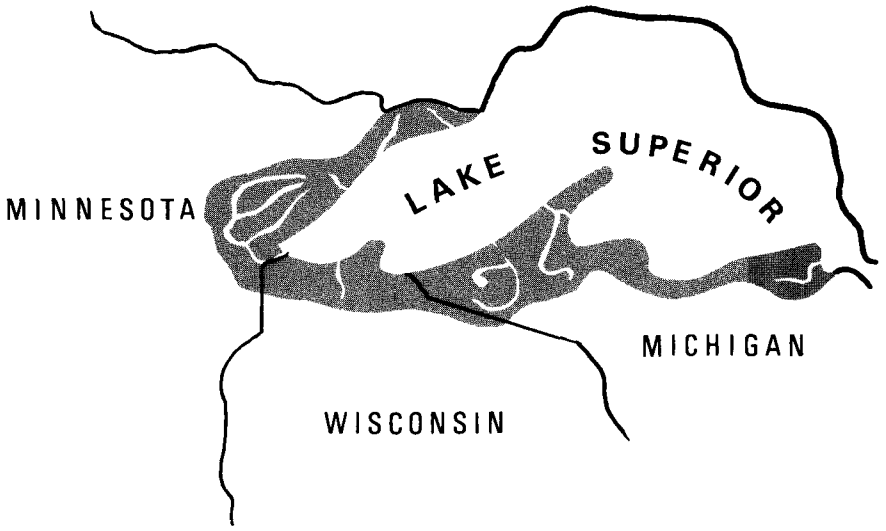
PROCEEDING

Volume 4



May 13-14-15, 1969
Duluth, Minnesota
Executive Session
September 30-October 1, 1969
Duluth, Minnesota

CONFERENCE

Pollution of Lake Superior and its Tributary Basin, Minnesota-Wisconsin-Michigan

U.S. Department of the Interior • Federal Water Pollution Control Administration

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(May 15, 1969, Afternoon Session)

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John Badalich

AFTERNOON SESSION

1:30 P.M.

MR. DOMINICK: Ladies and gentlemen, the conference will come to order.

We will turn the conference over to Mr. John Badalich at this time, who will have the remainder of the afternoon for Minnesota witnesses.

MR. BADALICH: Mr. Chairman.

First of all, I would like to introduce for the record the letter we sent to Reserve Mining regarding the conformance to the interstate water quality standards and also the letter received from Reserve Mining in answer to that letter. This was referred to in my presentation yesterday and also on Page 59. We ask that they be received for the record.

MR. DOMINICK: They will be received for the record.

(The above-mentioned letters follow.)

STATE OF MINNESOTA
Minnesota Pollution Control Agency
459 Board of Health Building
University Campus
Minneapolis
55440
September 17, 1968

VIA CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. J. William Bryant, President
Reserve Mining Company
Silver Bay, Minnesota 55614

Dear Mr. Bryant:

Interstate water quality standards for Minnesota developed in accordance with the Federal Water Pollution Control Act were approved by Secretary Udall of the Department of the Interior on June 18, 1968.

This is to inform you that the standards require a minimum of secondary treatment or the equivalent for wastes from all sources discharged to interstate waters. The implementation schedule for compliance started on June 18.

Our records indicate that construction of industrial waste treatment facilities will be necessary to achieve compliance with the standards. It is expected that adequate facilities will be provided in accordance with the following schedule:

Engineering reports due by - - - - - - - - - - - - December 18, 1968
Construction plans due by - - - - - - - - - - - - - June 18, 1969
Contract awarded by - - - - - - - - - - - - - - - - December 18, 1969
Works construction completed by - - - - - - - - - December 18, 1971

It is requested that this office be informed within thirty days as to the intentions of the company to proceed in accordance with the schedule outlined above. If desired, we shall be glad to arrange for a meeting in this office to discuss this matter in more detail.

Yours very truly,

/s/ John P. Badalich

John P. Badalich, PE
Executive Director

JPB/RDM:rw

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA 55614

E. M. FURNESS
PRESIDENT

October 10, 1968

Mr. John P. Badalich, Director
Minnesota Pollution Control Agency
459 Board of Health Building
University Campus
Minneapolis, Minnesota 55440

Dear Mr. Badalich:

We have received your letter of September 17, 1968, relative to possible secondary treatment of wastes discharged into interstate waters.

Reserve Mining Company discharges no sewage into interstate waters. The sewage from the taconite plant at Silver Bay goes into the sewage treatment plant of the Village of Silver Bay where--along with the municipal sewage--it receives both primary and secondary treatment before discharge into the lake.

Reserve discharges the "tailings" from its processing onto the beach at Silver Bay. This discharge spreads over the beach and a portion of it flows into Lake Superior. This is done under permits issued by the Minnesota Water Pollution Control Commission (the predecessor of the Minnesota Pollution Control Agency), the Commissioner of Conservation of the State of Minnesota, and the Corps of Engineers of the U. S. Army. The whole method of processing and treatment and discharge was thoroughly considered by these agencies when these permits were issued originally and when subsequently amended in recent years.

The taconite (one of the hardest rocks found on the surface of this continent) treated at this plant is crushed and ground to the fineness necessary for the separation of the iron bearing particles--called "concentrate"--from the crude taconite. This separation is achieved by gravity and magnetic processes. The remainder of the rock, called "tailings," is nothing but sand --a very dense, insoluble, inorganic sand. (Reserve's discharge does contain a comparatively small amount of fly ash which is pumped from the power plant into the tailings discharge stream during the winter months only, under a special temporary or revocable permit issued in recent years specifically for this purpose.)

The beach--or delta--upon which the water-borne tailings are deposited is located outside of Reserve's harbor on the easterly side of the east breakwater at Silver Bay. The coarse particles settle on the delta; the fine

particles are carried by the water over the delta to the lake. Because this water containing the particles is heavier than the lake water, it flows down under the lake water along the incline of the delta's face as a "heavy density current," and then along the lake bottom to the great depths of the lake where the fine particles of sand settle out. Reserve's discharge is similar to those of many rivers which in their natural state have flowed into Lake Superior for centuries without injury to the water, except that those rivers have carried greater loads of much finer materials--clays, silts, sands, decayed vegetation, etc.

Of course, Lake Superior is so deep and large that even if natural mixing or dispersion of sediments were a significant factor, there would be no adverse effect upon the quality of the water. However, the heavy density current performs so effectively that water samples taken within ten to twenty feet from the point where Reserve's discharge enters the lake consistently show that the water's quality will easily meet the highest criteria prescribed by state or federal authorities and, in fact, show that no changes in quality have occurred.

On numerous occasions, representatives of your agency as well as other state and federal agencies have inspected Reserve's operations and investigated our use of Lake Superior. We have given full cooperation in connection with such investigations, and have participated in various studies conducted by those agencies as well as carrying on our own extensive studies. These investigations and studies have demonstrated that the tailings contain no acids or offensive matter, are not bio-degradable wastes, and that no program for secondary treatment is necessary, required by law, feasible, or would serve any useful or advantageous purpose.

Sincerely,

S/Ed Furness

EMF/paa

John Badalich

MR. BADALICH: Then, Mr. Chairman, I would like to introduce for the record, and I have a number for the conferees, a number of permits issued by our predecessor, the Minnesota Water Pollution Control Commission regarding the Reserve Mining permit for application.

The first permit is the original permit issued in 1947, on December 16. This is in regard to a discharge of 130,000 gallons per minute of water used in power production and also for the beneficiation of taconite.

Permit No. 2 is an amended permit after a public hearing on September 25, 1956, for an increase in the discharge of power production and beneficiation waters to a discharge of 260,000 gallons per minute.

Permit No. 3 is an amended permit after public hearing on July 13, 1960, to increase the discharge of these waste-product waters up to 502,000 gallons per minute.

These permits were issued by the Minnesota Water Pollution Control Commission and the latter was issued on September 8, 1960.

There is also a Permit No. 4 which is a temporary permit. This was issued by the Water Pollution Control Commission on June 18, 1965, to the University of Minnesota, Mines Experiment Station, for the discharge to Lake Superior of wastewater and tailings from an experimental iron ore flotation pilot plant at Silver Bay, Minnesota, and not to exceed 500 gallons per minute. This permit is dated July 2, 1965.

MR. DOMINICK: These will be made a part of the record.

(The above-mentioned permits follow.)

RESOLUTION AUTHORIZING ISSUANCE OF PERMIT TO
RESERVE MINING COMPANY

RESOLVED by the Minnesota Water Pollution Control Commission, assembled in special meeting at St. Paul, Minnesota, December 16, 1947, all members being present, as follows:

That the report submitted by the chairman of the commission in the matter of the application of Reserve Mining Company, a Minnesota corporation, for a permit to discharge industrial waste be approved and filed, that the findings and recommendations of said report be and hereby are adopted as the findings and conclusions of the commission, and that in accordance therewith the secretary be and he hereby is authorized and directed to issue to said applicant a permit in the following form:

STATE OF MINNESOTA
WATER POLLUTION CONTROL COMMISSION

PERMIT TO DISCHARGE INDUSTRIAL WASTE

Pursuant to resolution adopted by the Minnesota Water Pollution Control Commission December 16, 1947, after due hearing and consideration as provided by law, there is hereby granted to Reserve Mining Company, a Minnesota corporation, in connection with the operation of a proposed taconite iron ore beneficiation plant and power plant located on the shore of Lake Superior northeast of Beaver Bay in Section 6, Township 55 North, Range 7 West, and adjacent portions of Sections 5 and 7 in said township and range, and Sections 31 and 32, Township 56 North, Range 7 West, in Lake County, Minnesota, for which operation water will be taken from Lake Superior at the rate of approximately 130,000 gallons per minute when operating continuously, a permit to return and discharge into Lake Superior the waters taken therefrom and used in the production of power and in beneficiating taconite in said plants, with tailings from such beneficiation plant in suspension, all upon the following conditions:

(a) The material processed in said taconite beneficiation plant shall consist only of taconite of the magnetic type from deposits lying in Townships 59 and 60 North, Range 13 West, and Township 60 North, Range 12 West, in St. Louis County, Minnesota, and shall not include any material quantity of hematite or red oxide of iron.

(b) The tailings discharged from said taconite beneficiation plant shall consist only of the crushed or ground residue of taconite as hereinbefore described after extraction of iron ore therefrom, with the water in which such residue is

suspended, and neither such tailings nor the water returned from the power plant shall include any material quantities of matter soluble in water, organic matter, oil, sewage, or other waste except such taconite residue.

(c) For the purposes hereinafter set forth, the following described area is designated as the zone of discharge:

> For the purpose of describing said zone of discharge a point called Point "A" is located on the shore of Lake Superior one and one-half miles southwesterly in a straight line from the intersection of said lake shore with the south line of Section 32, Township 56 North, Range 7 West, in Lake County, Minnesota, said intersection being the approximate location of the point of discharge; a point called Point "B" is located on said lake shore one and one-half miles northeasterly in a straight line from said intersection; a straight line joining said Points "A" and "B" is designated as the base line; said zone is bounded on the northwesterly side by that portion of said lake shore between said Points "A" and "B", on the southwesterly side by a line running southeasterly from said Point "A" at right angles with said base line, on the northeasterly side by a line running southeasterly from said Point "B" at right angles with said base line, and on the southeasterly side by a line running parallel with said base line and three miles distant therefrom.

(d) Such tailings shall not be discharged so as to result in any material clouding or discoloration of the water at the surface outside of said zone except during such time as turbidity from natural conditions in the adjacent portions of the lake outside of said zone may be caused by storms, nor shall such tailings be discharged so as to result in any material adverse effects on fish life or public water supplies or in any other material unlawful pollution of the waters of the lake or in any material interference with navigation or in any public nuisance outside of said zone.

(e) The permittee shall acquire all land riparian to the lake shore within the lateral limits of said zone of discharge, or such licenses, releases, or easements as may be necessary to evidence the consent of the owners of such riparian land to the operations of the permittee hereunder.

(f) The granting of this permit shall not impose any liability upon the State of Minnesota, its officers or agents, for any damage to any persons or property resulting from the operations of the permittee hereunder. This permit shall be permissive only, and shall not be construed as estopping or limiting any legal claims against the permittee, its agents or contractors, for any damage or injury to any person or property or to any public water supply resulting from such operations.

(g) The permittee shall comply with all regulations concerning navigation of any federal authority having jurisdiction over navigation, and shall obtain any and all permits from federal authorities that may be requisite for the construction and operation of the facilities covered hereby.

(h) The permittee shall commence substantial construction work upon said taconite beneficiation plant or upon the dock and harbor facilities connected therewith within five years from the date of the permit, and shall continue such construction work with reasonable dispatch thereafter, and shall have at least one unit of said beneficiation plant in operation within ten years after the date of this permit, unless such time or times shall be extended by the Water Pollution Control Commission or its successor in authority for good cause shown.

(i) This permit shall be for a term extending without limitation until the permittee shall surrender the same, or until revocation as hereinafter provided.

(j) This permit shall be subject to assignment, but no assignment shall be effective until notice thereof is filed in the office of the secretary of the commission or his successor in authority; provided, that the authorization of the permit so far as it relates to water taken from and returned to Lake Superior in connection with said power plant shall be separately transferable by assignment or license so long as the major purpose of said power plant is the production of power for said taconite beneficiation plant and facilities connected therewith.

(k) The permittee shall allow the Water Pollution Control Commission or its agents or successors in authority access to and inspection of the permittee's plants, premises, and operations under the permit at all reasonable times for the purposes of investigations and studies of the effects thereof on the interests of the public, and shall cooperate in such investigations and studies.

(1) The permit shall be subject to revocation only for violation of the conditions hereinbefore set forth. Before any such revocation, the Water Pollution Control Commission or its successor in authority shall hold a public hearing upon charges specifying the alleged violation, of which at least thirty days notice in writing shall be given to the permittee, and if such violation can be corrected the permittee shall be given a reasonable opportunity to correct the same.

Dated at St. Paul, Minnesota this 16th day of December, 1947.

Minnesota Water Pollution Control Commission

By /s/ A. J. Chesley, M.D.
Secretary

STATE OF MINNESOTA

WATER POLLUTION CONTROL COMMISSION

In the Matter of the Application of Reserve Mining Company for an Amendment to Permit Issued by the Commission on December 22, 1947, to Permit Discharge of Additional Quantities of Industrial Waste Into Lake Superior in Connection With Taconite Iron Ore Beneficiation Operations Near Beaver Bay in Lake County, Minnesota.

AMENDED PERMIT

The application of the Reserve Mining Company for an amendment to the permit heretofore issued came on for hearing on September 25, 1956, at 10 o'clock a.m. in the Court House in the City of Duluth, St. Louis County, Minnesota, before Dr. Ralph L. West, Vice-Chairman of said Commission, pursuant to authority heretofore granted by the Commission and due notice thereof, and the report of said hearing having been made and filed by Dr. Ralph L. West, and the Commission having duly approved and adopted said report, NOW, THEREFORE

IT IS ORDERED that the application of the Reserve Mining Company to amend the permit dated December 22, 1947, granted by the Commission, to take water from Lake Superior and to discharge industrial waste therein, be and the same is hereby granted, and said permit is hereby amended as follows:

In line nine of the first paragraph, on page 1 of said permit, delete the figure 130,000 and insert in lieu thereof the figure 260,000.

IT IS FURTHER ORDERED that the Reserve Mining Company submit semi-annual reports to the Commission in regard to the effect of tailing deposits in Lake Superior.

Dated at St. Paul, Minnesota, this 12th day of November, 1956.

MINNESOTA WATER POLLUTION CONTROL COMMISSION

By /s/ B. D. Barr
Secretary

STATE OF MINNESOTA

WATER POLLUTION CONTROL COMMISSION

In the Matter of the Application of Reserve Mining Company for an Amendment to Permit Issued by the Commission on December 22, 1947, as amended November 12, 1956, to Permit Discharge of Additional Quantities of Industrial Waste into Lake Superior in Connection with Taconite Iron Ore Beneficiation Operations in Silver Bay, Lake County, Minnesota.

AMENDED PERMIT

The application of the Reserve Mining Company for an amendment to the permit heretofore issued came on for hearing on July 13, 1960, at 10 o'clock a.m. in the Court House in the City of Duluth, St. Louis County, Minnesota, before Mr. Rector H. Putnam, Chairman of said Commission, pursuant to authority heretofore granted by the Commission and due notice thereof, and the report of said hearing having been made and filed by Mr. Rector H. Putnam, and the Commission having duly approved and adopted said report, NOW, THEREFORE

IT IS ORDERED that the application of the Reserve Mining Company to amend the permit dated December 22, 1947, as amended November 12, 1956, granted by the Commission, to take water from Lake Superior and to discharge industrial waste therein, be and the same hereby granted, and said permit is hereby amended as follows:

In line nine of the first paragraph, on page 1 of

said permit as amended, delete the figure 260,000 and insert in lieu thereof the figure 502,000.

IT IS FURTHER ORDERED (1) That the concentration of tailings in the waste discharged shall not be materially increased beyond that existing at the present time, (2) The semi-annual reports of the Company shall include more detailed information on the effect of the tailings on Lake Superior and on possible effects in the lake in general, including the following:

a. More extensive turbidity measurements, plus other related analyses, at differenct times of the year and under different weather conditions.

b. More extensive bottom sampling to account for a greater portion of the tailings which cannot now be accounted for in the delta deposit.

c. More extensive studies on possible causes and effects of the green color and net slime phenomena, including possible means of minimizing any effects of the tailings which might be found.

Dated at St. Paul, Minnesota, this 8th day of September, 1960.

MINNESOTA WATER POLLUTION CONTROL COMMISSION

By /s/ B. D. Barr
Secretary

MINNESOTA WATER POLLUTION CONTROL COMMISSION
Minnesota Department of Health Building
University Campus
Minneapolis, Minnesota 55440

Permit No. 520

Temporary Permit for Waste Discharge,
Pilot Iron Ore Flotation Plant, Mines Experiment Station,
University of Minnesota, Silver Bay

Pursuant to authorization by the Water Pollution Control Commission at a meeting held on June 18, 1965, and in accordance with provisions of the Minnesota Water Pollution Control Act, a permit is granted to the University of Minnesota, Mines Experiment Station, for the discharge to Lake Superior of waste water and tailings from an experimental iron ore flotation plant, subject to the following conditions:

1. The waste flow shall not exceed an average of 500 gallons/minute.
2. The flotation reagents in the waste shall not differ in type or exceed the concentration as specified in the permit application, unless prior consent is obtained from the Water Pollution Control Commission.
3. Appropriate bio-assay shall be made under controlled conditions to determine the toxicity to fish of the flotation reagents and combinations thereof with the plant tailings and the results reported to the Commission.

4. Sampling and analysis of the wastes shall be done as directed by the Commission, and an engineering evaluation of possible waste treatment methods shall be made if considered necessary by the Commission.

This permit is for a two-year period from the time the pilot plant is placed in operation, does not estop possible requirements for treatment of the wastes if found necessary, and is subject to termination or modification for cause at any time.

MINNESOTA WATER POLLUTION CONTROL COMMISSION

/s/ Lyle H. Smith
Lyle H. Smith, Executive Engineer

Dated: July 2, 1965

John Badalich

MR. BADALICH: Then, I would like to continue and complete the testimony by the Reserve Mining Company. I believe this will take an hour to an hour and a half.

I would like to call upon the Counsel for the Reserve Mining Company, Mr. Ed Fride.

MR. MERRITT: Mr. Chairman we would like to formally object to this procedure. Do you recognize us?

MR. DOMINICK: I recognize you.

MR. MERRITT: Last evening we were given the impression and specific instructions that Minnesota public witnesses would be next in the order in which they appear on the list, and then go back to Reserve Mining Company. A number of people are here, unpaid, and are expecting to go on this afternoon. We have been here since Tuesday morning. We thought Minnesota would be done late yesterday morning. Late yesterday afternoon we finally reached the Minnesota witnesses and I don't think it is fair; I don't think it is reasonable for Reserve to go ahead at this time without hearing from these public witnesses who are here and ready to go in the order in which they appear. We would request that they appear now. (Applause.)

MR. DOMINICK: Mr. Merritt, yesterday evening we were proceeding with public witnesses and we made a special dispensation in your case; you did not appear in the order in which you were listed. We made the point at that time that this was not an appropriate time for you to appear. We made a special consideration in your case before. Mr. Badalich now has the

entire afternoon for Minnesota witnesses and Reserve Mining is as much a Minnesota witness as anyone else.

The conference has been held, I believe, at a very high level. We have tried to be fair to all people concerned and you have my word that we intend to hear from all of the people concerned before this conference closes. We are attempting to finish today. If we do not finish today, I will stay over, and I am sure that the conferees will make arrangements to stay over. However, as we agreed among the conferees, this afternoon would be devoted exclusively to Mr. Badalich and Minnesota witnesses. I have turned it over to him, and whatever way he wishes to run it is satisfactory with the Chairman.

MR. PEGORS: Mr. Chairman, my name is John Pegors. I am President of Clean Air, Clean Water Unlimited. I am the party who substituted for Mr. Merritt last night.

As I recall the objection I raised at that time, it was your position that Mr. Merritt would follow at 2 o'clock. Mr. Badalich confirmed this in a conversation in the hall last night after we closed the session.

I wish to register for the record an objection to your decision and also to the decision of Mr. Badalich and Mr. Tuveson, the conferees for Minnesota.

MR. BADALICH: May we proceed?

I believe the schedule of the conference has been flexible and the conferees have agreed on how they should proceed. I believe that in all fairness to Reserve Mining, which is also a

a witness for the State of Minnesota, if Mr. Merritt does not know this, at the outset they requested 1½ to 2 days and the conferees and the Department of the Interior talked to Reserve Mining Company and they very decidely told us they would hold their testimony to approximately 3 hours. I think this is very well of them to do so, and I would like to say at this time I will proceed with Reserve Mining Company.

MR. MERRITT: A lot of our important witnesses didn't go on last night until 4:30 or 5:00 o'clock, including Dr. Dale Olsen and Dr. Williams. I think the same thing will happen this afternoon. It is unfair ---

MR. DOMINICK: (interrputing): If we continue to hassle, Mr. Merritt. We have run this conference fairly and we will continue to run it fairly, but if we get on with the program, we will be through by 3 o'clock and then hear all of the other witnesses.

MR. MERRITT: We will be on at 3 o'clock, is that it?

MR. DOMINICK: We have already used 15 minutes, so Reserve Mining has one hour and a half and that will be 3:15.

MR. FRIDE: Ladies and gentlemen:

We greatly appreciate the opportunity to continue the presentation we started earlier. I might say parenthetically that I am not very popular with a few select distinguished internationally-known scientists. A few weeks ago I asked them to compress the great volume of data which they had collected and their conclusions with respect to this subject matter and papers that will be presented not to exceed an hour. This morning I told them to take

that hour and compress it into a very few minutes, so perhaps I am not too popular with them.

The first witness we will be calling on to make a statement is Mr. Haley. He is the Vice-President and General Manager of Reserve Mining Company. He has been associated with the taconite production and pellets and dismissal of these pellets for the past 21 years.

Mr. Haley.

STATEMENT OF KENNETH HALEY, VICE-PRESIDENT,
RESERVE MINING COMPANY, SILVER BAY, MINNESOTA

MR. HALEY: Fellow conferees:

My name is Kenneth Haley, Vice-President of Reserve Mining Company and Manager of their Research and Development Division.

I am a resident of Silver Bay, Minnesota. I have a Bachelor of Metallurgical Engineering degree from Ohio State University. I have been associated with taconite processing into pellets since 1948.

To help our presentation, Reserve has made a 6-foot by 5-foot model of the western 20 percent of Lake Superior. This model is accurate according to Corps of Engineers and University of Michigan bathymetric charts. The vertical scale of the model is 3/8 of an inch equals 100 feet, and the horizontal scale is ½ inch equals 1 mile.

Kenneth Haley

The dominant feature of this is a deep area off Silver Bay. Our sonar readings at the bottom of this area have recorded a depth of 966 feet.

Reserve is discharging 60,000 tons of tailings a day, which sounds like an extremely large amount, but as reported, 45 percent of these tailings are heavy enough to settle on the beach or delta in front of the plant. The remainder travels by density current down into this deep area.

We also have made a scale model of our delta. My associate, Dr. Gay, will place this delta on the proper place on this lake model. Except for the delta the depth of tailings is not large enough to illustrate by such a model. Therefore, I will describe the flow and Dr. Gay will follow the flow with the pointer.

Tailings are quite deep adjacent to the toe of the delta, 40 to 50 feet. About halfway between the Beaver and Split Rock Rivers, the depth of tailings decreases to about 4 inches. This decrease in depth continues; 15-½ miles southwest of the discharge it has decreased to a 1-inch thickness of tailings. From here on the deposit gets very thin and spotty through the remainder of the area deeper than 900 feet. The farthest tailings have been found straight out from the Minnesota shore is 8 miles. The thickest layer of tailings in the deep 600- to 900-foot area is 6½ inches. All of these tailings' flow and deposition is as predicted before the permits were granted.

This data was obtained from about 150 bottom core samples taken during 1967, 1968, and 1969. The tailings deposit grows so

slowly on the lake bottom that we do not believe there are severe inaccuracies in at least the general shape of the deposit by using data taken over this long a time period.

Material is identified as tailings, natural bottom sediments, or a mixture of the two by chemical analysis. Tailings have a lower chemical analysis in most of the metals, except iron, than the natural lake bottom sediments. These differences can be used for identification. Titanium analysis is the most positive to use.

Dr. Gay is now going to replace the present tailings delta insert on the model with our predicted delta after 50 more years of operation.

The distance that tailings will travel before settling on the lake bottom is a function of their settling rate and the currents they are carried by (the heavy density current plus the lake currents). There is no reason to expect the settling rate or the currents to change. We expect that the tailings will be deposited in the same general area that they have been. The tailings will still be too thin to identify any change in the bottom contours of the model.

Also, we expect the heavy density current to have the same general direction of flow. The toe of the delta will then be in about 550 feet of water. From this toe it will slope in the same manner as it does today, reaching a depth of about 15 inches at the point halfway between the Beaver and Split Rock rivers, where it is now 4 inches. At 15½ miles down shore where tailings are now 1-inch

thick, we expect them to become 3½ inches thick. They will not be carried very much, if any, further than they have been so far. The same physical phenomena of the heavy density current plus lake currents and settling rates will continue to apply.

We have taken bottom core samples outside of these areas described along the Minnesota shore. On several occasions we have sampled from the Minnesota to the Wisconsin shore. Also we have been furnished bottom samples from the Wisconsin area for identification. These additional samples verify that tailings are not outside of the area previously described.

Analysis of Tailings and Sediments.

We have made a rather complete chemical analysis of a series of representative bottom cores. These chemical analyses show that the natural bottom sediments have higher aluminum, chromium, copper, nickel, titanium, and zinc analyses than the tailings sediments in the same area. They show that the natural bottom sediments and the tailings sediments in the same area have the same analyses of cadmium, cobalt, and lead. They show that tailings sediments have higher iron, magnesium and manganese analyses than the underlying natural bottom sediments. These chemical analyses show the natural bottom sediments contain more of the metals identified as objectionable heavy metals by the FWPCA than do tailings.

A typical complete chemical analysis of Reserve's tailings shows that the heavy metals that the FWPCA considered objectionable are very low in Reserve's tailings. The metals in the tailings are in the form of complex oxides or silicates which

are insoluble in Lake Superior water.

Reserve has used several methods of determining the chemical state of its tailings. These methods have shown that the elements in the tailings to which the FWPCA has referred to as objectionable heavy metals are insoluble in Lake Superior water. Some of these methods are: static or leaching tests; sorption tests; statistical variance analysis of FWPCA's 1968 data; ratios of the elements to iron analysis of FWPCA 1968 data; and the ratios of elements to iron analysis of the tailings sediment as compared to these same ratios for tailings themselves.

Screen analyses from the same bottom cores show that the natural sediments are much finer than the overlying tailings sediments.

You will notice I am not following our text closely, skipping four or five pages there.

Also, it shows that the tailings now being discharged by Reserve are of the same size analysis, or coarser, than the tailings discharged much earlier in their operation.

Bottom Fauna.

Reserve Mining Company has conducted a bottom fauna study during April and May of 1969. This data alone or in conjunction with the study conducted in July 1968 by the State of Minnesota shows that the tailings have not had an adverse effect on the total fish food organisms. I have two slides to show this data.

We now have several pages that talk about our scientific equipment, personnel, etc. We will take a little quicker way of

doing that. We have a 6 or 8 minute movie of our research launch in action, and Dr. Gay is going to narrate that, telling us how these samples are taken and the analyses that are performed on each of these samples.

Jim, would you take over and narrate this film, please.

(At this time a film was shown.)

MR. HALEY: Thank you very much, Jim.

Reserve Mining has kept the State of Minnesota personnel informed by regularly reporting to them the results of their lake studies. I have several pages of summary of some of those reports.

I will make one remark. The samplings from sediment traps set out in 1968 have verified the results of our bottom core samplings, so we have that in back of us.

We made our own analysis of data obtained by the study group which consisted of the FWPCA and four other bureaus or agencies of the United States Department of the Interior, two Minnesota agencies, and one Wisconsin department. Highlights of this analysis follow. FWPCA data shows that from a chemical and turbidity standpoint, the water in the Silver Bay area has higher purity than the balance of the lake which the FWPCA sampled.

Our comparisons show a 95 percent confidence level that the water in the Silver Bay area is lower than the rest of the lake sampled by the FWPCA in conductivity, sulfate, ammonia, lead, zinc, turbidity, and total phosphorus. They also showed that the water in the Silver Bay area had essentially the same content of chloride, nitrogen, total iron and nickel as the balance of the lake sampled

by the FWPCA.

The only analyses that were found to be higher in the Silver Bay area were pH and nitrite-nitrate. However, these analyses were well within the State and Federal water quality standards. Similar comparisons were inconclusive on alkalinity, dissolved oxygen and dissolved solids. Cadmium, chromium and copper analyses were not given for FWPCA 1966 and 1967 sampling. Therefore, like comparisons could not be made.

The FWPCA secured and analyzed samples from only 8 inches off the lake bottom in the Silver Bay area. The analyses, particularly the turbidity and iron analyses, of these samples are higher in the area of the heavy density current. This distribution of analyses clearly outlines the path of the heavy density current that is carrying tailings from the point of entry into the lake down the slope of the bottom into the 600- to 900-foot deep area of the lake. This is positive proof that the heavy density current is performing exactly as predicted from the tests that the St. Anthony Falls Laboratory and the Mines Experiment Station of the University of Minnesota conducted in the late 1940's. The FWPCA only sampled over a 9-mile by 5-mile area. The deepest point sampled was 840 feet. Had they sampled over a larger area, they would have detected the complete area over which the heavy density current is flowing.

None of the chemical analyses reported as soluble exceeded the State of Minnesota water quality standards.

MR. DOMINICK: Before you leave that, you are referring

to FWPCA data as collected and as reported in the December 1968 report which was the 4-Agency draft report?

MR. HALEY: The report I am referring to had the title "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota, U. S. Department of Interior, Federal Water Pollution Control Commission, Great Lakes Region, 1968."

MR. DOMINICK: And I believe that is the report that was submitted to us as an exhibit by Mr. Stoddard yesterday?

MR. HALEY: No, that is not the report.

MR. FRIDE: May I suggest this. The report Mr. Haley is just citing is the bibliography for the appraisal report of April 1969. It is not the so-called Stoddard report. It is the part of the group study report which was contained in the individual Agency's reports and this is part of the bibliography for the 1969 report.

MR. BADALICH: This was the report Mr. Risley sent from the FWPCA Chicago office and I asked it be made part of the record. I believe it was Bibliography No. 49.

MR. DOMINICK: Yes, we have it here. I think this is important to have this clarified for the record. Item No. 49 on Page 52 of the April 1969 report is listed as "Investigation of the Distribution of Taconite Tailings in Lake Superior, U. S. Department of the Interior, Federal Water Pollution Control Administration, Great Lakes Region, September-October 1968." So we are still finding some discrepancies as to what report we are referring to.

MR. BADALICH: Mr. Chairman, I believe Mr. Risley in

his testimony referred to some sampling done by the FWPCA office in Chicago, and he made reference to this report and I asked it be introduced into the record. I believe Mr. Risley indicated he had one or two copies available, but you did accept this as an exhibit.

