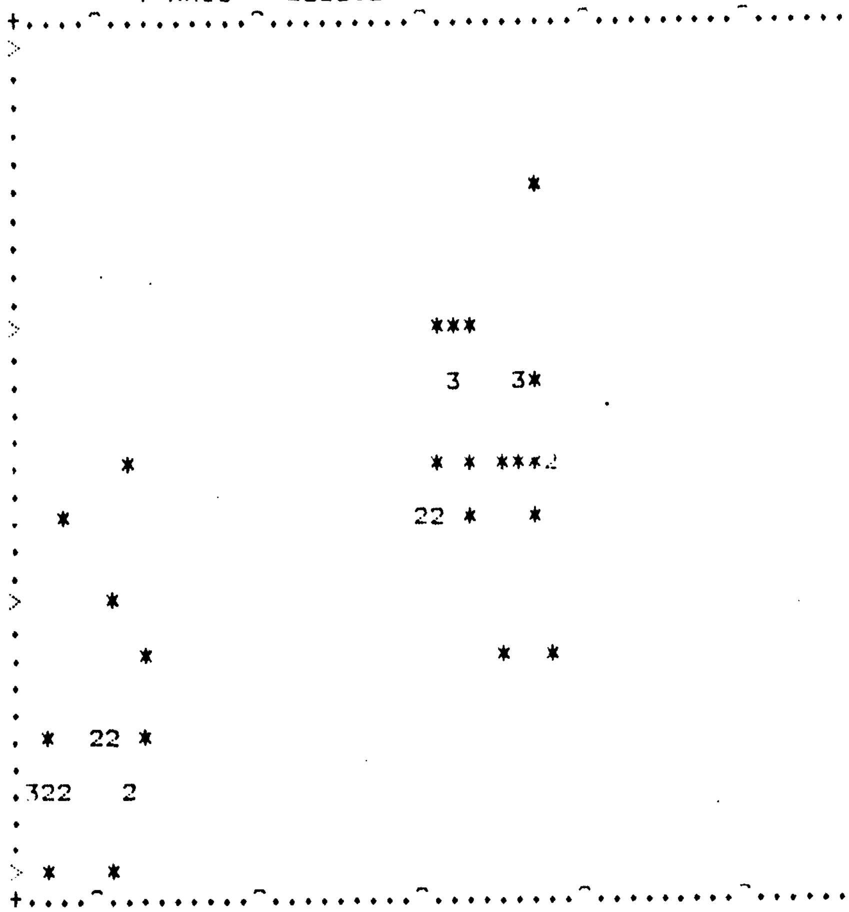
0  *  *                  * *2   2
+....^.........^.........^.........^.........^......

X AXIS: 1-ST TICK =    720.0    /INCREMENT =    40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =            0/INCREMENT =    5.000
  DATA: MINIMUM   =            0/MAXIMUM   =    15.00

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = sample serial number
Y-AXIS = dissolved nickel



```
X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     4.000    /INCREMENT =     4.000
  DATA: MINIMUM   =     4.000    /MAXIMUM   =     14.00
```

NEXT?

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved organic nitrogen
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     7.500
  DATA: MINIMUM   =             0/MAXIMUM   =     20.00

      NEXT?
```

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = total organic nitrogen
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X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =    832.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     10.00
  DATA: MINIMUM   =             0/MAXIMUM   =     25.00

     NEXT?
```

SCPLOT

```
SCPLOT: X-AXIS = sample serial number
        Y-AXIS = dissolved nitrite + nitrate
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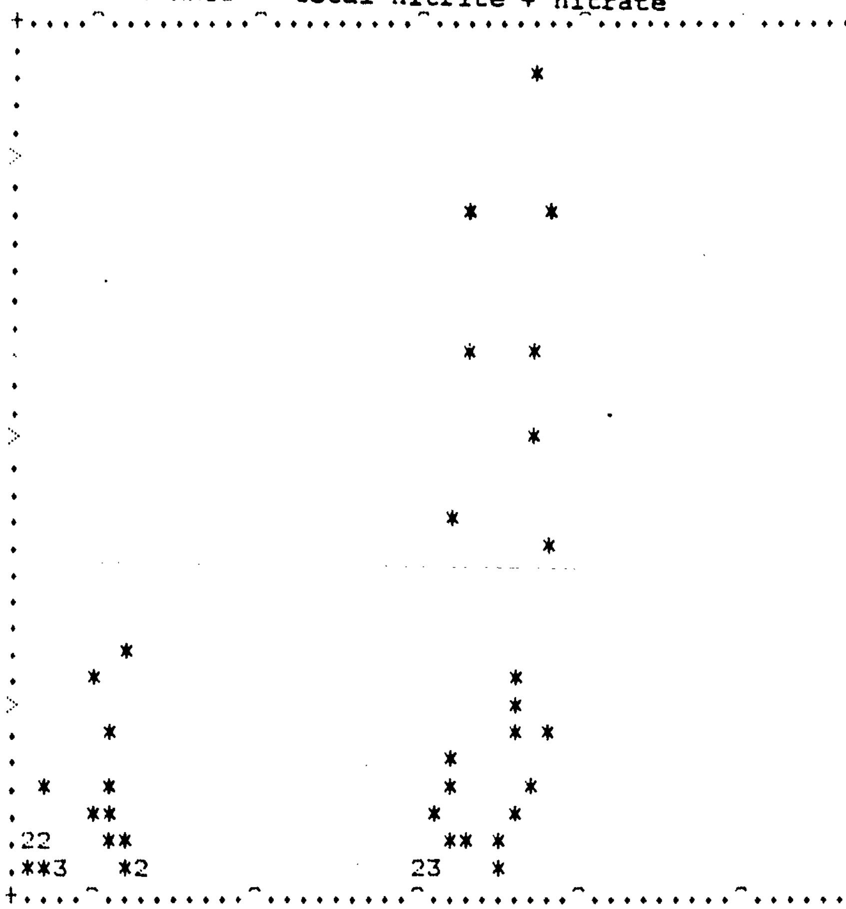
X AXIS: 1-ST TICK =     720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =     702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =     20.00    /INCREMENT =     20.00
  DATA: MINIMUM   =     20.00    /MAXIMUM   =     67.00

      NEXT?
```

SCPLOT

SCPLOT: X-AXIS = sample serial number
        Y-AXIS = total nitrite + nitrate



```
X AXIS: 1-ST TICK =    720.0    /INCREMENT =     40.00
  DATA: MINIMUM   =    702.0    /MAXIMUM   =     832.0
Y AXIS: 1-ST TICK =    60.00    /INCREMENT =     60.00
  DATA: MINIMUM   =    21.00    /MAXIMUM   =     200.0
```

NEXT?

III

DREDGE PLUME OBSERVATIONS

1. Data selection and examination

The data available for analysis are contained in Appendix 2. Specific variables were selected from this set for further investigation in a somewhat arbitrary manner. For instance, water temperature was omitted as being of little interest, and dissolved ammonia nitrogen was excluded but ammonia nitrogen was included. The set of variables studies is contained in the Dredge plume file, where it is again noted that decimal points have been dropped to conserve space.

There are two outstanding observations noted in the dredge plume file. These are sample 17 and sample 14. Also note that the turbidity reading for sample 20 is misrepresented as 014. Following preparation of Appendix 2 this reading was corrected and should read 144. All analysis done uses this correct value. Sample 17 possesses exceedingly high values which are consistent across all measured variables. It is judged to be a real datum and is set aside from further analysis because of its extreme nature. The maps in Appendix 3 indicate that it was drawn from the center of an eddy pool behind the run off site. Sample 14 is determined by statistical analysis to have an incorrect reading for turbidity. The 025 reading is much too low and since a corrected reading has not been supplied the datum is treated as an outlier. Samples 9 and 16 have turbidity readings missing and were determined to be of little use in forming relationships.

The most interesting variable in Appendix 2 which was not put into the dredge plume file is arsenic. Arsenic is generally at low levels and becomes quite elevated in an obvious way in the three samples which have high amounts of total suspended solids.

The highest Mercury concentration detected was 0.5 UG/L.

It is not the purpose of this plume analysis to establish the existence of a plume by statistical significance. The purpose rather is to investigate the relations between the many chemical variables and in particular the relation between these and turbidity. Strong correlations suggest the possibilities of economy of analysis in future studies by concentrating on the good indicator variables. It is unfortunately necessary to comment that any useful relations found here may not be exploitable in other dredge locations where the material being dredged may differ considerably.

A total of 26 samples were drawn over the two days, July 7 and 8 from various locations in and near the dredge plume. By design, there is wide spread in the quality of the water contained in these samples. Samples ranged from being drawn at the dredge pipe to several kilometers down stream, both inside and presumably outside the plume.

Dredge Plume File

SAMPLE SERIAL NUMBER	TURBIDITY	TOTAL SUSPENDED SOLIDS	DISSOLVED OXYGEN x 10	SUSPENDED CADMIUM	TOTAL ORGANIC CARBON	CHEMICAL OXYGEN DEMAND	TOTAL IRON x 1/10	DISSOLVED LEAD	SUSPENDED LEAD	DISSOLVED MANGANESE x 1/10	SUSPENDED MANGANESE x 1/10	SUSPENDED NICKEL	DISSOLVED ORGANIC NITROGEN x 10	TOTAL ORGANIC NITROGEN x 10	AMONIA NITROGEN x 10	DISSOLVED NITRITE + NITRATE x 100	TOTAL NITRITE + NITRATE x 100	TOTAL ORTHO PHOSPHORUS x 100	DISSOLVED SOLID RESIDUE	TOTAL RESIDUE
01	042	0055	31	02	013	044	0160	11	004	004	025	004	07	014	14	027	044	25	[illegible]	[illegible]
02	061	0078	38	02	014	046	0260	09	010	006	030	006	05	014	14	049	065	21	260	[illegible]
03	026	0028	38	01	014	037	0083	09	001	001	019	000	06	012	12	032	046	24	276	[illegible]
04	018	0021	37	00	013	030	0060	05	000	000	017	000	05	010	12	019	022	21	265	[illegible]
05	017	0013	39	00	014	037	0068	09	002	000	019	001	06	012	13	023	027	31	[illegible]	[illegible]
06	026	0027	35	01	015	033	0089	05	001	002	018	000	07	012	14	110	110	25	276	[illegible]
07	040	0063	59	01	013	044	0190	03	006	004	020	001	08	014	15	091	100	22	[illegible]	[illegible]
08	013	0012	08	02	012	035	0033	02	007	001	011	000	07	012	15	022	022	41	268	[illegible]
09		0904		16	064	180	3000	04	120	085	200	067	13	039	14	020	097	14	293	[illegible]
10	151	0352	25	08	035	092	1100	05	052	042	088	030	09	029	15	021	056	22	280	[illegible]
11	052	0020	21	01	012	034	0076	08	000	002	017	000	07	014	15	024	030	37	[illegible]	[illegible]
12	073	0210	24	05	020	068	0700	04	025	025	050	017	09	020	14	038	078	29	279	[illegible]
13	098	0042	32	01	017	035	0120	07	004	008	014	002	10	010	12	029	076	33	274	[illegible]
14	025	0430	19	05	032	097	1300	08	037	032	210	027	21	032	03	040	220	21	270	[illegible]
15	053	0168	20	02	018	053	0430	03	020	012	032	005	07	019	14	021	069	29	269	[illegible]
16		0113		00	019	054	0340	02	012	027	024	003	17	018	08	032	130	24	171	[illegible]
17	052	1930	43	30	164	540	9999	04	340	110	670	280	20	110	18	016	080	23	282	3680
18	028	0037	36	00	015	040	0130	04	004	011	012	005	08	014	14	066	077	32	273	[illegible]
19	030	0044	34	00	016	042	0160	04	016	011	013	001	10	009	13	100	140	36	272	[illegible]
20	014	0321	30	03	024	081	0920	06	026	022	056	015	18	020	05	100	230	22	280	0654
21	058	0152	28	02	019	053	0410	03	011	014	029	008	12	017	10	140	220	29	280	[illegible]
22	029	0045	26	01	014	041	0140	02	007	005	014	000	17	017	00	170	370	40	273	[illegible]
23	031	0059	22	00	015	040	0140	04	002	005	018	003	13	013	08	120	200	39	287	[illegible]
24	023	0035	21	00	013	037	0080	03	002	006	012	001	11	011	10	049	110	38	281	[illegible]
25	018	0044	18	01	013	038	0078	04	003	004	013	000	12	012	06	020	120	35	278	[illegible]
26	012	0012	24	01	013	031	0031	05	001	001	011	000	11	011	06	340	410	30	257	[illegible]

2.
Correlations

Sample 17 produced extreme values on a number of variables and, although real enough, is considered here to be atypical. As noted on the maps in Appendix 3, it was drawn from shallow water in the still area behind the run off site. The scatter plot of suspended solids with iron which contains sample 17 shows the effect it would have on a statistical or correlation analysis. The real interest lies in 24 observations crowded near the origin. Removal of sample 17 in the next plot vastly expands the remaining data and more properly represents the interesting range. For this reason 17 is omitted. Numbers in the scatter plot represent multiple points. The zero symbol represents over 9 points.

The plot of turbidity with suspended solids including sample 17 clearly suggests that in the turbidity relationship sample 17 is an outlier. The following plot with sample 17 removed further exposes sample 14 as an outlier in the turbidity relationships.

After omitting these outliers and the missing data and correcting the file entry for turbidity in sample 20, a correlation matrix was calculated with the variables arranged in descending order of their correlation coefficient with turbidity. It can be seen from the correlation matrix, that the variables having a good relationship with turbidity were also tightly related to total suspended solids, and, conversley, the ones not related closely to turbidity were not related to suspended solids. A line is drawn below this set at suspended cadmium. Phosphorus is negatively related to most variables with the exceptions of dissolved solid residues and dissolved nitrogen.

In the data of Appendix 2 which is not presented in detail here it is noteable that suspended copper and suspended zinc are highly correlated with suspended solids with coefficients of .980 and .977 respectively. B.O.D. has a .78 correlation with suspended solids.

Further examination of the correlation matrix shows that the set of correlations with suspended solids is much higher than the set of correlations with turbidity. The inherent variability in the measure of turbidity contributes substantially to an explanation of this fact. The correlations with turbidity are "bound" by lack of precision in the measurement of turbidity.

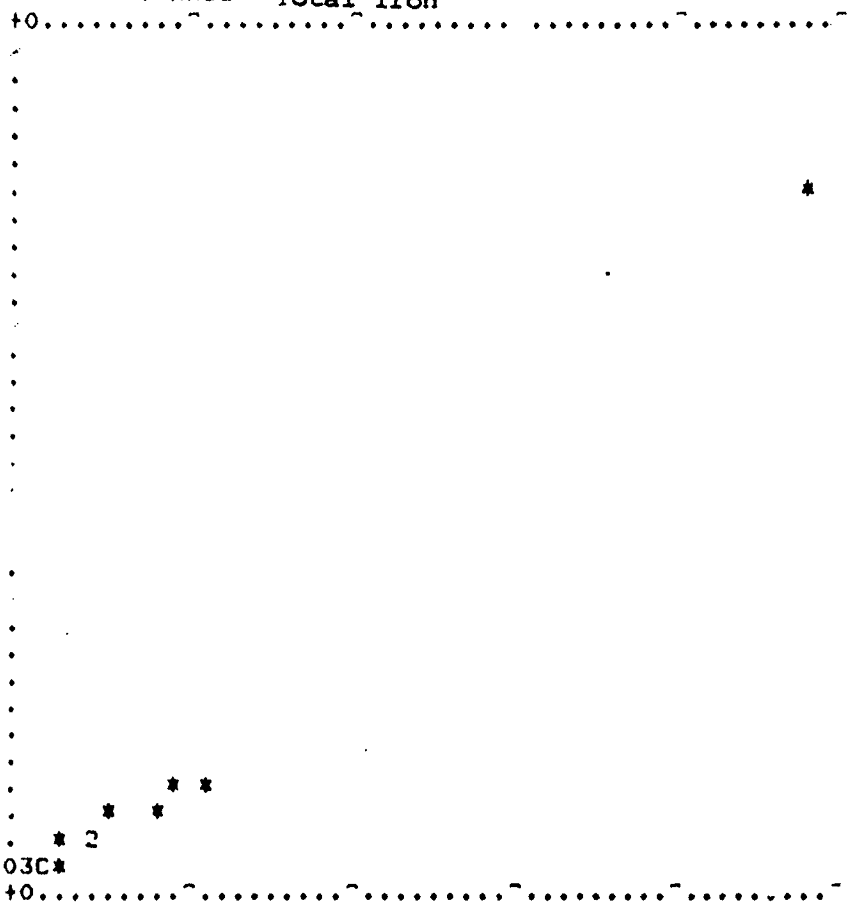
Next, scatter plots are presented with prediction equation coefficients for suspended solids and total residue using turbidity. In the prediction equation ($Y = a + bX$), X is a sample's turbidity reading, a is the B0 coefficient, and b is the V1 coefficient. For example total residue = 289.3 + 2.297 turbidity on the first scatter plot.

A set of similar plots and equations follows for predicting the remaining tightly related variables from total residues. It must be noted, however, that these prediction equations can only be expected to pertain when dealing with bottom sediments of the type found in this study.

SCPLOT

Observation 17 included in the plot

SCPLOT: X-AXIS = Total Suspended Solids
Y-AXIS = Total Iron

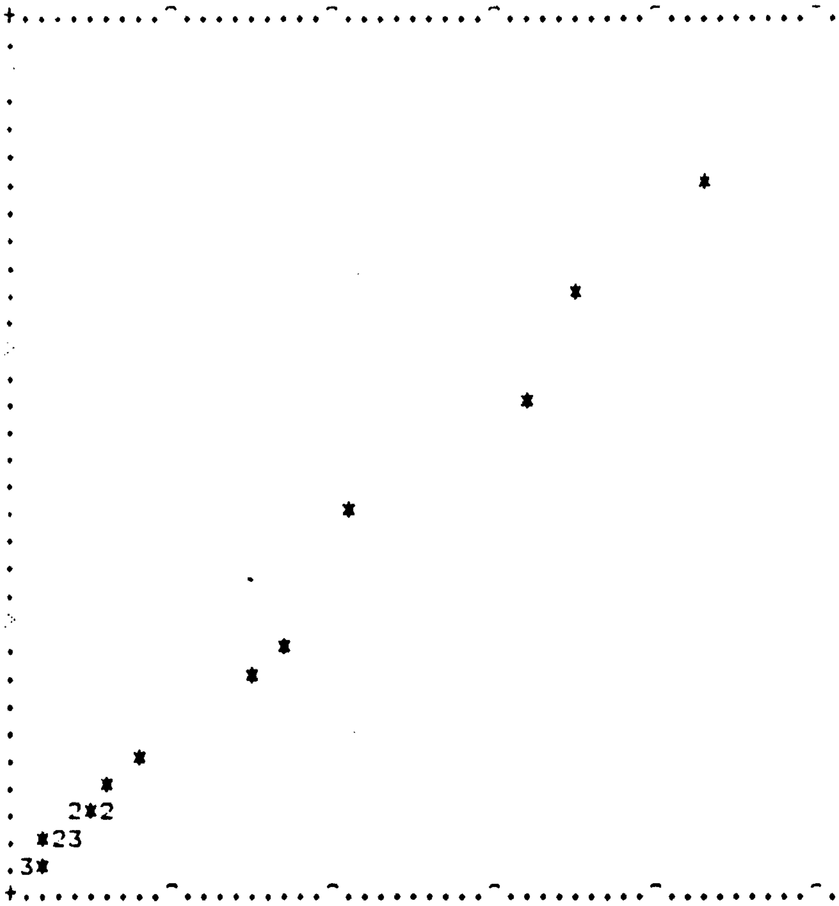


```
X AXIS: 1-ST TICK =                 0/INCREMENT =    400.0
  DATA: MINIMUM   =     12.00       /MAXIMUM   =    1930.
Y AXIS: 1-ST TICK =                 0/INCREMENT =    4000.
  DATA: MINIMUM   =     31.00       /MAXIMUM   =    9999.
```

NEXT?