MR. DOMINICK: Mr. Risley, do you have a copy of the report that has been cited by Mr. Haley on Page 16 of his testimony that he is giving right now, entitled "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota", U. S. Department of the Interior, Federal Water Pollution Control Administration, Great Lakes Region, December 1968?

MR. RISLEY: Yes, sir, I have that report.

MR. DOMINICK: And have you already submitted that as an exhibit?

MR. RISLEY: It is available for submission.

MR. DOMINICK: We will receive that as an exhibit. Have that reproduced and distributed to the conferees. Thank you very much.

(The "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota", will be on file at Headquarters, FWPCA, Washington, D. C., and the Regional Office, Chicago, Illinois.)

MR. HALEY: Yes. The FWPCA Silver Bay area water samples were analyzed for suspended solids, total chemical analysis, and soluble chemical analysis. The analysis of the suspended solids in these samples can be calculated from this data. These calculations have been made for copper, zinc, aluminum, iron, nickel,

manganese, and lead. The percentages of these elements in these suspended solids is so far different from that found in tailings that it is obvious that the source of most of these suspended solids was material other than tailings.

The work of the personnel from the National Water Quality Laboratory, Duluth, identified small amounts of tailings in "green water" in the Silver Bay area. These observations were made in late September and early October when there was a thermocline condition. The tailings beach is part of the shore line of the Silver Bay area. It would be expected that some tailings would be temporarily suspended in the water in the Silver Bay area in the same manner that other material is temporarily caused to be suspended by a thermocline in this and other parts of the lake.

On the Bureau of Commercial Fisheries report there are five summary sentences on paragraphs which state that tailings have no effect on commercial fishing.

The U. S. Bureau of Mines data verified Reserve's chemical and screen analysis of tailings.

On the Bureau of Sport Fisheries report, a series of tests showed that tailings had no effect on fish. One test on sac fry indicated tailings may have an adverse effect which needs further checking under lake conditions.

On the U. S. G. S. report, they made a contour map which I think had only a minor error in it. They did not note there were deeper areas of tailings adjacent to the delta.

On the Minnesota Department of Conservation report, Mr. Robert Riggs gave a very good analysis of that, and I will not

bore you with the repetition of that.

On the Wisconsin Department of Natural Resources report, comparisons of the data of this report show that the water in the Silver Bay area is far cleaner than the water in the Wisconsin area. This is determined by comparing the Secchi disc, turbidity, and phosphorus data of this report to be found by the FWPCA in the Silver Bay area.

The Secchi disc readings of the Wisconsin data averaged 7.2 feet. The FWPCA Secchi disc readings in the Silver Bay area averaged 21.5 feet. The fact that the Secchi disc could be seen in three times as deep water in the Silver Bay area as is possible to see it in the Wisconsin area certainly shows that the water of the Silver Bay area is much cleaner. The average turbidity data for the Wisconsin water is 18 times the average of the Lake Superior in the Vicinity turbidity.

Water samples from the Wisconsin area, which were all surface samples, averaged 5.01 turbidity. The FWPCA surface and mid-depth data for their Silver Bay area samples averaged 0.28 turbidity.

Total phosphorus analyses of the Wisconsin area water averaged 0.042 mg/l. Total phosphorus analyses of water samples secured in the Silver Bay area by the FWPCA averaged 0.010 mg/l. Thus, Wisconsin water contains 4 times as much total phosphorus as the Silver Bay water.

This comparison certainly indicates that after 13 years of Reserve's operation, the water in the Silver Bay area is cleaner

than other areas of the lake. This should be proof that Reserve's tailings are not having a deleterious effect on Lake Superior.

Some Comments on the FWPCA's April 1969 Report.

We believe the record of this conference should contain specific rebuttals to those assertions in the April FWPCA report which directly concern Reserve Mining Company. Our complete rebuttal is included as Appendix F. Some of the subjects of our rebuttal have already been covered in my previous discussion.

The subject of Conclusion No. 11 and the statement following it have not been covered sufficiently. I will confine my closing remarks to this subject.

This conclusion reads as follows:

"A distinguishing characteristic of tailings discharge by the Reserve Mining Company is the presence of large quantities of the amphibole commingtonite.

"Data gathered by the FWPCA since April 1, 1969, has shown the presence of taconite tailings (utilizing commingtonite as a tracer) in the municipal water systems of Beaver Bay, Two Harbors, and Duluth, Minnesota. There has not been sufficient time to determine what effect, if any, the presence of the tailings has on the quality of the water supply or the users thereof." Dr. Mount also added these are very important.

Cummingtonite is a species of mineral belonging to the silicate class. Quartz sand that is often used for the sand of water filter beds also belongs to this same silicate class. Cummingtonite and quartz are the most abundant minerals in Reserve's tailings.

Kenneth Haley

Cummingtonite is found throughout the eastern Mesabi Range. It could be a mineral present in the watershed of many of the streams entering Lake Superior. For example, the head waters of the St. Louis River are in the same general mineralogical area as is Reserve's taconite mine.

Evidence of cummingtonite has been found in the following North Shore streams: Little Marais River, Baptism River, Split Rock River, Gooseberry River, Encampment River, French River, Talmadge River and Lester River. Dr. Mount added the Nemaott and a small creek by Grand Portage on Tuesday, I believe.

In addition to the possibility of these streams bringing cummingtonite into the north shore of the lake, over a million tons of Reserve's tailings have been taken from their tailings beach by or for State and county highway departments.

In addition, when we heard we also had cummingtonite tailings in the Grand Marais water supply, we took some ore samples. The State Highway Department, one mile east of downtown Grand Marais, shows a very distinct cummingtonite peak. There is another sand pile there that does not show cummingtonite.

To determine if the use of these tailings by the highway departments was adding detectable amounts of cummingtonite to the soil alongside of roads, a series of samples of road gravel were analyzed. The following samples showed evidence of containing cummingtonite:

1. Gravel from the lake side of Highway #61 near the east end of the Lester River bridge.

2. Gravel from roadside at intersection of new and old Highway #61, Duluth end.

3. Gravel from lake side of old Highway #61 one block east of Duluth water pumping station.

4. Gravel from lake side of old Highway #61 at Talmadge River bridge.

5. Gravel from new Highway #61 near Sucker River bridge.

6. Gravel from old Highway #61 French River bridge.

7. Gravel from new Highway #61 at the junction of Knife River Road.

8. Gravel from new Highway #61 near Knife River bridge.

9. Gravel from old Highway #61 near Knife River bridege.

Cummingtonite is detected by an X-ray diffraction unit with a copper radiation X-ray source. Reserve's cummingtonite is indicated when a maximum diffraction or reflection of X-ray is obtained at an angle of 10.63° 2-Theta. Other minerals have diffraction peaks at about this same angle. All of the natural materials from the Silver Bay area that we have subject to X-ray diffraction show some peak of X-ray diffraction at about this angle. Therefore, an X-ray diffraction at about this angle is not a positive indication of the presence of Reserve's tailings.

With indications of cummingtonite being so widespread along the North Shore, it is a very weak identifier of tailings. Also, so much tailings have been used on North Shore highway building and maintenance that the presence of cummingtonite does not establish that tailings were carried to that location by lake currents.

Tailings were not used on the highways in the Duluth area until about 1967. The last time the Duluth reservoirs were dredged was 1962. Samples of this 1962 dredging do not show cummingtonite.

Kenneth Haley

The same size tailings were being discharged from Reserve prior to 1962 as today. The lake currents were the same, yet there were no tailings in the Duluth water sediment pond dredgings.

We have a slide showing tailings washing from the highway or depicting what would happen to tailings washing from the highway. It will normally be washed by water warmer than lake water. Therefore, it would be more likely to stay in the surface water than be carried by lake currents. Tailings from our beach have the force of the heavy density current, and will go to the bottom 600 to 900 feet deep. The tailings in the Grand Marais and Duluth water samples were transported by truck, not lake currents.

That is enough of the slides.

We believe firmly that the evidence of tailings outside of the 600 and 900-foot depth trough were transported to the location by truck for highway maintenance and use and not by lake currents.

We thank you, Mr. Chairman, for this opportunity to add our data to this massive data that you are collecting at this conference.

MR. DOMINICK: Thank you, Mr. Haley.

Mr. Fride, may we ask Mr. Haley a few questions?

MR. FRIDE: Certainly, Mr. Chairman.

MR. DOMINICK: Mr. Haley, on the subject of cummingtonite, is my understanding correct that the thrust of your testimony in the latter part of your statement is to the effect that the presence of the cummingtonite in the lake, if any, is in your

opinion, due to the use of taconite tailings for road construction purposes?

MR. HALEY: There could be other sources of cummingtonite that we are not aware of. I did leave out several paragraphs on that for brevity. Would you like for me to review those?

MR. DOMINICK: No. But the question is, you do recognize cummingtonite as being a significant tracer identifiable in taconite tailings?

MR. HALEY: It is one of the significant tracers for taconite tailings. Cummingtonite, as shown by the Encyclopedia Britannica, is a worldwide mineral. If you find some in Sault Ste. Marie, it is not necessarily Reserve's tailings. There must be other supporting evidence which would be certainly a continuation of tailings deposits such as we have on the bottom of the lake.

The other things we get into in potential supporting evidence is the analyses of our tailings, which is quite unique from a lot of the normal materials that are in the lake, that it is barren of many of the minerals. For example, if you take the oxygen, the iron, the iron silicates, manganese, magnesium, they will add up to 99.6 percent of the alloys. So there is no room for these other trace metals that you speak of.

MR. DOMINICK: I don't want to take your time unnecessarily. But the presentation we have now is that taconite tailings, from whatever source used in road construction may account for the presence of cummingtonite in the lake, and it appears that the culprit here is not the source of the taconite

tailings but the fact that taconite tailings are used is that correct?

MR. HALEY: That is one -- the most probable source that we know of today. We have found it in these various streams. We do not know the source in these streams.

There is another point that I did not mention, that cummingtonite shows a different X-ray peak at 10.32 with a copper tube. Anything we try to get a fraction peak on from the Lake Superior region shows some peak at this same point, and it is a matter of judgment. Many times the operator asks, does he have enough peak to these tailings or not?

MR. DOMINICK: Fine. Would you provide for the record the X-ray pattern which you have developed and have testified to here on Page 29 of this nine samples that were taken. I believe you added to that in your oral testimony. Would you provide those X-ray patterns of the cummingtonite in streams for the record?

MR. HALEY: Yes, sir. I do not have them with me. I have them in my room and I can bring them to the conference.*

MR. DOMINICK: Thank you very much.

Are there any questions from the conferees?

MR. PURDY: Yes.

Sir, are you using comparable sample preparation techniques with the techniques used by the Water Quality Laboratory?

MR. HALEY: I am not quite sure I understand your question.

MR. PURDY: You may be using the same instruments, but

*The above mentioned document follows.

SAMPLES EXAMINED BY X-RAY DIFFRACTION BY RESERVE MINING COMPANY

Sample Number	Date Taken	Material and Location
514	10-14-68	Solids filtered from Split Rock River water.
515	10-14-68	Solids filtered from Gooseberry River water.
519	10-14-68	Solids filtered from the French River water.
524	10-14-68	Solids filtered from Encampment River water.
69-119	4-9-69	Solids filtered from Split Rock River water.
69-121	4-12-69	Solids filtered from Baptism River water.
69-122	4-12-69	Solids filtered from Baptism River water
69-125	4-12-69	Solids filtered from Little Marais River water.
69-270	5-9-69	Solids filtered from Talmadge River water.
69-271	5-9-69	Solids filtered from Duluth Pumping Station water.
69-272	5-9-69	Solids filtered from Lester River water.
69-273	1962	Sediments from Duluth Pumping Station Retention Basin. Sample furnished by Duluth Water Works.
69-284	5-10-69	Sediment from Duluth Water Pumping Station Retention Basin. Taken from north-center opening.
69-285	5-10-69	Sediment from Duluth Water Pumping Station Retention Basin. Taken from west-center side opening.
69-286	5-10-69	Sediment from Duluth Water Pumping Station Retention Basin. Taken from east-center side opening.
69-287	5-10-69	Sediment from Duluth Water Pumping Station Retention Basin. Taken from south-center opening.
69-274	5-9-69	Gravel taken from roadside at Intersection of Highway #61 and Knife River Road.

Sample Number	Date Taken	Material and Location
69-276	5-10-69	Gravel taken from roadside east of Lester River Bridge.
69-277	5-10-69	Gravel taken from intersection of old and new Highways #61; Duluth end.
69-278	5-10-69	Gravel taken from roadside of old Highway #61 one block east of the Duluth City Water Pumping Station.
69-279	5-10-69	Gravel taken from roadside of old #61 near Talmadge River Bridge.
69-280	5-10-69	Gravel taken from roadside of old Highway #61 at the French River Bridge.
69-281	5-10-69	Gravel taken from edge of new Highway #61 near Sucker River Bridge.
69-282	5-10-69	Gravel taken from roadside of new Highway #61 near Knife River Bridge.
69-283	5-10-69	Gravel taken from roadside of old Highway #61 near Knife River Bridge.
69-300	5-14-69	Gravel taken from Minnesota State Highway Department stockpile 1 mile east of Grand Marais - grey pile.
69-301	5-14-69	Gravel taken from Minnesota State Highway Department stockpile 1 mile east of Grand Marais - brown pile.
69-302	5-14-69	Gravel taken from roadside parking area two miles west of Grand Marais on Highway #61.
69-303	5-14-69	Grey rock chips along slopes of creek two miles west of Grand Marais near Highway #61.
69-304	5-14-69	Grey rock chips taken from roadside of Highway #61 near Cascade River Bridge.
69-305	5-14-69	Grey rock chips taken from roadside of Highway #61 near Spruce Creek.
69-306	5-14-69	Grey rock chips taken from slopes of Two Island River near Highway #61.

100
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#514 SPLIT ROCK RIVER
GLASS
R.S.L. 10-18-68
40/18 1/4 min 30/hr
1X2X10³

#514

#515 GOOSEBERRY RIVER
GLASS
4 g/s 1/min 30 l/hr 1x2x10^3
R.S.K. 10-18-68
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#515

#519

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30/IN
10/18 14/min 30/hr 1.2x10^3
10.54
524 SEDIMENT RIVER
10-18-68
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#524

#119 Split Rock River
1/4° min. 30/hr.
B-2 W-INT 1.63
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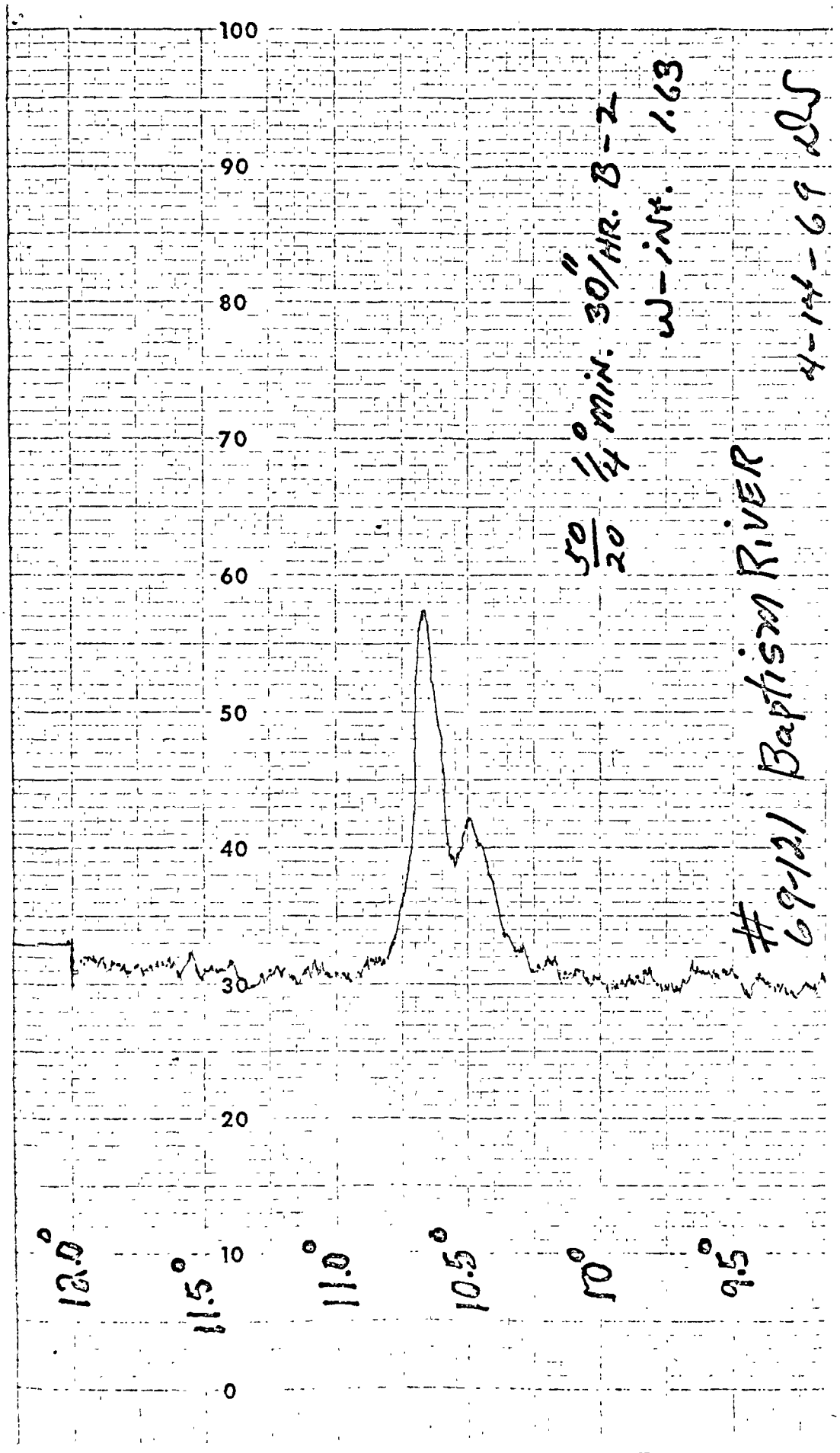
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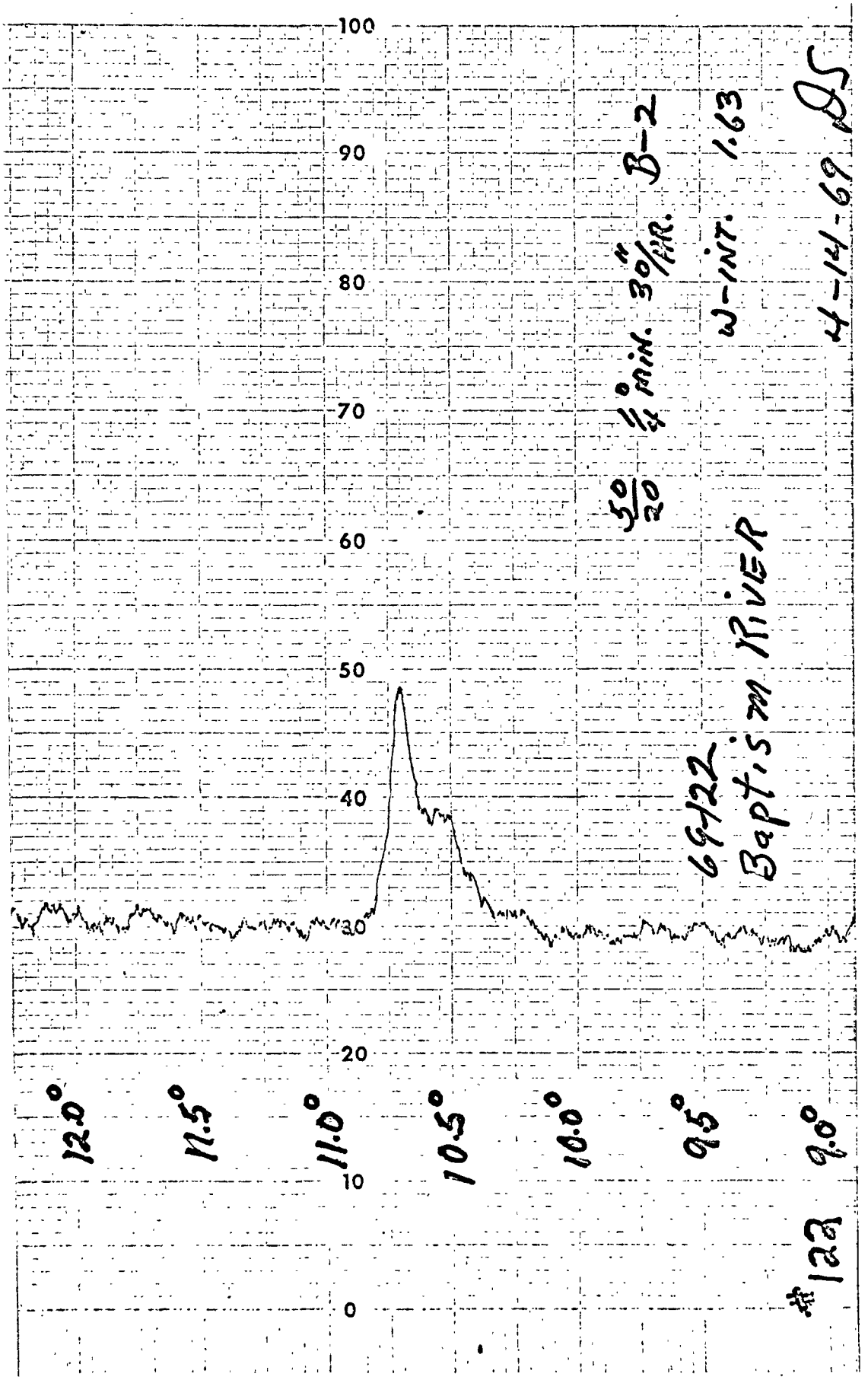
W-int. 1.63
4-14-69 RJS
#69-121 Baptism RIVER

#121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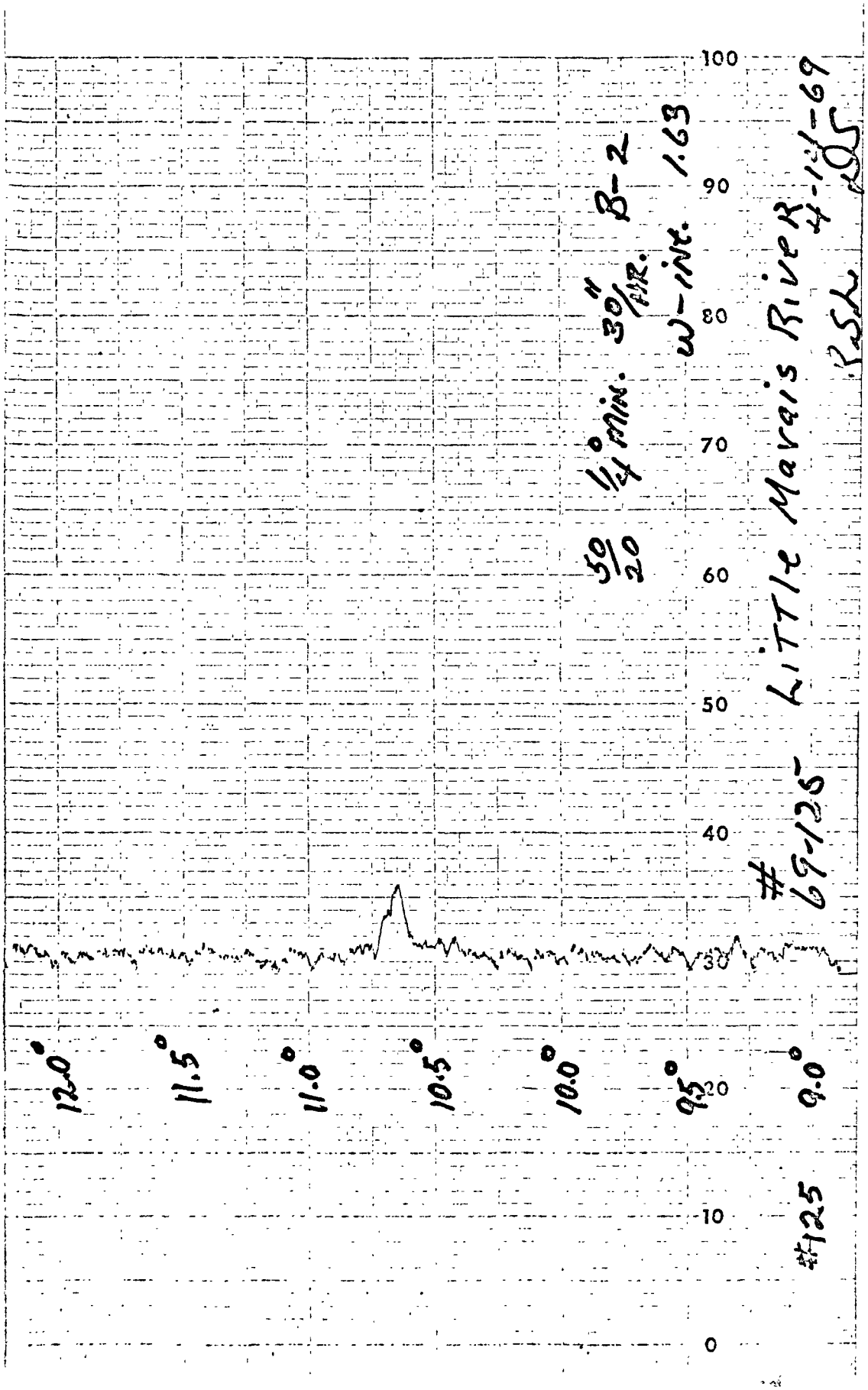
B-2
W-INT. 1.63
4-14-69
69-122
Baptism RIVER
#122

#122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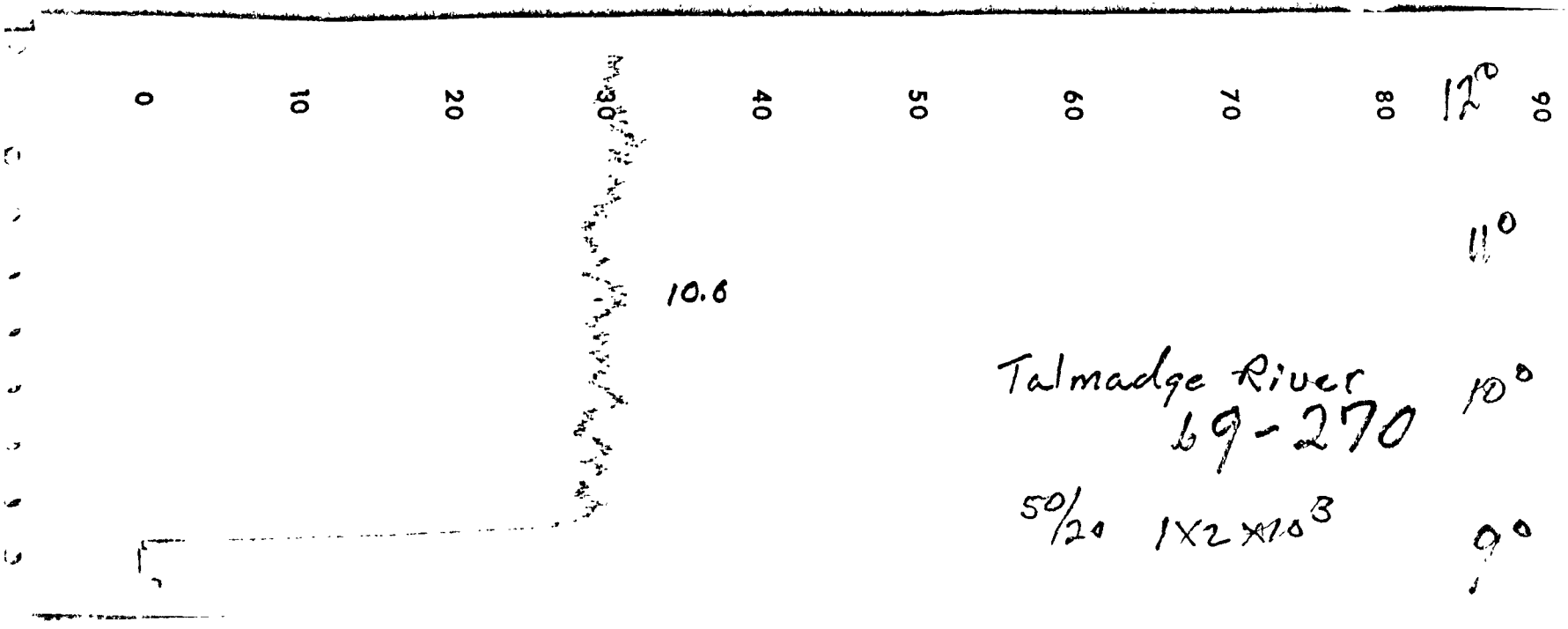
#125
#69-125
LITTLE Marais River
4-16-69
RSL
1/4 min.
30"/hr.
B-2
W-int. 1.63
50/20

125


90
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12°
11°
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9°
10.6
Talmadge River
69-270
50/20 1X2 ×10³

17°
14°
10°
9°
80
70
60
50
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10
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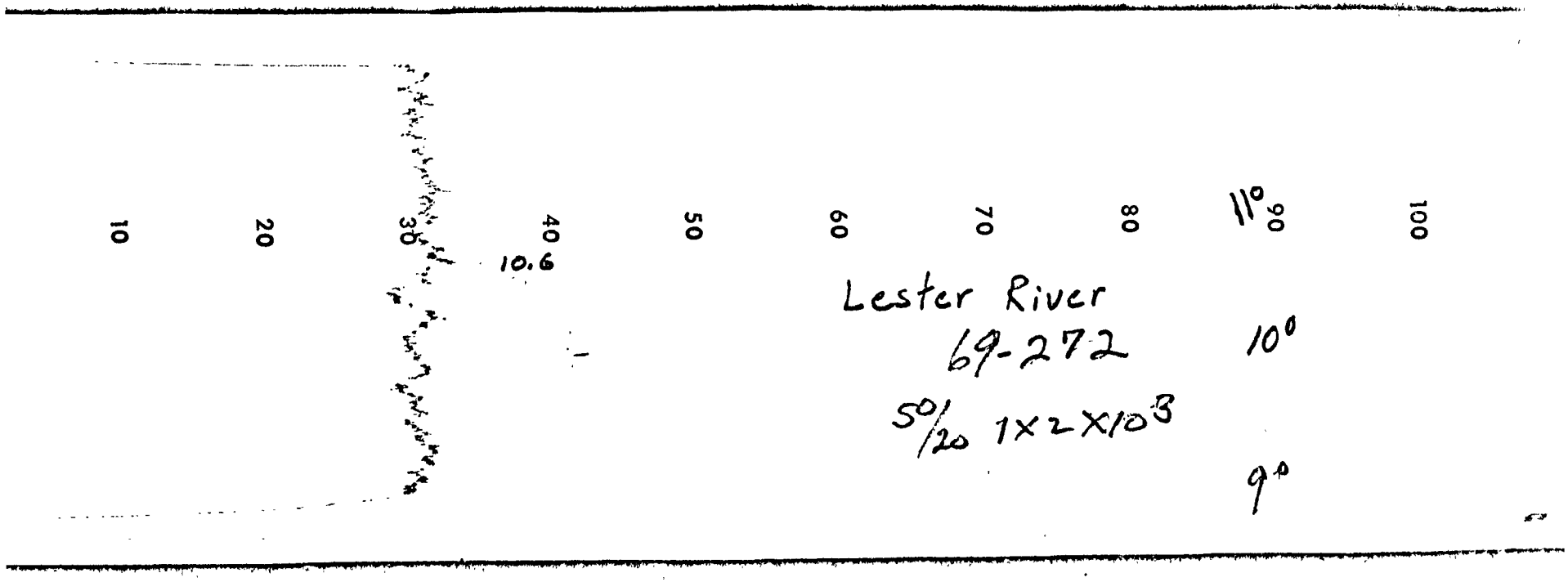
Dul. Pump. Sta.
Intake
69-271
50/20
1x2x10^3
10.7 cf. Cumm.


10
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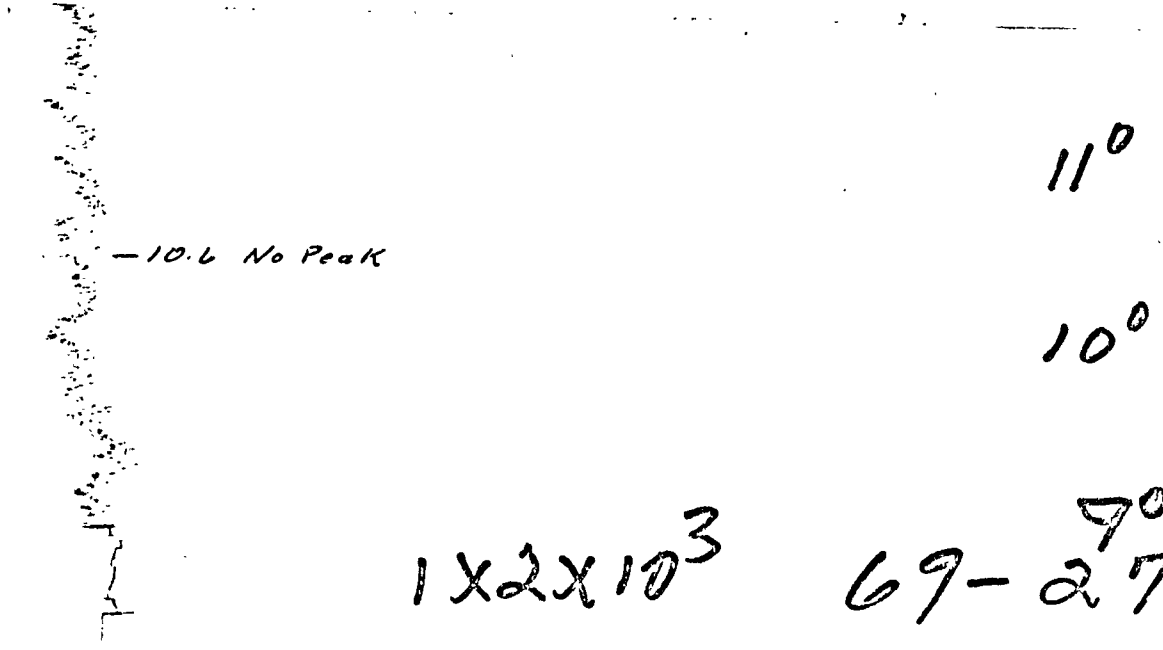
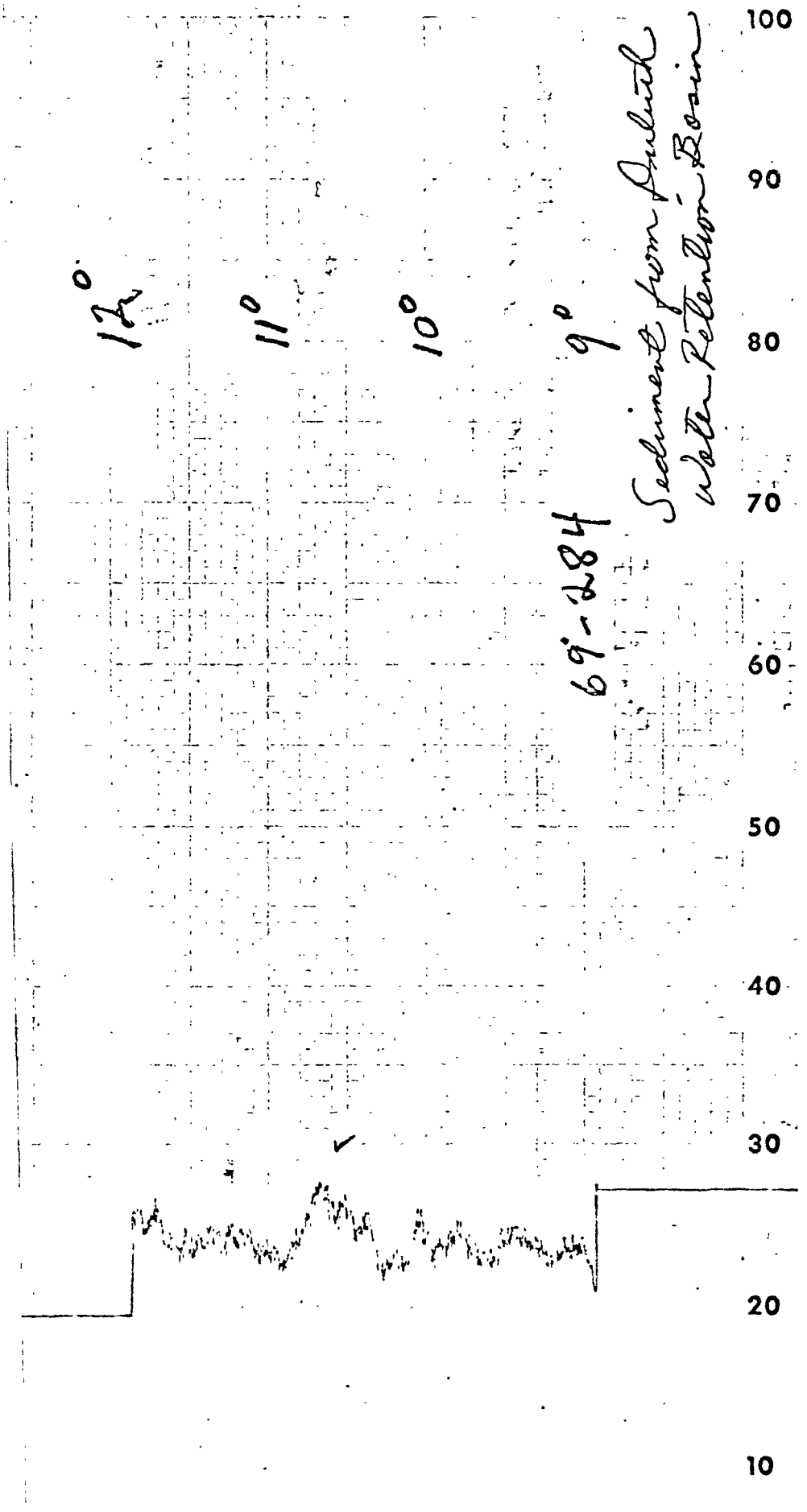
100
11°
Lester River
69-272
10°
5°/20 1×2×10^3
9°



$1 \times 2 \times 10^3$ 69-273

SEDIMENTS FROM DULUTH PUMPING STATION RETENTION BASIN. SAMPLE FURNISHED BY DULUTH WATER WORKS. TAKEN MAY 1962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69-284
Sediment from Duluth
Water Retention Basin
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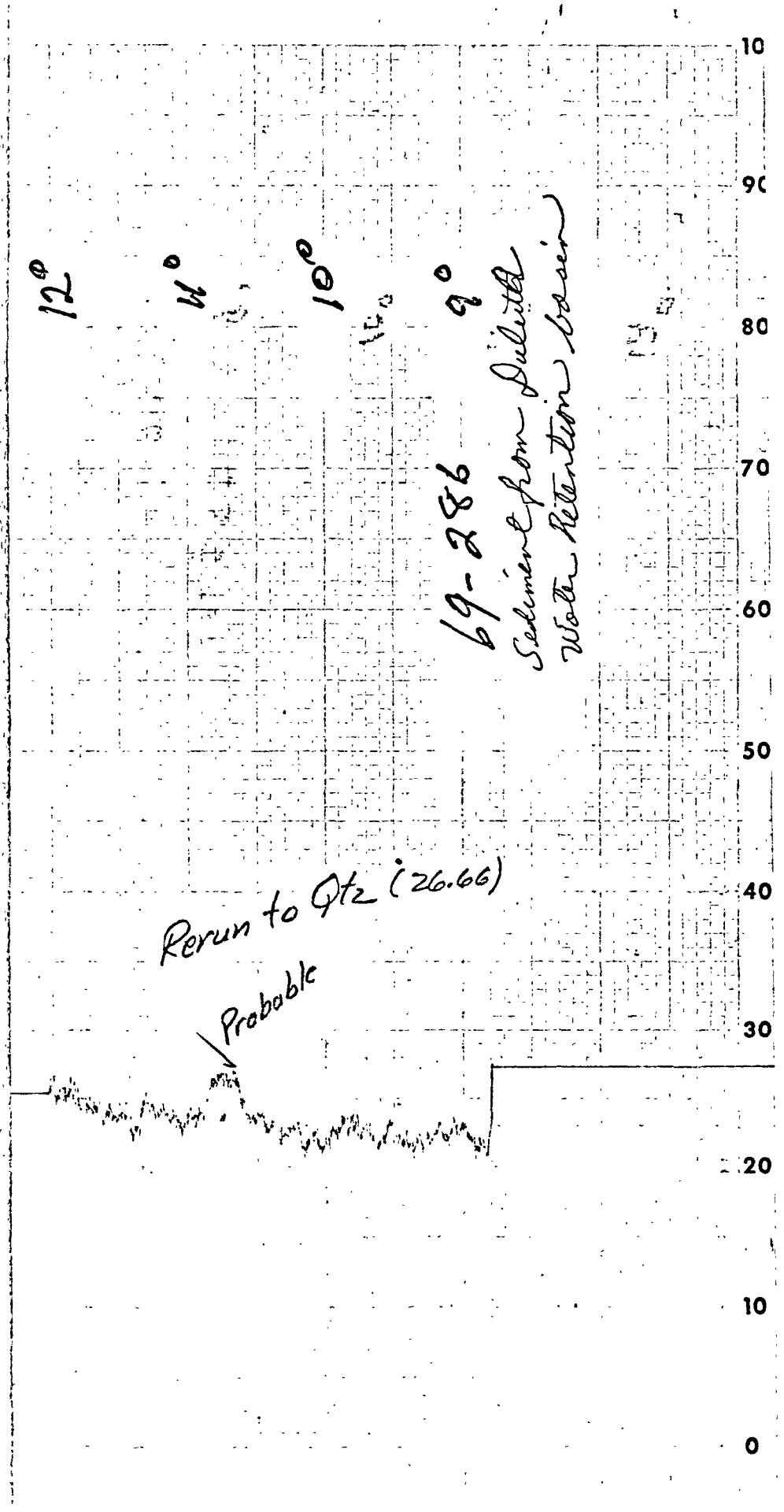
Sediment from Duluth
Water Retention Basin
69-285


12°
14°
16°
18°
69-286
Sediment from Dilutta
Water Retention basin
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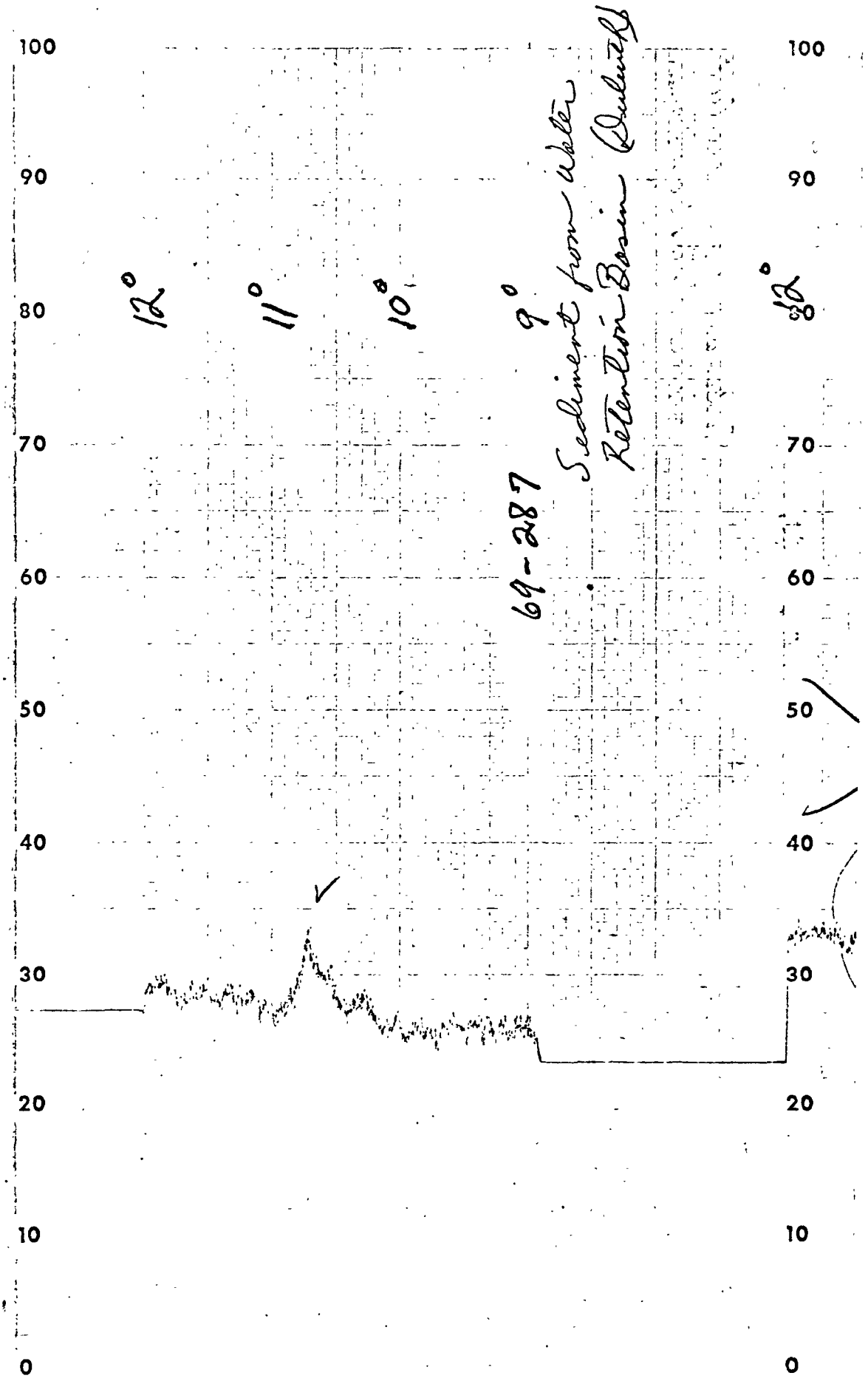
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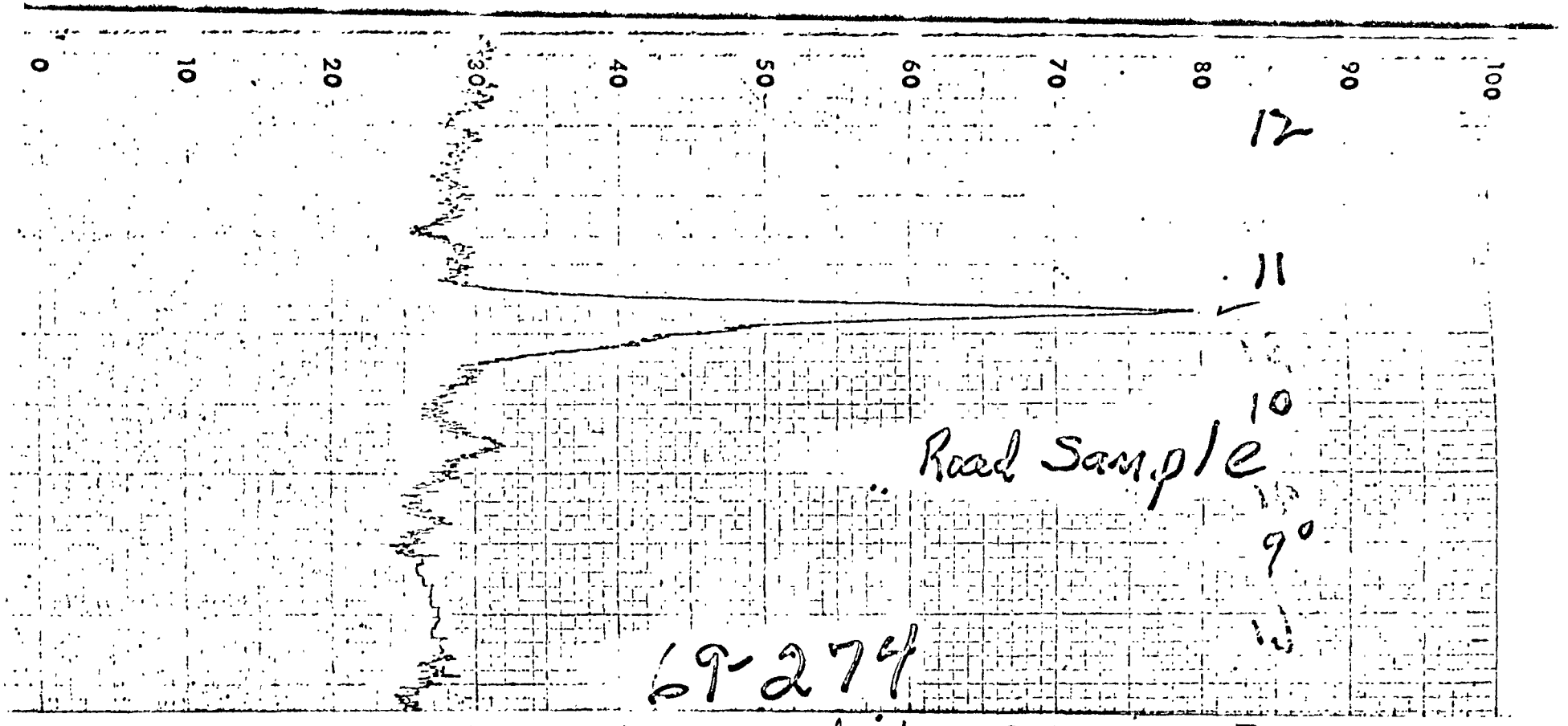
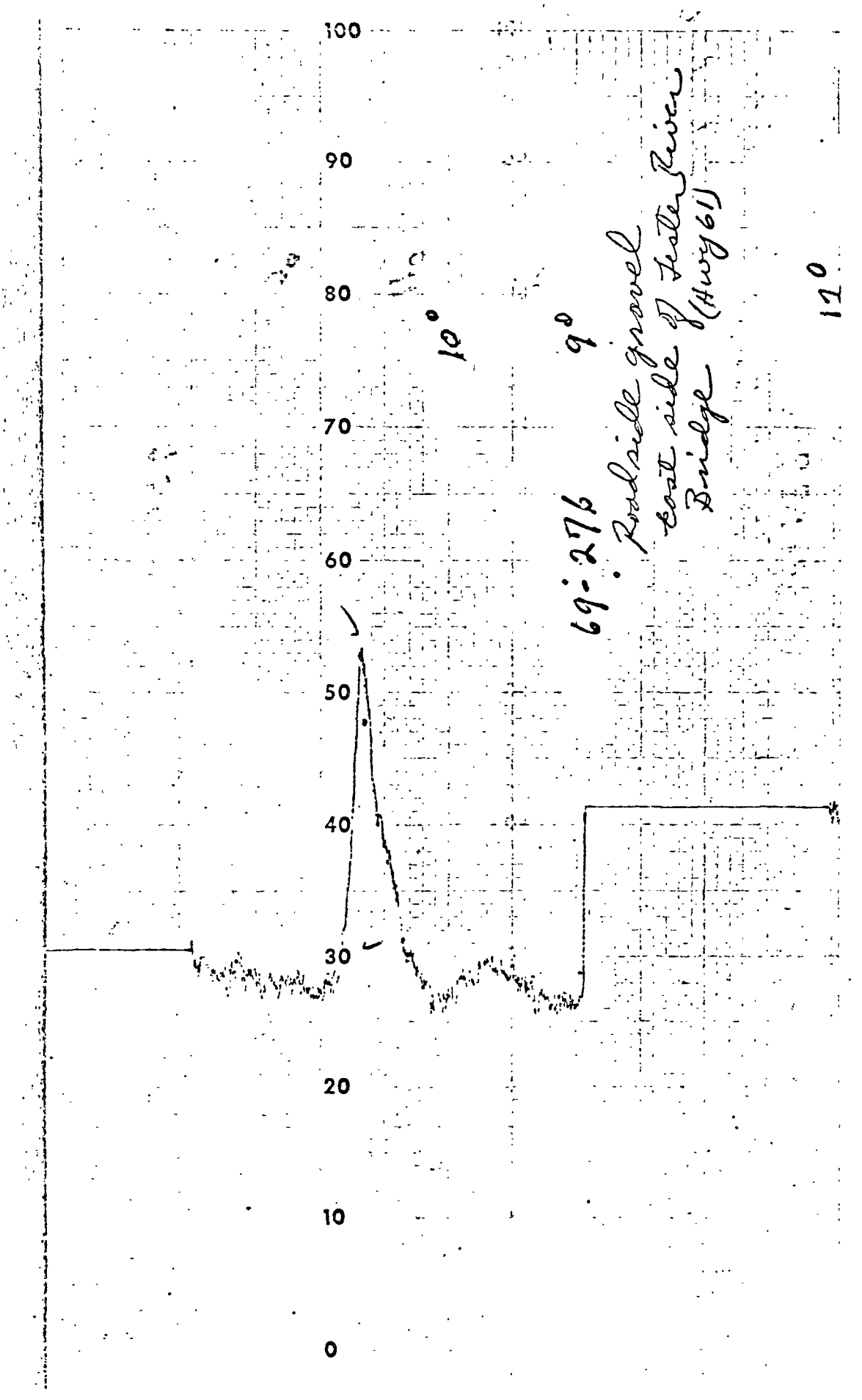
69-287
Sediment from water
Retention Basin (Submitted)



GRAVEL TAKEN from roadside at INTERSECTION OF Highway #61 and KNIFE RIVER Road


100
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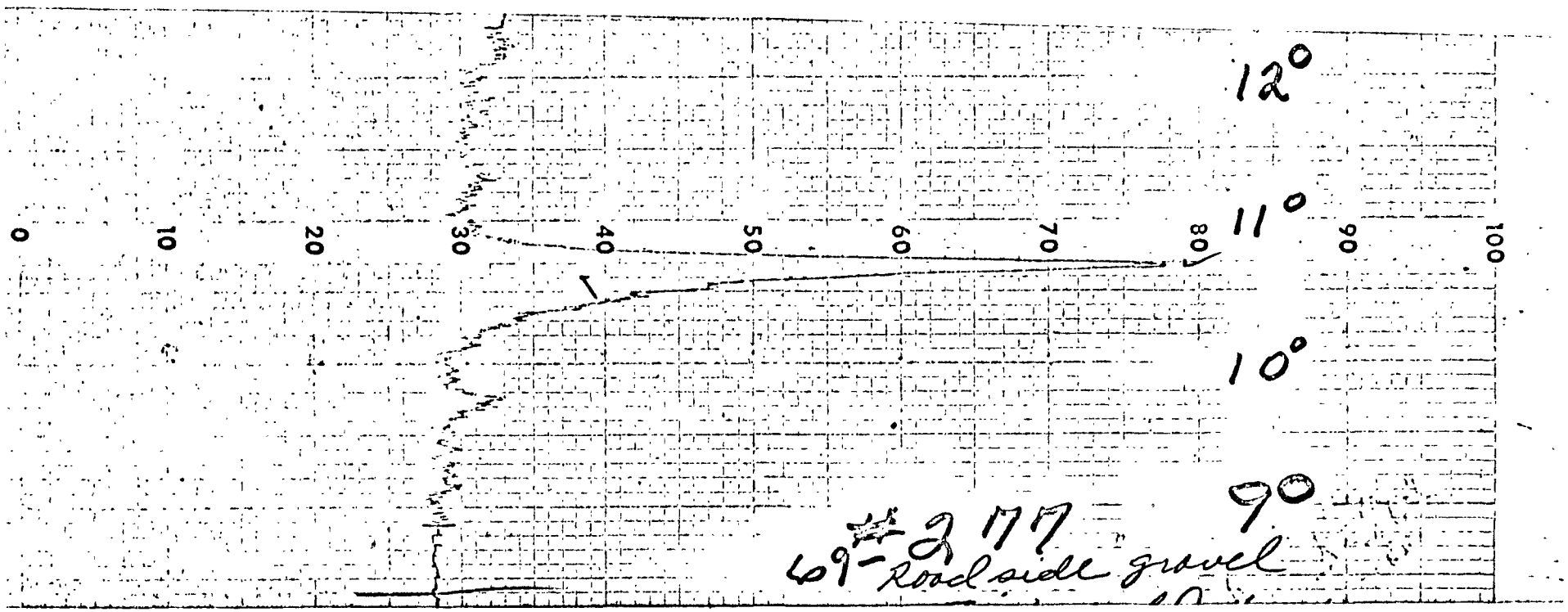
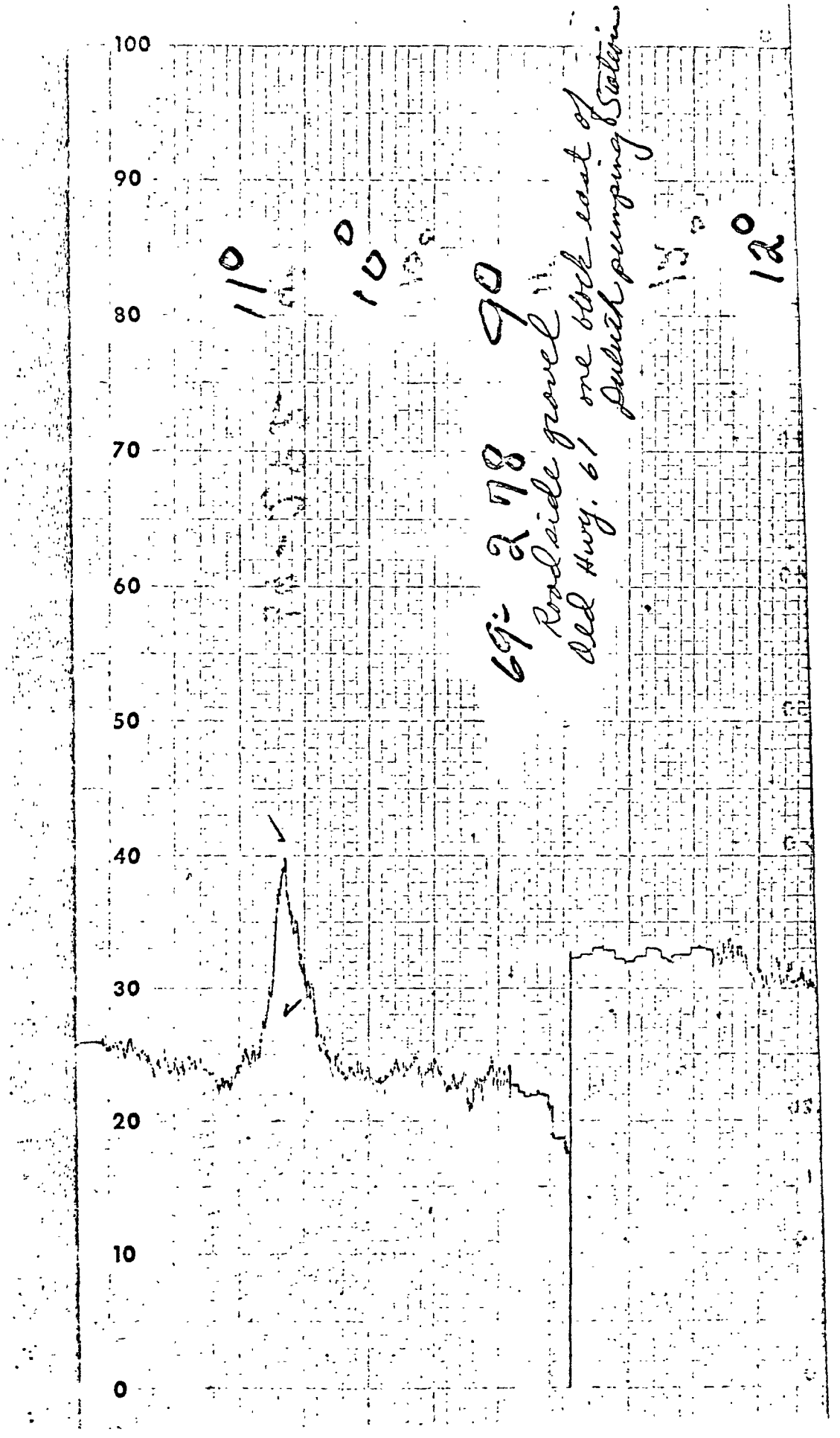
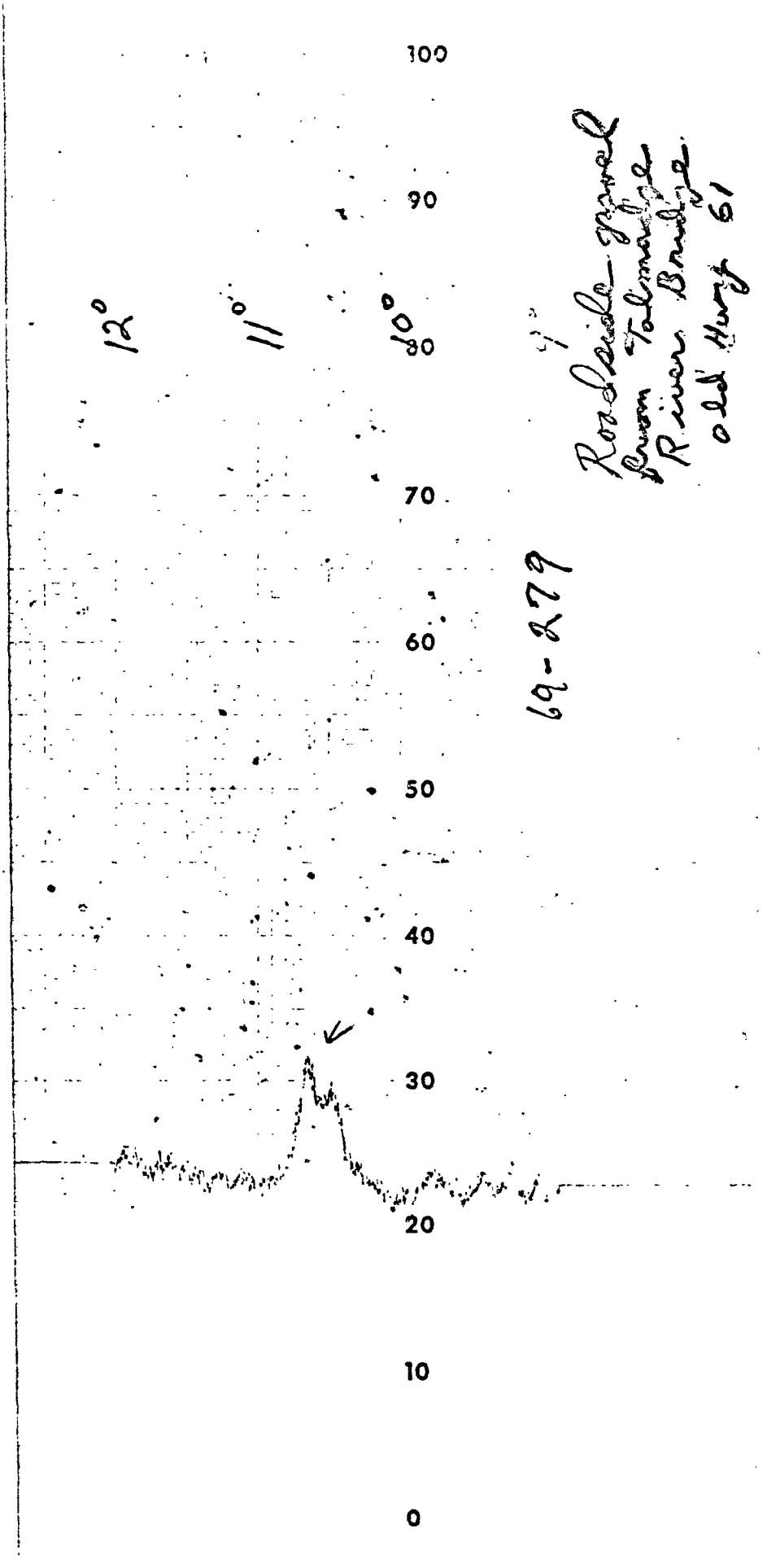
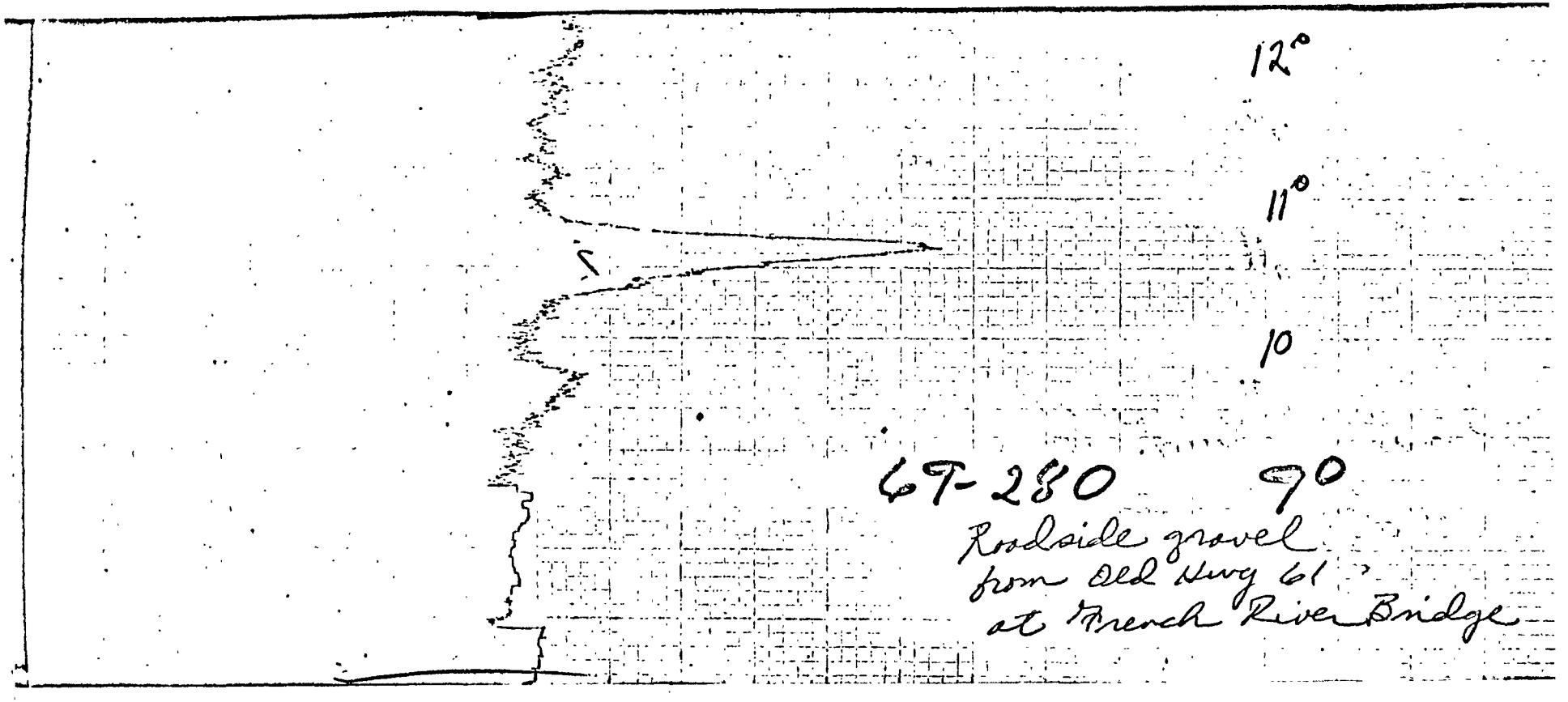
69-276
Roadside gravel
East side of Tesla River
Bridge
(Hwy 61)