SCPLOT Observation 17 excluded from the plot

SCPLOT: X-AXIS = Total Suspended Solids
Y-AXIS = Total Iron



```
X AXIS: 1-ST TICK =    100.0    /INCREMENT =    100.0
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    430.0
Y AXIS: 1-ST TICK =    500.0    /INCREMENT =    500.0
  DATA: MINIMUM   =    31.00    /MAXIMUM   =    1300.
```

NEXT?

SCPLOT Observation 17 included in the plot

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SCPLOT: X-AXIS =Turbidity
        Y-AXIS =Total Suspended Solids
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X AXIS: 1-ST TICK =     40.00    /INCREMENT =    40.00
  DATA: MINIMUM   =     12.00    /MAXIMUM   =    151.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    750.0
  DATA: MINIMUM   =     12.00    /MAXIMUM   =    1930.

     NEXT?
```
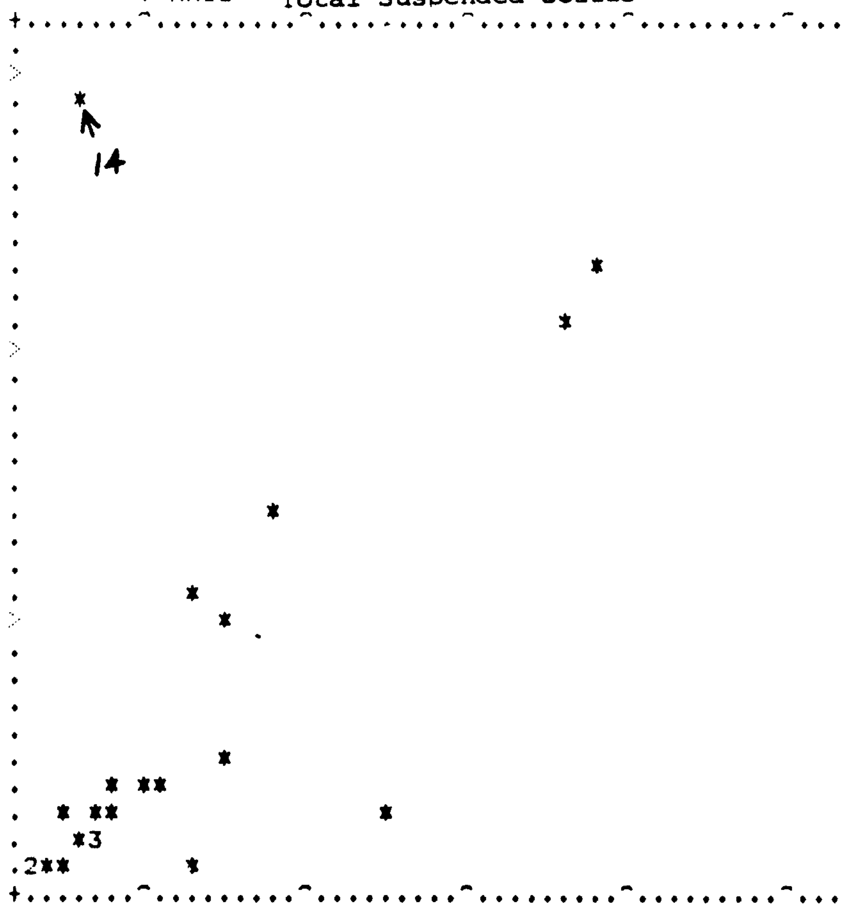

SCPLOT   Observation 17 excluded from the plot

```
SCPLOT: X-AXIS = Turbidity
        Y-AXIS = Total Suspended Solids
```




```
X AXIS: 1-ST TICK =    40.00    /INCREMENT =    40.00
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    151.0
Y AXIS: 1-ST TICK =    150.0    /INCREMENT =    150.0
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    430.0

     NEXT?
```

CORRELATION MATRIX

TURBIDITY	1.000					
TOTAL SUS SOLID	.8770	1.000				
TOTAL RESIDUE	.8568	.9928	1.000			
TOTAL IRON	.8812	.9933	.9902	1.000		
CHEM OX DEMAND	.8594	.9834	.9829	.9907	1.000	
DISS MANGANESE	.8291	.9208	.9247	.9413	.9386	[illegible]
SUS MANGANESE	.8523	.9451	.9284	.9642	.9562	[illegible]
SUS NICKEL	.8354	.9274	.9236	.9535	.9503	[illegible]
SUS LEAD	.7963	.9172	.9117	.9361	.9394	[illegible]
TOTAL ORG CARB	.8608	.9165	.9030	.9279	.9143	[illegible]
TOTAL ORG NITRO	.7471	.8962	.8928	.9041	.9095	[illegible]
SUS CADMIUM	.7536	.8380	.8271	.8678	.8640	[illegible]
DISS SOLID RESID	.3461	.3851	.4115	.3636	.3907	[illegible]
DISS NITROGEN	.3011	.3468	.4062	.3028	.3227	[illegible]
TOTAL N + N	-.4268E-01	.4745E-01	.1120	.1837E-01	.1483E-01	[illegible]
DISS N + N	-.1834	-.1081	-.5224E-01	-.1188	-.1361	[illegible]
AMONIA NITROGEN	.5323E-01	-.1198E-01	-.6329E-01	.3503E-01	.2548E-01	[illegible]
DISS LEAD	.1317	-.1055	-.1422	-.7615E-01	-.6819E-01	[illegible]
DISS OXYGEN	.3239E-03	-.1059	-.1242	-.7411E-01	-.6870E-01	[illegible]
TOTAL PHOSPHORUS	.4292	-.4431	-.3827	-.4552	-.4142	[illegible]
	V1	V2	V3	V4	V5	[illegible]

SUS MANGANESE	1.000					
SUS NICKEL	.9665	1.000				
SUS LEAD	.9250	.9283	1.000			
TOTAL ORG CARBON	.9284	.9390	.9343	1.000		
TOTAL ORG NITRO	.9123	.8978	.8761	.8549	1.000	
SUS CADMIUM	.9207	.9146	.8889	.8431	.8838	[illegible]
DISS SOLID RESID	.2865	.3360	.2711	.3716	.3384	[illegible]
DISS NITROGEN	.1286	.1713	.1958	.2548	.2373	[illegible]
TOTAL N + N	-.1037	-.6987E-01	-.3799E-01	.5278E-02	.3419E-01	[illegible]
DISS N + N	-.1967	-.1579	-.1519	-.1017	-.1123	[illegible]
AMONIA NITROGEN	.1496	.1471	.1313	.6386E-01	.2782E-01	[illegible]
DISS LEAD	.6838E-01	-.1896E-01	-.1614	-.8338E-01	-.1270	[illegible]
DISS OXYGEN	-.4265E-01	-.9956E-01	-.1401	-.8387E-01	-.1551	[illegible]
TOTAL PHOSPHORUS	-.5389	-.4340	-.3350	-.3997	-.3330	[illegible]
	V7	V8	V9	V10	V11	[illegible]

DISS SOLID RESID	1.000					
DISS NITROGEN	.4851	1.000				
TOTAL N + N	.1945E-01	.7508	1.000			
DISS N + N	-.2307	.4741	.9088	1.000		
AMONIA NITROGEN	-.1355	-.8383	-.8247	-.5652	1.000	
DISS LEAD	-.3211	-.4138	-.3683	-.2705	.2730	1.000
DISS OXYGEN	-.1304	-.2645	-.1288	.1228E-01	.2299	[illegible]
TOTAL PHOSPHORUS	.3169	.3215	.2201	.1140	-.2743	[illegible]
	V13	V14	V15	V16	V17	[illegible]

DISS OXYGEN	1.000	
TOTAL PHOSPHORUS	-.5251	1.000
	V19	V20

NEXT? SCPLOT 3 VS 1

)T: X-AXIS = V1 TURBIDITY
Y-AXIS = V3 TOTAL RESIDUE

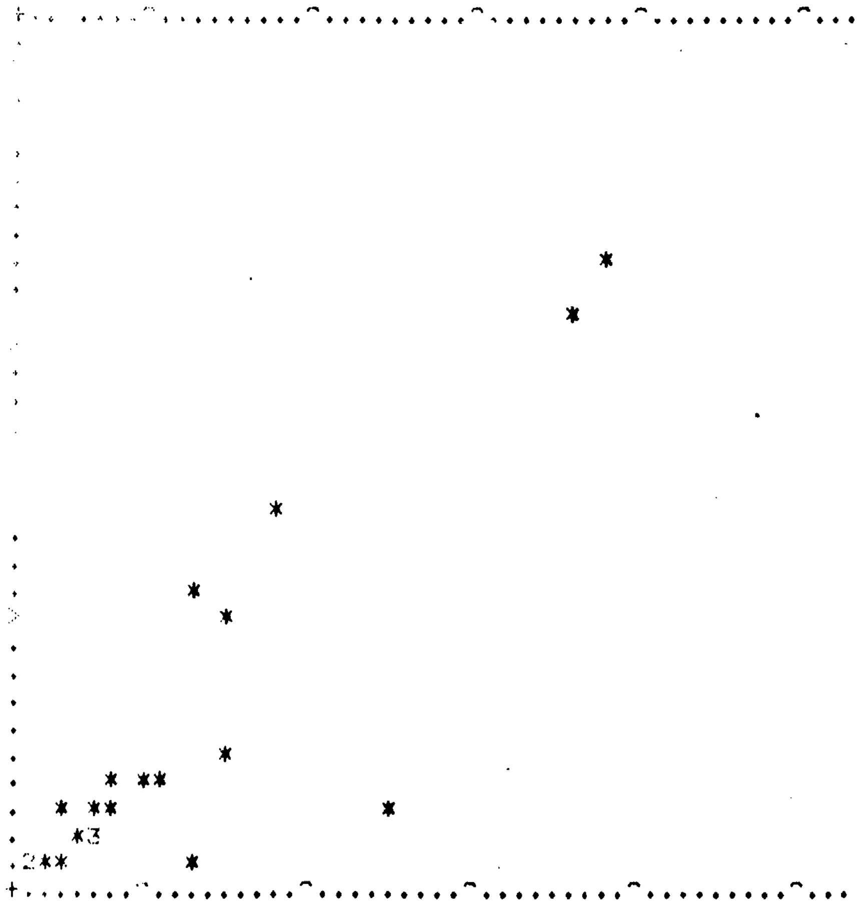
IS: 1-ST TICK = 40.00 /INCREMENT = 40.00
TA: MINIMUM = 12.00 /MAXIMUM = 151.0
IS: 1-ST TICK = 450.0 /INCREMENT = 150.0
TA: MINIMUM = 310.0 /MAXIMUM = 670.0

NEXT? REGS 3 ON 1
GS V3 ON V1

ABLE	COEF'T	ST. ERROR	T VALUE
)	289.2975	18.76899	15.41
.	2.297656	.3092277	7.43

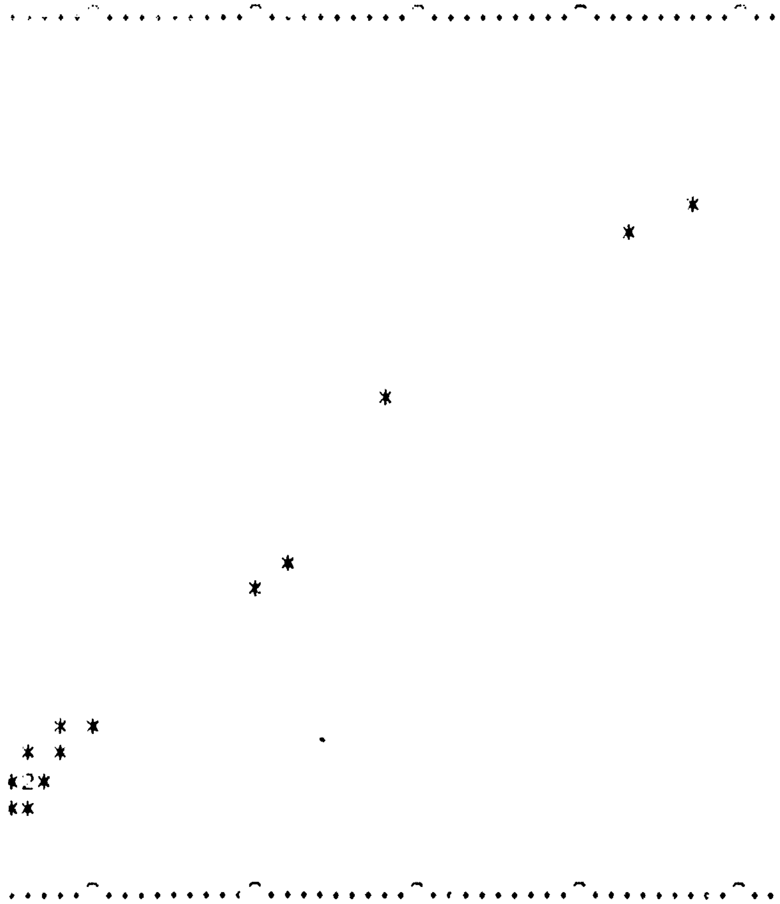
DEGREES OF FREEDOM = 20
RESIDUAL MEAN SQUARE= 3021.774
ROOT MEAN SQUARE = 54.97066
R-SQUARED = .7341

```
NEXT? SCPLOT 2 VS 1

SCPLOT: X-AXIS = V1 TURBIDITY
        Y-AXIS = V2 TOTAL SUSPENDED SOLIDS
```



```
X AXIS: 1-ST TICK =    40.00    /INCREMENT =    40.00
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    151.0
Y AXIS: 1-ST TICK =    150.0    /INCREMENT =    150.0
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    352.0

     NEXT? REGS 2 ON 1
  REGS     V2    ON    V1
VARIABLE       COEF'T            ST. ERROR              T VALUE
  B0        -20.64231            16.34266                -1.26
  V1          2.197633           .2692523                 8.16
          DEGREES OF FREEDOM   =      20
          RESIDUAL MEAN SQUARE=  2291.003
          ROOT MEAN SQUARE     =  47.86442
          R-SQUARED            =     .7691
```

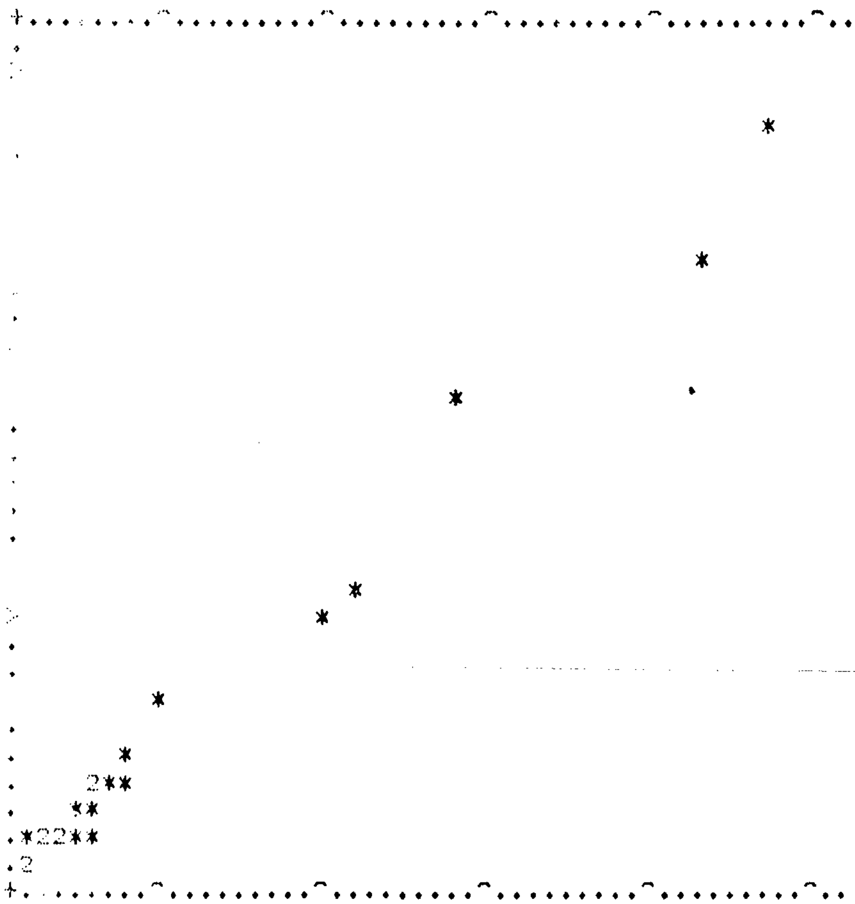
```
  NEXT? SCPLOT 3 VS 2

OT: X-AXIS = V2 SUSPENDED SOLIDS
    Y-AXIS = V3 TOTAL RESIDUE
```



```
IS: 1-ST TICK =     75.00    /INCREMENT =     75.00
TA: MINIMUM   =     12.00    /MAXIMUM   =     352.0
IS: 1-ST TICK =     450.0    /INCREMENT =     150.0
TA: MINIMUM   =     310.0    /MAXIMUM   =     670.0

  NEXT? REGS 3 ON 2
SS    V3    ON    V2
ABLE      COEF'T          ST. ERROR          T VALUE
       309.4631          3.624379             85.38
       1.062466          .2865331E-01         37.08
     DEGREES OF FREEDOM   =      20
     RESIDUAL MEAN SQUARE=  162.9229
     ROOT MEAN SQUARE     =  12.76412
     R-SQUARED            =     .9857

  NEXT?
```

88

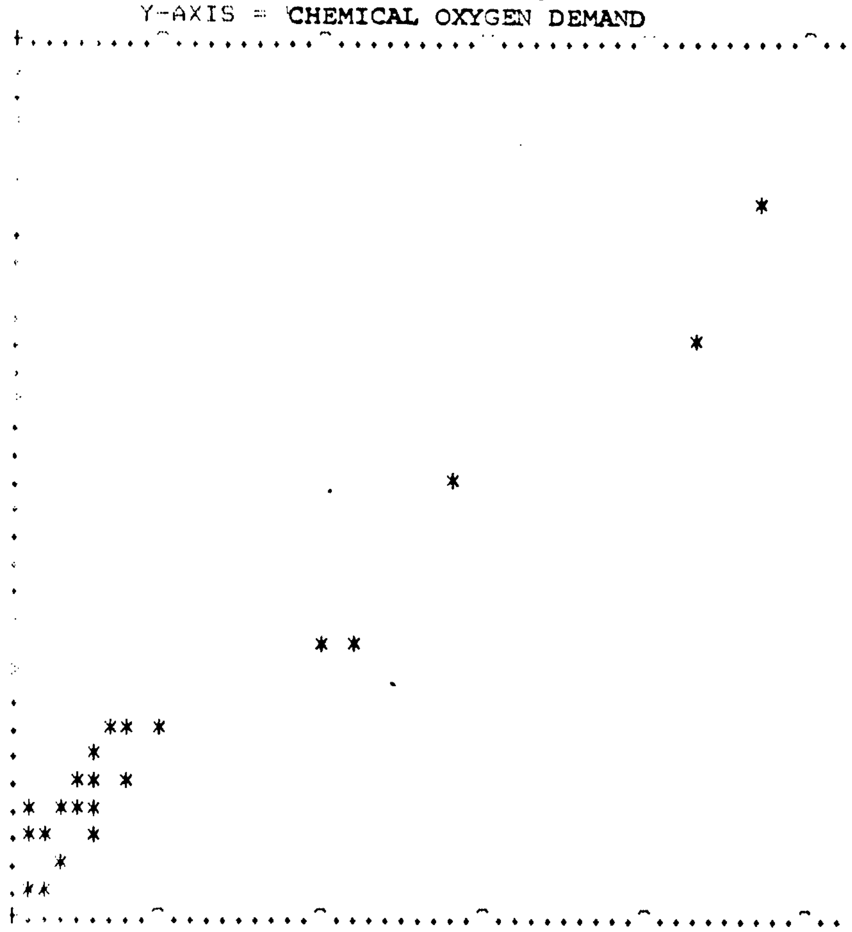
```
          SCPLOT 4 VS 2

SCPLOT: X-AXIS = V2 SUSPENDED SOLIDS
        Y-AXIS = V4 TOTAL IRON
```



```
X AXIS: 1-ST TICK =     75.00    /INCREMENT =     75.00
  DATA: MINIMUM   =     12.00    /MAXIMUM   =     352.0
Y AXIS: 1-ST TICK =     400.0    /INCREMENT =     400.0
  DATA: MINIMUM   =     31.00    /MAXIMUM   =     1100.