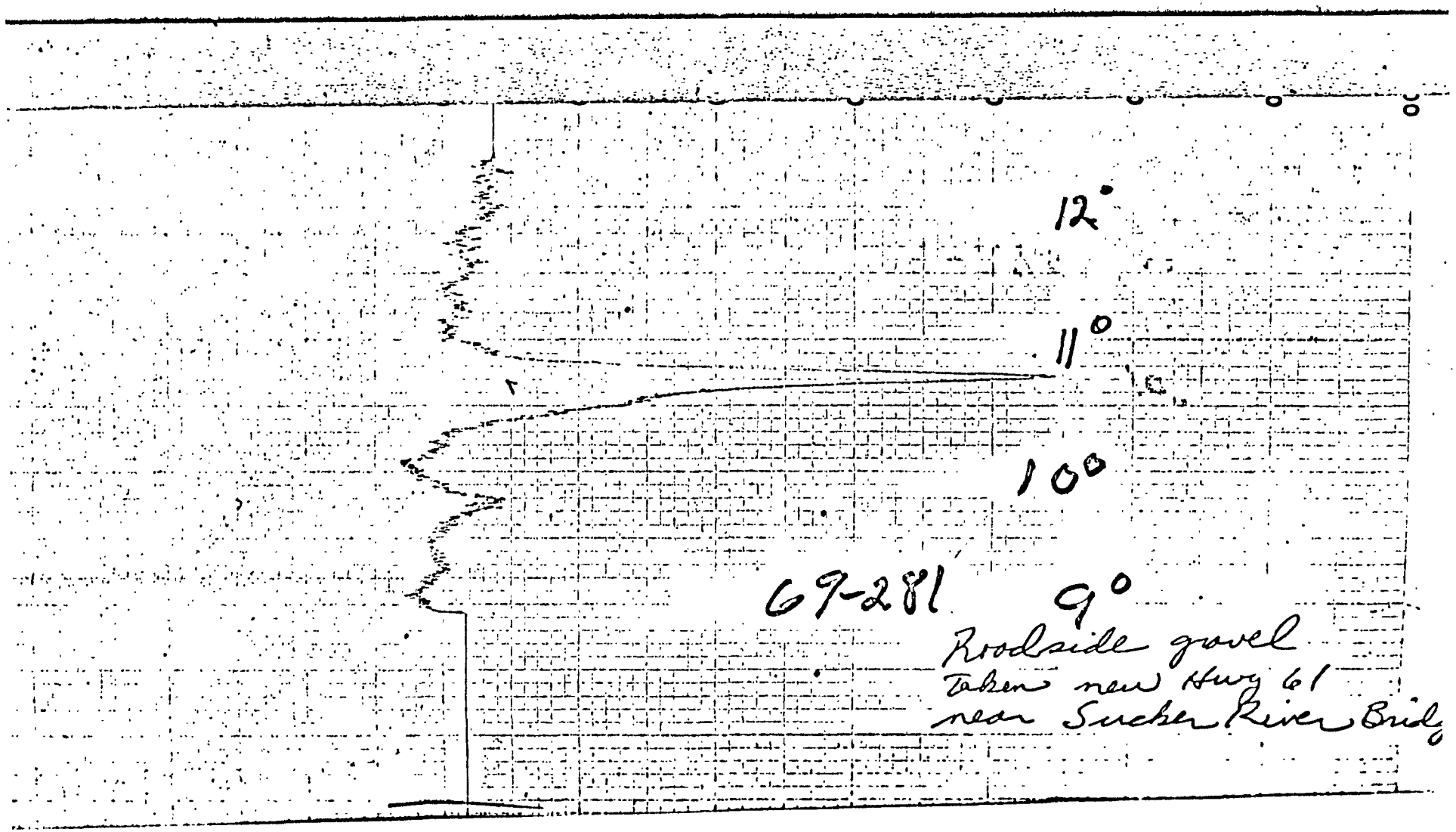


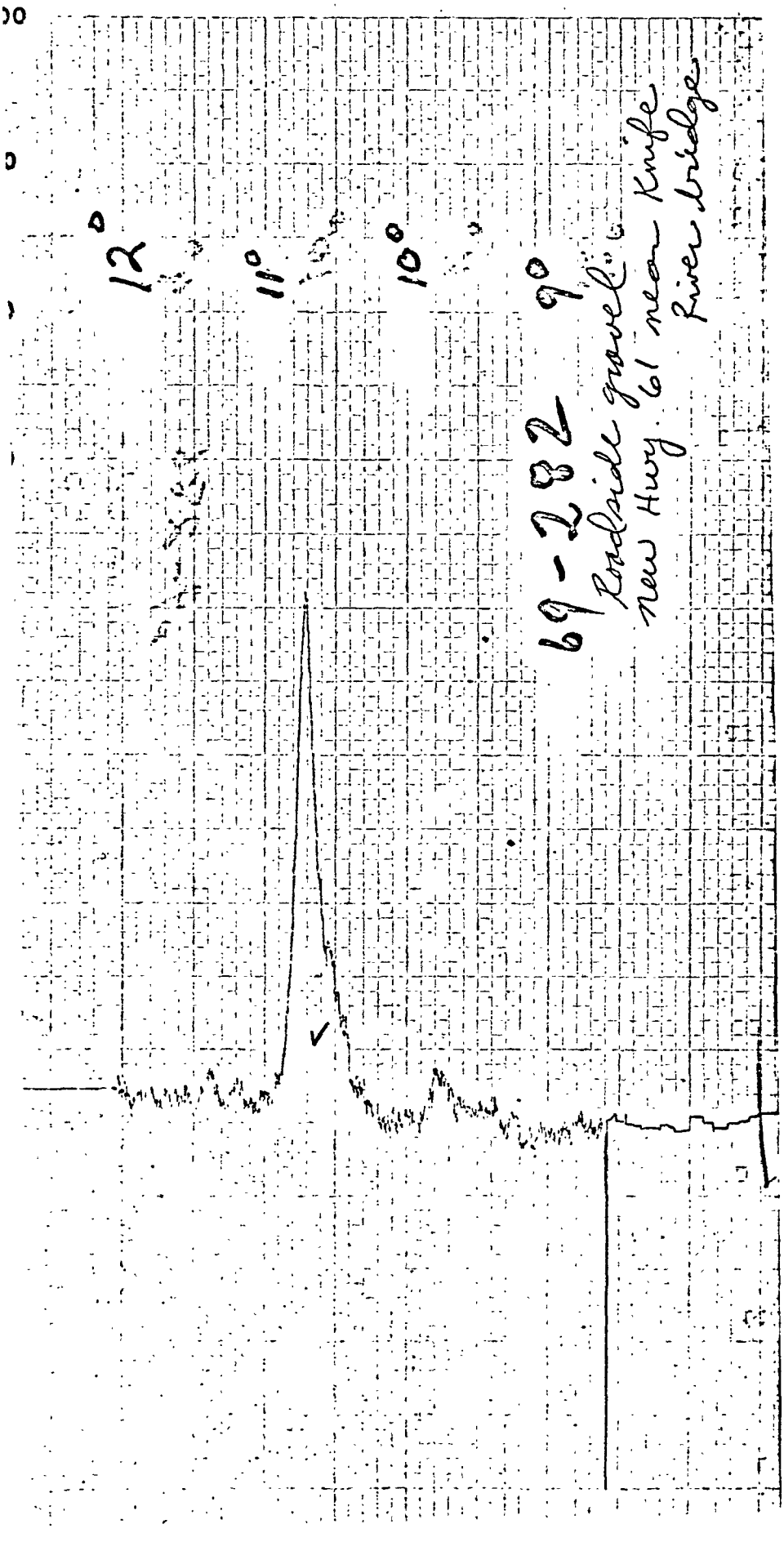
GRAVEL TAKEN FROM INTERSECTION OF OLD AND NEW HIGHWAYS #6
DULUTH end.

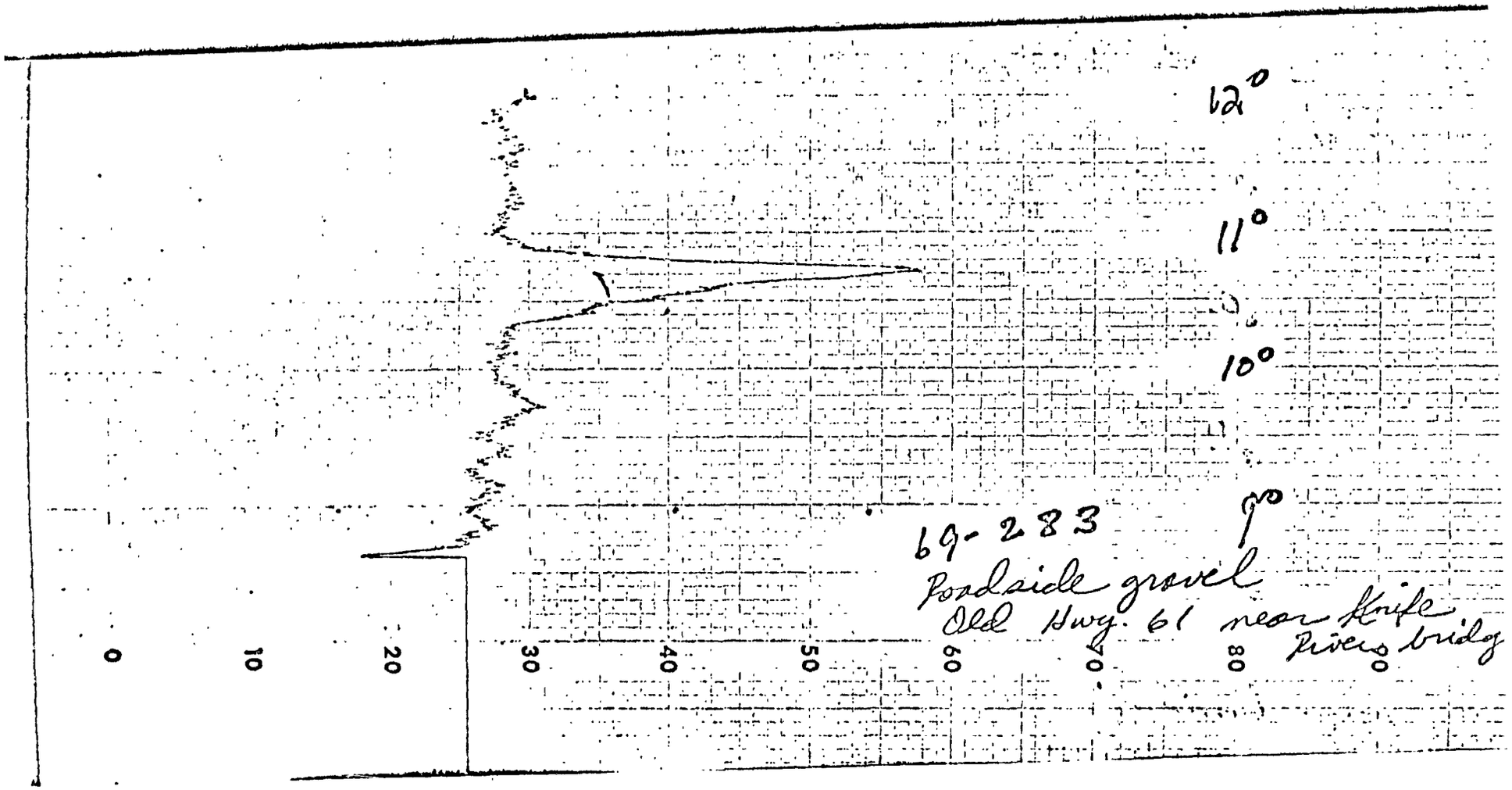

100
90
80
70
60
50
40
30
20
10
0
11
10
9
12
69-278
Roadside gravel
Old Hwy. 61
one block east of
Duluth pumping Station

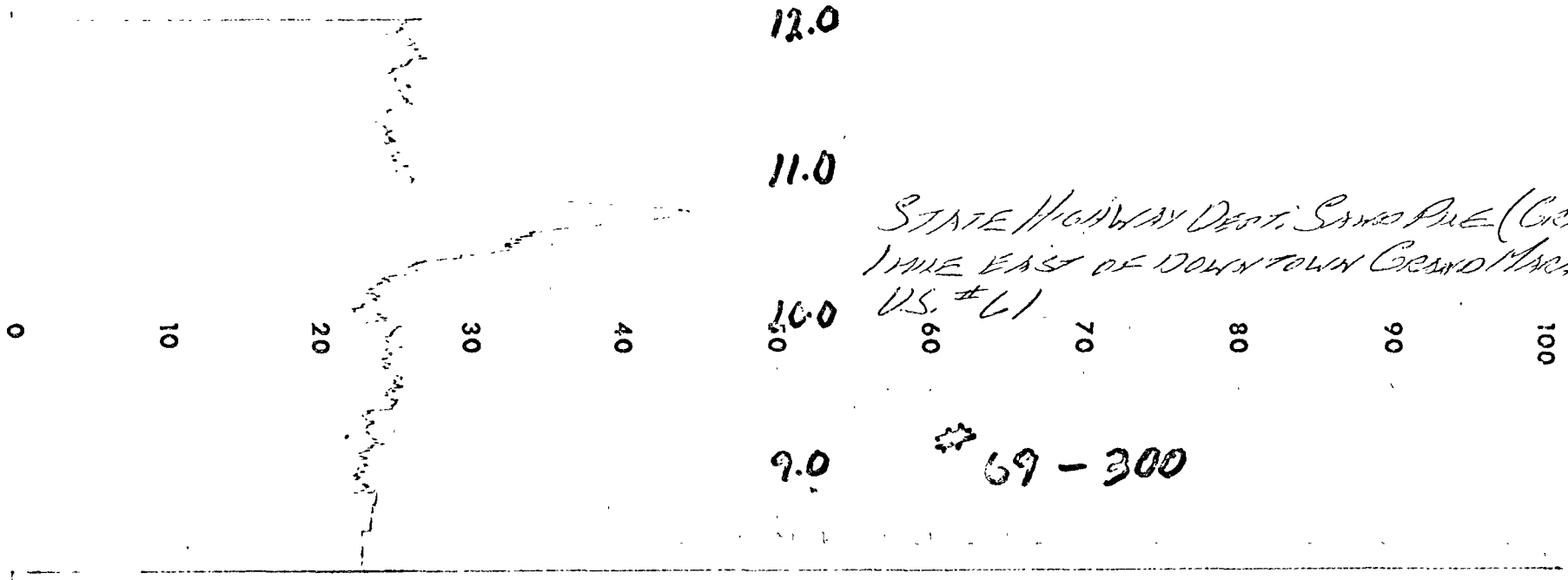

100
90
80
70
60
50
40
30
20
10
0
12°
11°
10°
Roadside gravel
from Talmadge
River Bridge
old Hwy 61
69-279


12°
11°
10
69-280
9°
Roadside gravel
from old Hwy 61
at French River Bridge


12°
11°
10°
9°
69-281
Roadside gravel
Taken new Hwy 61
near Sucker River Brid


12°
11°
10°
9°
69-282
Roadside gravel
near Hwy. 61 near Knife
River bridge


12°
11°
10°
9°
69-283
Roadside gravel
Old Hwy. 61 near Knife Rivers bridge
0
10
20
30
40
50
60
70
80
90



STATE HIGHWAY DEPT. SAND PILE (GRAY)
1 MILE EAST OF DOWNTOWN GRAND MESA
U.S. #61

#69-300

50/20, 1X2X10^3, W-INT.

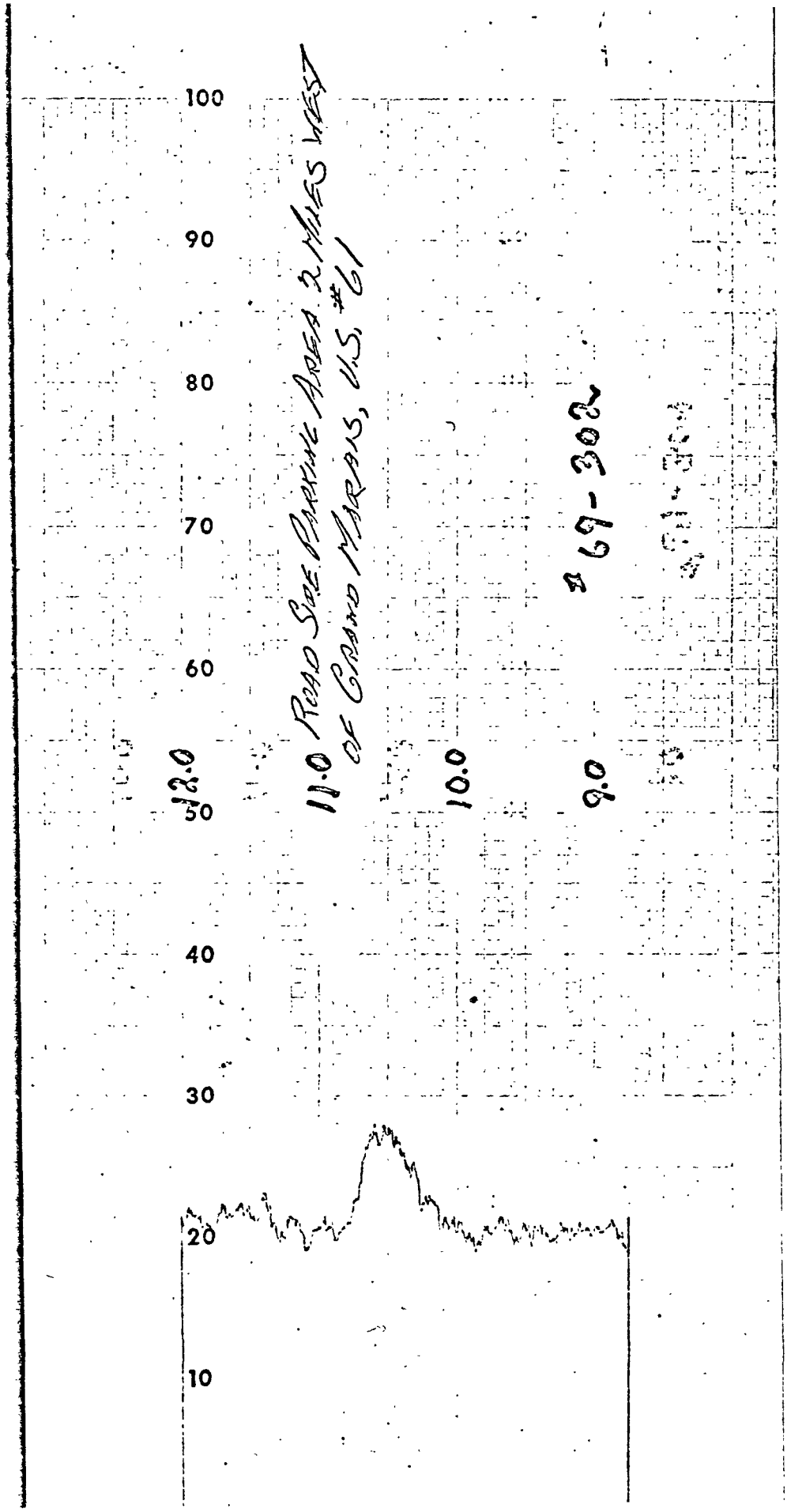
1°/MIN. 60"/HR.

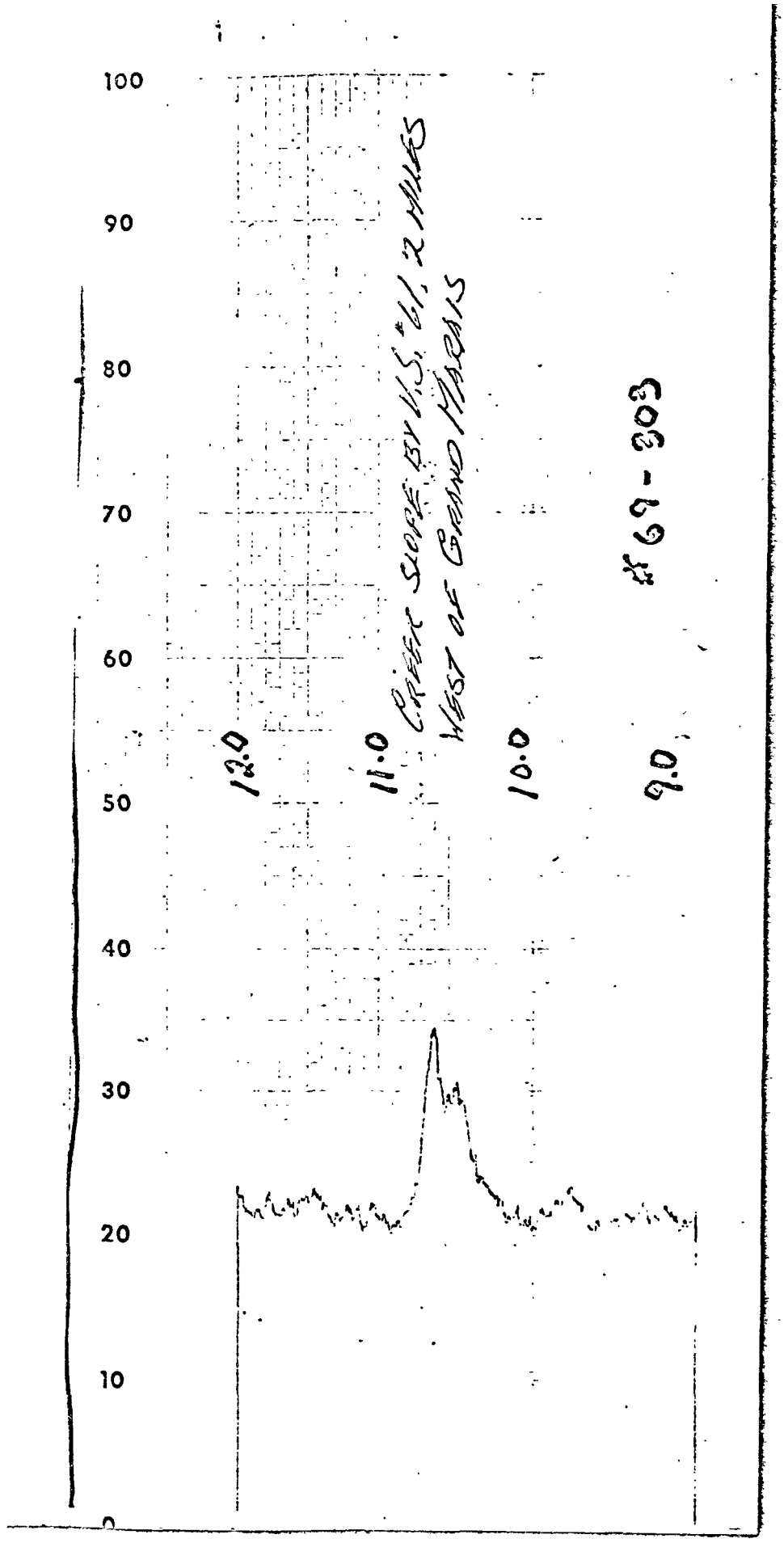
5-14-69

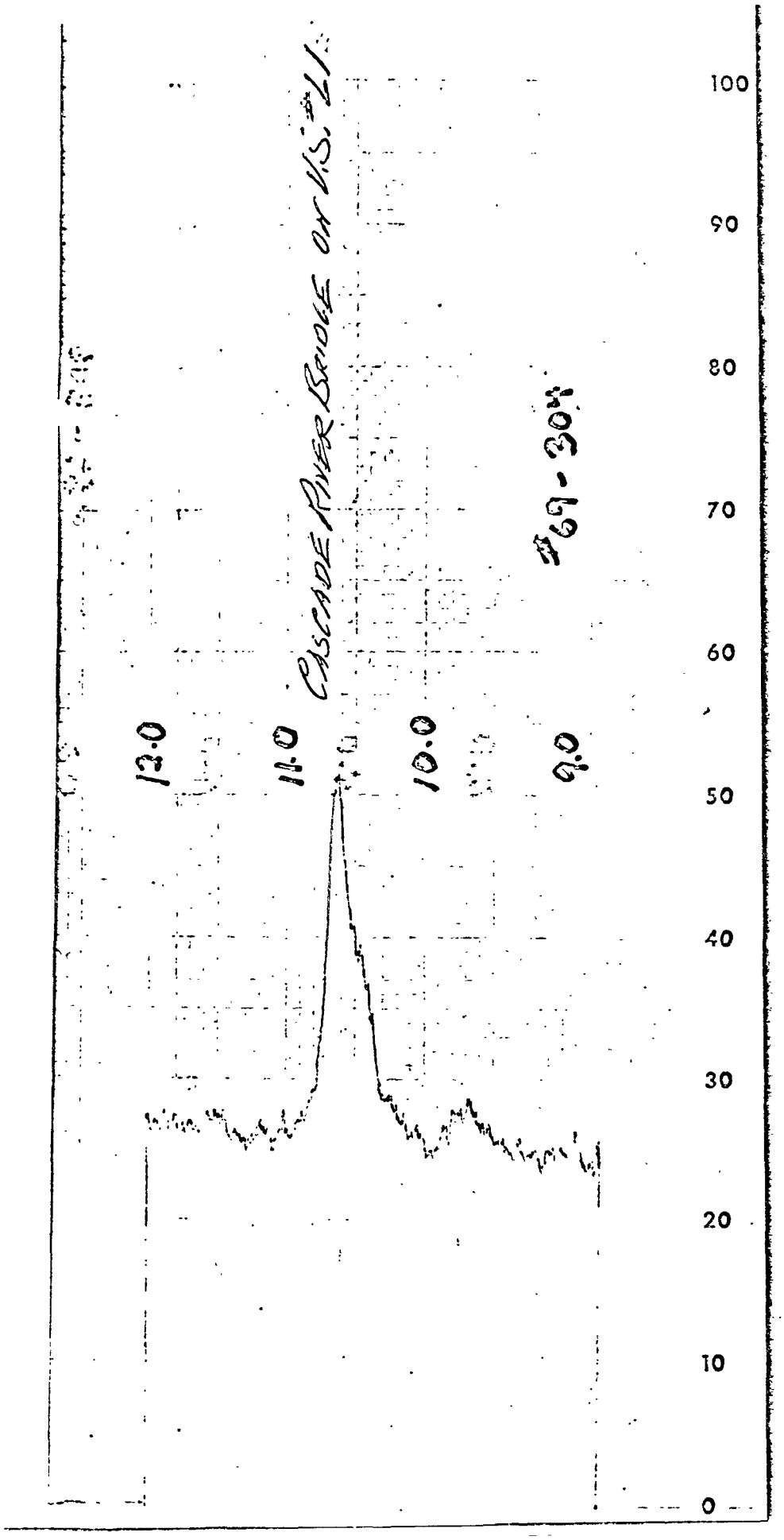
W. Schmidt

1248

State Highway Dept. Snapline (Brown)
1 Mile East of Grand Marais
Adjacent to Structure of 69-380
#69-301
12.0
11.0
10.0
9.0
100
90
80
70
60
50
40
30
20
10
0


100
90
80
70
60
50
40
30
20
10
12.0
11.0
10.0
9.0
ROAD SIDE PARKING AREA 2 MILES WEST OF GRAND MARAIS, U.S. #61
#67-302


100
90
80
70
60
50
40
30
20
10
0
12.0
11.0
10.0
9.0
CREEK SLOPE BY U.S. #1, 2 MILES
WEST OF GRAND MARAIS
#69-303


CASCADE RIVER BRIDGE on U.S. #21
#69-30%
12.0
11.0
10.0
9.0
100
90
80
70
60
50
40
30
20
10
0

Spring Dirt Road Service Creek
on U.S. #41, 16 miles West
of Grand Marais
#69-305
12.0
11.0
10.0
9.0
100
90
80
70
60
50
40
30
20
10
0

Stobbs anticline/Sanis River
in Granite Harbour Area V.S.#61
#69-306
12.0
11.0
10.0
9.0
100
90
80
70
60
50
40
30
20
10
0

certain interferences or other sample preparation techniques can make a difference in the particular results. I am wondering if you are using comparable sample preparation techniques.

MR. HALEY: We have endeavored to use the best possible laboratory sampling procedures that we could. We have some witnesses here who will testify to that -- to our techniques. We have exchanged samples with FWPCA in Chicago. We have done some exchanging with the National Water Quality Laboratory in Duluth, some with the Limnological Research Lab at the University of Minnesota, and many other places. We feel that we can match the quality of our work against anybody's in the United States.

MR. PURDY: I am not questioning the quality of your work. It seems that in this scientific field the scientists get together and resolve the apparent differences in scientific information. And I am wondering if it wouldn't be possible for the scientists from the National Water Quality Laboratory, along with the Reserve Mining Company, to develop a standard technique that they are in agreement with to resolve this difference in information and present it to the conferees.

MR. DOMINICK: That is an excellent suggestion. I would have to confer with our technical people before we made a judgment on that. But I would hope that an agreement could be reached, by way of stipulation or otherwise, as to the scientific techniques which are employed.

MR. HALEY: We will be happy to partake in any such exchange of scientific technique or procedures that we feel would

enhance the knowledge of our Lake Superior.

MR. DOMINICK: Mr. Haley, I have one more question.

A good part of your excellent presentation was devoted to methodology, and it appears to me that we have here a problem of very high public interest and we have some parties, on the one hand, saying there is pollutional effect, other parties saying there is no pollutional effect. The Government spends considerable amounts of money, which is public information, in the development of its research. Would you be prepared to describe to us your budget for research and development on the question of studying the effects of taconite tailings in the water of Lake Superior?

MR. HALEY: I don't have a figure right here. I am reasonably sure the figure would be in excess of $300,000 for last year.

MR. DOMINICK: Thank you.

Have you done any work, under your supervision as Vice-President and Manager of Research and Development for Reserve Mining Company, on developing alternate techniques for the disposal of taconite waste?

MR. HALEY: We have done some engineering work which we hope to be able to present at this conference today.

MR. DOMINICK: Thank you.

(The statement of Kenneth Haley in its entirety follows.)

Statement of
K. M. Haley
Vice President and Manager
Research and Development Division
Reserve Mining Company
Silver Bay, Minnesota

At the Conference on the Matter
of Pollution of the Interstate
Waters of the Lake Superior Basin

Hotel Duluth
Duluth, Minnesota
May 13, 1969

My name is Kenneth Haley. I am Vice President of Reserve Mining Company and Manager of their Research and Development Division.

I am a resident of Silver Bay, Minnesota. I have a Bachelor of Metallurgical Engineering degree from Ohio State University. I have been associated with taconite processing into pellets since 1948.

Reserve Mining Company has always supported the principle that it is possible to have both industry and clean water. And it is entirely possible for an industry such as ours to use water and not create a pollution problem. To follow up these principles, a lake study program was started as a part of the operating procedure of the E. W. Davis Works at Silver Bay, Minnesota in 1956.

The purpose of this program was to monitor the deposition of tailings in the lake and determine if any potential pollution was developing. If any sign of pollution was developing, we wanted to be the first to know it, so we could correct the condition while it was a minor occurrence instead of a major problem.

Charting Reserve's Tailings Deposit

It is important in presenting any large amount of information to present it in a manner that will give the proper perspective. To help our presentation, Reserve has made a 6 foot x 5 foot model of the western 20% of Lake Superior. This model is accurate according to Corps of Engineers and

University of Michigan bathymetric charts. The vertical scale of the model is: 3/8 inch equals 100 feet of lake depth. Horizontal scale is: 1/2 inch equals 1 mile.

The dominant contour on this scale model of the lake bottom is the deep area off Silver Bay. Our sonar readings have recorded a depth of 966 feet at the bottom of this area. This is the way the underwater shelf looked before Reserve began operating.

Reserve is discharging 60,000 tons of tailings a day, which sounds like an extremely large amount. But as has been reported, 45 percent of this tailings is heavy enough to settle out on a beach, or delta, in front of the plant, with the remainder traveling by density current down into the deep area.

To place this into perspective, we have made a scale model of the delta. I am going to mount this delta model in the proper place on the lake bottom model.

Except for the delta the depth of tailings is not large enough to illustrate by using the bottom on the model. Therefore, I will describe the flow and deposit of tailings. The steepest slope is south from our discharge, and the lake currents are generally from northeast to southwest. The principle flow of tailings as a heavy density current is somewhat south by southwest until it approaches the deeper area. Then it flows parallel to the Minnesota shore seeking the deeper area of the lake bottom. Tailings are quite deep adjacent to the toe of the delta. About half way between the Beaver and the Split Rock Rivers, the depth of tailings has decreased to 4 inches This decrease in depth continues; 15-1/2 miles southwest of the discharge, it has decreased to a one inch thickness of tailings. From here on, the

deposit gets very thin and spotty through the balance of this area deeper than 900 feet. The farthest tailings have been found straight out from the Minnesota shore is eight miles. The thickest layer of tailings in the deep 600 to 900 foot area is 6-1/2 inches. All of this tailings flow and deposition is as predicted before the permits were granted.

This data was obtained from about 150 bottom core samples taken during 1967, 1968 and 1969. The tailings deposit grows so slowly on the lake bottom that we do not believe there are severe inaccuracies in at least the general shape of the deposit by using data taken over this long a time period.

Material is identified as tailings, natural bottom sediments, or a mixture of the two by chemical analysis. Tailings have a lower chemical analysis in most of the metals, except iron, than the natural lake bottom sediments. These differences can be used for identification. Titanium analysis is the most positive one to use.

Bottom cores are taken with a Phleger core sampler. The top section is visually examined for an apparent tailings layer. If such a layer is noted, it is measured and sampled. If an apparent tailings layer is not visible, we remove a very thin section of the surface of the core. The natural bottom portion of the core is also sampled. Both samples are analyzed for titanium, and an X-ray diffraction scan is made. From these results the percentage of tailings in an apparent tailings layer can be calculated or the absence of tailings verified. A sample of apparent tailings 1/4 inch thick may actually be only 10 percent tailings. This core would be recorded as having 0.025 inches of tailings present.

Now I am going to replace the 1969 tailings delta insert on the lake bottom model with another which likewise has been constructed from

mathematical projections. This new model shows what the buildup of the delta and its underwater slope will look like after fifty more years of Reserve's operation. We do not expect the tailings to travel much farther than they have to date.

The distance that tailings will travel before settling on the lake bottom is a function of their settling rate and the currents they are carried by (the heavy density current plus the lake currents). There is no reason to expect the settling rate or the currents to change. We expect that the tailings will be deposited in the same general area that they have been. The tailings will still be too thin to identify any change in the bottom contours.

Also, we expect the heavy density current to have the same general direction of flow. The toe of the delta will then be in about 550 feet of water. From this toe it will slope in the same manner as it does today, reaching a depth of about 15 inches at the point half way between the Beaver and Split Rock Rivers where it is now 4 inches. At 15-1/2 miles down shore where tailings are now one inch thick, we expect them to become 3-1/2 inches thick. They will not be carried very much, if any, further than they have been so far. The same physical phenomena of the heavy density current plus lake currents and settling rates will continue to apply.

We have taken bottom core samples outside of these areas described along the Minnesota shore. On several occasions we have sampled from the Minnesota to the Wisconsin shore. Also, we have been furnished bottom samples from the Wisconsin area for identification. These additional samples verify that tailings are not outside of the area previously described.

Analysis of Tailings and Sediments

We have made a rather complete chemical analysis of a series of representative bottom cores. The detailed data is attached as Tables #1 through #12, Appendix A. These chemical analyses show that the natural bottom sediments have higher aluminum, chromium, copper, nickel, titanium, and zinc analyses than the tailings sediments in the same area. They show that the natural bottom sediments and the tailings sediments in the same area have the same analyses of cadmium, cobalt and lead. They show that tailings sediments have higher iron, magnesium, and manganese analyses than the underlying natural bottom sediments. These chemical analyses show that the natural bottom sediments contain more of the metals identified as objectionable heavy metals by the FWPCA than do tailings.

Table 1, Appendix B, shows a typical complete chemical analysis of Reserve's tailings. This analysis shows that the heavy metals that the FWPCA considered objectionable are very low in Reserve's tailings. The metals in the tailings are in the form of complex oxides or silicates which are inert to Lake Superior water. Reserve Mining Company in conjunction with two of their consultants, Dr. Bright and Dr. Lee, have conducted tests that show that the tailings are essentially inert, insoluble in Lake Superior water.

Table 2, Appendix B, gives fine size analyses of tailings sediments and the natural sediments from the same bottom cores. These size analyses show that the natural bottom sediments are much finer than the overlaying tailings sediments.

During the hearings before Reserve was given a permit to deposit tailings in Lake Superior, Dr. E. W. Davis, Director of the Mines Experiment Station of the University of Minnesota, presented a typical screen analysis of tailings from the Mines Experiment Station pilot plant operations. See Table #3, Appendix B. The amount of tailings finer than 325 mesh was 44.9%. All of Reserve's operations have produced tailings coarser than this prediction. Table #4, Appendix B, gives two typical screen analyses of total tailings from 1956 and 1957. The amount of tailings finer than 325 mesh is 41.0% and 43.3%, respectively. The Bureau of Mines sampled Reserve's tailings 5-6-68 through 5-9-68. Their Table A-3, page 35 of their report, shows the amount of tailings finer than 325 mesh was 40.4%, 33.2%, 41.0%, and 39.2% in their four days of sampling.

Early in Reserve's operation the finest laboratory screen normally available was 325 mesh. Today, much finer mesh screens are available. Table #5, Appendix B, gives three recent screen analyses of tailings, showing sizings through 5 microns. These show the amount finer than 5 microns to be 8.2%, 6.3%, and 4.2%. This agrees with the U. S. Geological Survey sizings of Reserve's tailings, which show the amount finer than 4 microns as 5.8%.

Recently, on April 21 and 24, Reserve operated the pilot concentrating equipment in the same manner as its 1956 and 1957 concentrating practice. Table #6, Appendix B, gives four screen analyses of tailings from this operation. The amount of material that is finer than 325 mesh is 43.3%, 41.3%, 41.7%, and 41.6%. This is the same range as screen analyses of tailings produced in 1956 and 1957. The amount of tailings finer than 5 microns is 9.8%, 8.1%, 9.1%, and 8.7%.

This series of screen analyses of tailings shows that Reserve Mining Company's tailings have not been finer than was predicted by the Mines Experiment Station. Also, it shows that the tailings now being discharged by Reserve are essentially the same size analysis, or coarser, than the tailings discharged much earlier in their operation.

Water Quality

In conjunction with Dr. Bright of the Limnological Research Center of the University of Minnesota, a series of seven sampling stations were laid out. Five of these stations were plotted to be within varying influence of tailings. Two were outside of the influence of tailings. These stations were sampled in June-July, September, and October-November in 1968. From two to three thousand chemical, physical and biotic analyses were made. The results show that tailings have no effect on the chemical or biotic analyses of Lake Superior water.

Bottom Fauna

Reserve Mining Company has conducted a bottom fauna study during April and May of 1969. This data alone or in conjunction with the study conducted in July, 1968, by the State of Minnesota shows that the tailings have not had an adverse effect on the total fish food organisms.

Reserve's Scientific Resources

Personnel - When Reserve started its lake study program back in 1956, the initial work was performed by members of our Process Engineering Department under the direction of E. W. Davis, Consultant, W. E. Apuli, Chief Chemist, the advice of member of the Water Pollution Control Commission, and Earl H. Ruble, Consulting Engineer. A 40-foot converted cabin cruiser was used for obtaining samples. The facilities of the Power

Plant water laboratory and chemical laboratory were used for preparation and analysis of the samples. The initial program consisted of measuring the tailings delta volume, sampling at depths of 2 feet and 20 feet for turbidity determinations, and core sampling the lake bottom to determine the distribution of the tailings.

This program was expanded through the years. In 1964 the scientific phases of the company were consolidated into a Research and Development Division. The R & D Division was given the responsibilities of the former Process Engineering Department, the lake studies program, and all other similar responsibilities. During and since this reorganization, the personnel and facilities for all phases of research have been increased. A five million dollar pilot plant, laboratories and office building were constructed. A force of 45 people have been developed to perform these research activities. About one-third of the total effort of this group is now spent on lake studies. In addition, the advice and assistance of various consultants are used.

Dr. R. C. Bright, of the University of Minnesota Limnological Research Center, advises us on our total program and has biotic analyses of water samples performed.

Dr. G. Fred Lee, Professor of Water Chemistry at the University of Wisconsin, advises and assists us in methods of water chemistry and tests pertaining to the chemistry of Lake Superior.

Dr. R. A. Ragotzkie, Director, Marine Studies Center, University of Wisconsin, advises us on studies pertaining to the tailings heavy density current.

Cyrus W. Rice and Company, Pittsburgh, Water Management Consultants, assist and advise us on data analysis.

Three R & D personnel are assigned permanently to lake studies. This is increased to eight people when the lake is open so that sampling can be performed. The three permanently assigned people are D. W. Anderson, University of North Dakota, Ph. D., Biology; A. W. Klaysmat, Bemidji State College, B.S., Biology; and W. J. Nosek, University of Minnesota - Duluth, B.S., Earth Sciences.

Water chemistry is performed under the direction of R. S. Lemire who received his B.S. degree in chemistry and biology from Bemidji State College in 1950. He has had 18 years of experience in the field of chemistry. Assisting Mr. Lemire are J. W. Wright, Bemidji State College, B.A., Chemistry; C. L. Allie, University of Minnesota - Duluth, B.A., Chemistry; D. H. Schnortz, Bemidji State College, B.A., Chemistry and Biology; D. M. Wagner, Wisconsin State University, 4 years, Chemistry; J. W. Johnson, Wisconsin State University, B.S., Biology and Chemistry; and D. A. Stulc, University of Minnesota - Duluth, B.A., Chemistry.

Planning, scheduling and statistical analysis of data are performed under the direction of J. C. Gay, Senior Research Engineer, who received his Ph. D., Metallurgical Engineering, from the University of Minnesota, and who served with the U. S. Bureau of Mines. Computer calculations with the data are programmed by J. W. Christiansen who has a B.S. degree in Physics from the University of Minnesota.

Equipment - I shall describe only a few items among a wide array of excellent equipment available for our environmental studies.

Among the instruments owned by our Research and Development Division are:

Atomic Absorption Spectrophotometer: The spectrophotometer is a Perkin-Elmer Model 303 with recorder readout and Texas Instruments 10 millivolt recorder. We use the Model 303 to determine calcium, magnesium sodium, potassium, and the trace metals on water and solid samples. (Appendix C)

X-ray: A Norelco water-colled 50 KV diffraction unit with copper radiation tubes is used for mineral identification. A proportional counter detects the X-rays. The signal is amplified and put into a strip chart recorder for measurement.

A Norelco water-cooled 50 KV X-ray emission unit with chromium target X-ray tube and vacuum head is used for the detection and semi-quantitative measurement of elements above Atomic Number 11 (sodium) in solid samples and quantitatively for titanium and silica. Detection is made with a flow proportional counter. Readout is by decatron tubes or strip chart recorder.

Conductivity Bridge: An Industrial Instruments Model RC16B2 conductivity bridge with a platinized disc is used for water electrical conductivity measurements.

Turbidimeters: We have three different turbidimeters as a check on accuracy; the Jackson Candle turbidimeter, used for high turbidities, i.e., 25 JTU and above; a Hellige turbidimeter used for turbidity measurements from 0 JTU to 25 JTU; and a Hach turbidimeter used for measuring sulfate in water.

pH Meter: pH is measured with a Beckman Instruments Instamatic II. It is standardized using Beckman standards. It is used for measurement of pH of water and determining alkalinity by acid titration to pH 4.4.

Spectrophotometers: The spectrophotometers are a Beckman Model DU-2 and a Bausch & Lomb Spectronic "20."

These instruments are used to determine phosphorus, silica, chloride, nitrate, and nitrite colorimetrically by methods from Standard Methods. They are also used to determine ammonia by the pyrazolone method, which we find more applicable to Lake Superior water than methods outlined in Standard Methods.

Laboratory Hydraulic Studies Tank: A tank 25 ft. long by 2 ft. square is available for laboratory heavy-density current studies. One side of the tank is plexiglas, through which current action can be visually observed. The effect on a heavy-density current of thermoclines and wave actions is being studied, as well as the basic behavior of the heavy-density current.

Equipment for Water Sample Storage and Temperature Control: The following equipment is used for storing or maintaining water samples at a constant temperature: Incubator, Labline Instruments, Inc., constant temperature, approximately 10 cubic foot capacity; refrigerator, Sears Roebuck, approximately 12 cubic feet; walk-in cooler, maintained at 4° C.

We are very proud of our scientific methodology and of the excellent equipment which proves it out. We believe we have a staff, the equipment to back them up, and that we are second to no company on the lakes when it comes to precise capability in water studies. I am not going to take your time detailing the high standards of precision we can achieve but Appendix C lists some estimated precisions.

IBM 1800 Computer: We have a fourth generation computer with time-sharing capabilities. The computer has 16,000 words of core memory and

two disc drives, each with 512,000 words mass storage capacity. It has an instruction execution time of 4 micro seconds. Associated with the computer is an operating console, card sorter, keypunch, card read/punch, line printer, two typewriters, and a keyboard input unit.

The computer can be programmed for more than one job at a time. By time sharing the programs are executed on a priority basis. At the present time 40% of each second is used to monitor and control the pilot plant. The other 60% of each second is available for scientific calculations. For example, we have programs for calculating means, standard deviations, "t" tests, analysis of variances, regressions analyses, materials balances, atomic absorption calculations, etc. All programs have been verified by manual calculations.

Research Launch and Equipment: A 32 foot Research launch with a 12 foot beam, is used for water resources studies. Two 290-horsepower Chrysler Crusader gas engines power the launch at speeds up to 35 mph. Hydraulic trimtabs were installed to insure a proper planing angle. Basic equipment includes a hydraulic winch for raising and lowering samplers and instruments, and a Koehler generator which supplied a steady source of 110 volt electrical power. The hydraulic winch has 1100 feet of 5/32 inch galvanized steel cable.

A Danforth-White spherical compass and a Decca Model 101 radar set are used to locate precisely the launch's position. The Decca radar has four ranges from a half-mile radius circle to a 15-mile radius circle. The launch has a full complement of Lake Superior navigation charts and instruments. Speed and distance are measured with a Kenyon marine speedometer-odometer.

Depth is precisely measured with a Raytheon DE-723 (A1/B1/C1 systems) depth sounder. The unit is equipped with a 200 KC transducer which measures depths up to 1500 feet. Maximum error is one-half percent.

We have two 16-liter, one 8-liter and one 2-liter Kemmerer water samplers. All water samplers are plastic to protect sample purity. Samples of Lake Superior bottom can be obtained with two Phleger core samplers or a Shipek sampler. Two Peterson dredges are available for collecting samples for bottom fauna studies. A Gelman vacuum pump is used to withdraw water samples from the lake through plastic tubing.

A Hydro Products Model 450S current speed and direction system is available for study of lake and density currents.

Turbidity, temperature and depth can be continuously and simultaneously measured and recorded with a Hydro Products Model #412-0101 transmissometer.

Three plastic-constructed pressure filters are available for separating solids from water. Tyler 12-inch diameter stainless steel 14-, 28-, and 48-mesh screens are used to separate bottom fauna from bottom material.

Dissolved oxygen measurements are made with a Yellow Springs Model 54 dissolved oxygen meter. pH measurements are made with a Photovolt pH meter.

Reserve's Report to the Minnesota
Pollution Authorities 1957 - 1968

Reserve Mining Company has kept the State of Minnesota personnel informed by regularly reporting to them the results of their lake studies. I will summarize our reporting to date. Further details will be found in Appendix D, attached to my statement.

Two engineering surveys of the tailings delta are made annually. Charts showing the profiles on four lines and a plan view of the deposit are included in each biannual report. The July-December, 1968, report shows the total tailings in the delta as of 11-19-68, to be 78.1 million long tons, the total tailings produced at 174.0 million tons, leaving 95.9 million tons carried by the density current. The water edge of the delta at its greatest thickness is 265 feet above the original bottom and the toe is 400 feet below the lake surface. The mean advance of the delta shoreline in the last six months was about 50 feet.

The perimeter of the permit area is sampled twice a year. Sample points are shown in Figure 1, Appendix D, and mean readings for the parameters of turbidity, temperature, dissolved oxygen, pH, and conductivity are shown in Appendix D.

Since 1966, the mill intake water and tailings discharge water have been monitored weekly and analyzed for temperature, dissolved solids, dissolved oxygen and pH. Mean values obtained over the three year period are detailed in Appendix D. But briefly, they show: A process induced temperature rise of 3.75° F., effect on dissolved solids is negligible, dissolved oxygen content of discharge waters is at saturation, no increase in

pH in the lake water has resulted from the discharge. All of the changes which occur in process are very minor and when the discharge water is diluted by lake water, the effect would not be detectable.

Much time and effort has been expended on the study of the causal factors responsible for the "green water" phenomenon. No firm conclusions have been reached but the techniques are now developed which should result in the resolution of the cause of "green water."

Bottom sampling was done to monitor the thickness and location of the tailings deposit as it progressed. Figure 2, Appendix D, is an isopach of the approximate thickness of tailings found in 1967 and 1968. This isopach shows positively that the density current carries the fine fraction of tailings into the deep basin where it then settles onto the bottom.

Twelve of fourteen sediment traps set out in 1968 were recovered. They were placed on the lake bottom in from 60 to 438 feet of water for 75 to 180 days. The dried sediments were weighed and analyzed by X-ray diffraction for the percentage of tailings present. An approximation of the rate per year of tailings deposition was calculated. The maximum rate was 0.32 inch per year in a sample on which we also had core data. The core data and sediment trap data were in agreement.

1968 Findings by Eight Government Agencies

The data and observations obtained by a group of State and Federal agencies during 1968 show conclusively that the depositing of tailings in Lake Superior has not had any harmful effect on the water quality.

This group of State and Federal agencies performed studies in order to advise the Corps of Engineers on the question of revalidating Reserve's Lake Superior permits for an additional five years. A number of questions on Reserve's use of Lake Superior had been raised and this group organized to obtain data to answer these questions. Most of these same questions were considered before the permits were granted. State, Federal and other scientists who studied these questions in the late 1940's predicted that no pollution would result from Reserve's deposition of tailings in Lake Superior. Therefore, the original permits were granted. These new, more complete studies verify the early predictions that the water quality would not be affected.

This study group consisted of the FWPCA and four other bureaus or agencies of the U. S. Department of the Interior, two Minnesota agencies, and one Wisconsin department.

"Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota," U. S. Department of the Interior, Federal Water Pollution Control Administration, Great Lakes Region, December, 1968:

This report covers the work performed by both the Chicago Program Office and the National Water Quality Laboratory, Duluth.

This report's data shows that from a chemical and turbidity standpoint, the water in the Silver Bay area has higher purity than the balance of the lake which the FWPCA sampled.

During 1966 and 1967, the FWPCA sampled water from essentially all areas of the U. S. portion of Lake Superior. The analyses of these water samples were compared by Reserve Mining Company personnel to the analyses of the water samples secured by the FWPCA in the Silver Bay area in 1968. Standard accepted statistical procedures were used, and the calculations were performed on an IBM 1800 computer.

Our comparisons show on a 95% confidence level that the water in the Silver Bay area is lower than the rest of the lake sampled by the FWPCA in conductivity, sulfate, ammonia, lead, zinc, turbidity, and total phosphorus. They also showed that the water in the Silver Bay area had essentially the same content of chloride, nitrogen, total iron and nickel as the balance of the lake sampled by the FWPCA.

The only analyses that were found to be higher in the Silver Bay area were pH and nitrite-nitrate. However, these analyses were well within the State and Federal water quality standards. Similar comparisons were inconclusive on alkalinity, dissolved oxygen and dissolved solids. Cadmium, chromium and copper analyses were not given for FWPCA 1966 and 1967 sampling. Therefore, like comparisons could not be made.

The FWPCA secured and analyzed samples from only eight inches off of the lake bottom in the Silver Bay area. The analyses, particularly the turbidity and iron analyses, of these samples are higher in the area of the heavy density current. This distribution of analyses clearly outlines the path of the heavy density current that is carrying tailings from the point of entry into the lake down the slope of the bottom into the 600 to 900 foot deep area of the lake. This is positive proof that the heavy density current is performing exactly as predicted from the tests that the St. Anthony Falls Laboratory and the

Mines Experiment Station of the University of Minnesota conducted in the late 1940's. The FWPCA only sampled over a 9 mile by 5 mile area. The deepest point sampled was 840 feet. Had they sampled over a larger area, they would have detected the complete area over which the heavy density current is flowing.

None of the chemical analyses reported as soluble exceeded the State of Minnesota water quality standards. The results of chemical analyses of samples after filtering through a Whatman No. 2V filter are listed as soluble.

No total copper, cadmium or zinc analytical results exceeded the State of Minnesota water quality standards.

One total manganese value exceeded the State of Minnesota water quality standard. However, this sample was secured from the heavy density current.

Four total lead results and four chromium results exceeded the State of Minnesota water quality standard. These higher values were in no way connected to Reserve's tailings.

Eighteen total iron values out of 179 analyses exceed the State of Minnesota Water Quality Standard of Domestic Consumption of 0.3 mg/l. All of these higher values were from samples secured either from the heavy density current only 8 inches off of the lake bottom or they were in no way connected to the tailings discharge. Further, iron is specified in Domestic Consumption only because the hydroxide form of iron will give rust stains. The iron found in the tailings in the heavy density current is not in the hydroxide form and is not readily converted to this form.

Only two samples from the heavy density current exceeded the State of

Minnesota Water Quality Standard for Domestic Consumption for turbidity of 5 JTU. A total of 155 turbidity measurements were made.

The FWPCA Silver Bay area water samples were analyzed for suspended solids, total chemical analysis and soluble chemical analysis. The analysis of the suspended solids in these samples can be calculated from this data. These calculations have been made for copper, zinc, aluminum, iron, nickel, manganese and lead. The percentages of these elements in these suspended solids is so far different from that found in tailings that it is obvious that the source of most of these suspended solids was material other than tailings.

The work of the personnel from the National Water Quality Laboratory, Duluth, identified small amounts of tailings in "green water" in the Silver Bay area. These observations were made in late September and early October when there was a thermocline condition. The tailings beach is part of the shore line of the Silver Bay area. It would be expected that some tailings would be temporarily suspended in the water in the Silver Bay area in the same manner that other material is temporarily caused to be suspended by a thermocline in this and other parts of the lake. In other words, the presence of tailings in "green water" does not prove that tailings are the basic cause of "green water."

Data on pages 388 and 389 shows the turbidity data expressed as suspended solids for these observations. The suspended solids values of "clear" lake water range from 0.1 mg/l to 0.9 mg/l. The suspended solids values of "green" water range from 0.5 mg/l to 3.7 mg/l. There is some overlap of readings. Some "clear" water has suspended solids of 0.4, 0.4, 0.8, and 0.9 mg/l. Some "green" water has suspended solids

of 0.5, 0.8, and 0.9 mg/l. These suspended solids values are all so low and the data overlaps so much that a firm conclusion cannot be drawn. All of the values are less than the most rigid State Water Quality Standard for Class "A" Domestic Consumption Water for turbidity of 5.

These observations and data were not complete enough to establish the basic cause of the "green water."

Bureau of Commercial Fisheries: This U. S. agency issued a report dated August 14, 1968, on a study of the effect of taconite tailings on commercial fishing. I quote verbatum from summary sentences and paragraphs of this report:

> "The increase of smelt was nearly coincident with the decline of lake trout and may have been related to it. The timing of the changes in the smelt population shows no relation to the Reserve taconite operation."
>
> "The changes in the chub fishery appear to be related mainly to economic factors and show no relation to taconite operation."
>
> "The records of the fishermen in the immediate vicinity of the plant do not indicate the taconite plant has had any effect on their operations."
>
> "This information along with the statistical data from Minnesota suggests strongly that the decline of herring was caused by a factor or factors that operate in all U. S. waters of Lake Superior and is unrelated to the Reserve Mining Co. operation."
>
> "Great changes have taken place in the fish populations of Lake Superior in the years since Reserve Mining Co. began operations but most of the changes have been lakewide and not confined to the vicinity of the taconite plant, or they were continuation of trends that began several years before the plant went into operation, or they were caused by other known factors. In brief, to the author's knowledge, no evidence is available to indicate that any fish population in Lake Superior has been adversely affected by the Reserve Mining Co. taconite plant."

Although the last paragraph of this report expresses some concern about tailings being deposited in the lake, the data and general observations of the report do not present any reason for such concern.

U. S. Bureau of Mines: A 1968 report by the Bureau reviewed findings by that agency on Reserve's tailings disposal. The Bureau surveyed samples of each type of tailings discharged and the composite or total tailings.

Their analysis shows that the elements that the FWPCA normally considered harmful are extremely low in Reserve's tailings. It also showed that the tailings are somewhat coarser than was predicted by the basic work done back in the 1940's by the Mines Experiment Station of the University of Minnesota.

Average total tailings analysis shows that the silicon, iron, calcium, aluminum, and magnesium oxides account for 98.6% of the total elements present. Copper, nickel, zinc, chromium, cadmium, and arsenic analyses of these tailings are very low, 0.005%, or less. Phosphorus averaged 0.044%.

Their screen analyses show that Reserve's tailings are slightly coarser than predicted by E. W. Davis, Director of the Mines Experiment Station, who presented data during the hearings on Reserve's lake permit application which showed that 45% of the total tailings would pass through a 325 mesh screen. The screen opening on a 325 mesh screen is 44 microns or 0.0017 inches. The U.S.B.M.'s data showed the average amount of total tailings that will pass through this 325 mesh screen as 38.4%.

Bureau of Sport Fisheries: An October, 1968, report by this agency evaluated the effect of taconite tailings on fish and other aquatic organisms. This report covers a series of laboratory tests using tailings effluent over 1,000 times more concentrated than would be found in the lake. Fingerling fish and other aquatic life were subjected to 100% tailings effluent or partially diluted tailings effluent. The samples for these tests were taken from our tailings launder before any material settled from the effluent onto the tailings beach. Even under these severe conditions, only one test showed any effect. Ten of the test results showed tailings to have no adverse effect on aquatic life.

Here are some direct quotes from this report:

> "Taconite wastes are not acutely toxic to fingerling-size coho salmon, rainbow trout, white suckers, black bullheads, bluegills, and yellow perch in 196-hour, static bioassays."
>
> "Taconite wastes are not lethal to eyed eggs of rainbow trout and apparently have no harmful effect on the hatchability of the eggs."
>
> "High concentrations of taconite waste cause mortalities among sac fry of rainbow trout in 4-day exposures."
>
> "Taconite wastes are not acutely toxic to backswimmers, midge larvae, and water-fleas in 96-hour bioassays."
>
> "Taconite wastes should be bioassayed against sac fry of lake trout and other salmonids which live and spawn in Lake Superior."
>
> "Whereas strong concentrations of taconite have little acute effects on fish and aquatic invertebrates, there are possibilities for chronic and other effects. Long-term bioassays in flowing systems would be required to demonstrate chronic toxicities to aquatic life due to heavy metals, mechanical damage to gills by particulate taconite, and repellency to fish."

The tests on rainbow trout sac fry were conducted in a concentration of one part tailings effluent to ten parts water and higher concentrations of tailings. It may be possible to find concentrations of tailings this high within a few feet of the point that tailings are entering the lake from the tailings beach. At any other spot in the lake, the tailings will be much less concentrated. Most of the FWPCA turbidity results are less than 1 Hellige unit, which is less than one part per million. A more realistic concentration for all of these type tests would be one part tailings effluent to 1,000 parts of water or more.

Reserve's tests, in conjunction with Dr. Bright and Dr. Lee, have established the chemical state of the elements that the FWPCA considers heavy metals in their tailings as being insoluble in Lake Superior. The screen analyses of tailings and tailings sediments compared to natural sediments indicate that tailings should have less probability of causing mechanical damage to fish gills than natural material. Tailings are much coarser, therefore, will stay in suspension much less time than natural material.

U. S. Geological Survey: The Water Resources Division of the U. S. G. S. issued a report dated November, 1968, on a study of streamflow conditions and sedimentation in the vicinity of Silver Bay. It outlines distribution of tailings on the bottom of Lake Superior. By sketching contours of the lake bottom on this figure, it can be seen that tailings are flowing down the most accessible slope into the 600 to 900 foot deep area. This is additional substantiating evidence that the tailings are flowing according to plan in a heavy density current to the lake bottom.

The U. S. G. S. report shows that only 5.8% of Reserve's tailings are finer than 4 microns. A portion of these 4 micron particles remain on the tailings beach, so less than this amount flows off the edge of the beach as part of the heavy density current.

The report summarizes the sediment load of western Lake Superior streams by stating that they are discharging 60,700 long tons per year, equivalent to about one day's discharge of Reserve's tailings. But these sediments and Reserve's tailings have settled in a layer in the deep trough with a maximum combined thickness of about 7 inches for 13 years of Reserve's operation. At this rate, if Reserve continues to operate for another 50 years, the maximum thickness of total sediments, tailings and natural, will only be about three feet in an area that is over 900 feet deep.

This layer of inert material would not have any adverse effect on the lake. It would make very little difference to the lake total to raise this trough bottom a maximum of three feet.

Minnesota Department of Conservation: The department's division of game and fish on October 10, 1968, issued a study on tailings and fish production done in cooperation with the State's Pollution Control Agency. It shows that the total amount of fish food organisms found on the bottom of the lake in the Silver Bay area have no relation to the presence or absence of tailings on the bottom of the lake.