      NEXT? REGS 4 ON 2
  REGS     V4    ON    V2
VARIABLE      COEF'T             ST. ERROR           T VALUE
  B0       -2.821444            9.868103               -.29
  V2        3.003303           .7801443E-01           38.50
         DEGREES OF FREEDOM   =      20
         RESIDUAL MEAN SQUARE=  1207.764
         ROOT MEAN SQUARE     =  34.75291
         R-SQUARED            =      .9857

      NEXT?
```

SCPLOT 5 VS 2

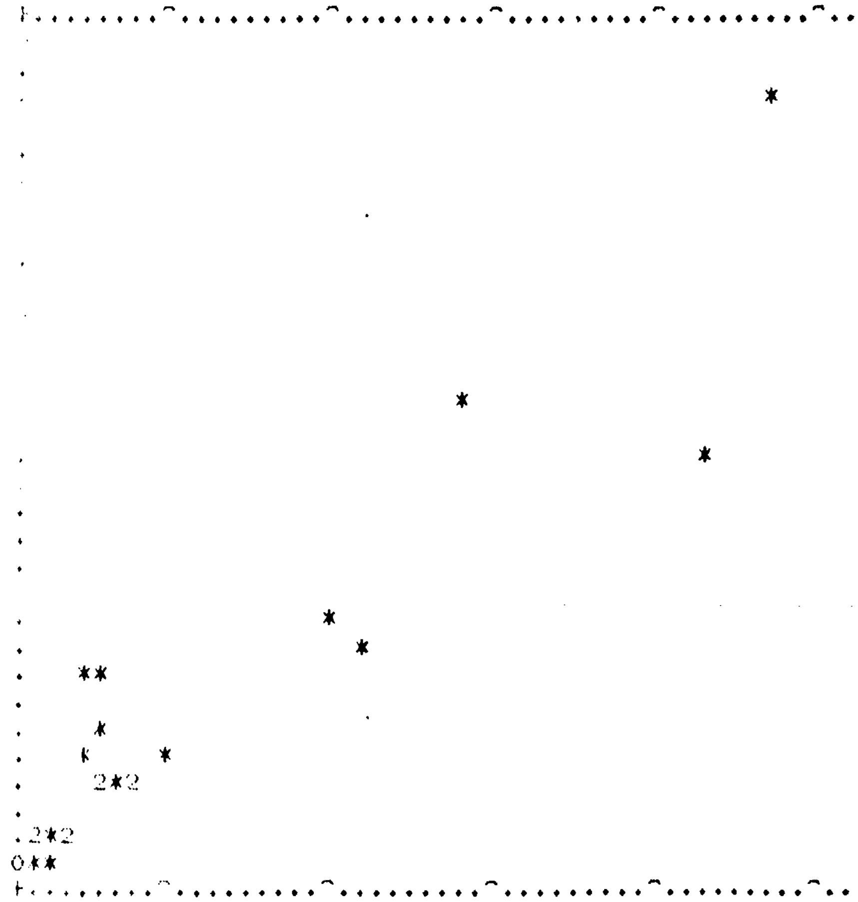
SCPLOT: X-AXIS = SUSPENDED SOLIDS
Y-AXIS = CHEMICAL OXYGEN DEMAND



```
X AXIS: 1-ST TICK =    75.00    /INCREMENT =    75.00
  DATA: MINIMUM   =    12.00    /MAXIMUM   =    352.0
Y AXIS: 1-ST TICK =    50.00    /INCREMENT =    25.00
  DATA: MINIMUM   =    30.00    /MAXIMUM   =    92.00

     NEXT? REGS 5 ON 2
 REGS    V5   ON   V2
VARIABLE     COEF'T          ST. ERROR            T VALUE
 B0        31.53469          .8452117              37.31
 V2        .1617175          .6682004E-02          24.20
          DEGREES OF FREEDOM   =       20
          RESIDUAL MEAN SQUARE=  8.860248
          ROOT MEAN SQUARE     =  2.976617
          R-SQUARED            =      .9670

     NEXT?
```

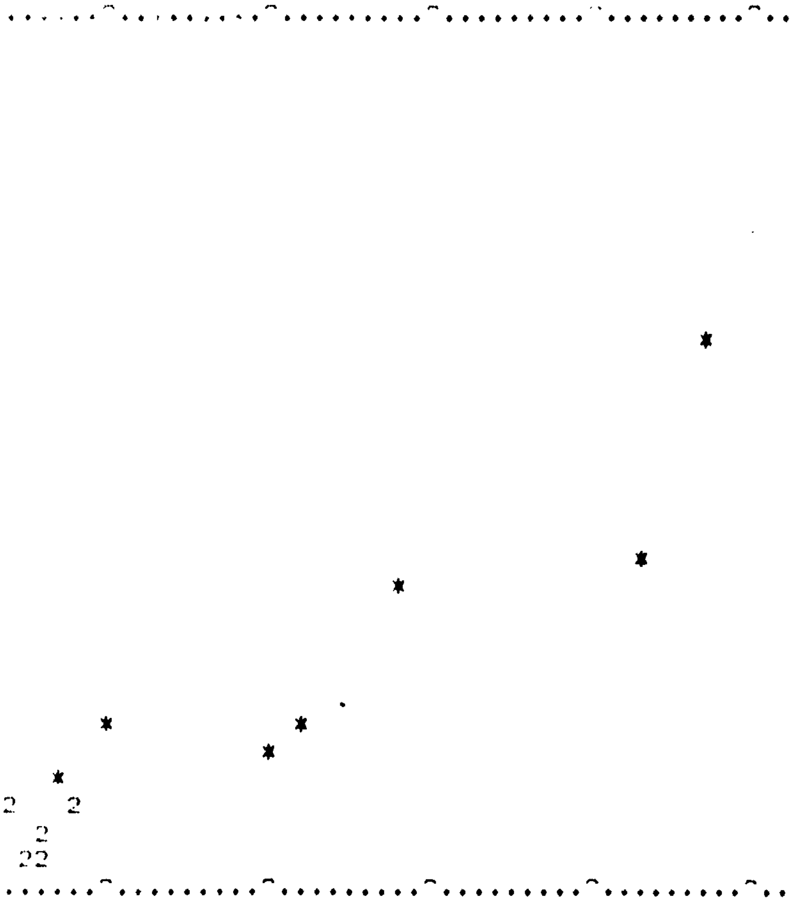
SCPLOT 6 VS 2

```
SCPLOT: X-AXIS = V2 SUSPENDED SOLIDS
        Y-AXIS = V6 DISSOLVED MANGANESE
```



```
X AXIS: 1-ST TICK =     75.00    /INCREMENT =    75.00
  DATA: MINIMUM   =     12.00    /MAXIMUM   =    352.0
Y AXIS: 1-ST TICK =             0/INCREMENT =    15.00
  DATA: MINIMUM   =             0/MAXIMUM   =    42.00

     NEXT? REGS 6 ON 2
  REGS     V6    ON    V2
VARIABLE       COEF'T          ST. ERROR          T VALUE
  B0          .4892641         1.142265               .43
  V2          .9534069E-01     .9030420E-02         10.56
            DEGREES OF FREEDOM   =      20
            RESIDUAL MEAN SQUARE=  16.18260
            ROOT MEAN SQUARE     =  4.022760
            R-SQUARED            =     .8479

     NEXT?
```

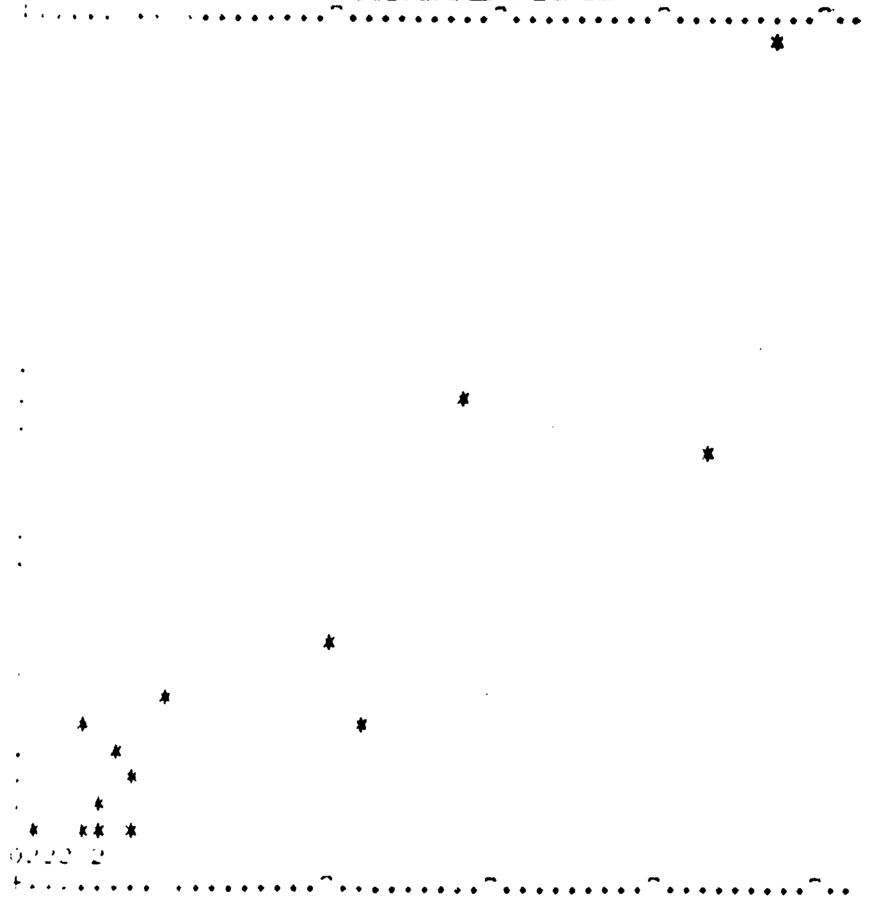
```
        SCPLOT 7 VS 2

LOT: X-AXIS = V2 SUSPENDED SOLIDS
     Y AXIS = V7 SUSPENDED MANGANESE
```



```
XIS: 1-ST TICK =     75.00    /INCREMENT =     75.00
ATA: MINIMUM   =     12.00    /MAXIMUM   =     352.0
XIS: 1-ST TICK =     40.00    /INCREMENT =     40.00
ATA: MINIMUM   =     11.00    /MAXIMUM   =     68.00

   NEXT? REGS 7 ON 2
EGS    V7   ON   V2
IABLE       COEF'T          ST. ERROR          T VALUE
0        9.391910        1.763038                5.33
2        .1802977        .1393808E-01           12.94
      DEGREES OF FREEDOM   =      20
      RESIDUAL MEAN SQUARE=  38.55122
      ROOT MEAN SQUARE     =  6.208963
      R-SQUARED            =      .8932

   NEXT?
```

SCPLOT 8 VS 2

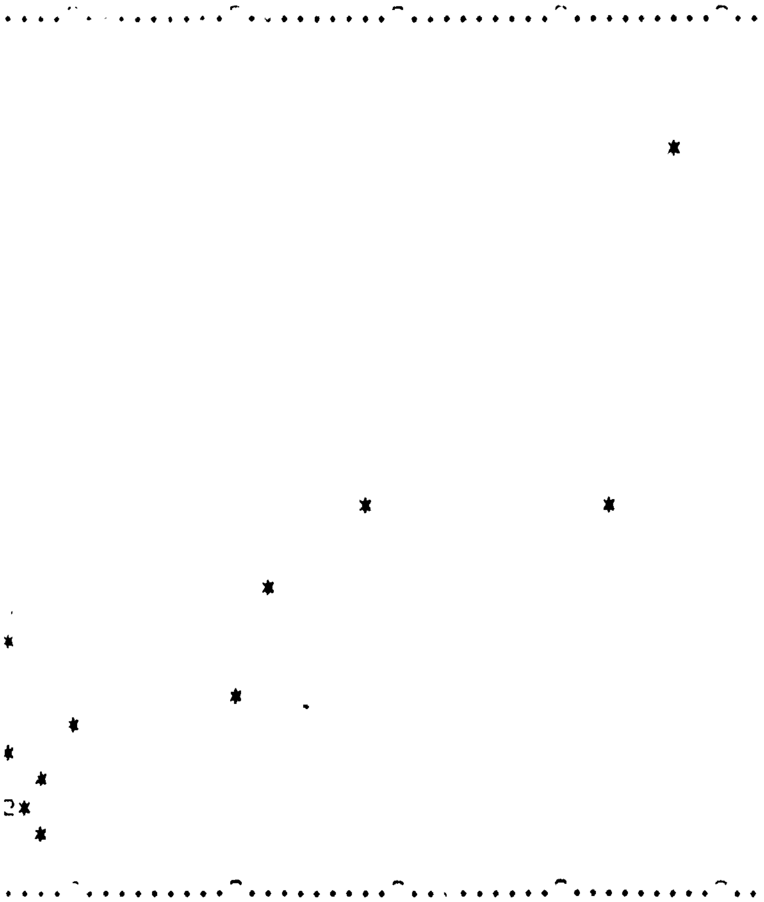
SCPLOT: X AXIS = V2 **SUSPENDED SOLIDS**
Y AXIS = V8 **SUSPENDED NICKEL**



```
X AXIS: 1-ST TICK =     75.00    /INCREMENT =     75.00
  DATA: MINIMUM   =     12.00    /MAXIMUM   =     352.0
Y AXIS: 1-ST TICK =             0/INCREMENT =     10.00
  DATA: MINIMUM   =             0/MAXIMUM   =     30.00

      NEXT? REGS 8 ON 2
  REGS    V8   ON   V2
VARIABLE      COEF'T            ST. ERROR          T VALUE
  B0       -1.402112           .8059403             -1.74
  V2        .7064552E-01       .6371536E-02         11.09
         DEGREES OF FREEDOM   =      20
         RESIDUAL MEAN SQUARE=  8.056022
         ROOT MEAN SQUARE     =  2.838313
         R-SQUARED            =      .8601

      NEXT?
```

SCPLOT 9 VS 2

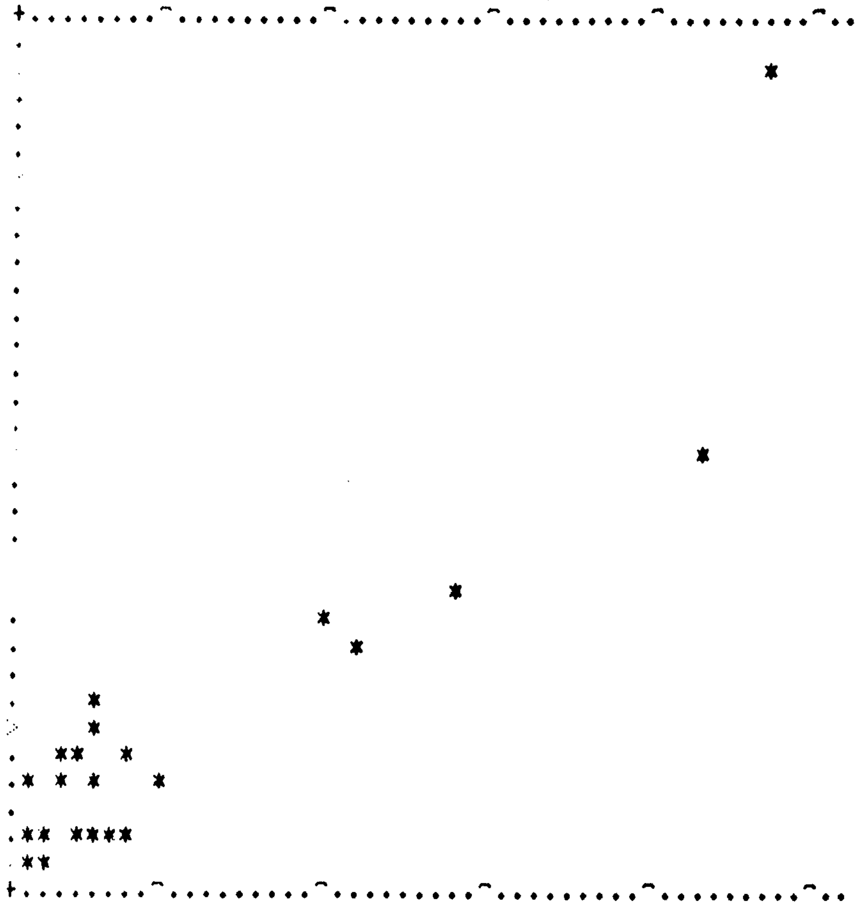
I: X AXIS = V2 **SUSPENDED SOLIDS**
Y AXIS = V9 **SUSPENDED LEAD**