An area of about 20 square miles along the Minnesota shore was studied. Samples were taken on six sample lines with five sample stations per line at water depths of 100 feet, 175 feet, 250 feet, 325 feet, and 400 feet. The first sample line was 5 miles northwest of Reserve's taconite plant and the sixth was 15-1/2 miles southwest of the plant.

All of the bottom fauna found were counted. This data is tabulated in their report. All of the organisms reported in the data, except Sphaeriidae, are fish food organisms. The total of these fish food organisms show no relation to the presence or absence of tailings on the bottom of the lake. This data is shown as Table 1, Appendix E.

Sample line #4, five miles southwest of the plant, which had tailings present at all sampling stations, produced the largest count of fish food organisms, 1,287 per square meter. The next highest count, 1,255 per square meter, was at sample line #1, five miles northeast of the plant, where no tailings were found.

There are variations in the type of fish food bottom fauna organisms throughout the 20-mile area sampled. There is a decrease in the number of Pontoporeia from the most easterly sample line, 5 miles northeast of Reserve's discharge, to the most westerly sample line, 15-1/2 miles southwest of the tailings discharge. This same trend was found by the Minnesota Conservation Department sampling in July, 1949, before Reserve started operations.

This trend of decreased Pontoporeia cannot be attributed to tailings inasmuch as there is a continuous trend regardless of a lack or abundance of tailings on the bottom. No sampling was done beyond the tailings deposit to the southwest. Additional sampling could substantiate that this is purely a directional trend and has no relationship to tailings.

The Minnesota Conservation Department reported that Pontoporeia is principally a food for smelt and the small decrease of Pontoporeia might affect the commercial smelt catch approximately $100 per year.

This Minnesota report, after discussing the Pontoporeia trend and commercial smelt catch data, concluded:

> "There is no evidence that there has been a decline in the Minnesota catch of smelt because of operation of the taconite plant."

These findings would seem to be convincing proof that tailings are not affecting the total amount of fish food organisms in Lake Superior.

Wisconsin Department of Natural Resources: The department's Division of Environmental Protection studied water quality off the Wisconsin shore and issued a report dated October 23, 1968. Comparison of their data shows that water in the Silver Bay area is far cleaner than the water of the Wisconsin area. This is determined by comparing the Secchi disc, turbidity, and phosphorus data of this report to that found by the FWPCA in the Silver Bay area.

The Secchi disc readings of the Wisconsin data averaged 7.2 feet. The FWPCA Secchi disc readings in the Silver Bay area averaged 21.5 feet. The fact that the Secchi disc could be seen in three times as deep water in the Silver Bay area as is possible to see it in the Wisconsin area certainly shows that the water of the Silver Bay area is much cleaner. The average turbidity data for the Wisconsin water is 18 times the average of the Silver Bay area turbidity.

Turbidity of Wisconsin area water was determined with a Hach turbidimeter. Turbidity of Silver Bay area water was established by the FWPCA with a Hellige turbidimeter. These two instruments are manufactured to produce the same numerical data in JTU when measuring water turbidity. They do not agree on individual samples. However, the data is in the same order of magnitude and often gives about the same average on a larger number of samples.

Water samples from the Wisconsin area, which were all surface samples, averaged 5.01 turbidity. The FWPCA surface and mid-depth data for their Silver Bay area samples averaged 0.28 turbidity. Details on their turbidity study for Silver Bay and the Wisconsin area are presented in Table 2 of Appendix E of my statement.

Chequamegon Bay, Wisconsin, had an average turbidity of 8.08, 29 times as turbid as the Silver Bay area. Oronto Bay, the least turbid Wisconsin water tested, had an average turbidity of 0.53, or twice as turbid as the Silver Bay area. The Apostle Island area had an average turbidity of 1.04, 3-1/2 times as turbid as the Silver Bay area.

Total phosphorus analyses of the Wisconsin area water averaged 0.042 mg/l. Total phosphorus analyses of water samples secured in the Silver Bay area by the FWPCA averaged 0.010 mg/l. Thus, Wisconsin water contains four times as much total phosphorus as the Silver Bay water.

This comparison certainly indicates that after 13 years of Reserve's operation, the water in the Silver Bay area is cleaner than other areas of the lake. This should be proof that Reserve's tailings are not having a deleterious effect on Lake Superior.

Some Comments on the FWPCA's April, 1969 Report

We believe the record of this conference should contain specific rebuttals to those assertions in the April FWPCA report which directly concern Reserve Mining Company. Our complete rebuttal is included as Appendix F Most of the comments of our rebuttal have already been covered in my previous discussion.

The subject of Conclusion #11 and the statement following it have not been covered sufficiently. I will confine my closing remarks to this subject.

This conclusion and its following statement is as follows:

> "A distinguishing characteristic of tailings discharge by the Reserve Mining Company is the presence of large quantities of the amphibole cummingtonite. This the following statement is
>
> Data gathered by the FWPCA since April 1, 1969 has shown the presence of taconite tailings (utilizing cummingtonite as a tracer) in the municipal water systems of Beaver Bay, Two Harbors, and Duluth, Minnesota. There has not been sufficient time to determine what effect, if any, the presence of the tailings has on the quality of the water supply or the users thereof."

Cummingtonite is a species of mineral belonging to the silicate class. Quartz sand that is often used for the sand of water filter beds also belongs to this same silicate class. Cummingtonite and quartz are the most abundant minerals in Reserve's tailings. Cummingtonite is found throughout the eastern Mesabi Range. It could be a mineral present in the watershed of many of the streams entering Lake Superior. For example, the head waters of the St. Louis River are in the same general mineralogical area as is Reserve's taconite mine.

Evidence of cummingtonite has been found in the following North Shore streams: Little Marais River, Baptism River, Split Rock River, Gooseberry River, Encampment River, French River, Talmadge River and Lester River. In addition to the possibility of these streams bringing cummingtonite into the north shore of the lake, over a million tons of Reserve's tailings have been taken from their tailings beach by or for State and County Highway Departments.

To determine if the use of these tailings by the highway departments was adding detectable amounts of cummingtonite to the soil alongside of roads, a series of samples of road gravel were analyzed. The following

samples showed evidence of containing cummingtonite:

1. Gravel from the lake side of Highway #61 near the east end of the Lester River bridge.

2. Gravel from roadside at intersection of new and old Highway #61, Duluth end.

3. Gravel from lake side of old Highway #61 one block east of Duluth water pumping station.

4. Gravel from lake side of old Highway #61 at Talmadge River bridge.

5. Gravel from new Highway #61 near Sucker River bridge.

6. Gravel from old Highway #61 French River bridge.

7. Gravel from new Highway #61 at the junction of Knife River road.

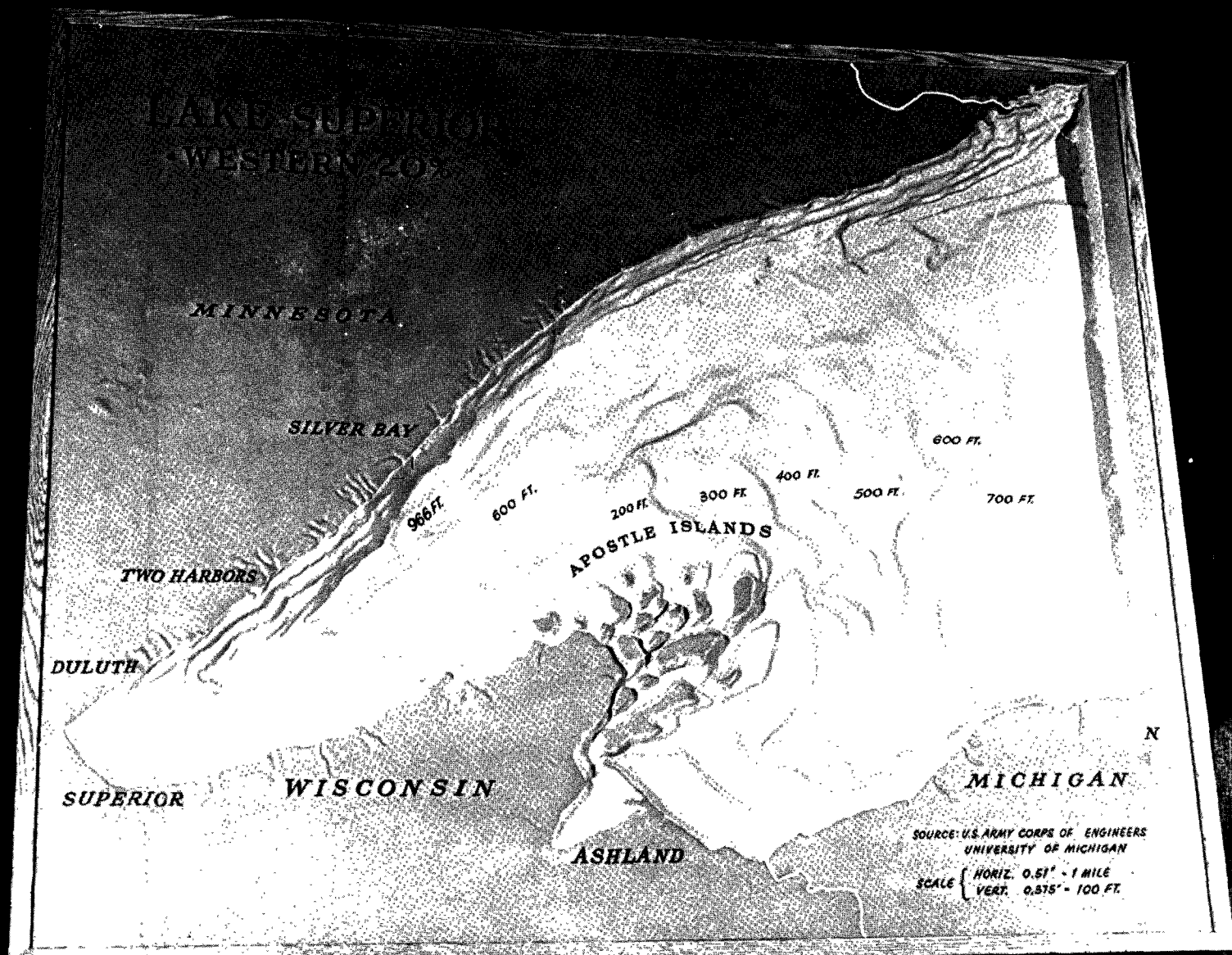
8. Gravel from new Highway #61 near Knife River bridge.

9. Gravel from old Highway #61 near Knife River bridge.

Cummingtonite is detected by an X-ray diffraction unit with a copper radiation X-ray source. Reserve's cummingtonite is indicated when a maximum diffraction or reflection of X-rays is obtained at an angle of 10.63° 2-Theta. Other minerals have diffraction peaks at about this same angle. All of the natural materials from the Silver Bay area that we have subjected to X-ray diffraction show some peak of X-ray diffraction at about this angle. Therefore, an X-ray diffraction at about this angle is not a positive indication of the presence of Reserve's tailings.

With indications of cummingtonite being so widespread along the North Shore, it is a very weak identifier of tailings. Also, so much tailings have been used on North Shore highway building and maintenance that the presence of cummingtonite does not establish that tailings were carried to that location by lake currents.

My thanks to you, Mr. Chairman, and to the conferees for giving me and my associates, Dr. Gay and Dr. Anderson, this opportunity to make available for the record the results of Reserve Mining Company's la studies. Dr. Anderson's complete paper is attached as Appendix G


LAKE SUPERIOR
WESTERN 20%
MINNESOTA
SILVER BAY
TWO HARBORS
DULUTH
SUPERIOR
WISCONSIN
ASHLAND
MICHIGAN
APOSTLE ISLANDS
966 FT.
600 FT.
200 FT.
300 FT.
400 FT.
500 FT.
600 FT.
700 FT.
N
SOURCE: U.S. ARMY CORPS OF ENGINEERS
UNIVERSITY OF MICHIGAN
SCALE { HORIZ. 0.51" - 1 MILE
VERT. 0.375" - 100 FT.

APPENDIX A

Table 1

COMPARISON OF ALUMINUM ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Aluminum Natural Sediments	% Aluminum Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	7.0	.8	-6.2	95
116-117	10 W	3	4.4	8.2	.8	-7.4	95
142-143	5 W	0.8	3.1	6.6	.8	-5.8	95
148-149	5 W	3.2	5.7	7.4	.8	-6.6	95
150-151	5 W	4	2.5	8.4	1.0	-7.4	95
314-315***	2½ W	378 Ft. Depth	10.0	6.2	.8	-5.4	95
201-202	5 W	0.5	5.7	6.2	1.0	-5.2	94
118-119	10 W	4	2.8	7.6	.8	-6.8	93
273-274	10 W	402 Ft. Depth	2.0	5.6	1.0	-4.6	92
120-121	10 W	5	4.4	7.4	1.2	-6.2	91
154-155	5 W	5.5	1.9	7.4	1.4	-6.0	88
92-93	5 E	2	1.2	7.6	2.0	-5.6	85
276-277	10 W	360 Ft. Depth	3.0	5.2	1.4	-3.8	85
152-153	5 W	4.7	2.5	7.2	2.0	-5.2	82
86-87	0	4	7.6	5.8	1.4	-4.4	80
94-95	5 E	3	1.9	7.0	2.4	-4.6	70
99-100	0	6	5.0	9.6	2.4	-7.2	68
103-104	0	8	3.8	9.0	2.8	-6.2	65
105-106	0	9	3.8	8.0	3.2	-4.8	65
101-102	0	7	3.8	8.2	3.2	-5.0	60
111-112	10 W	1	0.1	7.4	2.8	-4.6	59
109-110	0	11	1.9	7.8	4.2	-3.6	33
107-108	0	10	2.5	7.0	4.4	-2.6	29
80 T	0	1	13.9	*	.4	--	100
81 T	0	1	13.9	*	.4	--	100
147 T	5 W	2.4	17.1	*	.6	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.8	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.6	--	95
295 T	5 W	402 Ft. Depth	9.5	*	1.0	--	94
285 T	5 W	264 Ft. Depth	5.5	*	1.0	--	93
159 T	5 W	6.3	1.9	*	2.2	--	78
189 T	5 W	7	0.3	*	7.4	--	10
113 B	10 W	2	--	8.0	**	--	--
160 B	5 W	7.1	--	6.8	**	--	--
168 B	5 W	9.5	--	6.8	**	--	--
169 B	5 W	9.5	--	6.8	**	--	--
176 B	5 E	2	--	6.8	**	--	--
177 B	5 E	2	--	6.8	**	--	--
181 B	5 E	4	--	7.2	**	--	--
197 B	5 E	10	--	7.6	**	--	--
198 B Sands	5 W	200 Yards.	--	5.2	**	--	--
284 B	5 W	354 Ft. Depth	--	5.2	**	--	--
			High	9.6	7.4		
			Low	5.2	.4		
			Average	7.1	1.8		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

Table 2

COMPARISON OF CADMIUM ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Cadmium Natural Sediments	% Cadmium Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.0003	.0002	-.0001	95
116-117	10 W	3	4.4	.0005	.0004	-.0001	95
142-143	5 W	0.8	3.1	.0004	.0004	--	95
148-149	5 W	3.2	5.7	.0004	.0005	+.0001	95
150-151	5 W	4	2.5	.0004	.0002	-.0002	95
314-315***	2½ W	378 Ft. Depth	10.0	.0003	.0003	--	95
201-202	5 W	0.5	5.7	.0002	.0002	--	94
118-119	10 W	4	2.8	.0003	.0003	--	93
273-274	10 W	402 Ft. Depth	2.0	.0002	.0003	+.0001	92
120-121	10 W	5	4.4	.0004	.0004	--	91
154-155	5 W	5.5	1.9	.0002	.0002	--	88
92-93	5 E	2	1.2	.0001	.0003	+.0002	85
276-277	10 W	360 Ft. Depth	3.0	.0004	.0002	-.0002	85
152-153	5 W	4.7	2.5	.0003	.0003	--	82
86-87	0	4	7.6	.0003	Not Measurable	--	80
94-95	5 E	3	1.9	.0003	.0002	-.0001	70
99-100	0	6	5.0	.0002	.0002		68
103-104	0	8	3.8	.0001	.0003	+.0002	65
105-106	0	9	3.8	.0003	.0006	+.0003	65
101-102	0	7	3.8	.0004	.0003	-.0001	60
111-112	10 W	1	0.1	.0003	.0002	-.0001	59
109-110	0	11	1.9	.0004	.0003	-.0001	33
107-108	0	10	2.5	.0003	.0004	+.0001	29
80 T	0	1	13.9	*	.0002	--	100
81 T	0	1	13.9	*	.0002	--	100
147 T	5 W	2.4	17.1	*	.0005	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.0002	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.0002	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.0002	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.0003	--	93
159 T	5 W	6.3	1.9	*	.0003	--	78
189 T	5 W	7	0.3	*	.0004	--	10
113 B	10 W	2	--	.0003	**	--	--
160 B	5 W	7.1	--	.0003	**	--	--
168 B	5 W	9.5	--	.0002	**	--	--
169 B	5 W	9.5	--	.0003	**	--	--
176 B	5 E	2	--	.0002	**	--	--
177 B	5 E	2	--	.0003	**	--	--
181 B	5 E	4	--	.0004	**	--	--
197 B	5 E	10	--	.0003	**	--	--
198 B Sands	5 W	200 Yards.	--	.0002	**	--	--
284 B	5 W	354 Ft. Depth	--	.0004	**	--	--
		High		.0005	.0006		
		Low		.0001	.0002		
		Average		.0003	.0003		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 3

COMPARISON OF CHROMIUM ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Chromium		Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
				Natural Sediments	Apparent Tailings		
84-85	0	3	4.4	.009	.009	--	95
116-117	10 W	3	4.4	.015	.001	-.014	95
142-143	5 W	0.8	3.1	.015	.007	-.008	95
148-149	5 W	3.2	5.7	.014	.006	-.008	95
150-151	5 W	4	2.5	.015	.002	-.013	95
314-315***	2½ W	378 Ft. Depth	10.0	.014	.004	-.010	95
201-202	5 W	0.5	5.7	.013	.001	-.012	94
118-119	10 W	4	2.8	.012	.001	-.011	93
273-274	10 W	402 Ft. Depth	2.0	.010	.002	-.008	92
120-121	10 W	5	4.4	.010	.003	-.007	91
154-155	5 W	5.5	1.9	.012	.004	-.008	88
92-93	5 E	2	1.2	.016	.011	-.005	85
276-277	10 W	360 Ft. Depth	3.0	.010	.002	-.008	85
152-153	5 W	4.7	2.5	.013	.004	-.009	82
86-87	0	4	7.6	.015	.016	+.001	80
94-95	5 E	3	1.9	.015	.017	+.002	70
99-100	0	6	5.0	.015	.015	--	68
103-104	0	8	3.8	.010	.006	-.004	65
105-106	0	9	3.8	.010	.009	-.001	65
101-102	0	7	3.8	.010	.011	+.001	60
111-112	10 W	1	0.1	.001	.001	--	59
109-110	0	11	1.9	.011	.001	-.010	33
107-108	0	10	2.5	.011	.010	-.001	29
80 T	0	1	13.9	*	.003	--	100
81 T	0	1	13.9	*	.017	--	100
147 T	5 W	2.4	17.1	*	.020	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.002	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.002	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.002	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.002	--	93
159 T	5 W	6.3	1.9	*	.005	--	78
189 T	5 W	7	0.3	*	.016	--	10
113 B	10 W	2	--	.015	**	--	--
160 B	5 W	7.1	--	.011	**	--	--
168 B	5 W	9.5	--	.012	**	--	--
169 B	5 W	9.5	--	.010	**	--	--
176 B	5 E	2	--	.014	**	--	--
177 B	5 E	2	--	.014	**	--	--
181 B	5 E	4	--	.012	**	--	--
197 B	5 E	10	--	.014	**	--	--
198 B Sands	5 W	200 Yards.	--	.006	**	--	--
284 B	5 W	354 Ft. Depth	--	.010	**	--	--
		High		.016	.017		
		Low		.001	.001		
		Average		.012	.007		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 4

COMPARISON OF COBALT ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Cobalt Natural Sediments	% Cobalt Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.003	.002	-.001	95
116-117	10 W	3	4.4	.003	.001	-.002	95
142-143	5 W	0.8	3.1	.002	.001	-.001	95
148-149	5 W	3.2	5.7	.001	.001	--	95
150-151	5 W	4	2.5	.002	.001	-.001	95
314-315 ***	2½ W	378 Ft. Depth	10.0	.001	.001	--	95
201-202	5 W	0.5	5.7	.002	.001	-.001	94
118-119	10 W	4	2.8	.001	.001	--	93
273-274	10 W	402 Ft. Depth	2.0	.001	.002	+.001	92
120-121	10 W	5	4.4	.001	.001	--	91
154-155	5 W	5.5	1.9	.002	.001	-.001	88
92-93	5 E	2	1.2	.004	.004	--	85
276-277	10 W	360 Ft. Depth	3.0	.002	.003	+.001	85
152-153	5 W	4.7	2.5	.003	.001	-.002	82
86-87	0	4	7.6	.004	.002	-.002	80
94-95	5 E	3	1.9	.004	.003	-.001	70
99-100	0	6	5.0	.004	.002	-.002	68
103-104	0	8	3.8	.003	.002	-.001	65
105-106	0	9	3.8	.003	.002	-.001	65
101-102	0	7	3.8	.002	.003	+.001	60
111-112	10 W	1	0.1	.001	.001	--	59
109-110	0	11	1.9	.002	.001	-.001	33
107-108	0	10	2.5	.002	.001	-.001	29
80 T	0	1	13.9	*	.001	--	100
81 T	0	1	13.9	*	.001	--	100
147 T	5 W	2.4	17.1	*	.001	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.001	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.001	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.001	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.001	--	93
159 T	5 W	6.3	1.9	*	.001	--	78
189 T	5 W	7	0.3	*	.002	--	10
113 B	10 W	2	--	.001	**	--	--
160 B	5 W	7.1	--	.004	**	--	--
168 B	5 W	9.5	--	.003	**	--	--
169 B	5 W	9.5	--	.004	**	--	--
176 B	5 E	2	--	.004	**	--	--
177 B	5 E	2	--	.004	**	--	--
181 B	5 E	4	--	.002	**	--	--
197 B	5 E	10	--	.002	**	--	--
198 B Sands	5 W	200 Yards.	--	.001	**	--	--
284 B	5 W	354 Ft. Depth	--	.002	**	--	--
		High		.004	.004		
		Low		.001	.001		
		Average		.002	.002		

[1] Estimated from titanium analyses
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

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Table 5

COMPARISON OF COPPER ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Copper Natural Sediments	% Copper Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.008	.002	-.006	95
116-117	10 W	3	4.4	.006	.006	--	95
142-143	5 W	0.8	3.1	.003	.002	-.001	95
148-149	5 W	3.2	5.7	.005	.002	-.003	95
150-151	5 W	4	2.5	.004	.001	-.003	95
314-315***	2½ W	378 Ft. Depth	10.0	.003	.002	-.001	95
201-202	5 W	0.5	5.7	.003	.001	-.002	94
118-119	10 W	4	2.8	.007	.002	-.005	93
273-274	10 W	402 Ft. Depth	2.0	.005	.002	-.003	92
120-121	10 W	5	4.4	.006	.003	-.003	91
154-155	5 W	5.5	1.9	.005	.002	-.003	88
92-93	5 E	2	1.2	.004	.003	-.001	85
276-277	10 W	360 Ft. Depth	3.0	.006	.003	-.003	85
152-153	5 W	4.7	2.5	.004	.002	-.002	82
86-87	0	4	7.6	.003	.002	-.001	80
94-95	5 E	3	1.9	.004	.001	-.003	70
99-100	0	6	5.0	.003	.003	--	68
103-104	0	8	3.8	.006	.006	--	65
105-106	0	9	3.8	.006	.006	--	65
101-102	0	7	3.8	.005	.006	+.001	60
111-112	10 W	1	0.1	.004	.002	-.002	59
109-110	0	11	1.9	.007	.004	-.003	33
107-108	0	10	2.5	.007	.007	--	29
80 T	0	1	13.9	*	.001	--	100
81 T	0	1	13.9	*	.001	--	100
147 T	5 W	2.4	17.1	*	.002	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.001	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.002	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.001	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.002	--	93
159 T	5 W	6.3	1.9	*	.004	--	78
189 T	5 W	7	0.3	*	.004	--	10
113 B	10 W	2	--	.005	**	--	--
160 B	5 W	7.1	--	.004	**	--	--
168 B	5 W	9.5	--	.005	**	--	--
169 B	5 W	9.5	--	.005	**	--	--
176 B	5 E	2	--	.004	**	--	--
177 B	5 E	2	--	.005	**	--	--
181 B	5 E	4	--	.004	**	--	--
197 B	5 E	10	--	.004	**	--	--
198 B Sands	5 W	200 Yards.	--	.003	**	--	--
284 B	5 W	354 Ft. Depth	--	.006	**	---	--
		High		.008	.007		
		Low		.003	.001		
		Average		.005	.003		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

Table 6

COMPARISON OF IRON ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Iron Natural Sediments	% Iron Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	8.2	17.0	+8.8	95
116-117	10 W	3	4.4	6.0	15.6	+9.6	95
142-143	5 W	0.8	3.1	6.0	15.2	+9.2	95
148-149	5 W	3.2	5.7	6.0	15.0	+9.0	95
150-151	5 W	4	2.5	6.0	15.4	+9.4	95
314-315 ***	2½ W	378 Ft. Depth	10.0	6.2	14.4	+8.2	95
201-202	5 W	0.5	5.7	6.6	14.8	+8.2	94
118-119	10 W	4	2.8	6.0	15.0	+9.0	93
273-274	10 W	402 Ft. Depth	2.0	6.5	15.2	+8.7	92
120-121	10 W	5	4.4	6.0	15.0	+9.0	91
154-155	5 W	5.5	1.9	6.0	14.0	+8.0	88
92-93	5 E	2	1.2	7.2	16.0	+8.8	85
276-277	10 W	360 Ft. Depth	3.0	7.0	13.8	+6.8	85
152-153	5 W	4.7	2.5	5.8	12.0	+6.2	82
86-87	0	4	7.6	12.8	18.0	+5.2	80
94-95	5 E	3	1.9	12.0	16.0	+4.0	70
99-100	0	6	5.0	7.2	14.0	+6.8	68
103-104	0	8	3.8	14.7	16.2	+1.5	65
105-106	0	9	3.8	7.2	13.2	+6.0	65
101-102	0	7	3.8	8.8	15.0	+6.2	60
111-112	10 W	1	0.1	5.4	12.8	+7.4	59
109-110	0	11	1.9	6.2	8.8	+2.6	33
107-108	0	10	2.5	10.0	9.8	-0.2	29
80 T	0	1	13.9	*	18.0	--	100
81 T	0	1	13.9	*	17.4	--	100
147 T	5 W	2.4	17.1	*	14.4	--	96
294 T	5 W	402 Ft. Depth	9.5	*	15.0	--	96
313 T ***	2½ W	378 Ft. Depth	10.0	*	15.0		95
295 T	5 W	402 Ft. Depth	9.5	*	14.0	--	94
285 T	5 W	264 Ft. Depth	5.5	*	14.0	--	93
159 T	5 W	6.3	1.9	*	13.4	--	78
189 T	5 W	7	0.3	*	6.6	--	10
113 B	10 W	2	--	6.0	**	--	--
160 B	5 W	7.1	--	6.6	**	--	--
168 B	5 W	9.5	--	7.2	**	--	--
169 B	5 W	9.5	--	7.8	**	--	--
176 B	5 E	2	--	6.4	**	--	--
177 B	5 E	2	--	7.0	**	--	--
181 B	5 E	4	--	6.4	**	--	--
197 B	5 E	10	--	6.2	**	--	--
198 B Sands	5 W	200 Yards.	--	9.4	**	--	--
284 B	5 W	354 Ft. Depth	--	7.0	**	--	--
		High		14.7	18.0		
		Low		5.4	6.6		
		Average		7.4	14.4		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 7

COMPARISON OF LEAD ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles from Shore	Depth of Apparent Tailings (cm)	% Lead Natural Sediments	% Lead Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.005	.001	-.004	95
116-117	10 W	3	4.4	.002	.003	+.001	95
142-143	5 W	0.8	3.1	.001	.002	+.001	95
148-149	5 W	3.2	5.7	.001	.001	--	95
150-151	5 W	4	2.5	.003	.001	-.002	95
314-315***	2½ W	378 Ft. Depth	10.0	.001	.002	+.001	95
201-202	5 W	0.5	5.7	.001	.001	--	94
118-119	10 W	4	2.8	.002	.001	-.001	93
273-274	10 W	402 Ft. Depth	2.0	.002	.002	--	92
120-121	10 W	5	4.4	.003	.001	.002	91
154-155	5 W	5.5	1.9	.003	.002	-.001	88
92-93	5 E	2	1.2	.002	.002	--	85
276-277	10 W	360 Ft. Depth	3.0	.002	.002	--	85
152-153	5 W	4.7	2.5	.003	.001	-.002	82
86-87	0	4	7.6	.002	.002	--	80
94-95	5 E	3	1.9	.002	.001	-.001	70
99-100	0	6	5.0	.003	.003	--	68
103-104	0	8	3.8	.005	.004	-.001	65
105-106	0	9	3.8	.003	.006	+.003	65
101-102	0	7	3.8	.004	.005	+.001	60
111-112	10 W	1	0.1	.006	.003	-.003	59
109-110	0	11	1.9	.001	.005	+.004	33
107-108	0	10	2.5	.004	.006	+.002	29
80 T	0	1	13.9	*	.001	--	100
81 T	0	1	13.9	*	.002	--	100
147 T	5 W	2.4	17.1	*	.001	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.001	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.005	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.001	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.001	--	93
159 T	5 W	6.3	1.9	*	.003	--	78
189 T	5 W	7	0.3		.002	--	10
113 B	10 W	2	--	.001	**	--	-
160 B	5 W	7.1	--	.001	**	--	-
168 B	5 W	9.5	--	.002	**	--	-
169 B	5 W	9.5	--	.002	**	--	-
176 B	5 E	2	--	.002	**	--	-
177 B	5 E	2	--	.002	**	--	--
181 B	5 E	4	--	.002	**	--	--
197 B	5 E	10	--	.002	**	--	--
198 B Sands	5 W	200 Yards.	--	.002	**	--	--
284 B	5 W	354 Ft. Depth	--	.001	**	--	--
		High		.006	.006		
		Low		.001	.001		
		Average		.002	.002		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 8

COMPARISON OF MAGNESIUM ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Magnesium Natural Sediments	% Magnesium Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	2.10	2.20	+.10	9[illegible]
116-117	10 W	3	4.4	1.70	2.60	+.90	95
142-143	5 W	0.8	3.1	2.00	2.00	--	95
148-149	5 W	3.2	5.7	1.80	2.42	+.62	95
150-151	5 W	4	2.5	2.36	1.80	-.56	95
314-315***	2½ W	378 Ft. Depth	10.0	2.00	2.63	+.63	95
201-202	5 W	0.5	5.7	2.30	2.90	+.60	94
118-119	10 W	4	2.8	1.80	2.54	+.74	93
273-274	10 W	402 Ft. Depth	2.0	2.46	3.00	+.54	92
120-121	10 W	5	4.4	1.66	2.54	+.88	91
154-155	5 W	5.5	1.9	1.80	2.42	+.62	88
92-93	5 E	2	1.2	2.30	2.70	+.40	85
276-277	10 W	360 Ft. Depth	3.0	2.46	3.00	+.54	85
152-153	5 W	4.7	2.5	2.20	2.30	+.10	82
86-87	0	4	7.6	2.22	2.12	-.10	80
94-95	5 E	3	1.9	1.90	2.74	+.84	70
99-100	0	6	5.0	2.46	2.80	+.34	68
103-104	0	8	3.8	2.72	2.72	--	65
105-106	0	9	3.8	2.10	2.70	+.60	65
101-102	0	7	3.8	2.72	2.10	-.62	60
111-112	10 W	1	0.1	1.90	2.30	+ 40	59
109-110	0	11	1.9	1.90	2.08	+.18	33
107-108	0	10	2.5	1.90	2.42	+.52	29
80 T	0	1	13.9	*	2.00	--	100
81 T	0	1	13.9	*	1.90	--	100
147 T	5 W	2.4	17.1	*	2.20	--	96
294 T	5 W	402 Ft. Depth	9.5	*	3.00	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	2.42	--	95
295 T	5 W	402 Ft. Depth	9.5	*	3.00	--	94
285 T	5 W	264 Ft. Depth	5.5	*	3.10	--	93
159 T	5 W	6.3	1.9	*	3.00	--	78
189 T	5 W	7	0.3	*	2.80	--	10
113 B	10 W	2	--	1.86	**	--	--
160 B	5 W	7.1	--	2.20	**	--	--
168 B	5 W	9.5	--	2.20	**	--	--
169 B	5 W	9.5	--	2.06	**	--	--
176 B	5 E	2	--	2.40	**	--	--
177 B	5 E	2	--	2.40	**	--	--
181 B	5 E	4	--	2.30	**	--	--
197 B	5 E	10	--	2.40	**	--	--
198 B Sands	5 W	200 Yards.	--	2.20	**	--	--
284 B	5 W	354 Ft. Depth	--	2.26	**	--	--
		High		2.72	3.10		
		Low		1.66	1.80		
		Average		2.15	2.51		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 9