```
 : 1-ST TICK =     75.00    /INCREMENT =    75.00
A: MINIMUM   =     12.00    /MAXIMUM   =    352.0
 : 1-ST TICK =             0/INCREMENT =    20.00
A: MINIMUM   =             0/MAXIMUM   =    52.00

 NEXT? REGS 9 ON 2
S     V9    ON    V2
BLE       COEF'T            ST. ERROR           T VALUE
     -.4520234           1.430580                 -.32
      .1164007           .1130976E-01             10.29
    DEGREES OF FREEDOM  =       20
    RESIDUAL MEAN SQUARE=  25.38276
    ROOT MEAN SQUARE    =  5.038131
    R-SQUARED           =      .8412

 NEXT?
```

SCPLOT 10 VS 2

```
SCPLOT: X-AXIS = V2  SUSPENDED SOLIDS
        Y-AXIS = V10 TOTAL ORGANIC CARBON
```



```
X AXIS: 1-ST TICK =     75.00     /INCREMENT =     75.00
  DATA: MINIMUM   =     12.00     /MAXIMUM   =     352.0
Y AXIS: 1-ST TICK =     16.00     /INCREMENT =     8.000
  DATA: MINIMUM   =     12.00     /MAXIMUM   =     35.00

      NEXT? REGS 10 ON 2
  REGS     V10   ON    V2
VARIABLE        COEF'T          ST. ERROR           T VALUE
  BO         11.93264          .6012116             19.85
  V2          .4868438E-01     .4753008E-02         10.24
         DEGREES OF FREEDOM   =      20
         RESIDUAL MEAN SQUARE=  4.483008
         ROOT MEAN SQUARE     =  2.117312
         R-SQUARED            =     .8399

      NEXT?
```

SCPLOT 11 VS 2

1: X-AXIS = V2 **SUSPENDED SOLIDS**
Y-AXIS = V11 **TOTAL ORGANIC NITROGEN**

```
IS: 1-ST TICK =     75.00    /INCREMENT =    75.00
TA: MINIMUM   =     12.00    /MAXIMUM   =    352.0
IS: 1-ST TICK =     15.00    /INCREMENT =    7.500
TA: MINIMUM   =     9.000    /MAXIMUM   =    29.00
```

NEXT? REGS 11 ON 2

```
GS      V11   ON    V2
ABLE       COEF'T            ST. ERROR          T VALUE
         10.86563           .5861111             18.54
         .4186946E-01       .4633629E-02          9.04
      DEGREES OF FREEDOM   =       20
      RESIDUAL MEAN SQUARE=  4.260640
      ROOT MEAN SQUARE     =  2.064132
      R-SQUARED            =      .8032
```

NEXT?

SCPLOT 12 VS 2

```
SCPLOT: X-AXIS = V2  SUSPENDED SOLIDS
        Y-AXIS = V12 SUSPENDED CADMINUM
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O** 2* *
+........^.........^.........^.........^.........^..

X AXIS: 1-ST TICK =     75.00    /INCREMENT =    75.00
  DATA: MINIMUM   =     12.00    /MAXIMUM   =    352.0
Y AXIS: 1-ST TICK =             O/INCREMENT =    4.000
  DATA: MINIMUM   =             O/MAXIMUM   =    8.000

      NEXT? REGS 12 ON 2
  REGS    V12  ON   V2
VARIABLE      COEF'T            ST. ERROR             T VALUE
  BO        .1984583           .2969286                  .67
  V2        .1612291E-01       .2347434E-02             6.87
         DEGREES OF FREEDOM   =      20
         RESIDUAL MEAN SQUARE=  1.093501
         ROOT MEAN SQUARE     =  1.045706
         R-SQUARED            =      .7023

      NEXT?
```

3.
Dredge Plume as a Function of Distance

On July 8 a specific run was made in the channel to record turbidity at increasing distances from the run off site. Samples 20 through 25 are in this set. Sample 20 was taken at the site and the remaining were in the channel at about 10 foot depths.

The plot of turbidity against distance indicates an exponential or geometric relation commonly seen in dilution models. Here distance is the dilution factor.

A transformation of distance to log distance immediately linearizes this relationship and very high correlations can be seen with turbidity, suspended solids and total residues, three good indicators of plume density. Prediction equations are included with each of the three plots of these variables against log distance. The prediction equations can, of course, pertain only to the very low flow conditions experienced at the time of the study. They can be used to fairly accurately determine the effective length of the dredge plume in the channel by calculating the distance required to return the predicted variable to background level.

If an assumption is made that average background turbidity in the channel at the time of the study was 14 ntu (this is supported by the data), then a quick calculation on the prediction equation

$$\text{Turbidity} = 156.88 - 69.84 \log (D + 1)$$

yields D = 110.16. Because decimal points were dropped in the files, the file reading on distance is actually kilometers x 100. Thus, D = 110.16 converts to 1.1 kilometers as the distance at which the turbidity of the plume approaches background.

Using the variable suspended solids, with a well established background level of 12 and a prediction equation

$$\text{Suspended solids} = 358.73 - 163.72 \log (D + 1)$$

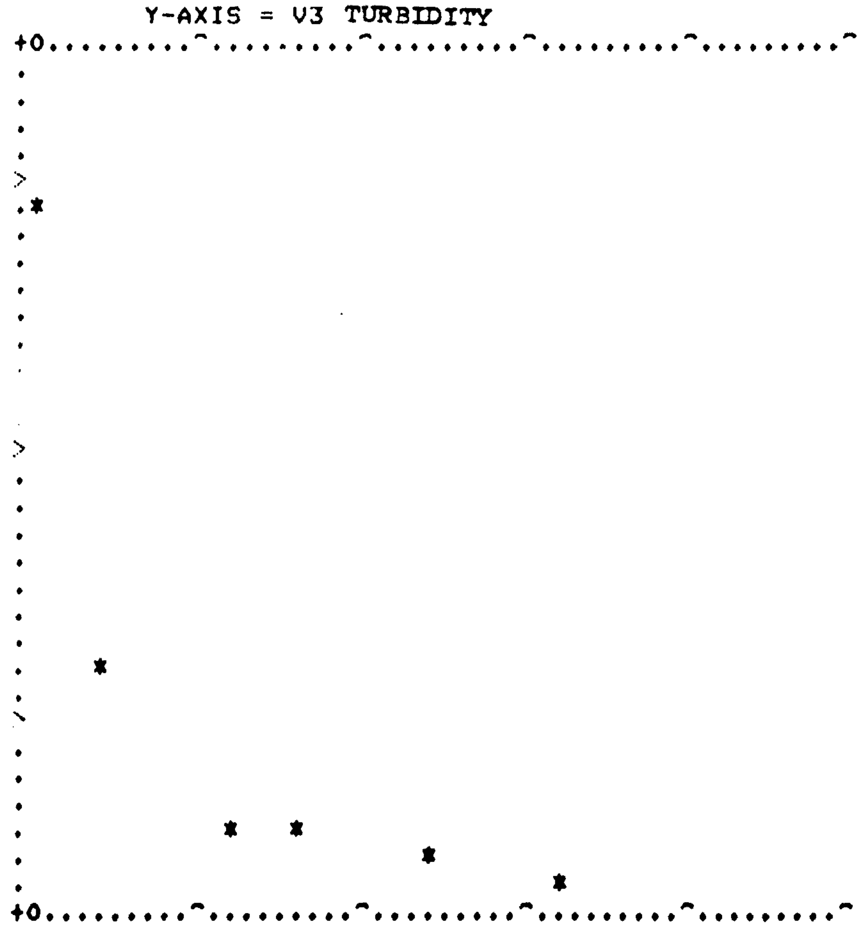
yields D = 131.1. Converting to kilometers gives 1.3 which is in reasonable agreement with the previous determination.

It may be confidently concluded that the effective length of the dredge plume in this study was quite near to 1.2 kilometers.

SELECTED DATA FILE AND PLOT OF TURBIDITY AGAINST DISTANCE FROM RUN OFF SITE FOR SAMPLES KNOWN TO BE IN THE PLUME MOVED BY CURRENT, ON ONE DAY.

sample number	distance	turbidity	suspended solids	total residue
20	001	144	0321	0654
21	016	058	0152	0467
22	048	029	0045	0379
23	064	031	0059	0384
24	097	023	0035	0348
25	129	018	0044	0356

SCPLOT: X-AXIS = V2 DISTANCE
Y-AXIS = V3 TURBIDITY

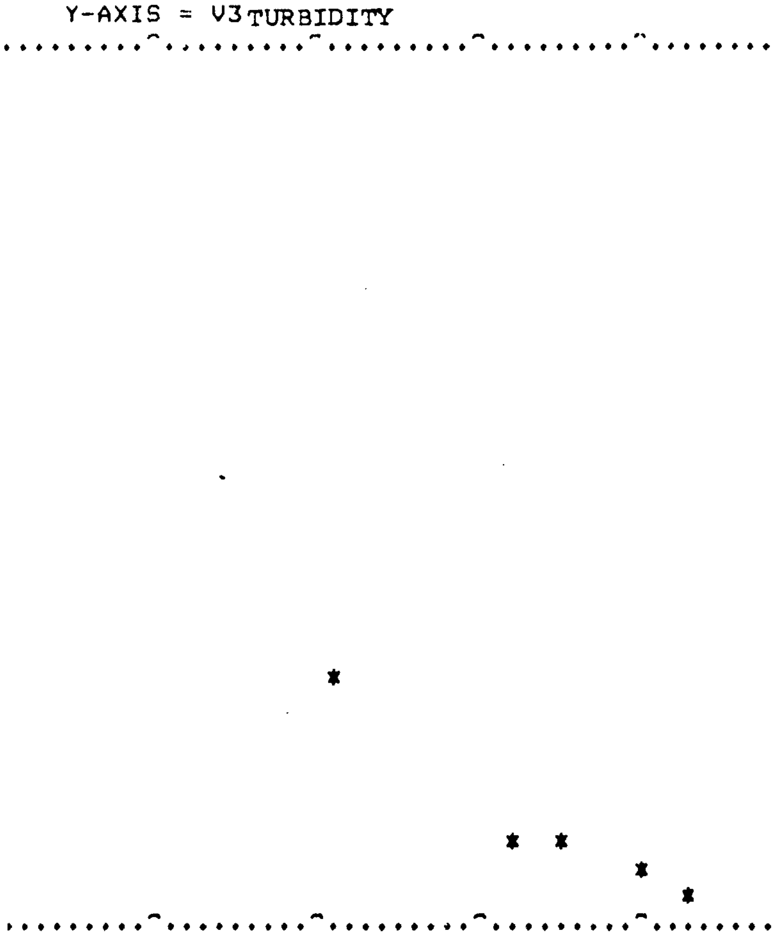


X AXIS: 1-ST TICK = 0/INCREMENT = 40.00
DATA: MINIMUM = 1.000 /MAXIMUM = 129.0
Y AXIS: 1-ST TICK = 50.00 /INCREMENT = 50.00
DATA: MINIMUM = 18.00 /MAXIMUM = 144.0

CORRELATION MATRIX

LOG DISTANCE	V1	1.000			
TURBIDITY	V3	-.9808	1.000		
SUSPENDED SOLIDS	V4	-.9798	.9911	1.000	
TOTAL RESIDUES	V22	-.9880	.9955	.9970	1.000
		V1	V3	V4	V22

OT: X-AXIS = V1 LOG DISTANCE
Y-AXIS = V3 TURBIDITY



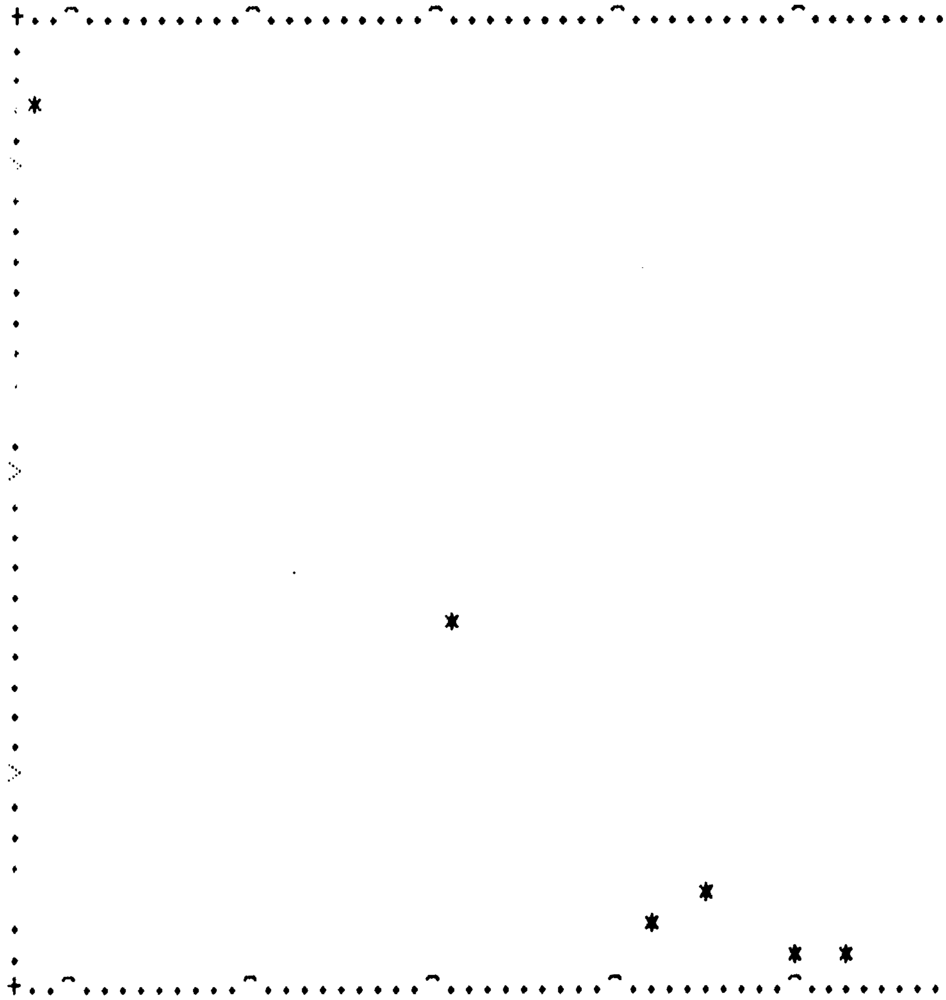
IS: 1-ST TICK = .4000 /INCREMENT = .4000
TA: MINIMUM = .3010 /MAXIMUM = 2.114
IS: 1-ST TICK = 50.00 /INCREMENT = 50.00
TA: MINIMUM = 18.00 /MAXIMUM = 144.0

REGS V3 ON V1

VARIABLE	COEF'T	ST. ERROR	T VALUE
BO	156.8815	11.39140	13.77
V1	-69.83654	6.936486	-10.07

DEGREES OF FREEDOM = 4
RESIDUAL MEAN SQUARE = 108.7034
ROOT MEAN SQUARE = 10.42609
R-SQUARED = .9620

SCPLOT: X-AXIS = V1 LOG DISTANCE
Y-AXIS = V4 TOTAL SUSPENDED SOLIDS



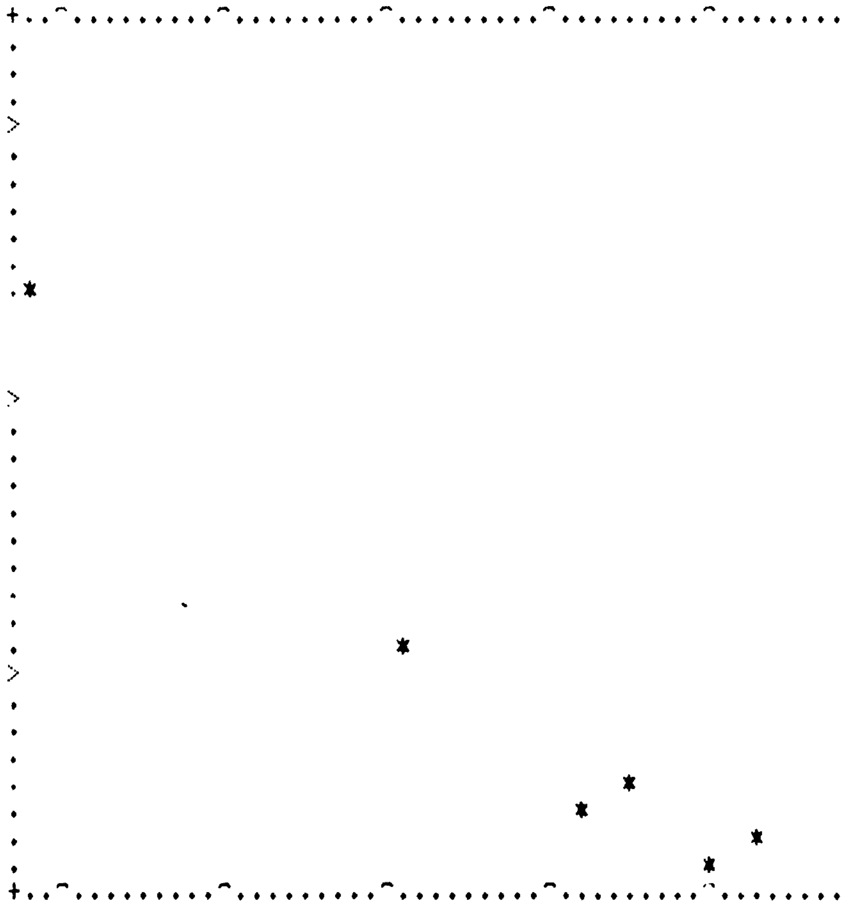
X AXIS:	1-ST TICK =	.4000	/INCREMENT =	.4000
DATA:	MINIMUM =	.3010	/MAXIMUM =	2.114
Y AXIS:	1-ST TICK =	100.0	/INCREMENT =	100.0
DATA:	MINIMUM =	35.00	/MAXIMUM =	321.0

REGS V4 ON V1

VARIABLE	COEF'T	ST. ERROR	T VALUE
B0	358.7334	27.47077	13.06
V1	-163.7243	16.72759	-9.79

DEGREES OF FREEDOM	=	4
RESIDUAL MEAN SQUARE	=	632.1660
ROOT MEAN SQUARE	=	25.14291
R-SQUARED	=	.9599

SCPLOT: X-AXIS = V1 LOG DISTANCE
Y-AXIS = V22 TOTAL RESIDUES



X AXIS:	1-ST TICK =	.4000	/INCREMENT	=	.4000
DATA:	MINIMUM =	.3010	/MAXIMUM	=	2.114
Y AXIS:	1-ST TICK =	450.0	/INCREMENT	=	150.0
DATA:	MINIMUM =	348.0	/MAXIMUM	=	654.0

REGS V22 ON V1

VARIABLE	COEF'T	ST. ERROR	T VALUE
BO	693.3022	22.07471	31.41
V1	-171.9754	13.44190	-12.79

DEGREES OF FREEDOM = 4
RESIDUAL MEAN SQUARE= 408.2059
ROOT MEAN SQUARE = 20.20411
R-SQUARED = .9761

IV.

Bottom Sediment Samples

A total of 8 sediment samples were drawn from the the two dredge cut locations prior to dredging. They are refered to as samples wrom E and W in Appendix 4. The most interesting question concerns whether thate are any definitive relationships observable between the variables present (or not present) in the bottom samples and the variables on which there is an observed effect of dredging. A series of specific observations and comments can be made in regerd to this question.

Arsenic averaged 70 UG/G in the bottom samples and showed elevated concentrations in the very high residue samples in the plume study.

Mercury was not present on the bottom and did not show up at all as an effect of dredging.

Chemicals which showed statistically significant and trackable elevations due to dredging were Organic Carbon, Iron, and Manganese which had bottom concentrations of 1.59 G/KG,1350 UG/G, and 200 UG/G respectively.
Cyanide was zero in the bottom samples and also in the plume samples, with the exception of sample 17 in which it showed a concentration of 1 MG/L

Cadmium showed a concentration of 1 UG/G in the bottom samples and no effect due to dredging in the above to below comparison, but was however present in the plume samples with a concentration of about 3 to 5 UG/L and the exceptional value of 30 UG/G in the number 17 sample.

Lead and Chromium were quite low in both the bottom and water samples. Copper was as low as chromium but showed higher elevations than chromium in the plue samples

Oil and Grease were found to be distributed on the bottom in a spotty fashion with 4 samples having none and 4 samples having concentrations of 3000 to 4000 MG/G,and were not found in the transect or the plume samples.

Zinc, at about 13 UG/G in the bottom samples showed a slight increase from above to below on July 7 but not on July 8.

Total nitrogen at about 320 MG/G in the bottom samples did not show an increase from above to below on either sampling day.

Phosphorus was present in the bottom samples at a concentration of about 230 MG/KG. As noted elsewhere phosphorus showed significant decreases on bot days as well as the dramatic block of water effect from day 7 to day 8.

APPENDIX 1.

Transect data

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
ANALYSES OF MISCELLANEOUS STATIONS

PROCESS DATE 11/06/76

01

DATE	TIME	DIS-SOLVED ARSENIC (AS) (UG/L) (01000)	SUS-PENDED ARSENIC (AS) (UG/L) (01001)	DIS-SOLVED CAD-MIUM (CD) (UG/L) (01025)	SUS-PENDED CAD-MIUM (CD) (UG/L) (01026)	TOTAL ORGANIC CARBON (C) (MG/L) (00680)	DIS-SOLVED CHLO-RIDE (CL) (MG/L) (00940)	DIS-SOLVED CHRO-MIUM (CR) (UG/L) (01030)	SUS-PENDED CHRO-MIUM (CR) (UG/L) (01031)	CHEM-ICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L) (00340)
444904093001801 - MISS R (A-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.01)										
JULY, 1976										
07...	0720	--	--	--	--	--	--	--	--	31
07...	0800	0	2	1	0	12	25	10	0	29
07...	0845	2	0	0	1	13	26	10	0	24
07...	0930	--	--	--	--	13	--	--	--	35
07...	1030	0	0	1	1	12	24	10	0	40
07...	1130	0	2	0	1	13	24	10	0	35
07...	1220	0	2	0	1	14	24	10	0	33
07...	1320	0	2	1	0	15	24	10	0	32
07...	1430	0	1	1	0	13	26	<10	0	31
07...	1545	0	2	0	1	12	26	10	0	--
07...	1605	0	1	0	1	15	27	<10	0	37
07...	1705	2	0	0	1	13	27	10	0	36
08...	0735	1	1	0	2	14	27	<10	0	35
08...	0815	0	2	0	2	13	26	10	0	35
08...	0915	0	0	0	1	13	26	10	0	34
08...	1020	0	6	0	2	13	26	10	0	39
08...	1115	2	0	1	0	14	27	<10	0	34
08...	1215	1	1	1	0	13	26	<10	0	24
08...	1345	3	0	0	1	14	27	10	10	33
08...	1410	2	0	0	1	12	26	10	0	32
08...	1505	1	0	0	1	13	25	<10	0	36
08...	1610	2	0	0	1	13	26	<10	0	33
08...	1715	3	0	0	2	13	26	<10	10	41
08...	1840	3	0	1	0	12	26	<10	0	38
08...	0630	1	0	1	1	9.0	27	10	0	28
444904093001802 - MISS R (C-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.02)										
JULY, 1976										
07...	0838	2	0	1	2	13	23	10	0	44

DATE	DIS-SOLVED COPPER (CU) (UG/L) (01040)	SUS-PENDED COPPER (CU) (UG/L) (01041)	CYANIDE (CN) (MG/L) (00720)	DIS-SOLVED IRON (FE) (UG/L) (01046)	TOTAL IRON (FE) (UG/L) (01045)	DIS-SOLVED LEAD (PB) (UG/L) (01049)	SUS-PENDED LEAD (PB) (UG/L) (01050)	DIS-SOLVED MAN-GANESE (MN) (UG/L) (01056)	SUS-PENDED MAN-GANESE (MN) (UG/L) (01054)	DIS-SOLVED MERCURY (HG) (UG/L) (71890)

444904093001801 - MISS R (A-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,01)

DATE										
JULY, 1976										
07...	--	--	.00	--	680	--	--	--	--	--
07...	0	0	.00	10	720	5	0	20	160	<.5
07...	0	0	.00	10	640	6	0	20	160	<.5
07...	--	--	.00	--	690	--	--	--	--	--
07...	0	0	.00	10	680	11	0	20	160	<.5
07...	0	10	.00	10	660	0	6	10	170	<.5
07...	0	0	.00	20	640	5	2	10	140	<.5
07...	0	0	.00	20	630	6	0	10	160	<.5
07...	0	0	.00	10	600	5	0	10	160	<.5
07...	0	0	.00	10	630	3	3	20	150	<.5
07...	0	10	.00	20	880	6	2	30	170	<.5
07...	0	10	.00	20	450	6	1	20	120	<.5
08...	0	10	.00	10	330	3	9	10	110	<.5
08...	0	10	.00	20	340	3	10	10	110	<.5
08...	0	0	.00	10	460	6	7	10	120	.5
08...	0	10	.00	10	380	5	4	10	110	<.5
08...	0	10	.00	10	310	5	2	10	110	<.5
08...	10	0	.00	0	360	5	2	10	110	<.5
08...	0	10	.00	0	340	1	6	10	110	<.5
08...	0	10	.00	0	310	3	4	10	110	<.5
08...	10	0	.00	0	380	3	5	10	110	<.5
08...	0	10	.00	0	410	5	0	10	130	<.5
08...	0	10	.00	20	790	2	4	20	150	<.5
08...	0	10	.00	10	410	4	0	20	120	<.5
08...	0	10	.00	20	1000	6	10	10	130	<.5

444904093001802 - MISS R (C-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,02)

DATE										
JULY, 1976										
07...	0	10	.00	10	1000	11	4	40	250	<.5

DATE	PH (UNITS) (00400)	DIS-SOLVED ORTHO, PHOS-PHORUS (P) (MG/L) (00671)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L) (70507)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L) (70300)	SUS-PENDED SOLIDS (MG/L) (70299)	TOTAL RESI-DUE (MG/L) (00500)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS) (00095)	TOTAL SUL-FIDE (S) (MG/L) (00745)	DIS-SOLVED ZINC (ZN) (UG/L) (01090)	SUS-PENDED ZINC (ZN) (UG/L) (01091)
444904093001801 - MISS R (A-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,01)										
JULY, 1976										
07...	8.2	--	.27	--	30	320	495	.2	--	--
07...	8.2	.25	.27	273	20	319	505	.7	0	20
07...	8.1	.26	.28	267	28	316	520	.5	0	20
07...	8.1	--	.28	--	30	325	510	.5	--	--
07...	8.2	.26	.29	274	30	320	520	.4	0	20
07...	8.1	.28	.30	267	25	331	515	.8	0	10
07...	8.2	.26	.26	260	19	323	515	.5	10	10
07...	8.1	.26	.28	271	31	313	520	.5	0	20
07...	8.1	.32	.32	278	14	332	520	.6	0	30
07...	8.2	.31	.33	273	18	317	520	.9	0	20
07...	8.2	.32	.33	277	19	338	525	.3	0	30
07...	8.2	.35	.36	279	14	311	500	1.0	10	0
08...	7.9	.41	.44	274	4	324	525	.4	10	0
08...	7.9	.39	.43	260	10	326	510	.9	0	10
08...	7.9	.38	.39	279	13	325	520	.8	0	20
08...	7.9	.36	.41	260	10	321	525	.8	0	10
08...	7.9	.38	.40	270	12	327	520	.0	0	10
08...	8.0	.40	.41	270	10	317	525	.3	10	20
08...	8.1	.37	.38	265	13	323	515	.6	10	0
08...	8.0	.35	.37	264	14	320	505	.0	0	10
08...	8.1	.32	.38	264	15	315	505	.2	10	10
08...	8.1	.35	.35	265	23	325	495	.0	0	10
08...	8.1	.31	.34	270	37	344	500	.1	10	0
08...	8.1	.33	.33	273	22	324	495	1.0	10	0
08...	8.0	.39	.42	282	10	314	515	.9	30	150
444904093001802 - MISS R (C-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 16,02)										
JULY, 1976										
07...	8.2	.22	.25	264	55	358	505	1.1	10	20

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444904093001801 - MISS R (A-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.01)

DATE	SUS- PENDED MERCURY (HG) (UG/L) (71895)	DIS- SOLVED NICKEL (NI) (UG/L) (01065)	SUS- PENDED NICKEL (NI) (UG/L) (01066)	DIS- SOLVED ORGANIC NITRO- GEN (N) (MG/L) (00607)	TOTAL ORGANIC NITRO- GEN (N) (MG/L) (00605)	DIS- SOLVED AMMONIA NITRO- GEN (N) (MG/L) (00608)	AMMONIA NITRO- GEN (N) (MG/L) (00610)	DIS- SOLVED NITRITE PLUS NITRATE (N) (MG/L) (00631)	TOTAL NITRITE PLUS NITRATE (N) (MG/L) (00630)	OIL AND GREASE (MG/L) (00550)