COMPARISON OF MANGANESE ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Manganese Natural Sediments	% Manganese Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.21	.70	+.49	95
116-117	10 W	3	4.4	.07	.59	+.52	95
142-143	5 W	0.8	3.1	.10	.69	+.59	95
148-149	5 W	3.2	5.7	.09	.78	+.69	95
150-151	5 W	4	2.5	.09	.66	+.57	95
314-315 ***	2½ W	378 Ft. Depth	10.0	.15	.55	+.40	95
201-202	5 W	0.5	5.7	.16	.76	+.60	94
118-119	10 W	4	2.8	.20	.80	+.60	93
273-274	10 W	402 Ft. Depth	2.0	.13	.72	+.59	92
120-121	10 W	5	4.4	.16	.78	+.62	91
154-155	5 W	5.5	1.9	.09	.71	+.62	88
92-93	5 E	2	1.2	.11	.70	+.59	85
276-277	10 W	360 Ft. Depth	3.0	.14	.68	+.54	85
152-153	5 W	4.7	2.5	.12	.65	+.53	82
86-87	0	4	7.6	.24	.51	+.26	80
94-95	5 E	3	1.9	.40	.65	+.25	70
99-100	0	6	5.0	.11	.68	+.57	68
103-104	0	8	3.8	.48	.55	+.07	65
105-106	0	9	3.8	.06	.58	+.52	65
101-102	0	7	3.8	.09	.60	+.51	60
111-112	10 W	1	0.1	.07	.66	+.59	59
109-110	0	11	1.9	.09	.39	+.30	33
107-108	0	10	2.5	.10	.43	+.33	29
80 T	0	1	13.9	*	.52	--	100
81 T	0	1	13.9	*	.50	--	100
147 T	5 W	2.4	17.1	*	.72	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.62	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.66	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.46	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.54	--	93
159 T	5 W	6.3	1.9	*	.74	--	78
189 T	5 W	7	0.3	*	.11	--	10
113 B	10 W	2	--	.10	**	--	--
160 B	5 W	7.1	--	.17	**	--	--
168 B	5 W	9.5	--	.10	**	--	--
169 B	5 W	9.5	--	.19	**	--	--
176 B	5 E	2	--	.13	**	--	--
177 B	5 E	2	--	.46	**	--	--
181 B	5 E	4	--	.11	**	--	--
197 B	5 E	10	--	.11	**	--	--
198 B Sands	5 W	200 Yards.	--	.14	**	--	--
284 B	5 W	354 Ft. Depth	--	.11	**	--	--
		High		.48	.80		
		Low		.06	.11		
		Average		.15	.62		

[1]Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 10

COMPARISON OF NICKEL ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Nickel Natural Sediments	% Nickel Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.005	.005	--	95
116-117	10 W	3	4.4	.006	.007	+.001	95
142-143	5 W	0.8	3.1	.007	.002	-.005	95
148-149	5 W	3.2	5.7	.004	002	-.002	95
150-151	5 W	4	2.5	.006	.002	-.004	95
314-315***	2½ W	378 Ft. Depth	10.0	.005	.003	-.002	95
201-202	5 W	0.5	5.7	.007	.008	+.001	94
118-119	10 W	4	2.8	.003	.002	-.001	93
273-274	10 W	402 Ft. Depth	2.0	.006	.002	-.004	92
120-121	10 W	5	4.4	.005	.003	-.002	91
154-155	5 W	5.5	1.9	.006	.002	-.004	88
92-93	5 E	2	1.2	.006	.003	-.003	85
276-277	10 W	360 Ft. Depth	3.0	.004	.001	-.003	85
152-153	5 W	4.7	2.5	.005	.002	-.003	82
86-87	0	4	7.6	.005	.006	+.001	80
94-95	5 E	3	1.9	.006	.002	-.004	70
99-100	0	6	5.0	.006	.009	+.003	68
103-104	0	8	3.8	.003	.007	+.004	65
105-106	0	9	3.8	.008	.004	-.004	65
101-102	0	7	3.8	.008	.003	-.005	60
111-112	10 W	1	0.1	.003	.003	--	59
109-110	0	11	1.9	.003	.005	+.002	33
107-108	0	10	2.5	.007	.005	-.002	29
80 T	0	1	13.9	*	.004	--	100
81 T	0	1	13.9	*	.009	--	100
147 T	5 W	2.4	17.1	*	.006	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.001	--	96
313 T ***	2½ W	378 Ft. Depth	10.0	*	.001	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.002	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.002	--	93
159 T	5 W	6.3	1.9	*	.004	--	78
189 T	5 W	7	0.3	*	.008	--	10
113 B	10 W	2	--	.006	**	--	--
160 B	5 W	7.1	--	.005	**	--	--
168 B	5 W	9.5	--	.006	**	--	--
169 B	5 W	9.5	--	.006	**	--	--
176 B	5 E	2	--	.006	**	--	-
177 B	5 E	2	--	.008	**	--	--
181 B	5 E	4	--	.006	**	--	--
197 B	5 E	10	--	.006	**	--	--
198 B Sands	5 W	200 Yards.	--	.007	**	--	--
284 B	5 W	354 Ft. Depth	--	.005	**	--	--
		High		.008	.009		
		Low		.003	.001		
		Average		.006	.004		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

Table 11

COMPARISON OF TITANIUM ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Titanium Natural Sediments	% Titanium Apparent Tailings	Tailings Minus Natural Sediments	Estimated % Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.37	.07	-.30	95
116-117	10 W	3	4.4	.43	.05	-.38	95
142-143	5 W	0.8	3.1	.79	.07	-.72	95
148-149	5 W	3.2	5.7	.45	.05	-.40	95
150-151	5 W	4	2.5	.38	.05	-.33	95
314-315***	2½ W	378 Ft. Depth	10.0	.69	.06	-.63	95
201-202	5 W	0.5	5.7	.72	.07	-.65	94
118-119	10 W	4	2.8	.45	.06	-.39	93
273-274	10 W	402 Ft. Depth	2.0	.63	.08	-.55	92
120-121	10 W	5	4.4	.41	.07	-.34	91
154-155	5 W	5.5	1.9	.44	.08	-.36	88
92-93	5 E	2	1.2	.46	.11	-.35	85
276-277	10 W	360 Ft. Depth	3.0	.62	.11	-.51	85
152-153	5 W	4.7	2.5	.43	.10	-.33	82
86-87	0	4	7.6	.32	.10	-.22	80
94-95	5 E	3	1.9	.37	.14	-.23	70
99-100	0	6	5.0	.46	.16	-.30	68
103-104	0	8	3.8	.40	.16	-.24	65
105-106	0	9	3.8	.44	.13	-.31	65
101-102	0	7	3.8	.44	.20	-.24	60
111-112	10 W	1	0.1	.54	.24	-.30	59
109-110	0	11	1.9	.40	.28	-.12	33
107-108	0	10	2.5	.38	.28	-.10	29
80 T	0	1	13.9	*	.02	--	100
81 T	0	1	13.9	*	.02	--	100
147 T	5 W	2.4	17.1	*	.05	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.05	--	96
313 T***	2½ W	378 Ft. Depth	10.0	*	.05	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.07	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.08	--	93
159 T	5 W	6.3	1.9	*	.13	--	78
189 T	5 W	7	0.3	*	.40	--	10
113 B	10 W	2	--	.58	**	--	--
160 B	5 W	7.1	--	.47	**	--	--
168 B	5 W	9.5	--	.45	**	--	--
169 B	5 W	9.5	--	.41	**	--	--
176 B	5 E	2	--	.52	**	--	--
177 B	5 E	2	--	.47	**	--	--
181 B	5 E	4	--	.43	**	--	--
197 B	5 E	10	--	.41	**	--	--
198 B Sands	5 W	200 Yards.	--	2.00			
284 B	5 W	354 Ft. Depth		.77			
		High		2.00	.40		
		Low		.32	.02		
		Average		.53	.11		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analyses.
*** Different apparent tailings fractions cut from the same core.

R. S. Lemire
January 15, 1969

APPENDIX A

Table 12

COMPARISON OF ZINC ANALYSES ON TAILINGS
AND NATURAL SEDIMENTS FROM LAKE BOTTOM CORE SAMPLES

Sample Number	Grid	Miles From Shore	Depth of Apparent Tailings (cm)	% Zinc Natural Sediments	% Zinc Apparent Tailings	Tailings Minus Natural Sediments	Estimated Tailings In Apparent Tailings Layer[1]
84-85	0	3	4.4	.015	.003	-.012	95
116-117	10 W	3	4.4	.010	.003	-.007	95
142-143	5 W	0.8	3.1	.008	.003	-.005	95
148-149	5 W	3.2	5.7	.010	.002	-.008	95
150-151	5 W	4	2.5	.010	.001	-.009	95
314-315 ***	2½ W	378 Ft. Depth	10.0	.008	.002	-.006	95
201-202	5 W	0.5	5.7	.009	.002	-.007	94
118-119	10 W	4	2.8	.010	.003	-.007	93
273-274	10 W	402 Ft. Depth	2.0	.008	.003	-.005	92
120-121	10 W	5	4.4	.011	.003	-.008	91
154-155	5 W	5.5	1.9	.010	.004	-.006	88
92-93	5 E	2	1.2	.012	.007	-.005	85
276-277	10 W	360 Ft. Depth	3.0	.008	.004	-.004	85
152-153	5 W	4.7	2.5	.010	.004	-.006	82
86-87	0	4	7.6	.010	.003	-.007	80
94-95	5 E	3	1.9	.012	.009	-.003	70
99-100	0	6	5.0	.012	.004	-.008	68
103-104	0	8	3.8	.010	.010	--	65
105-106	0	9	3.8	.013	.008	-.005	65
101-102	0	7	3.8	.010	.013	+.003	60
111-112	10 W	1	0.1	.007	.005	-.002	59
109-110	0	11	1.9	.010	.010	--	33
107-108	0	10	2.5	.009	.011	+.002	29
80 T	0	1	13.9	*	.001	--	100
81 T	0	1	13.9	*	.001	--	100
147 T	5 W	2.4	17.1	*	.002	--	96
294 T	5 W	402 Ft. Depth	9.5	*	.002	--	96
313 T **	2½ W	378 Ft. Depth	10.0	*	.002	--	95
295 T	5 W	402 Ft. Depth	9.5	*	.002	--	94
285 T	5 W	264 Ft. Depth	5.5	*	.003	--	93
159 T	5 W	6.3	1.9	*	.006	--	78
189 T	5 W	7	0.3	*	.011	--	10
113 B	10 W	2	--	.009	**	--	--
160 B	5 W	7.1	--	.009	**	--	--
168 B	5 W	9.5	--	.010	**	--	--
169 B	5 W	9.5	--	.010		--	--
176 B	5 E	2	--	.009	*	--	-
177 B	5 E	2	--	.010	*	--	--
181 B	5 E	4	--	.010	*	--	--
197 B	5 E	10	--	.010	**	--	--
198 B Sands	5 W	200 Yards.	--	.009	**	--	--
284 B	5 W	354 Ft. Depth	--	.008	*	--	--
		High		.015	.013		
		Low		.007	.001		
		Average		.010	.005		

[1] Estimated from titanium analyses.
* Insufficient sample for natural sediment analyses.
** Insufficient sample for apparent tailings analysis.
*** Different apparent tailings fractions cut from the same core.

[illegible]
[illegible] 15, 1969

APPENDIX B

TABLE #1

Typical Chemical Analysis of
Reserve Mining Company Tailings

	%
Iron	14.93
Silicon	33.59
Aluminum	.35
Calcium	1.67
Magnesium	1.96
Manganese	.37
Titanium	.030
Phosphorus	.026
Sodium	.040
Potassium	.040
Sulfur	.03
Lead	.007
Zinc	.004
Nickel	.002
Copper	.004
Chromium	.004
Cadmium	.0003
Molybdenum	<.001
Vanadium	<.001
Cobalt	.002
Carbon	.11
Hydrogen	.10
Oxygen	46.54
	99.8113

APPENDIX B

TABLE 2

Reserve Mining Company
Size Distribution of Tailing Sediments
and
Natural Sediments

	Core Sample No. L-231		Core Sample No. L-294		Core Sample No. L-446		Core Sample No. L-471	
Size μ	Tailing Layer % Finer	Natural Sediment % Finer	Tailing Layer % Finer	Natural Sediment % Finer	Tailing Layer % Finer	Natural Sediment % Finer	Tailing Layer % Finer	Natural Sediment % Finer
61	98.6	92.9	0.0	82.8	0.0	94.4	0.0	98.9
44	88.9	75.5	98.1	64.9	98.5	93.8	99.5	87.9
30	72.2	69.0	93.7	50.1	96.7	92.6	97.5	85.3
20	41.9	65.2	81.1	44.0	89.3	91.1	91.6	81.7
10	15.6	62.4	50.1	37.0	67.4	89.5	74.0	73.0
5	3.0	60.1	23.4	32.9	42.4	79.3	46.7	63.1

APPENDIX B

TABLE # 3

Predicted Tailings Screen Analysis
by Dr. E. W. Davis
Mines Experiment Station, University of Minnesota

Screen Size			Wt. %
		On 3 Mesh	0.000
Through	3 Mesh	On 4 Mesh	1.581
Through	4 Mesh	On 8 Mesh	7.970
Through	8 Mesh	On 14 Mesh	6.523
Through	14 Mesh	On 28 Mesh	3.578
Through	28 Mesh	On 48 Mesh	3.290
Through	48 Mesh	On 65 Mesh	2.689
Through	65 Mesh	On 100 Mesh	5.002
Through	100 Mesh	On 150 Mesh	5.691
Through	150 Mesh	On 200 Mesh	10.186
Through	200 Mesh	On 325 Mesh	8.552
Through	325 Mesh		44.938
		Total	100.00

From "Exhibit #7" - Water Permit
Hearing - June 5, 1947

APPENDIX B

TABLE #4

Screen Analysis of Tailings from Reserve's Early Operations

Screen Size		Wt. %	Wt. %
	On 3 Mesh	.6	.2
Through 3 Mesh	On 4 Mesh	2.0	1.0
Through 4 Mesh	On 8 Mesh	7.7	5.2
Through 8 Mesh	On 14 Mesh	7.6	6.6
Through 14 Mesh	On 28 Mesh	5.9	5.8
Through 28 Mesh	On 48 Mesh	5.4	5.9
Through 48 Mesh	On 65 Mesh	3.2	3.9
Through 65 Mesh	On 100 Mesh	4.7	6.2
Through 100 Mesh	On 150 Mesh	5.9	5.7
Through 150 Mesh	On 200 Mesh	7.7	7.3
Through 200 Mesh	On 325 Mesh	6.0	11.2
Through 325 Mesh		43.3	41.0
		100.0	100.0

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TABLE #5

Recent Practice Tailings Screen Analyses

Screen Size			Wt. %	Wt. %	Wt. %
		On 3 Mesh	1.1	.3	0
Through	3 Mesh	On 4 Mesh	2.9	2.1	.5
Through	4 Mesh	On 6 Mesh	5.1	4.3	3.0
Through	6 Mesh	On 8 Mesh	5.7	7.1	5.5
Through	8 Mesh	On 10 Mesh	5.3	6.9	7.6
Through	10 Mesh	On 14 Mesh	4.8	5.0	6.2
Through	14 Mesh	On 20 Mesh	3.6	4.2	5.4
Through	20 Mesh	On 28 Mesh	2.9	3.1	4.1
Through	28 Mesh	On 35 Mesh	2.5	2.8	3.6
Through	35 Mesh	On 48 Mesh	1.9	2.5	3.2
Through	48 Mesh	On 65 Mesh	2.4	2.2	2.9
Through	65 Mesh	On 100 Mesh	3.2	3.0	3.4
Through	100 Mesh	On 150 Mesh	5.8	3.5	4.1
Through	150 Mesh	On 200 Mesh	4.0	3.8	4.6
Through	200 Mesh	On 270 Mesh	4.7	5.0	5.3
Through	270 Mesh	On 325 Mesh	5.9	4.5	3.6
Through	325 Mesh	On 20 Micron	13.6	16.2	18.0
Through	20 Micron	On 10 Micron	9.5	12.4	11.3
Through	10 Micron	On 5 Micron	6.9	4.8	3.5
Through	5 Micron		8.2	6.3	4.2
			100.0	100.0	100.0
(Through 325 Mesh			38.2	39.7	37.0)

APPENDIX B

TABLE #6

Screen Analyses of Tailings from Reserve's Pilot Plant
Using 1956 and 1957 Operating Practice

Screen Size			Wt.%	Wt.%	Wt.%	Wt.%
	On	3 Mesh	1.0	1.2	0	.3
Through 3 Mesh	On	4 Mesh	1.8	1.9	.6	.3
Through 4 Mesh	On	6 Mesh	3.8	.5	1.8	2.4
Through 6 Mesh	On	8 Mesh	6.7	7.7	5.0	5.2
Through 8 Mesh	On	10 Mesh	5.6	6.7	6.9	7.6
Through 10 Mesh	On	14 Mesh	4.9	4.9	5.9	6.0
Through 12 Mesh	On	20 Mesh	4.1	4.2	6.0	5.7
Through 20 Mesh	On	28 Mesh	3.0	3.2	4.1	4.1
Through 28 Mesh	On	35 Mesh	2.3	2.5	3.7	3.4
Through 35 Mesh	On	48 Mesh	2.4	2.6	3.4	3.1
Through 48 Mesh	On	65 Mesh	2.4	2.7	3.2	3.0
Through 65 Mesh	On	100 Mesh	3.1	3.4	3.4	3.4
Through 100 Mesh	On	150 Mesh	2.8	3.9	2.7	1.9
Through 150 Mesh	On	200 Mesh	6.3	6.7	5.7	6.2
Through 200 Mesh	On	270 Mesh	4.4	3.7	3.8	3.8
Through 270 Mesh	On	325 Mesh	2.1	2.9	2.1	2.0
Through 325 Mesh	On	30 Micron	5.9	5.7	5.6	5.3
Through 30 Micron	On	20 Micron	11.8	11.3	10.8	10.7
Through 20 Micron	On	10 Micron	10.9	11.3	11.3	11.5
Through 10 Micron	On	5 Micron	4.9	4.9	4.9	5.4
Through 5 Micron			9.8	8.1	9.1	8.7
			100.0	100.0	100.0	100.0
(Through 325 Mesh			43.3	41.3	41.7	41.6)

APPENDIX C

ATOMIC ABSORPTION SPECTROPHOTOMETER

In water samples, calcium, magnesium, sodium and potassium are determined by atomic absorption after the addition of lanthanum as an interference suppressor. Trace metals are chelated and extracted into an organic solvent by the Fishman Procedure (Marvin Fishman, U. S. Geological Survey Methods and Development Laboratory, Denver, Colorado) before analysis.

Precision of analyses for calcium is ±0.1 ppm; magnesium and sodium, ±0.1 ppm; and potassium, ±0.05 ppm.

Detection limits for iron, manganese, copper, zinc, nickel, lead and cadmium are all below one ppb. Precision for iron is 3 ppb; nickel, manganese, copper, lead, and cadmium are ±2 ppb or better.

Solid samples are put into solution by acid and fusion techniques, as required. Solutions are analyzed by atomic absorption. All standardization is made using Harleco certified standards.

ESTIMATED PRECISIONS

Alkalinity	±1.0	ppm
Sulfate	±0.6	ppm
Chloride	±0.2	ppm
Silica	±0.4	ppm
Phosphorus	±0.005	ppm, detection limit 0.005 ppm
Ammonia	±0.005	ppm, detection limit 0.010 ppm
Nitrate	±0.2	ppm
Nitrite	±0.005	ppm, detection limit 0.005 ppm
pH	±0.05	pH units
Turbidity	±0.1	JTU up to 1
	±0.2	JTU 1 to 2
	±0.5	JTU 2 to 5
	±1	JTU 5 to 10
	±5	JTU 10 to 100
Dissolved Oxygen	±0.1	ppm

APPENDIX D

SUMMARY OF DATA REPORTED TO THE MINNESOTA POLLUTION CONTROL AGENCY FROM 1957 THROUGH 1968.

A discussion and summary of the data as reported is herewith categorized.

1. The perimeter of the permit area is sampled twice a year. The sample points are shown in Figure 1. The parameters are:

   a. Turbidity: The mean turbidities over the twelve year period are 0.38 JTU taken 2' below the surface and 0.36 JTU at a depth of 20'.

   b. Temperature ^{o}F: Temperatures were taken only in 1968. The mean temperature at 2' was 42.6^{o} F and 41.4^{o} F at 20'.

   c. Dissolved oxygen mg/l: Dissolved oxygen was analyzed for only in 1968. The mean values were 12.4 mg/l at both the 2' and 20' depths. These values are near saturation, at temperature.

   d. pH: pH readings were taken only in 1968. The mean values were 7.9 for both the 2' and 20' samples.

   e. Conductivity μmho/cm^2 at 25° C: Conductivity measurements were made only for the 1968 fall survey. The mean values were 93.4 and 93.8 μmho at 2' and 20' depths, respectively.

2. Mill intake and tailings discharge water:

   Mean Values Obtained Since 1966:

   a. Temperature ^{o} F: The mean temperature values for the three year period are shown by quarters to reflect seasonal temperature changes in the lake surface water.

	^{o}F	
	Intake	Discharge
Jan-Feb-Mar	34	38
Apr-May-June	38	42
July-Aug-Sept	48	52
Oct-Nov-Dec	42	45

   The mean process induced temperature rise is 3.75^{o} F which includes the rise due to Powerhouse cooling water. When the discharge water is diluted by lake water, the rise in temperature cannot be detected.

APPENDIX D

b. Dissolved solids mg/l: The values for dissolved solids are obtained by measuring the conductivity. By experimentation we find that conductivity in μmho/cm^2 at 25° C times 0.605 is equal to mg/l of dissolved solids. The mean values for the three year period are 57 mg/l in the intake water and 67 mg/l in the discharge. When the discharge water is diluted by lake water the effect is negligible.

c. Dissolved oxygen mg/l: The mean values for the three year period are 12.2 mg/l in the intake water and 9.3 mg/l in the water discharged to the lake. When the discharge water is diluted by the lake the dissolved oxygen content is always found to be at saturation.

d. pH: The mean values for pH in the three year period are 7.8 in the intake water and 8.3 in the discharge. No increase in pH in the lake water has resulted from the discharge.

e. Complete analysis of intake and discharge water: A complete analysis was made of three samples of intake and discharge water obtained in Sept.-Oct. 1968. The samples were filtered on a 0.45 μ membrane filter and analyzed. The following is a tabulation of the means of the results obtained on the three sets of samples.

Parameter		Intake mg/l	Discharge mg/l
Calcium	Ca	13.2	12.8
Magnesium	Mg	2.8	3.5
Sodium	Na	1.4	2.0
Potassium	K	.6	1.5
Total Alkalinity as $CaCO_3$		42.9	46.3
Sulfate	SO_4	2.1	2.8
Chlorine	Cl	1.6	2.1
Silica	SiO_2	2.5	3.7
Phosphorus	P	.005	.006
Iron	Fe	.007	.010
Manganese	Mn	.002	.036
Copper	Cu	.003	.003
Zinc	Zn	.012	.003
Nickel	Ni	.002	.002
Ammonia	NH_3	.053	.146
Nitrite	NO_2	.009	.017
Nitrate	NO_3	1.06	1.28

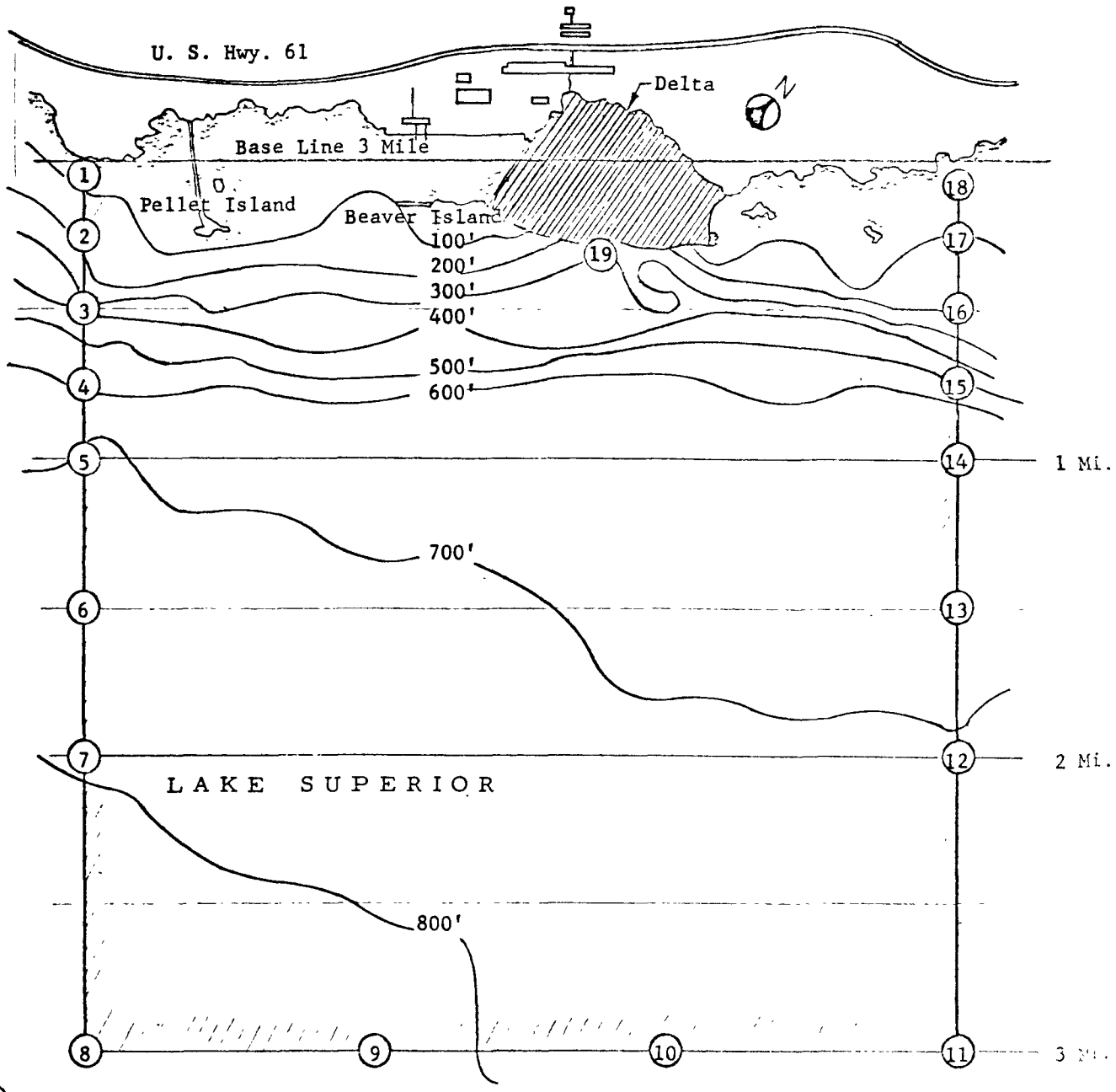
Lead and cadmium were less than the detection limit of .001 mg/l.

All of the changes which occur in process are very minor and when the discharge water is diluted by lake water the effect would not be detectable.

APPENDIX D

3. Bottom Samples:

Figure 2 is an isopach of the approximate thickness of tailings found by this study. This isopach shows positively that the density current carries the fine fraction of tailings into the deep basin where it then settles onto the bottom.



○ Indicate water sampling points.

Turbidity, temperature, dissolved oxygen, pH and conductivity readings are tabulated in Exhibit 2.

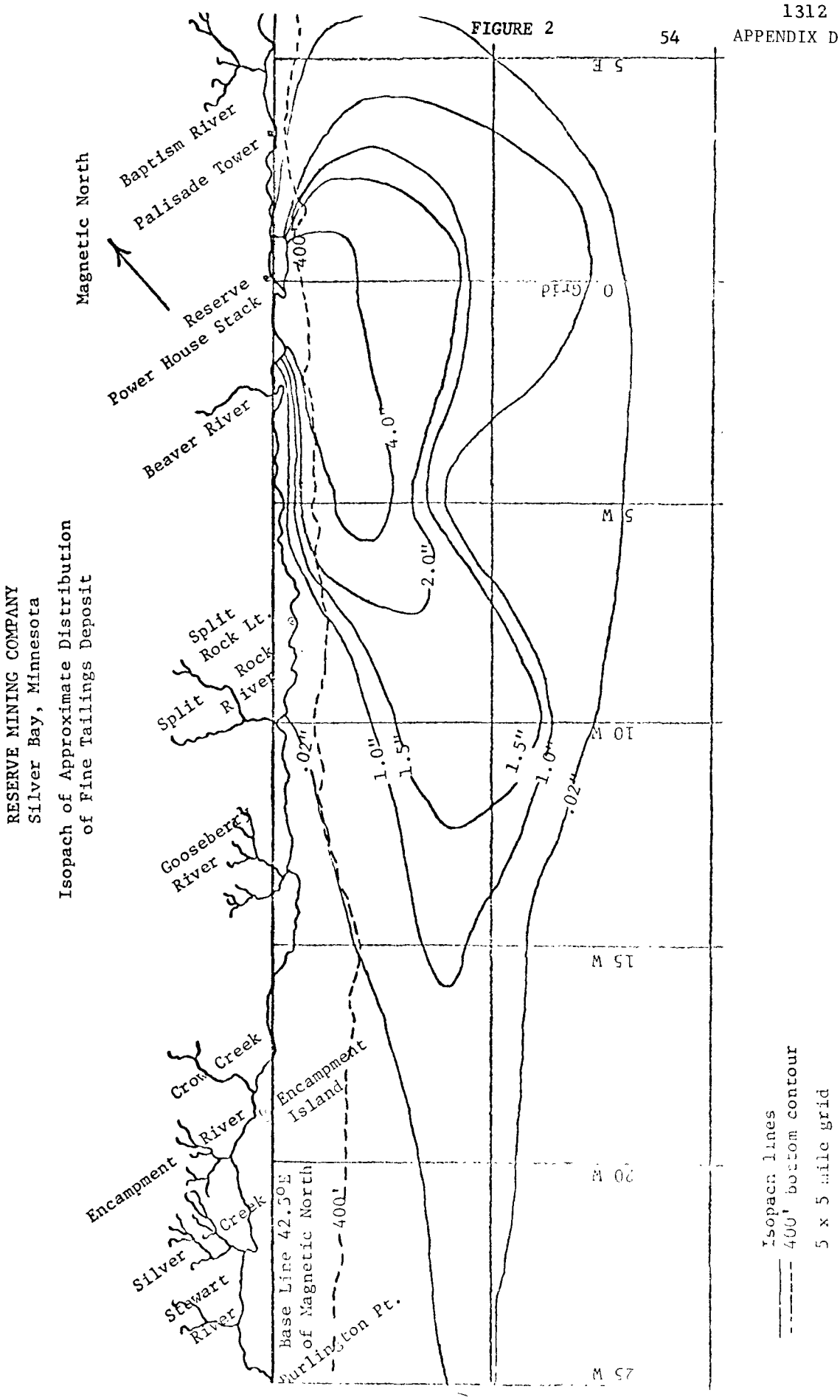
PERMIT AREA - PLAN

Water samples around permit area taken _____, intake water temp. ____, discharge water temp. _____, pumps ____, wind _____.