JULY, 1976										
07...	--	--	--	--	1.2	--	1.3	--	.25	--
07...	.0	5	0	.50	1.1	1.2	1.4	.21	.26	3
07...	.0	5	0	.60	1.1	1.2	1.4	.25	.26	0
07...	--	--	--	--	1.2	--	1.3	--	.30	0
07...	.0	5	2	.90	1.2	1.2	1.4	.22	.32	0
07...	.0	4	0	.90	1.1	1.2	1.3	.23	.26	1
07...	.0	5	0	.70	1.4	1.1	1.3	.22	.25	0
07...	.0	6	0	.60	1.3	1.2	1.3	.38	.43	1
07...	.0	5	0	.50	1.2	1.3	1.4	.29	.29	0
07...	.0	5	0	.60	1.2	1.3	1.4	.22	.24	0
07...	.0	5	0	.60	1.3	1.3	1.4	.22	.25	0
07...	.0	9	0	.70	1.2	1.4	1.6	.21	.24	2
08...	.0	9	2	.60	1.0	1.5	1.6	.21	.23	1
08...	.0	10	0	.60	1.2	1.6	1.6	.21	.22	1
08...	.0	9	0	.80	1.1	1.4	1.7	.22	.23	0
08...	.0	9	0	.70	1.0	1.3	1.5	.21	.21	0
08...	.0	12	2	.60	1.3	1.4	1.4	.23	.36	2
08...	.0	12	3	.60	.03	--	--	.21	.99	1
08...	.0	11	1	.90	1.3	1.3	1.3	.21	.43	0
08...	.0	11	12	.70	1.2	1.2	1.3	.22	.28	1
08...	.0	11	11	.60	1.1	1.1	1.1	.21	.46	0
08...	.0	12	2	.90	1.6	1.1	1.2	.22	.31	1
08...	.0	9	0	1.2	1.2	.32	.32	.24	1.4	4
08...	.0	10	0	1.2	1.2	.05	.05	.22	1.7	2
08...	.8	9	3	.90	1.0	1.5	1.6	.24	.26	1

444904093001802 - MISS R (C-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.02)

DATE	SUS- PENDED MERCURY (HG) (UG/L) (71895)	DIS- SOLVED NICKEL (NI) (UG/L) (01065)	SUS- PENDED NICKEL (NI) (UG/L) (01066)	DIS- SOLVED ORGANIC NITRO- GEN (N) (MG/L) (00607)	TOTAL ORGANIC NITRO- GEN (N) (MG/L) (00605)	DIS- SOLVED AMMONIA NITRO- GEN (N) (MG/L) (00608)	AMMONIA NITRO- GEN (N) (MG/L) (00610)	DIS- SOLVED NITRITE PLUS NITRATE (N) (MG/L) (00631)	TOTAL NITRITE PLUS NITRATE (N) (MG/L) (00630)	OIL AND GREASE (MG/L) (00550)
JULY, 1976										
07...	.0	4	4	.70	1.4	1.4	1.4	.27	.44	2

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PROCESS DATE 11/06/76

DATE	TIME	DIS-SOLVED ARSENIC (AS) (UG/L) (01000)	SUS-PENDED ARSENIC (AS) (UG/L) (01001)	DIS-SOLVED CAD-MIUM (CD) (UG/L) (01025)	SUS-PENDED CAD-MIUM (CD) (UG/L) (01026)	TOTAL ORGANIC CARBON (C) (MG/L) (00680)	DIS-SOLVED CHLO-RIDE (CL) (MG/L) (00940)	DIS-SOLVED CHRO-MIUM (CR) (UG/L) (01030)	SUS-PENDED CHRO-MIUM (CR) (UG/L) (01031)	CHEM-ICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L) (00340)

444904093001827 - MISS R (C-26) NR GREY CLOUD IS AT INVER GR HT MN (LAT 44 49 04 LONG 093 00 18,27)

DATE	TIME	(01000)	(01001)	(01025)	(01026)	(00680)	(00940)	(01030)	(01031)	(00340)
JULY, 1976										
08...	1945	3	0	0	1	13	24	<10	0	31

444904093001870 - MISS R (B) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,70)

DATE	TIME	(01000)	(01001)	(01025)	(01026)	(00680)	(00940)	(01030)	(01031)	(00340)
JULY, 1976										
07...	0915	0	3	0	2	10	23	10	0	40
07...	1010	0	0	0	1	12	22	10	0	36
07...	1115	0	2	0	2	15	23	10	0	37
07...	1200	3	0	2	0	14	23	10	0	37
07...	1300	0	2	1	1	13	23	10	0	36
07...	1400	1	1	1	1	17	24	10	0	36
07...	1500	0	2	2	0	17	23	10	0	42
07...	1600	0	2	0	2	13	26	10	0	42
07...	1700	0	2	9	1	[illegible]	24	10	0	37
07...	1800	2	3	0	3	25	26	10	0	58
07...	1845	0	2	0	2	17	28	10	0	42
07...	2000	0	3	0	2	18	26	10	0	41
08...	0900	0	2	0	2	22	24	10	0	43
08...	1000	0	0	0	1	15	27	10	0	31
08...	1100	0	2	0	0	18	28	<10	0	25
08...	1200	2	0	1	0	15	26	<10	10	34
08...	1300	2	0	0	1	14	27	<10	0	34
08...	1445	2	0	1	0	14	28	<10	10	32
08...	1530	2	2	0	3	13	27	<10	0	38
08...	1545	2	0	0	1	11	26	10	30	39
08...	1705	3	0	0	1	25	28	<10	0	34
08...	1745	3	1	0	1	13	27	<10	10	39
08...	1845	3	0	0	1	12	27	10	0	34
08...	1945	2	2	0	1	17	26	<10	10	34
08...	2045	3	0	1	2	19	23	<10	20	45

DATE	DIS-SOLVED COPPER (CU) (UG/L) (01040)	SUS-PENDED COPPER (CU) (UG/L) (01041)	CYANIDE (CN) (MG/L) (00720)	DIS-SOLVED IRON (FE) (UG/L) (01046)	TOTAL IRON (FE) (UG/L) (01045)	DIS-SOLVED LEAD (PB) (UG/L) (01049)	SUS-PENDED LEAD (PB) (UG/L) (01050)	DIS-SOLVED MAN-GANESE (MN) (UG/L) (01056)	SUS-PENDED MAN-GANESE (MN) (UG/L) (01054)	DIS-SOLVED MERCURY (HG) (UG/L) (71890)
444904093001827 - MISS R (C-26) NR GREY CLOUD IS AT INVER GR HT MN (LAT 44 49 04 LONG 093 00 18,27)										
JULY, 1976										
08...	0	10	.00	10	310	5	1	10	110	<.5
444904093001870 - MISS R (B) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,70)										
JULY, 1976										
07...	0	10	--	0	1300	8	0	10	210	<.5
07...	0	10	.00	10	1200	4	4	30	180	<.5
07...	0	10	.00	0	1400	7	3	20	210	<.5
07...	0	10	.00	20	1200	8	0	10	200	<.5
07...	0	0	.00	10	1200	7	0	10	190	<.5
07...	0	10	.00	10	1300	8	0	10	200	.5
07...	0	10	.00	10	1600	11	0	20	220	<.5
07...	0	10	.00	10	1600	4	6	20	220	<.5
07...	--*	10	.20	10 --	960 --	4 --	4	20 --	190	<.5 --
07...	0	10	.00	30	4500	7	15	150	310	<.5
07...	0	10	.00	30	1800	4	7	30	210	<.5
07...	0	10	.00	10	1700	5	6	30	200	<.5
08...	0	10	.00	10	2200	4	8	30	200	<.5
08...	0	10	.00	20	340	3	4	10	110	<.5
08...	0	10	.00	10	450	2	3	10	120	.5
08...	10	0	.00	10	450	7	6	10	110	<.5
08...	0	10	.00	0	660	3	6	20	130	<.5
08...	0	10	.00	10	650	4	3	10	130	<.5
08...	0	10	.00	0	860	2	12	30	140	<.5
08...	10	0	.00	0	830	3	5	20	130	<.5
08...	0	10	.00	0	550	4	1	30	120	<.5
08...	0	10	5.0	0	410	5	5	30	140	<.5
08...	0	10	.00	10	530	4	0	30	110	<.5
08...	10	0	.00	0	490	2	5	40	110	.5
08...	0	10	.00	10	1700	3	10	60	170	<.5

DATE	SUS-PENDED MERCURY (HG) (UG/L) (71895)	DIS-SOLVED NICKEL (NI) (UG/L) (01065)	SUS-PENDED NICKEL (NI) (UG/L) (01064)	DIS-SOLVED ORGANIC NITRO-GEN (N) (MG/L) (00607)	TOTAL ORGANIC NITRO-GEN (N) (MG/L) (00605)	DIS-SOLVED AMMONIA NITRO-GEN (N) (MG/L) (00608)	AMMONIA NITRO-GEN (N) (MG/L) (00610)	DIS-SOLVED NITRITE PLUS NITRATE (N) (MG/L) (00631)	TOTAL NITRITE PLUS NITRATE (N) (MG/L) (00630)	OIL AND GREASE (MG/L) (00550)

444908093001927 - MISS R (C-26) NR GREY CLOUD IS AT INVER GR HT MN (LAT 44 49 04 LONG 093 00 18,27)

DATE	SUS-PENDED MERCURY	DIS-SOLVED NICKEL	SUS-PENDED NICKEL	DIS-SOLVED ORGANIC NITROGEN	TOTAL ORGANIC NITROGEN	DIS-SOLVED AMMONIA NITROGEN	AMMONIA NITROGEN	DIS-SOLVED NITRITE PLUS NITRATE	TOTAL NITRITE PLUS NITRATE	OIL AND GREASE
JULY, 1976										
08...	.0	7	0	1.1	1.1	.68	.68	3.4	4.1	0

444908093001878 - MISS R (B) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 08 LONG 093 00 18,70)

DATE	SUS-PENDED MERCURY	DIS-SOLVED NICKEL	SUS-PENDED NICKEL	DIS-SOLVED ORGANIC NITROGEN	TOTAL ORGANIC NITROGEN	DIS-SOLVED AMMONIA NITROGEN	AMMONIA NITROGEN	DIS-SOLVED NITRITE PLUS NITRATE	TOTAL NITRITE PLUS NITRATE	OIL AND GREASE
JULY, 1976										
07...	.0	6	0	.80	1.2	1.1	1.2	.20	.37	1
07...	.0	6	0	1.0	1.6	1.2	1.4	6.7	6.9	0
07...	.0	6	0	.50	1.2	1.2	1.3	.55	.56	0
07...	.0	6	0	.70	1.4	1.1	1.2	.36	.39	1
07...	.0	8	2	.60	1.3	1.2	1.3	.25	.40	1
07...	.0	4	5	.60	1.3	1.2	1.3	.24	.35	1
07...	.0	10	0	.70	1.4	1.2	1.4	.25	.72	0
07...	.0	5	0	.90	1.5	1.2	1.4	.23	.25	0
07...	.0	-- 5	0	.90	1.4	1.2	1.4 --	.28 --	.28 --	-- 0
07...	.0	9	9	.80	2.0	1.4	1.5	.88	1.1	0
07...	.0	7	1	.80	1.6	1.2	1.4	.23	.23	0
07...	.0	6	1	.70	1.4	1.2	1.4	.23	.26	0
08...	.0	7	3	.90	1.6	1.2	1.5	.22	.29	0
08...	.0	10	0	.40	1.1	1.4	1.6	.21	.22	0
08...	.0	11	3	.80	1.2	1.4	1.4	.22	.51	0
08...	.0	10	11	.00	.60	1.4	.90	.23	.68	1
08...	.0	11	4	1.0	1.3	1.3	1.3	.21	.60	0
08...	.0	11	5	.80	1.4	1.4	1.4	.22	.36	0
08...	.0	11	1	.70	1.3	1.4	1.4	.22	.42	2
08...	.0	10	6	2.0	2.5	.00	.01	.20	2.0	3
08...	.0	14	4	1.0	1.0	1.1	1.1	.67	1.2	2
08...	.0	9	0	.20	.60	.50	.50	.20	1.4	1
08...	.0	10	0	.95	.95	.15	.15	.20	1.7	1
08...	.0	7	3	.00	.11	--	--	.21	.96	0
08...	.0	10	10	.60	1.3	1.2	1.2	.22	.56	-- 0

111

DATE	PH (UNITS) (00400)	DIS-SOLVED ORTHO, PHOS-PHORUS (P) (MG/L) (00671)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L) (70507)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L) (70300)	SUS-PENDED SOLIDS (MG/L) (70299)	TOTAL RESI-DUE (MG/L) (00500)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS) (00095)	TOTAL SUL-FIDE (S) (MG/L) (00745)	DIS-SOLVED ZINC (ZN) (UG/L) (01090)	SUS-PENDED ZINC (ZN) (UG/L) (01091)
444908093001827 - MISS R (C-26) NR GREY CLOUD IS AT INVER GR HT MN (LAT 44 49 08 LONG 093 00 18,27)										
JULY, 1976										
08...	7.9	.30	.30	257	12	335	500	.0	10	0
444908093001870 - MISS R (B) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,70)										
JULY, 1976										
07...	8.2	.23	.24	267	26	355	515	.9	0	30
07...	7.6	.23	.25	303	31	361	530	.4	10	20
07...	8.1	.19	.20	256	55	321	505	.0	10	0
07...	8.2	.23	.23	272	33	335	515	.3	0	40
07...	8.2	.24	.25	267	33	324	510	.6	10	20
07...	8.2	.25	.26	270	30	349	515	.6	0	30
07...	8.2	.26	.27	265	49.	352	515	.7	10	20
07...	8.2	.23	.25	270	51	343	510	.3	0	30
07...	8.2--	.26--	.27--	270--	35--	[illegible] --	5[illegible]--	.1 --	0 --	20
07...	6.2	.33	.34	276	154	452	520	1.3	0	40
07...	8.2	.27	.28	269	53	360	515	.4	10	30
07...	8.2	.27	.27	287	55	355	510	.1	0	40
08...	7.9	.27	.29	293	80	381	520	1.1	0	40
08...	7.9	.40	.40	300	6	322	525	.8	10	10
08...	8.0	.33	.38	274	16	333	520	.0	0	20
08...	7.9	.38	.40	267	15	331	525	.2	10	10
08...	8.0	.37	.38	270	25	339	530	.0	0	10
08...	8.1	.37	.39	273	27	343	535	.0	10	10
08...	8.1	.37	.37	266	54	373	525	.6	10	0
08...	8.1	.36	.42	275	32	347	515	.0	0	20
08...	8.2	.35	.38	281	25	337	520	.0	10	0
08...	8.1	.35	.36	275	34	[illegible]	535	.0	0	20
08...	8.1	.33	.33	273	30	326	505	.0	0	10
08...	8.1	.32	.32	265	25	334	495	.0	10	70
08...	8.0	.30	.33	267	72	386	510	--	0	30

BOD Results for the Corps Dredging Project
(July 1976)

A		B		C		Date
5.8	(0800)	6.2	(1010)	8.1	(no time)	7-7-76
8.8	(0845)	6.3	(1115)	8.7	(no time)	7-7-76
6.2	(1220)	6.3	(1300)	5.7	(1330)	7-7-76
7.0	(1320)	6.6	(1400)	5.1	(1525)	7-7-76
4.4	(1430)	6.9	(1500)	6.3	(1625)	7-7-76
5.4	(1545)	7.5	(1600)			7-7-76
5.4	(1605)	6.6	(1800)			7-7-76
7.0	(1705)	~~8.7~~	~~(1800)~~			7-7-76
		7.2	(1845)			7-7-76
		7.2	(2000)			7-7-76
4.8	(0645)	6.8	(0900)	7.8	(1020)	7-8-76
7.2	(0735)	5.4	(1000)	12.9	(0816)	7-8-76
6.6	(0815)	6.0	(1100)	10.8	(0835)	7-8-76
7.0	(0915)	6.0	(1200)	7.0	(0900)	7-8-76
5.6	(1020)	8.0	(1300)	8.7	(0935)	7-8-76
6.0	(1215)	7.0	(1500)	11.2	(0942)	7-8-76
6.6	(1345)	5.2	(1545)	11.4	(1020)	7-8-76
4.5	(1410)	6.4	(1705)	5.4	(1345)	7-8-76
5.7	(1505)	6.2	(1745)	9.2	(1410)	7-8-76
5.7	(1715)	7.8	(1845)	5.8	(1415)	7-8-76
6.4	(1840)	4.8	(1945)	6.3	(1433)	7-8-76
		6.0	(2045)	5.8	(1450)	7-8-76
				11.8	(1454)	7-8-76
				7.5	(1522)	7-8-76
				6.3	(1544)	7-8-76
				6.4	(1607)	7-8-76
				4.8	(1630)	7-8-76
				4.8	(1945)	7-8-76

CH, 7-9-76
at 1130
BOD = 5.1

APPENDIX 2.

Dredge Plume Data

Sample No.	Date	Time	Location	Probe depth (ft)	Turbidity (JTU)	Total Suspended Solids (mg/l)	Temperature (°C)	Dissolved oxygen (mg/l)	Biological ox - demand (mg/l)	Total Aldrin (ug/l)	Total Chlordane (ug/l)	Total DDD (ug/l)
	7-7-76	0800	T-#4 Bk-Buoy	5	42.3 ± 6.8	55	25.5	3.1	?			
	7-7-76	0820	T-#4 Bk-Shore	3.5 - 4.0	61.4 ± 21.4	78	25.5	3.8-4.1	?			
	7-7-76	0950	Sta. 19.5 Mid-channel	11.0	26.2 ± 1.0	28	26.2	3.8	?			
)	7-7-76	1034	Mile-825.0 Bk-Shore	12.0	18.9 ± 0.6	21	26.0	3.7	?	.00	.0	.00
round	7-7-76	1330	T-A Mid-channel	Sample 7' Total depth 14'	17.7 ± 0.4	13	25	3.9	5.7	.00	.0	.00
	7-7-76	1525	T-13 D. Buoy + Bk Shore 30m fr shore	SD-10 TD-12	26.6 ± 1.2	27	25.0	3.5	5.1			
	7-7-76	1625	T-4 Bk shore 30-60 mi below disch.	SD-3.5 TD-3.7	40.8 ± 3.0	63	26	5.9	6.3			
round :)	7-7-76	1943	T-A Bk-Buoy	SD-8	13.6 ± 1.5	12	25.4	0.8		.00	.0	.00
:)	7-8-76	0816	End of discharge pipe			904			12.9	.00	.0	.00
)	7-8-76	0835	Sd. of spoil island - adjacent	SD-2.5'	151.4 ± 6.9	352	25.1	2.5	10.8	.00	.0	.00
1	7-8-76	0900	20-30' west spoil island	SD-2.5'	52.0 ± 8.0	20	25.1	2.1	7.0			
2	7-8-76	0935	Immed. west of spoil pile	SD-2.5'	73 ± 5.5	210	25.2	2.4	8.7			
3	7-8-76	0942	Immed. west of spoil pile	2.5	98 ± 29	42	24.9	3.2	11.2			
a) 4	7-8-76	1320	T-7 Bk shore	2.5	25 ± 5.0	430	25.0	1.9	11.4	.00	.0	.00
5	7-8-76	1335	Immed. east of spoil pile		53 ± 8	168	25.5	2.0	5.4	.00	.0	.00
Nom) 6	7-8-76	1343	Grab sample runoff → channel	spoil pile		113			?	.00	.0	.00
Nom) 7	7-8-76	1410	Immed. NW of spoil pile	SD - Surface	52 ± 9	1930	26.5	4.3	9.2	.00	.0	.00
8	7-8-76	1433	Immed. SE of spoil pile	Surface	28 ± 3	37	26.3	3.4	6.3			
9	7-8-76	1450	Immed. E of spoil pile	Surface	30.5 ± 5.39	44	26.5	3.4	5.8			
10	7-8-76	1458	Immed. E of spoil pile	Surface	148.9 ± 19.2	321	25.8	3.0	11.8			
11	7-8-76	1522	T-6.5 Bk. Buoy	SD-10' TD-12-13'	58 ± 15	152	25.8	2.8	7.5			
12	7-8-76	1544	T-8 Bk-Buoy	SD-12 TD-15	29 ± 6.5	45	26.1	2.6	6.3			
13	7-8-76	1607	T-9 inside Bk-Buoy	SD-10 TD-12	31 ± 1.88	59	25.5	2.2-2.5	6.4			
14	7-8-76	1630	T-11 (also B) Bk-Buoy + Bk-Cree	SD-9 TD-11	23.0 ± 0.45	35	25.8-25.5	2.1-2.0	4.8			
15	7-8-76	1702	T-13 Bk-Buoy	SD-12 TD-14	18.6 ± 0.89	44	25.5	1.8	?			
round 16	7-8-76	1945	T-A Mid-channel	SD-8 TD-11	12.27 ± 0.2	12	25.9	2.4	4.8			

*Data on 11/6/76 print-out different from earlier print-outs.

otal DD (ug/l)	Total DDE (ug/l)	Total DDT (ug/l)	Total Dieldrin (ug/l)	Total Endrin (ug/l)	Total Heptachlor (ug/l)	Total Heptachlor Epoxide (ug/l)	Total Lindane (ug/l)	Total Toxaphene (ug/l)	Total PCB (ug/l)	Dissolved Arsenic (As) (ug/l)	Suspended Arsenic (A (ug/l)
										2	0
										1	2
										2	0
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	0	1
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	0	2
										0	2
										0	-
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	0	2
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	1	17
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	3	4
										1	1
										0	4
										1	3
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	3	12
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	3	1
.00	.00	.00	.00	.00	.00	.00	.00	0	0.1	3	2
.00	.00	.00	.00	.00	.00	.00	.00	0	.0	9	32
										2	0
										2	0
										4	6
										2	2
										2	0
										1	2
										3	0
										2	3
										3	0

Suspended Arsenic (As) (ug/l)	Dissolved Cadmium (Cd) (ug/l)	Suspended Cadmium (Cd) (ug/l)	Total Organic Carbon (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Chromium (Cr) (ug/l)	Suspended Chromium (Cr) (ug/l)	Chem. Oxygen Demand (High Level) (mg/l)	Dissolved Copper (Cu) (ug/l)	Suspended Copper (Cu) (ug/l)	Cyanide (Cn) (mg/l)	Dissolved Iron (Fe) (ug/l)
0	1	2	13	23	30 / 10*	0	44	0	10	0.00	10
2	1	2	14	22	10	0	46	0	10	0.00	10
0	1	1	14	24	10	0	37	0	10	0.00	50
1	1	0	13	23	<10	0	30	0	10	0.00	10
2	1	0	14	23	10	0	37	0	0	0.00	10
2	0	1	15	23	10	0	33	0	10	0.00	10
-	0	1	13	25	20 / 10*	0	44	0	10	0.00	10
2	0	2	12	27	10	0	35	0	0	0.00	10
17	0	16	64	24	10	110	180	0	80	0.00	10
4	0	8	35	26	10	20	92	0	30	0.00	20
1	0	1	12	26	10	0	34	0	10	0.00	20
4	0	5	20	[illegible]	10	0	68	0	20	0.00	10
3	1	1	17	27	10	0	35	0	10	0.00	20
12	1	5	32	24	<10	50	97	0	40	0.00	0
1	0	2	18	27	< 10	0	53	0	20	0.00	10
2	2	0	19	27	10	20	54	0	10	0.00	0
32	0	30	164	25	< 10	350	540	0	260	1.0	20
0	1	0	15	28	< 10	0	40	0	10	0.00	0
0	1	0	16	26	<10	10	42	0	10	0.00	0
6	1	3	24	27	20	10	81	0	30	0.00	0
2	0	2	19	27	< 10	10	53	0	20	0.00	0
0	0	1	14	27	< 10	20	41	0	10	0.00	0
2	1	0	15	27	10	0	40	0	10	0.00	0
0	1	0	13	28	< 10	0	37	0	10	0.00	0
3	0	1	13	28	10	10	38	0	10	0.00	0
0	9	1	13	24	< 10	0	31	0	10	0.00	10

- "Phase 4 Results - 1976 Pilot Study"

Cyanide (Cn) (mg/l)	Dissolved Iron (Fe) (ug/l)	Total Iron (Fe) (ug/l)	Dissolved Lead (Pb) (ug/l)	Suspended Lead (Pb) (ug/l)	Dissolved Manganese (Mn) (ug/l)	Suspended Manganese (Mn) (ug/l)	Dissolved Mercury (Hg) (ug/l)	Suspended Mercury (Hg) (ug/l)	Dissolved Nickel (Ni) (ug/l)	Suspended Nickel (Ni) (ug/l)	Dis. Org. Nitrogen (N) (mg/l)
0.00	10	1,600	11	4	40	250	< 0.5	0.0	4	4	0.70
0.00	10	2,600	9	10	60	300	0.5	0.7	5	6	0.50
0.00	50	830	9	1	10	190	0.5	0.0	7	0	0.60
0.00	10	600	5	0	0	170	< 0.5	0.0	7 / 5*	0	0.50
0.00	10	680	9	2	0	190	< 0.5	0.0	5	1	0.60
0.00	10	890	5	1	20	180	< 0.5	0.0	7 / 5*	0	0.70
0.00	10	1,900	3	6	40	200	< 0.5	-	6	1	0.80
0.00	10	330	2	7	10	110	< 0.5	0.0	10	0	0.70
0.00	10	30,000	4	120	850	2,000	< 0.5	0.0	7	67	1.3
0.00	20	11,000	5	52	420	880	< 0.5	0.0	7	30	0.90
0.00	20	760	8	0	20	170	< 0.5	0.0	6	0	0.70
0.00	10	7,000	4	25	250	500	< 0.5	0.0	7	17	0.90
0.00	20	1,200	7	4	80	140	< 0.5	0.0	9	2	1.0
0.00	0	13,000	8	37	320	2,100	< 0.5	0.0	7	27	2.1
0.00	10	4,300	3	20	120	320	< 0.5	0.0	10	5	0.70
0.00	0	3,400	2	12	270	240	< 0.5	0.0	11	3	1.7
1.0	20	110,000	4	340	1,100	6,700	< 0.5	0.0	9	280	2.0
0.00	0	1,300	4	4	110	120	< 0.5	0.0	10	5	0.80
0.00	0	1,600	4	16	110	130	< 0.5	0.0	11	1	1.0 / 0.90*
0.00	0	9,200	6	26	220	560	< 0.5	0.0	9	15	1.8
0.00	0	4,100	3	11	140	290	< 0.5	0.0	9	8	1.2
0.00	0	1,400	2	7	50	140	< 0.5	0.0	9	0	1.7
0.00	0	1,400	4	2	50	180	< 0.5	0.0	9	3	1.3
0.00	10	800	3	2	60	120	< 0.5	0.0	10	1	1.1
0.00	0	780	4	3	40	130	< 0.5	0.0	11	0	1.2
0.00	10	310	5	1	10	110	< 0.5	0.0	7	0	1.1

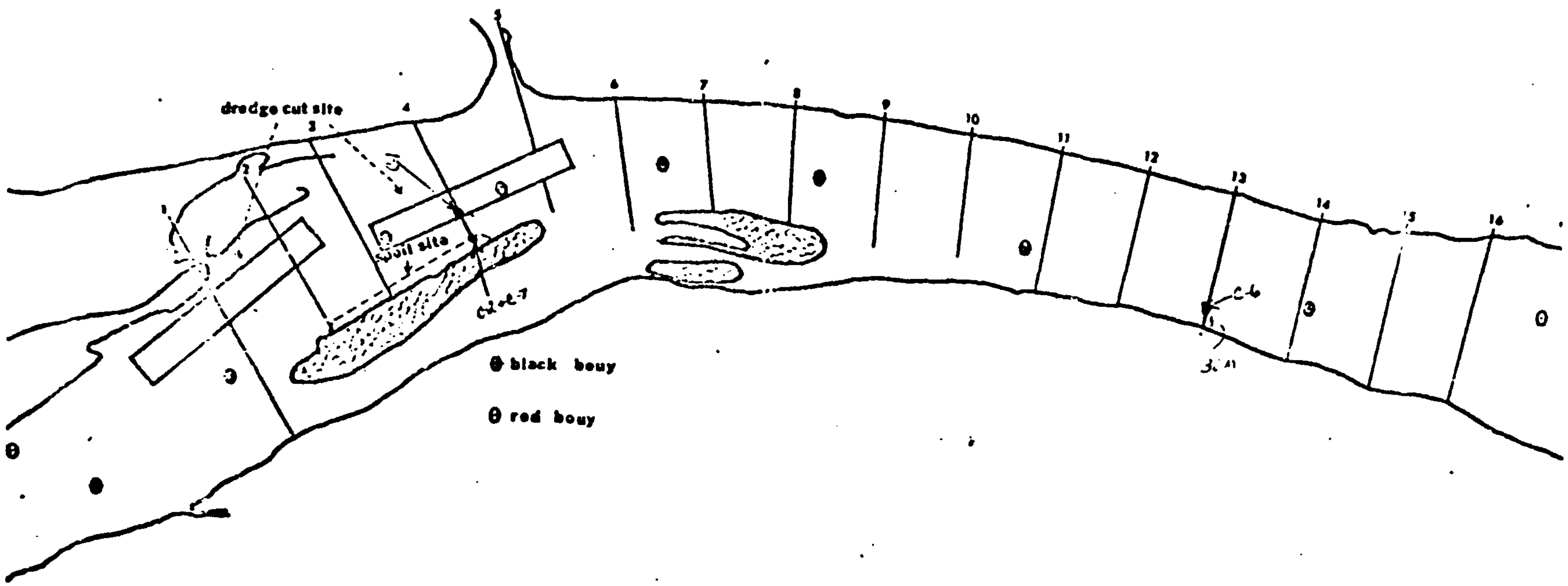
ed	Suspended Nickel (Ni) (ug/l)	Dis. Org. Nitrogen (N) (mg/l)	Total Org. Nitrogen (N) (mg/l)	Dis. Ammonia Nitrogen (N) (mg/l)	Ammonia Nitrogen (N) (mg/l)	Dissol. Nitrite plus Nitrate (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Oil and Grease (mg/l)	pH	Dissolved Ortho Phosphorus (P) (mg/l)	Total Ortho Phosphorus (P) (mg/l)	Dis. Solids Residue at 180C (mg/l)
	4	0.70	1.4	1.4	1.4	0.27	0.44	2	8.2	0.22	0.25	266
	6	0.50	1.4	1.4	1.4	0.49	0.65	1	8.2	0.16	0.21	260
	0	0.60	1.2	1.1	1.2	0.32	0.46	2	8.2	0.21	0.24	270
5*	0	0.50	1.0	1.0	1.2	0.19	.22	2	8.2	0.20	0.21	265
	1	0.60	1.2	1.2	1.3	0.23	0.27	1	8.1	0.30	0.31	273
5*	0	0.70	1.2	1.3	1.4	1.1	1.1	1	8.1	0.23	0.25	270
	1	0.80	1.4	1.3	1.5	0.91	1.0	0	8.1	0.26	0.27	277
	0	0.70	1.2	1.4	1.5	0.22	.22	1	8.1	0.39	0.41	268
	67	1.3	3.9	1.4	1.4	0.20	0.97	2	7.7	0.10	0.14	293
	30	0.90	2.9	1.5	1.5	0.21	0.56	1	7.9	0.21	0.22	280
	0	0.70	1.4	1.3	1.5	0.24	0.30	0	7.9	0.35	0.37	277
	17	0.90	2.0	1.4	1.4	0.38	0.78	2	8.0	0.28	0.29	278
	2	1.0	[illegible]	1.2	1.2	0.29	0.76	0	8.0	0.33	0.33	274
	27	2.1	3.2	[illegible]	0.32	0.40	2.2	1	8.0	0.21	0.21	270
	5	[illegible]	1.9 / 1.6*	[illegible]	1.1 / 1.4*	0.21	0.69	0.0	8.0	0.30	0.29	269
	3	1.7	1.5	0.85	0.85	0.32	1.3	0.0	7.6	0.24	0.24	171
	280	1.0	11	[illegible]	1.8	0.16	0.80	--	8.1	0.07	0.23	282
	5	0.60	1.4	1.4	1.4	0.66	0.77	1	8.1	0.30	0.32	273
	1	1.0 / 0.90*	.90	1.4 / 1.3*	1.3	1.0	1.4	0	8.0	0.34	0.36	272
	15	1.8	2.0	0.58	0.58	1.0	2.3	--	7.9	0.21	0.22	280
	8	1.2	1.7	1.0	1.0	1.4	2.2	1	7.9	0.29	0.29	280
	0	1.7	1.7	0.01	0.01	1.7	3.7	0	8.1	0.36	0.40	273
	3	1.3	1.3	0.82	0.82	1.2	2.0	1	8.0	0.34	0.39	287
	1	1.1	1.1	1.0	1.0	0.49	1.1	1	8.0	0.37	0.38	281
	0	1.2	1.2	0.64	0.64	0.20	1.2	2	8.0	0.33	0.35	278
	0	1.1	1.1	0.68	0.69	3.4	8.1	0	7.9	0.30	0.30	257

r- e- (F)	Dis. Solids Residue at 180C (mg/1)	Total Residue (mg/1)	Specific Conduct-ance (Micromhos)	Total Sulfide (S) (mg/1)	Dissolved Zinc (Zn) (ug/1)	Suspended Zinc (Zn) (ug/1)	Total Coliforms	Fecal Coliforms	Fecal Strep-tococci	Salmonella	Shigella	Polio Virus
	266	358	505	1.1	10	20						
	260	384	500	0.8	10	30						
	270	323	495	0.8	10	0						
	265	310	500	0.1	0	20						
	273	333	520	0.6	0	20						
	270	337	510	0.5	10	10						
	277	373	515	0.5	0	40						
	268	317	570	0.3	0	10						
	293	1,370	565	2.2	0	250						
	280	670	530	1.4	0	90						
	277	327	525	1.3	0	30						
	278	563	520	0.8	10	50						
	274	348	525	0.0	10	40						
	270	798	520	0.0	10	90						
	269	476	515	0.0	0.0	40						
	171	424	560	0.0	0.0	40						
	282	3,600	520	--	0.0	860						
	273	383	530	0.4	10	20						
	272	366	520	0.1	0	30						
	280	654	525	0.0	10	80						
	280	467	520	0.1	10	30						
	273	379	520	0.2	0	20						
	287	384	515	0.0	0	20						
	281	348	515	0.0	10	0						
	278	356	505	0.5	10	0						
	257	335	500	*0.0	10	0						

APPENDIX 3.

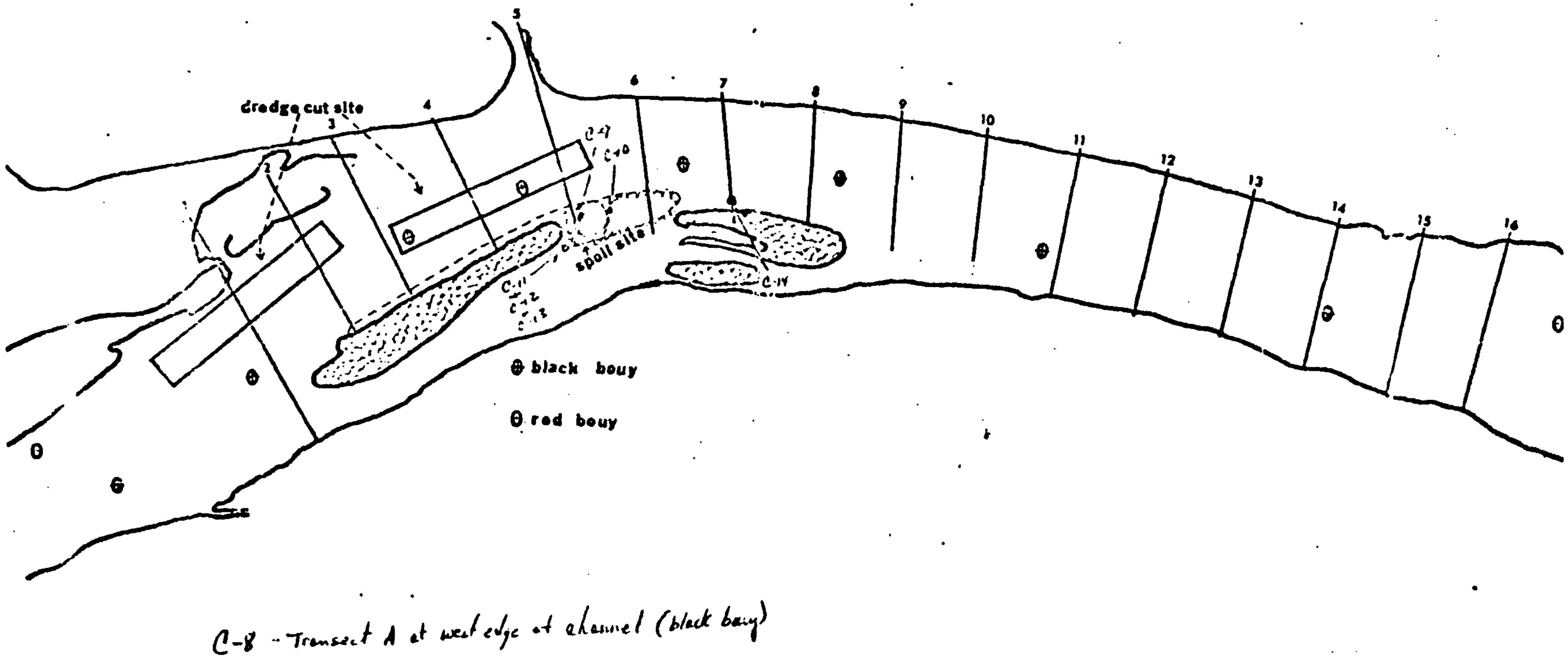
Dredge Plume Sample Maps

Pilot Study
Mississippi River
Dredge Disposal Site
July 7, 1976

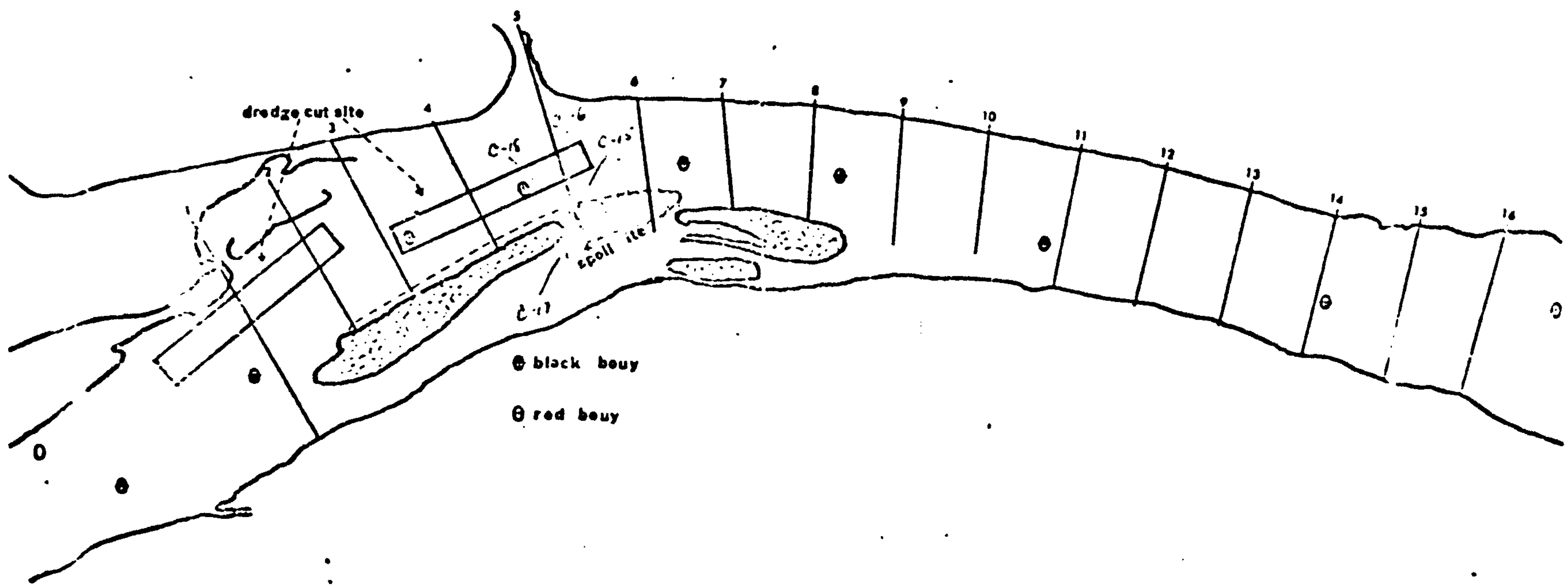


C-4 at River Mile 825.0
between edge of channel & west shore
C-5 Mid channel at Transect 7

Dredge Disposal Site
July 8, 1976



Pilot Study
Mississippi River
Dredge Disposal Site
July 8, 1976



Dredge Disposal Site
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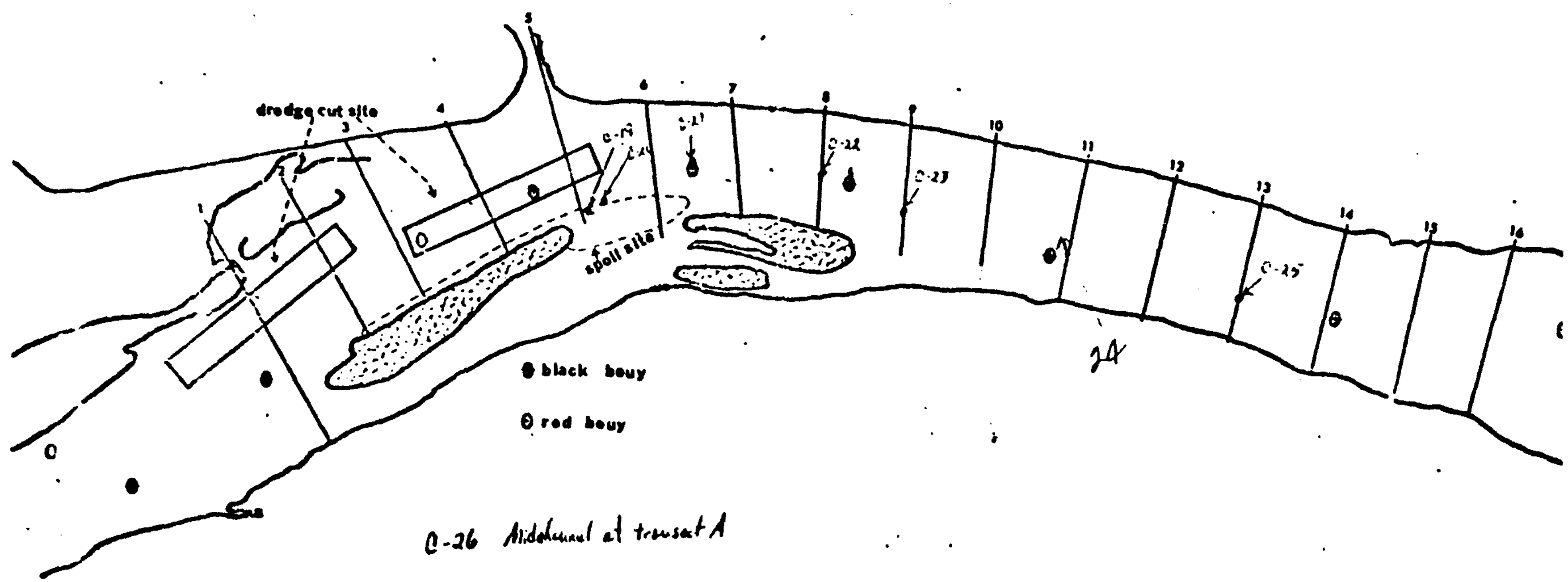

APPENDIX 4.

Bottom Sediments Samples

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY
ANALYSES OF MISCELLANEOUS STATIONS

PROCESS DATE 11/06/7[illegible]

DATE	TIME	TOTAL ARSENIC IN BOTTOM MATERIAL (UG/G) (01003)	TOTAL CADMIUM IN BOTTOM MATERIAL (UG/G) (01028)	ORGANIC CARBON IN BOTTOM MATERIAL (C) (G/KG) (00687)	TOTAL CHROMIUM IN BOTTOM MATERIAL (UG/G) (01029)	TOTAL COPPER IN BOTTOM MATERIAL (UG/G) (01043)	TOTAL CYANIDE IN BOTTOM MATERIAL (UG/G) (00721)	TOTAL IRON IN BOTTOM MATERIAL (UG/G) (01170)	TOTAL LEAD IN BOTTOM MATERIAL (UG/G) (01052)	TOTAL MERCURY IN BOTTOM MATERIAL (UG/G) (71921)	TOTAL ZINC IN BOTTOM MATERIAL (UG/G) (01053)
444944093001841 - MISS R (E-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 02 18,41)											
JULY, 1976 06...	1000	80	1	1.3	2	3	0	1200	4	.0	140
444944093001842 - MISS R (E-2) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,42)											
JULY, 1976 06...	1015	80	1	.2	1	2	0	970	4	.0	160
444944093001843 - MISS R (E-3) NR GREYCLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,43)											
JULY, 1976 06...	1030	90	1	1.4	5	4	0	1300	5	.0	220
444944093001844 - MISS R (E-4) NR GREY CLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18,44)											
JULY, 1976 06...	1045	80	1	2.4	7	5	0	1600	4	.0	230
444944093001851 - MISS R (W-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,51)											
JULY, 1976 06...	1100	70	1	2.4	[illegible]	4	0	1500	8	.0	190
444944093001852 - MISS R (W-2) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18,52)											
JULY, 1976 06...	1115	70	1	1.6	6	4	0	1500	4	.0	220

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DATE	TOTAL KJEL. NITRO-GEN IN BOTTOM MAT. (MG/KG) (00626)	TOTAL PHOS-PHORUS IN BOT-TOM MA-TERIAL (MG/KG) (00668)	LOSS ON IGNI-TION IN BOTTOM MA-TERIAL (MG/KG) (00496)	TOTAL ZINC IN BOTTOM MA-TERIAL (UG/G) (01093)	TOTAL NICKEL IN BOTTOM MA-TERIAL (UG/G) (01068)	TOTAL AMMONIA NITRO-GEN IN BOTTOM MAT. (MG/KG) (00611)	OIL AND GREASE IN BOT-TOM MA-TERIAL (MG/KG) (00553)	COD IN BOTTOM MA-TERIAL (MG/KG) (00339)	ALDRIN IN BOTTOM MA-TERIAL (UG/KG) (39333)	CHLOR-DANE IN BOTTOM MA-TERIAL (UG/KG) (39351)
444904093001841 - MISS R (E-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,41)										
JULY, 1976 06...	270	190	14000	12	3	24	,0	3600	,0	0
444904093001842 - MISS R (F-2) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,42)										
JULY, 1976 06...	370	160	12000	8	3	,0	,0	1400	,0	0
444904093001843 - MISS R (E-3) NR GREYCLOUD IS AT INVER GR HTS M (LAT 44 49 04 LONG 093 00 18,43)										
JULY, 1976 06...	370	180	18000	13	4	32	3200	6400	,0	3
444904093001844 - MISS R (E-4) NR GREY CLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18,44)										
JULY, 1976 06...	260	300	22000	17	5	59	3200	20000	,0	4
444904093001851 - MISS R (W-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,51)										
JULY, 1976 06...	370	280	20000	13	4	35	,0	5300	,0	1
444904093001852 - MISS R (W-2) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18,52)										
JULY, 1976 06...	300	190	18000	13	4	27	4500	4100	,0	0

DATE	DDD IN BOTTOM MATERIAL (UG/KG) (39363)	DDE IN BOTTOM MATERIAL (UG/KG) (39368)	DDT IN BOTTOM MATERIAL (UG/KG) (39373)	DIELDRIN IN BOTTOM MATERIAL (UG/KG) (39383)	ENDRIN BOTTOM MATERIAL (UG/KG) (39393)	HEPTACHLOR IN BOTTOM MATERIAL (UG/KG) (39413)	HEPTACHLOR EPOXIDE IN BOTTOM MATERIAL (UG/KG) (39423)	LINDANE IN BOTTOM MATERIAL (UG/KG) (39343)	TOXAPHENE IN BOTTOM MATERIAL (UG/KG) (39403)	PCB IN BOTTOM MATERIAL (UG/KG) (39519)
444904093001841 - MISS R (F-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.41)										
JULY, 1976 06...	.2	.0	.0	.0	.0	.0	.0	.0	0	0
444904093001842 - MISS R (F-2) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.42)										
JULY, 1976 06...	.0	.0	.0	.0	.0	.0	.0	.0	0	0
444904093001843 - MISS R (F-3) NR GREYCLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.43)										
JULY, 1976 06...	.5	.0	.0	.0	.0	.0	.0	.0	0	10
444904093001844 - MISS R (F-4) NR GREY CLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18.44)										
JULY, 1976 06...	.4	.0	.0	.1	.0	.0	.0	.0	0	10
444904093001851 - MISS R (F-1) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.51)										
JULY, 1976 06...	.2	.0	.0	.1	.0	.0	.0	.0	0	0
444904093001852 - MISS R (F-2) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18.52)										
JULY, 1976 06...	.2	.0	.0	.0	.0	.0	.0	.0	0	0

DATE	TIME	IN BOTTOM MA- TERIAL (UG/G) (01003)	IN BOTTOM MA- TERIAL (UG/G) (01028)	IN BOT- TOM MA- TERIAL (C) (G/KG) (00687)	MIUM IN BOTTOM MA- TERIAL (UG/G) (01029)	IN BOTTOM MA- TERIAL (UG/G) (01043)	IN BOTTOM MA- TERIAL (UG/G) (00721)	IN BOTTOM MA- TERIAL (UG/G) (01170)	IN BOTTOM MA- TERIAL (UG/G) (01052)	IN BOTTOM MA- TERIAL (UG/G) (71921)	NESE IN BOTTOM MA- TERIAL (UG/G) (01053)

444904093001853 - MISS R (M-3) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18,53)

DATE	TIME	(01003)	(01028)	(00687)	(01029)	(01043)	(00721)	(01170)	(01052)	(71921)	(01053)
JULY, 1976 06...	1130	110	1	2.4	6	4	0	1500	4	.0	250

444904093001854 - MISS R (M-4) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18,54)

DATE	TIME	(01003)	(01028)	(00687)	(01029)	(01043)	(00721)	(01170)	(01052)	(71921)	(01053)
JULY, 1976 06...	1145	60	1	.8	2	2	0	1200	4	.0	170

DATE	DDD IN BOTTOM MA-TERIAL (UG/KG) (39363)	DDE IN BOTTOM MA-TERIAL (UG/KG) (39368)	DDT IN BOTTOM MA-TERIAL (UG/KG) (39373)	DI-ELDRIN IN BOTTOM MA-TERIAL (UG/KG) (39383)	ENDRIN IN BOTTOM MA-TERIAL (UG/KG) (39393)	HEPTA-CHLOR IN BOTTOM MA-TERIAL (UG/KG) (39413)	HEPTA-CHLOR EPOXIDE IN BOT-TOM MA-TERIAL (UG/KG) (39423)	LINDANE IN BOTTOM MA-TERIAL (UG/KG) (39343)	TOX-APHENE IN BOTTOM MA-TERIAL (UG/KG) (39403)	PCB IN BOTTOM MA-TERIAL (UG/KG) (39519)
444904093001853 - MISS R (N-3) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18.53)										
JULY, 1976										
06...	.3	.0	.0	.0	.0	.0	.0	.0	0	7
444904093001854 - MISS R (N-4) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.54)										
JULY, 1976										
06...	.0	.0	.0	.0	.0	.0	.0	.0	0	0

ANALYSES OF MISCELLANEOUS STATIONS

DATE	TOTAL KJEL. NITRO-GEN IN BOTTOM MAT. (MG/KG) (00626)	TOTAL PHOS-PHORUS IN BOT-TOM MA-TERIAL (MG/KG) (00668)	LOSS ON IGNI-TION IN BOTTOM MA-TERIAL (MG/KG) (00496)	TOTAL ZINC IN BOTTOM MA-TERIAL (UG/G) (01093)	TOTAL NICKEL IN BOTTOM MA-TERIAL (UG/G) (01068)	TOTAL AMMONIA NITRO-GEN IN BOTTOM MAT. (MG/KG) (00611)	OIL AND GREASE IN BOT-TOM MA-TERIAL (MG/KG) (00553)	COD IN BOTTOM MA-TERIAL (MG/KG) (00339)	ALDRIN IN BOTTOM MA-TERIAL (UG/KG) (39333)	CHLOR-DANE IN BOTTOM MA-TERIAL (UG/KG) (39351)
444904093001853 - MISS R (W-3) NR GREYCLOUD IS AT INVER GR HTS (LAT 44 49 04 LONG 093 00 18.53)										
JULY, 1976										
06...	350	180	20000	13	4	24	4300	4600	.0	0
444904093001854 - MISS R (W-4) NR GREY CLOUD IS AT INVER GR HTS MN (LAT 44 49 04 LONG 093 00 18.54)										
JULY, 1976										
06...	180	190	11000	26	3	15	.0	2400	.0	0

APPENDIX B

ANALYSIS OF SEDIMENT DATA FROM 1974 TO 1975

Table B-1 - Analysis of Upper Mississippi River Bottom Sediment Samples Collected November 1974 (Laboratory Analysis Performed by SERCO, Inc., for U.S. Army Corps of Engineers, St. Paul, Minnesota)

Sample (dry wt)	(River Mile)	Arsenic µg/g	Cadmium µg/g	Total Chromium µg/g	Copper µg/g	Lead µg/g	Mercury µg/g	Nickel µg/g	Zinc µg/g	Oil µg/g	Total Phosphorus µg/g	COD mg/Kg	Kjeldahl mg/Kg	% Volatile Solids	% Total Solids
1	(857.48)	<0.8	1	8	6	<10	0.7	6	15	238	139	1705	241	0.5	79.5
1	(857.48)	<0.9	1	10	5	<10	0.7	8	33	190	175	2247	150	0.4	80.1
4	(851.63)	<0.8	<1	8	5	<10	0.3	5	16	247	135	4300	269	0.5	82.4
5	(850.11)	<1.0	2	10	10	19	1.1	7	29	354	201	5032	548	0.7	77.4
6	(848.24)	<0.8	1	8	11	<11	1.1	6	24	396	170	5243	156	0.5	78.1
6	(848.24)	<0.9	<1	9	12	<12	0.6	3	23	374	406	8243	145	0.5	75.4
9	(843.36)	<0.8	<1	15	10	<10	4.6	12	19	256	192	1401	186	0.7	84.1
11	(840.32)	<0.8	<1	12	3	12	0.6	12	18	773	216	<487	447	0.5	79.0
13	(837.20)	<0.8	0.9	9	2	<9	1.1	5	12	318	210	1874	134	0.6	84.2
14	(835.07)	1.8	6	43	33	95	0.8	33	143	1269	1130	101,355	422	6.2	42.8
15	(833.03)	1.2	15	115	36	73	0.8	42	170	894	1687	75,148	2797	8.3	34.5
17	(827.84)	<0.8	<1	12	5	<10	0.7	10	19	76	177	950	236	0.4	78.3
17	(827.84)	<0.9	<1	10	2	<10	0.4	7	20	64	250	511	138	0.4	77.8
19	(823.39)	<1.0	1	29	5	<11	0.8	19	14	285	143	4079	99	0.4	75.0
20	(821.00)	<0.8	1	8	2	<10	1.8	5	19	204	217	2872	73	0.5	83.0
23	(815.39)	1.0	3	39	10	<13	0.7	29	44	163	980	14,184	288	28.7	54.9
30	(802.69)	<0.9	<1	6	3	< 9	0.5	3	76	<6	247	431	235	0.5	84.3
35	(792.54)	<0.7	<1	17	10	< 6	0.4	77	15	58	164	2553	61	0.7	77.4
38	(785.00)	<1.0	<1	29	2	< 9	<0.1	17	13	149	205	1712	88	0.6	83.2
38	(785.00)	<1.0	<1	30	5	< 9	<0.1	18	12	147	225	2303	148	0.7	83.5
39	(772.79)	4.0	9	116	58	47	5.4	35	185	2825	1769	113,005	4121	14.5	19.3
41	(763.00)	<0.9	<1	8	10	< 7	0.3	8	19	85	232	772	48	0.6	80.5
41	(763.00)	<1.0	<1	5	7	< 7	0.2	5	13	60	227	960	44	0.7	81.9
42	(759.08)	<0.9	1	7	7	< 7	1.4	7	17	101	235	<481	117	0.4	82.8
42	(759.08)	1.0	1	7	7	< 7	0.6	7	17	126	188	<453	42	0.6	82.2
43	(757.49)	0.9	1	6	6	<11	0.4	6	16	801	117	<515	66	0.5	84.0
44	(756.32)	<0.8	<1	7	10	< 7	0.4	5	15	756	229	<400	13	0.7	85.8
45	(754.00)	<0.7	<1	23	8	28	0.4	17	17	624	166	5867	273	0.7	84.8
48	(747.72)	<0.6	1	7	7	<10	0.9	5	30	699	177	1096	52	0.4	84.3
49	(745.00)	10.9	<1	5	10	<10	0.3	5	13	<6	104	1278	52	0.3	81.6
49	(745.00)	0.9	<1	5	8	<10	0.2	5	13	<6	119	964	134	0.4	82.3
50	(743.22)	<0.6	<0.7	33	5	< 7	0.4	26	13	530	142	1397	109	0.4	83.8
54	(734.00)	0.8	<1	7	5	< 9	0.2	10	23	398	140	414	48	0.4	86.0
55	(732.60)	0.7	<0.8	8	6	< 8	0.3	6	35	385	152	<401	123	0.3	86.9
56	(730.32)	<0.8	<0.8	6	6	< 8	0.2	6	16	64	142	<458	90	0.5	85.3
58	(726.40)	<1.0	0.7	5	4	< 7	0.3	4	13	58	155	404	270	0.4	85.7
61	(720.46)	<0.7	<1	7	5	< 9	0.2	5	17	452	167	484	180	0.9	83.7
65	(711.64)	<0.9	<1	7	5	< 9	0.2	9	16	439	209	<461	11	0.4	84.0
66	(709.00)	<0.8	1	8	5	10	0.4	5	15	409	205	418	123	0.4	83.8
66	(709.00)	<0.9	<0.9	7	4	< 9	0.3	7	16	371	207	1417	145	0.4	82.8
67	(706.32)	<0.9	<0.9	7	5	9	0.1	5	14	34	200	444	112	0.4	86.7
68	(704.92)	<0.9	<0.6	6	6	< 6	0.4	6	19	139	375	475	108	0.6	85.9
73	(694.72)	<0.7	<0.9	7	5	< 9	0.4	7	14	673	191	3073	187	0.4	80.1
74	(692.00)	<0.7	<0.8	6	6	< 8	0.2	8	15	538	194	3378	123	0.4	80.0
74	(692.00)	<0.7	0.9	7	5	< 9	<0.1	7	14	538	190	3306	147	0.5	80.1
76	(688.08)	<0.8	0.9	106	7	< 9	0.5	36	16	536	101	1333	105	0.3	84.6
84	(671.44)	<0.9	0.9	14	4	< 9	0.1	7	15	23	126	2903	134	0.5	86.1
87	(664.44)	<0.7	0.9	24	4	9	0.5	4	12	326	95	3488	147	0.3	85.0
93	(651.00)	<0.8	0.9	11	4	< 9	0.2	4	13	11	164	5797	160	0.5	85.1
95	(646.24)	<0.8	<0.9	4	2	< 9	0.6	4	9	330	102	3271	90	0.3	84.4
100	(633.20)	0.9	1	94	5	11	0.2	28	25	393	358	12,705	379	1.7	72.2
102	(627.64)	<0.8	<0.9	9	2	< 9	<0.1	2	11	327	140	1545	155	0.4	85.2
102	(627.64)	<0.9	<0.9	9	2	< 9	<0.1	2	11	625	158	2189	135	0.3	65.8
105	(618.56)	<0.8	<0.9	4	2	< 9	0.3	2	10	312	82	3514	75	0.3	84.0

Sample (Dry wt)	(River Mile)	Aldrin µg/g	Chlordane µg/g	Methoxychlor µg/g	Toxaphene µg/g	Dieldrin µg/g	Endrin µg/g	Thiodan µg/g	DDE µg/g	TDE µg/g	DDT µg/g	Lindane µg/g	BHC µg/g	Heptachlor µg/g	Heptachlor Expoxide µg/g
1	(857.48)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1	(857.48)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	(851.63)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
5	(850.11)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	(848.24)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	(848.24)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9	(832.36)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
11	(840.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13	(837.20)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
14	(835.07)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
15	(833.03)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.09	<0.01	<0.01	<0.01	<0.01	<0.01
17	(827.84)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
17.	(827.84)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	(823.39)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	(821.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23	(815.39)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
30	(802.69)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
35	(792.54)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
38	(785.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
38	(785.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
39	(772.79)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
41	(763.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
41	(763.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
42	(759.08)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
42	(759.08)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
43	(757.49)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
44	(756.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
45	(754.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
48	(747.72)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
49	(745.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
49	(745.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
50	(743.22)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
54	(734.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
55	(732.60)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
56	(730.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
58	(726.40)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
61	(720.46)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
65	(711.64)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
66	(709.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
66	(709.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
67	(706.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
68	(704.92)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
73	(694.72)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
74	(692.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
74	(692.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
76	(688.08)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
84	(671.44)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
87	(664.44)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
93	(651.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
95	(646.24)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
100	(633.20)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
102	(627.54)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
102	(627.54)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
105	(618.56)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table B2. Analysis of Upper Mississippi River Bottom Sediment Samples Collected April, 1975 (Laboratory Analysis Performed by Twin City Testing and Engineering Lab., Inc. for U. S. Army Corps of Engineers, St. Paul, Minnesota).

Sample (river mile)	Arsenic µg/g	Cadmium µg/g	Total Chromium µg/g	Copper µg/g	Lead µg/g	Mercury µg/g	Zinc µg/g	Oil & Grease µg/g	Total Phosphorus µg/g	Chemical Oxygen Demand mg/Kg	Total Kjeldahl Nitrogen mg/Kg	Ammonia Nitrogen mg/Kg	% Volatile Solids (dry wt.)	% Total Solids (dry wt)
1 (745.2-left)	0.40	< 0.1	5.9	6.6	<0.1	0.036	24.5	62	0.26	1226	2.61	0.01	1.4	98.24
2 (745.2-center)	0.41	< 0.1	4.9	6.0	<0.1	0.035	16.2	15	0.21	1103	2.35	0.11	1.5	99.4
2-1 (745.2-center)	0.45	< 0.1	5.8	5.4	<0.1	0.029	16.4	29	0.24	1274	3.11	0.12	1.5	99.6
3 (745.2-right)	0.38	< 0.1	5.9	5.7	<0.1	0.031	19	973	0.31	2810	9.61	0.05	1.6	98.3
4 (747.7-right)	0.57	< 0.1	7.7	19.8	<0.1	0.059	21.1	1471	0.45	4340	6.06	0.40	1.8	94.3
5 (848)	2.2	4.3	37.5	39.7	118	0.40	158	3160	1.10	91600	58.2	1.98	11.0	83.2
6 (848)	1.6	< 0.1	9.6	24.0	<0.1	0.09	40.9	1147	0.90	26334	10.4	0.50	2.9	92.1
7 (837.5-right)	1.50	1.0	13.3	10.4	36.5	0.051	42.7	1712	0.75	16600	14.3	0.58	3.0	97.8
7-1 (837.5-right)	1.56	0.9	10.9	9.7	28.4	0.058	41.3	1625	0.68	15755	13.8	0.55	2.7	95.5
8 (840.4-center)	0.36	< 0.1	8.6	3.5	<0.1	0.079	16.1	47	0.24	1850	3.25	0.10	1.4	99.7
9 (851.6-left)	0.46	< 0.1	8.0	4.3	<0.1	0.14	24.0	245	0.28	3700	7.56	0.75	1.7	99.3
10 (855.1-center)	0.55	< 0.1	7.4	6.3	<0.1	0.12	19.9	399	0.20	6860	8.26	0.32	1.7	96.0
11 (12.0-center)*	0.83	< 0.1	7.0	2.8	<0.1	0.13	14.9	218	0.54	1950	3.65	0.10	1.6	99.5
12 (822.9-left)	0.94	2.7	31.7	13.9	10.0	0.07	55.3	483	2.60	15600	15.1	0.51	3.0	99.2
13 (822.9-center)	0.62	1.3	16.5	9.0	9.7	0.048	30.7	374	1.11	7050	6.35	0.10	2.0	99.4
14 (822.9-right)	0.30	< 0.1	9.2	5.0	<0.1	0.064	21.3	284	0.80	2386	5.1	0.14	1.3	97.5
14-1 (822.9-right)	0.23	< 0.1	9.2	4.9	<0.1	0.043	20.5	204	0.88	1848	3.0	0.10	1.7	97.9
15 (827.7-right)	0.45	< 0.1	16.5	7.9	<0.1	0.097	29.7	133	1.82	4850	5.74	0.20	1.8	98.6

* Minnesota River