Scale 2" = 1 Mile

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA

FIGURE 2


RESERVE MINING COMPANY
Silver Bay, Minnesota
Isopach of Approximate Distribution
of Fine Tailings Deposit
Magnetic North
Baptism River
Palisade Tower
Reserve
Power House Stack
Beaver River
Split Rock Lt.
Split Rock River
Gooseberry River
Crow Creek
Encampment River
Silver Creek
Stewart River
Encampment Island
Base Line 42.5°E
of Magnetic North
Burlington Pt.
400'
4.0"
2.0"
1.0"
1.5"
.02"
5 E
0 Grid
5 W
10 W
15 W
20 W
25 W
Isopach lines
400' bottom contour
5 x 5 mile grid

APPENDIX E

TABLE 1

1968 BOTTOM FAUNA CENSUS BY MINNESOTA DEPARTMENT OF CONSERVATION

Sample Line	Comments on Presence of Tailings on Lake Bottom	Total Fish Food Bottom Fauna Organisms Per Square Meter
#1 - 5 mi. NE of plant	No tailings	1255
#2 - 1.7 mi. NE of plant	Tailings present at one of 5 stations	1052
#3 - 2 mi. SW of plant	Tailings present at all 5 stations	863
#4 - 5 mi. SW of plant	Tailings present at all 5 stations	1287
#5 - 10 mi. SW of plant	Tailings present at 3 of 5 stations	602
#6 - 15.5 mi. SW of plant	Tailings present at 3 of 5 stations	431

APPENDIX E

TABLE 2

Secchi Disc and Turbidity Statistics
In The Silver Bay Area and In The Wisconsin
Area of Lake Superior

Location	Measurement	Mean Value	Standard Deviation	Range
Wisconsin Area	Secchi Disc	7.20 ft.	4.60	1.0 - 30.0
Silver Bay Area	Secchi Disc	21.5 ft.	7.74 ft.	6.0 - 39.4 ft.
Wisconsin Area	Hach Turbidity*	5.01	8.46	0.08 - 54.0
Silver Bay Area (surface and mid-depth)	Hellige Turbidity	0.28	0.27	0.03 - 2.7

*One Hach Turbidity reading of 253.0 was deleted from this group of data.

Secchi Disc and Turbidity Statistics
in the Wisconsin Area of Lake Superior
Listed According to Sub-Areas

Area	Sample No.	Measurement	Mean Value	Standard Deviation	Range
Duluth-Superior	1-15 & 22-33	Secchi Disc	4.87 ft.	2.99 ft.	1.0 - 13.0
		Hach Turbidity	5.86	5.82	0.60 - 27.0
Lake Center	16-21	Secchi Disc	12.5 ft.	0.71 ft.	12.0 - 13.0
		Hach Turbidity	1.37	1.63	0.45 - 5.0
Poplar River Area to Cornucopia	34-48	Secchi Disc	5.43	2.76 ft.	2.0 - 9.0
		Hach Turbidity	4.81	6.22	0.72 - 22.0
Apostle Islands	49-58	Secchi Disc	12.8 ft.	3.76 ft.	8.0 - 20.0
		Hach Turbidity	1.04	0.83	0.08 - 2.50
Chequamegon Bay	59-79 and 90	Secchi Disc	6.45 ft.	3.58 ft.	1.0 - 14.5
		Hach Turbidity*	8.08	13.90	0.61 - 54.0
Oronto Bay	80-84	Secchi Disc	15.4 ft.	0.53 ft.	11.0 - 18.0
		Hach Turbidity	0.53	0.24	0.26 - 0.85

*One Hach Turbidity reading of 253.0 was deleted from this group of data.

APPENDIX F

COMMENTS ON PORTIONS OF "AN APPRAISAL OF WATER POLLUTION IN THE LAKE SUPERIOR BASIN"

These comments have been prepared on the portions of this report that directly concern Reserve Mining Company. There are many portions of this report that are general in nature and are somewhat of concern to all users of Lake Superior water. These general portions are not included in these comments.

1. Conclusion #1, page 27:

> "Approximately 45 percent of the tailings waste discharged between 1956 and 1967 were deposited on the delta off shore from the plant. The remaining 55 percent, or approximately 95 million tons, traveled down the face of the delta into the lake. Tailings are deposited on the lake bottom at least 10 miles off shore and 15 miles southwest of the plant."

Reserve's comments:

The location of the tailings deposited on the bottom of the lake is regularly determined by Reserve Mining Company. This information is reported to the MPCA. Tailings have not been found outside of the general area that Reserve has reported them to be deposited on the bottom of the Minnesota portion of Lake Superior.

The maximum depth of this tailings deposit in the areas away from the delta is 6-1/2 inches for 13 years of operation or about 1/2 inch per year of operation in an area of the lake that ranges from 600 to 900 feet deep. This deposit will still be insignificant and have no harmful effect on the lake after Reserve has operated another 50 years in the same manner.

2. Conclusion #2, page 27:

> "Approximately 60,000 long tons of taconite waste are discharged daily from the plant. Fifty-four hundred long tons per day of the waste solids discharged to Lake Superior are less than 4 microns (1 micron equals 1/25,400th of an inch) in diameter. Particles of this diameter are capable of remaining suspended in water for a considerable time after discharge."

APPENDIX F

Reserve's comments:

The U. S. G. S. "Preliminary Report on Streamflow Conditions and Sedimentation in the Vicinity of Silver Bay," (#53) page 13, shows 5.8% or 3,480 tons per day of total tailings are less than 4 microns. Some of this is entrapped and remains on the delta. Therefore, the statement that 5,400 long tons per day of waste solids discharged to Lake Superior are less than 4 microns is in error.

Conclusion #2 further states that these particles are capable of remaining suspended for a considerable time. Being capable is conjecture not based on fact. The conclusion does not take into consideration the action of the heavy density current that carries the tailings into the 600-900 foot deep basin. If the inference of being capable were true, the turbidity of the Silver Bay area should be higher than the balance of the lake. Actually, the opposite is the case. The turbidity of the surface and mid-depth water in the Silver Bay area is less than that of other areas of the lake. In 1966 and 1967 the FWPCA secured and analyzed samples of water from practically all areas of the lake. The turbidity of these samples, as reported by the FWPCA, averages 0.35 Hellige units. The lake water samples secured in the Silver Bay area by the FWPCA in June, 1968, have an average turbidity of 0.29 Hellige units, and those in July, 1968, averaged 0.26 Hellige units. This FWPCA data shows conclusively that depositing tailings in Lake Superior by Reserve Mining Company has not increased the turbidity of the lake as this conclusion implies.

3. Conclusion #3, page 27:

> "Current measurements in the vicinity of Silver Bay show that the prevailing current is to the southwest and of sufficient velocity to transport particles of 4 microns or less more than nine miles per day."

Reserve's comments:

Conclusion #3 implies that minus 4 micron particles of tailings are carried by surface or near surface currents. Again, if this were true, the turbidity of the water in the Silver Bay area would have a higher turbidity than the balance of the lake. The FWPCA data, as presented in the comments on Conclusion #2, shows that this is not true. The Silver Bay area has cleaner, less turbid water than the other areas of the lake which the FWPCA sampled and analyzed.

This conclusion completely ignores the force of the heavy density current which is carrying Reserve's tailings into the 600-900 foot deep areas of the lake. Measurements of the heavy density current show that it has a velocity up to 1.2 feet per second as it flows down the face of the delta. Figure 4 from "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota," (#49) is a plotting of the "Mean Horizontal Speeds at Various Depths." The maximum horizontal velocity plotted is about 0.63 foot per second at a depth of 30 feet.

A tailings particle will travel from the top of Reserve's tailings beach to a depth of 600 feet in approximately 35 minutes. At 600 feet the FWPCA Figure #4 only shows the lake currents to have a horizontal velocity of 0.2 foot per second. At this depth the heavy density current is still the predominant current and will carry the particles of tailings into the deep areas of the lake.

4. Conclusion #4, page 27:

> "As the tailings meet Lake Superior water, "billowy gray clouds" of waste were visible leaving the density current, both at and under the water surface near the shore line. Extending off shore as far as 300 feet, these clouds were observed and photographed at a depth of 35 feet. It appeared that "green water" was formed as gray tailings clouds diffused (became less concentrated) and more daylight penetrated among the particles."

Reserve's comments:

The interface of a heavy density current and the less dense lake water is not uniform. This is true with the heavy density current generated by Reserve's tailings and all other heavy density currents generated by turbid stream flows entering the lake. On bright sunny days these billows or clouds can readily be seen from a boat adjacent to Reserve's tailings flowing into the lake. These billows appear to be everchanging, a billow forming in one place, moving away as it moves with the heavy density current and/or particles settle from it, then other billows form. At times some of the tailings become suspended on a thermocline and are held in suspension for a longer interval of time before settling to the bottom. The presence of thermoclines is acknowledged on pages 17 and 18 of the group report. Even these conditions have not caused turbidities to exceed the State's most rigid standard of 5, as shown by the FWPCA data accompanying these observations. Also, this has not caused the turbidity of the water in the Silver Bay area to exceed the turbidity of the balance of the lake, as covered in our comments on Conclusion #2. The last sentence in the conclusion infers without supporting data that "green water" was formed as the tailings clouds diffused.

APPENDIX F

5. Conclusion #5, page 28:

> "The occurrence of tailings was evident in "green water" masses. In one instance the "green water" containing tailings was visibly present 18 miles southwest from the plant. "Green water" was observed along the Wisconsin shore line and did not contain tailings."

Reserve's comments:

The tailings beach is part of the shore line of the Silver Bay area. Reserve's data shows that there was a thermocline condition, similar to that referred to on pages 17 and 18, at the time this data was obtained. It would be expected that some tailings would be temporarily suspended in the water in the Silver Bay area in the same manner that other material is temporarily caused to be in suspension by a thermocline in this and other parts of the lake.

6. Conclusion #6, page 28:

> "Green water' containing tailings has a measurably increased turbidity and contains at least two to three times more suspended solids than does water that appears clear to the eye."

Reserve's comments:

The data of the FWPCA "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota," (#49) does not substantiate this conclusion. Data on pages 388 and 389 shows the turbidity expressed as suspended solids. The suspended solids values of "clear" lake water range from 0.1 mg/l to 0.9 mg/l. The suspended solids values of "green" water range from 0.5 mg/l to 3.7 mg/l. There is some overlap of readings. Some "clear" water has suspended solids of 0.4, 0.4, 0.8, and 0.9 mg/l. Some "green" water has suspended solids of 0.5, 0.8, and 0.9 mg/l. These suspended solids values are all so low and the data overlaps so much that a firm conclusion cannot be drawn. All of the values are less than the most rigid State Water Quality Standard for turbidity of 5.

These observations and data were not complete enough to establish the basic cause of the "green" water. For example, the temperature readings are only recorded to the nearest degree. At times a small change of temperature as low as 0.2° C will cause a thermal bar or thermocline that will be the basic cause of a "green water" condition. Also, both surface and bottom or depth temperatures are shown on only eight of 25 dives. No temperatures are recorded for the areas where the "green water" changes into blue or clear water. Apparently, no effort was made to detect the presence of a thermal bar condition, which could have been the basic cause of the "green water."

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7. Conclusion #7, page 28:

> "The State of Minnesota report (54) reported a reduction in the abundance of fish food organisms associated with the deposition of taconite tailings on the bottom of Lake Superior. It was estimated the reduction in fish food organisms could be expected to result in a reduction of the total annual fish catch (commercial and estimated sport fishing) of 5 percent or less for the area having tailings on the bottom."

Reserve's comments:

All of the bottom fauna organisms reported in the data, Table #6 of the Minnesota report, except sphaeriidae, are fish food organisms. The total of these fish food organisms shows no relation to the presence or absence of tailings on the bottom of the lake. This shown by the following data from Table #6.

Sample Line	Comments on Presence of Tailings on Lake Bottom	Total Fish Food Bottom Fauna Organisms Per Square Meter
#1 - 5 mi. NE of plant	No tailings	1255
#2 - 1.7 mi. NE of plant	Tailings present on one of 5 stations	1052
#3 - 2 mi. SW of plant	Tailings present on all 5 stations	863
#4 - 5 mi. SW of plant	Tailings present on all 5 stations	1287
#5 - 10 mi. SW of plant	Tailings present on 3 or 5 stations	602
#6 - 15.5 mi. SW of plant	Tailings present on 3 of 5 stations	431

Sample line #4, which had tailings present on all sampling stations, has the largest amount of fish food organisms, 1,287 per square meter.

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There are variations in the type of fish food bottom fauna organisms throughout the 20-mile area sampled. There is a decrease in the number of Pontoporeia from the most easterly sample line 5 miles northeast of Reserve's discharge to the most westerly sample line 15-1/2 miles southwest of the tailings discharge. This same trend is shown by the Minnesota Conservation Department sampling in July, 1949, before Reserve started operations. This trend of decreased Pontoporeia cannot be attributed to tailings inasmuch as there is a continuous trend regardless of a lack or abundance of tailings on the bottom. No sampling was done beyond the tailings deposit to the southwest. This additional sampling could substantiate that this is purely a directional trend and has no relationship to tailings.

The Minnesota Conservation Department reported that Pontoporeia is principally a food for smelt. This trend of decrease of Pontoporeia could account for a decrease in commercial smelt catch value of approximately $100 per year. This Minnesota report, after discussing this Pontoporeia trend, went on to say on page 9:

> "There is no evidence that there has been a decline in the Minnesota catch of smelt because of operation of the taconite plant."

8. Conclusion #8, page 28:

> "The study area selected (nine miles by five miles) for sampling was too small to define the full extent of the area adversely affected. Analysis of data by the Study Group indicates that the area affected extended beyond the furthest sampling point."

Reserve's comments:

We agree with this conclusion that the area studied was too small. For example, the turbidity, iron and phosphorus analyses of the water samples taken by the FWPCA 8 inches off the bottom in the Silver Bay area very clearly show the path of the heavy density current from Reserve's tailings beach and give very strong indication that the tailings are definitely being carried into the 600-900 foot deep basin. Had sampling been done over a more extensive area, they would have obtained greater proof that the heavy density current is performing exactly as predicted by the tests that the St. Anthony Falls Laboratory and the Mines Experiment Station of the University of Minnesota conducted in the late 1940's.

The implication in this conclusion that the area has been adversely affected has not been established by any data or observations. There is no data presented by the FWPCA that indicates that there is an adverse effect, and certainly no data indicates that there is any extension of the adverse effect.

APPENDIX F

9. Conclusion #9, page 28:

> "High concentrations (10 percent and 25 percent) of taconite wastes caused mortailities among sac fry of rainbow trout in 4-day exposure. The wastes were not acutely toxic to fingerling sized coho salmon, rainbow trout, white suckers, black bullheads, blue gills, and yellow perch in 96-hour, static bioassays."

Reserve's comments:

Data for this conclusion is from "Bioassays of Taconite Wastes Against Fish and Other Aquatic Organisms," (#52). The facts reported in this conclusion that the taconite tailings had no effect on the fingerling-size fish of six species certainly indicates that taconite tailings should have no effect on fish life in Lake Superior. The dilution of 10 percent taconite tailings with water for the test on sac fry is unrealistic to lake conditions. The greatest dilution that could ever be encountered in the shallower areas where trout may be spawning would be more like 1,000 to 1, rather than 10 to 1. Before any conclusions can be drawn about sac fry of rainbow trout, these tests should be repeated with dilutions of 1,000 parts of lake water to 1 part of tailings effluent.

10. Conclusion #10, page 28:

> "Chemical analysis projected to the probable daily discharge shows the following discharge, measured in pounds of certain parameters: copper, 4,100; nickel, 2,500; zinc, 2,500; lead, 6,100; chromium, 6,200; phosphorus, 51,500; and manganese, 629,000. Other elements in the discharge include silica, arsenic, and substantial quantities of iron. The chemical state of these metals was not assessed and it would be presumptious at this time to say what portion of the elements enter into solution."

Reserve's comments:

From Reserve's latest engineering survey, 45% of the inert, coarse solids remain in the delta. The remaining 55% of the inert, fine solids flow into the bottom of the 600 to 900 feet deep basin as a density current and settle on the lake bottom. The distribution of the elements shown in Conclusion #10 are tabulated on the following page. This distribution is based on Table 6 from the U.S. Bureau of Mines "Report on Tailings Disposal at Reserve Mining Company's Plant, Silver Bay Minnesota."

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Element	Total Pounds of Element in Discharge	Pounds in Delta Deposit	Pounds in Density Current
Copper	4,076.8	1,836.8	2,240
Nickel	2,486.4	1,120	1,366.4
Zinc	2,486.4	1,120	1,366.4
Lead	6,092.8	2,732.8	3,360
Chromium	6,160	2,777.6	3,382.4
Phosphorus	51,520	22,400	29,120
Manganese	629,440	283,360	346,080

The delta deposit is a firm hard sand land fill into the lake. It does not have any more effect on the water chemistry than the original shore.

Reserve Mining Company has determined the chemical state of the elements of their tailings. These tests show that none of the elements from Reserve's tailings that the FWPCA has been labeling heavy metals go into solution in Lake Superior water. Therefore, the addition of these elements as part of Reserve's tailings will not affect the lake water chemistry.

11. Conclusion #11, page 41:

> "A distinguishing characteristic of tailings discharged by the Reserve Mining Company is the presence of large quantities of the amphibole cummingtonite."

Reserve's comments:

Cummingtonite is an amphibole that is a major mineral of Reserve's tailings. However, cummingtonite is found from time to time in the waters of the North Shore streams. It could be a mineral present in the watershed of many of the streams entering Lake Superior. For example, the head waters of the St. Louis River are in the same general mineralogical area as is Reserve's taconite mine.

Cummingtonite is detected by an X-ray diffraction unit with a copper radiation X-ray source. Reserve's cummingtonite is indicated when a maximum diffraction or reflection of X-rays is obtained at an angle of 10.63° 2-Theta. Other minerals have diffraction peaks at about this same angle. All of the natural materials from the Silver Bay area that we have subjected to X-ray diffraction show some peak of X-ray diffraction at about this angle. Therefore, an X-ray diffraction at about this angle is not a positive indication of the presence of Reserve's tailings.

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Cummingtonite is a common amphibole or that is quite common on the Mesabi. Following is the analysis of typical eastern Mesabi cummingtonite from page 76 of Geology of the Biwabik Formation by Gunderson and Schwartz:

Silica	54.67
Alumina	.27
Titania	.03
Hematite	.73
Ferrous Iron	27.16
Manganese Oxide	.80
Magnesium Oxide	13.66
Calcium Oxide	.99
Sodium Oxide	.05
Potassium Oxide	.06
Water	1.27
	99.69

It is one of the most inert minerals in Reserve's tailings. It will not affect the water chemistry of Lake Superior or cause a polluting condition in any manner.

The following quotation from page 840 of the Encyclopedia Britannica shows the wide distribution of cummingtonite as rock forming mineral:

> "Amphiboles, as a group, form over most of the temperature range observed in the earth's crust. For example, amphiboles can be present in volcanic rocks, metamorphic rocks and as overgrowths on detrital grains in slightly metamorphosed sediments. Amphiboles can be found in most of the igneous rocks as minor and major constituents and form the major constituent in many metamorphic gneisses and schists. Hornblende schist, anthophyllite schist and cummingtonite schist are the commonest. Amphiboles from gangue (waste) minerals in certain ore deposits, and contact metamorphic deposits often include some of the amphiboles."

3. Summary and Conclusion #3, page 46:

> "Because of the low mineral content of Lake Superior's waters, increases in the range of 2 to 50 parts per billion of heavy metals such as copper, chromium, zinc and cadmium will have lasting deleterious effects upon the lake."

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Reserve's comments:

Reserve's tailings will not increase these elements in solution in Lake Superior. Water tests performed by Reserve Mining Company show that the only elements that show even the smallest tendency to go into solution in Lake Superior water are iron and manganese.

During 1968 the FWPCA secured samples of water from the surface, mid-depth and the bottom, only 8 inches off of the bottom. There is no statistical difference in the copper and zinc analyses of the bottom water samples and the water samples from the surface and mid-depth. Many of the bottom water samples were shown by their turbidity and iron analyses to have been taken from the tailings heavy density current. If tailings influenced the copper and zinc analyses of the water, the samples from 8 inches off of the bottom should have been higher in copper and zinc. The copper analysis of the surface water samples averaged 0.011 mg/l; mid-depth, 0.011 mg/l; and the bottom water samples averaged 0.010 mg/l. The zinc analyses of the surface water samples averaged 0.020 mg/l; mid-depth, 0.038 mg/l; and the bottom water samples averaged 0.008 mg/l.

Chemical analyses by Reserve show that the natural bottom sediments in the Silver Bay area have higher chromium, copper and zinc analyses than the overlying layer of tailings. The cadmium analyses of the natural bottom sediments are the same as the overlying tailings layer.

The FWPCA did not report sufficient data on cadmium or chromium analyses to make a similar comparison.

4. Summary and Conclusion #4, page 46:

> "The extreme clarity and cold temperature of the waters of Lake Superior are a necessity to support its present ecology A reduction in light penetration will significantly alter the types of life therin. The clarity of the lake is extremely susceptible to being reduced by pollutants."

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Reserve's comments:

Reserve's tailings are not causing increased turbidity of the surface and mid-depth area that would reduce light penetration or lake water clarity. The FWPCA 1966 and 1967 data shows that the areas of the lake that they tested had an average turbidity of 0.35 Hellige units. The water samples the FWPCA took from the Silver Bay area in 1968 averaged 0.28 Hellige units. This data shows that the water of the Silver Bay area is less turbid, therefore, cleaner than the balance of the lake.

Also, both the State of Minnesota and Reserve's bottom fauna data show that tailings are not affecting the total bottom fauna available for fish food. This is further verification that tailings are not affecting the ecology.

5. Summary and Conclusion #5, page 46:

> "The portion of Lake Superior shallow enough to provide suitable fish spawning areas is limited to a small band around the shoreline. This area is most susceptible to the influence of natural and man-made sediments. Deposition on the bottom of fine particles discharged to Lake Superior is a threat to the inshore food producing area and to the incubation of important fish species."

Reserve's comments:

There has not been any data presented by the FWPCA or other agencies of their study group to indicate that the deposition of tailings on the lake bottom in the Silver Bay area has affected the fish food or incubation of fish species. The data of "Bottom Fauna of the Minnesota North Shore of Lake Superior as Related to Deposition of Taconite Tailings and Fish Production" (#54) shows there is no relationship between the amount of fish food bottom fauna organisms and the presence or absence of tailings on the lake bottom.

A test on sac fry of rainbow trout was reported in "Bioassays of Taconite Wastes Against Fish and Other Aquatic Organisms" (#52). This test subjected the sac fry to taconite tailings effluent diluted to 1 part tailings effluent and 10 parts water. The sac fry did not survive this test. However, the test was unrealistic. The greatest density that sac fry would be subjected to in Lake Superior would be 1 part tailings effluent and 1,000 parts lake water. Because the sac fry did not survive the very strongest test of 10-1 dilution of tailings is no indication that tailings are affecting sac fry in the lake.

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9. Summary and Conclusion #9, page 46:

> "The discharge of taconite tailings to Lake Superior from the Reserve Mining Company, E. W. Davis Works, has a deleterious effect on the ecology of a portion of the lake by reducing organisms necessary to support fish life."

Reserve's comments:

The data presented in the reports of the 1968 study does not support this conclusion. The study of bottom fauna, "Bottom Fauna of the Minnesota North Shore of Lake Superior as Related to Deposition of Taconite Tailings and Fish Production" (#54) does not establish that there was any change of bottom fauna that could be attributed to tailings. In fact, a final statement in the total discussion of the bottom fauna and commercial fish catch in this report states:

> "There is no evidence that there has been a decline in the Minnesota catch of smelt because of operation of the taconite plant."

A statistical analysis of the FWPCA data shows that the water quality of the Silver Bay area is actually superior to that of all the other areas of the lake which they report sampling. This study compared the FWPCA 1966 and 1967 data for many other areas of the lake to the data they secured in 1968 in the Silver Bay area. It shows that at a 95% confidence level the water in the Silver Bay area is lower than other parts of the lake in conductivity, sulfate, ammonia, lead, zinc, turbidity and total phosphorus. It shows that the water in the Silver Bay area was essentially the same analysis in chloride, nitrogen, total iron and nickel. The only analyses that were found to be higher in the Silver Bay area were pH and nitrite-nitrate, but both of these were well within the State or Federal water quality standards.

The Wisconsin Department of Natural Resources also conducted a lake study in 1968, "Report on the Water Quality Survey in Wisconsin Water of Lake Superior made during July, 1968." This Wisconsin data was compared to the FWPCA data secured in the Silver Bay area in 1968. These comparisons show that the water in the Silver Bay area is cleaner, has deeper Secchi disc readings, has lower turbidity, and lower total phosphorus than water in the Wisconsin area.

All of this data shows that after 13 years of Reserve Mining Company operation, the water in the Silver Bay area is superior to that in the balance of the lake. Therefore, any contention that Reserve's tailings has had a deleterious effect on the ecology of any portion of the lake is unwarranted.

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16. Summary and Conclusion #16, page 47:

> "A persistent pollutant entering directly into the waters of Lake Superior or dissolved in the water that feeds the lake mixes with and becomes an integral part of a significant portion of the lake water."

Reserve's comments:

To be complete, this conclusion should point out that to be a pollutant, a material must dissolve into or remain in suspension in the water to a degree that is harmful to the water. Reserve's tailings are an example of material being entered into the lake in a proper manner so that there is no pollution. The tailings are inert so they do not dissolve into the water. They are carried to the 600 to 900 foot depth of the lake by the heavy density current. Therefore, they do not remain suspended in the water sufficiently to be a pollutant.

A paragraph on page 21 reads as follows:

> "The addition of certain kinds of toxic materials into Lake Superior is of prime importance. The heavy metals (i.e., copper, iron, zinc, etc.) are highly toxic at low concentrations because the water is soft, the fish species found in the lake are sensitive to metals and because the metals are persistent and will remain in the lake for longer periods of time due to the lake's slow flushing rate. Many of the common metals found in the surface waters could seriously affect the reproductive potentials of the fish species in Lake Superior at concentrations in the range of 2 to 50 parts per billion."

A paragraph on page 22 reads as follows:

> "The heavy metals, as a group, are especially important in Lake Superior for several reasons. Because there is a low mineral concentration in the lake, metals are more toxic than they would be in average waters in the United States. In addition, several important species of fish, especially lake trout, whitefish, and lake herring, are unusually sensitive to such metals as copper, zinc and chromium. Natural agents are lacking in the lake to bind such metals and render them inactive."

APPENDIX F

Reserve's comments:

These two paragraphs and the balance of the report completely ignore the physical and organic chemistry of the lake. All bodies of water are naturally active chemically. This should be taken into consideration and included as part of such a discussion. Omitting this fact leaves the implication that all heavy metals or other material discharge into a lake become part of the lake water and remain so forever, which is not correct.

Also, the chemical state of the material entering the lake needs to be considered. Inert material, such as Reserve Mining Company tailings, will have no effect on the amount of the heavy metals or toxic materials in solution in the lake water.

Comments on Proposed Water Quality Criteria for the Open Waters of Lake Superior, page 44, Appendix C:

Before this criteria can be evaluated, a number of points need to be clarified. The major points are:

1. Do the values represent results based on total (unfiltered) or soluble (filtered) analyses?

2. Are the values recommended analyses of the receiving waters in the adjacent vicinity of the point of effluent discharge?

3. Where, when and how should the samples be taken?

4. What is the minimum number of samples upon which the 90% level shall be determined?

The criteria has been compared to the data of Tables 6, 7, 18 and 19 from "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay," U. S. Department of Interior, FWPCA, Great Lakes Region, and from the FWPCA Duluth Monitoring Station. Data is not available from the FWPCA St. Mary's River monitoring system.

Excluding the Silver Bay area data, the data for ammonia, iron, cadmium, chromium, copper, lead, nickel, zinc, and phosphorus are too meager to base conclusions upon.

Based on the Duluth Station and total lake data, the standards pH, turbidity, iron, cadmium, lead, zinc and phosphorus are unrealistic. The data indicates that the general lake level exceeds the proposed standards.

APPENDIX F

Silver Bay area data indicates that the nickel, copper, zinc, lead, iron, and phosphorus standards are unrealistic.

Since 9-23-63, turbidity has been monitored at the Duluth Station as less than 25 JTU. Much better measurement is required if the standard is to be less than 0.5 JTU.

The attached Table #1 gives the details of this comparison.

TABLE 1

Comparison of FWPCA Proposed Lake Superior Water Quality Standards and FWPCA Lake Superior Duluth Monitoring Station and 1966 & 1967 Lake Survey Data

Criteria	Recommendation	1964-1968 Duluth Station				1966-1967 FWPCA Lake Survey			1968 FWPCA Silver Bay Area Survey			Comments
		Mean Total	Mean Last 5 Years	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	
Dissolved Oxygen	Bulk lake minimum 9 mg/l Shallow bays minimum 5 mg/l	-	12.6 mg/l	14.4 mg/l	5.8 mg/l	12.8 mg/l	14.0 mg/l	10.8 mg/l	13.2 mg/l	15.0 mg/l	12.1 mg/l	14/264 (5%) of Duluth data are less than 9.0 mg/l All 1968 FWPCA Silver Bay area measurements exceed 9.0 mg/l
pH	6.8 - 8.5	-	7.7	8.5	7.3	6.86	7.5	6.1	7.46	7.85	6.80	19/41 (46%) of 1966-67 Lake Survey data are less than 6.8 All 1968 FWPCA Silver Bay area data is within proposed criteria
Turbidity	Less than 0.5 JTU 90% of time; not to exceed 5.0 JTU as maximum	All readings shown as less than 25 JTU since 9-23-63. Exceptions 56 (7-27-64), 56 (9-8-64) and 59 (3-14-66).				0.36 JTU	1.0 JTU	0.0 JTU	0.66 JTU 0.29 JTU	12.00 JTU 2.70 JTU (w/o bottom samples)	0.03 JTU 0.03 JTU	12/76 (16%) of 1966-67 Lake Survey data exceed 5.0 JTU 6/104 (6%) of 1968 FWPCA Silver Bay area surface & mid-depth data exceed 5.0 JTU.
Color	Less than 0.010 absorbance Units over wavelength 3500-8000 Å & less than 0.050 absorbance units over wavelength 2400-3500 Å 90% of time. Maximum is 5 X these values.	-	2.4 Pt-Co Units	10.0 Pt-Co Units	0	-	-	-	-	-	-	-
Dissolved Solids	Mean value not to exceed 65 mg/l	-	-	-	-	62.6 mg/l	143 mg/l	45 mg/l	67.4 mg/l 67.6 mg/l	136 mg/l (w/o bottom samples)	38 mg/l	-
Bacteria	Maximum not to exceed 1000/100 ml. 90% to be less than 10/100 ml	-	12.8/100ml	320/100ml	1/100 ml	-	-	-	-	-	-	Mean value at Duluth for last five years exceeds 90% limit of 10/100 ml
Detergents	Maximum 0.4 mg/l MBAS 90% less than 0.1 mg/l MBAS	-	-	-	-	-	-	-	-	-	-	-
Phenols & Phenolic Cpds.	Maximum 0.001 mg/l 90% less than 0.001 mg/l	-	-	-	-	-	-	-	-	-	-	-
Ammonia	Maximum 0.1 mg/l as Ammonia Nitrogen	-	No data listed after 3-22-65. 33 readings of 0.100 or less prior to that date all other readings 0.000.			0.027 mg/l	0.070 mg/l	0.010 mg/l	0.016mg/l	0.060 mg/l	0.010 mg/l	All data less than proposed standard

TABLE 1
(Continued)

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Criteria	Recommendation	Total Mean	1964-1968 Duluth Station Mean Last 5 years	1964-1968 Duluth Station Maximum	1964-1968 Duluth Station Minimum	1966-1967 FWPCA Lake Survey Mean	1966-1967 FWPCA Lake Survey Maximum	1966-1967 FWPCA Lake Survey Minimum	1968 FWPCA Silver Bay Area Survey Mean	1968 FWPCA Silver Bay Area Survey Maximum	1968 FWPCA Silver Bay Area Survey Minimum	Comments
Iron	Maximum 0.100 mg/1 90% less than 0.030 mg/1	0.020 mg/1	-	0.083 mg/1	0.002mg/1	0.150mg/1	1.300mg/1	0.020mg/1	0.246mg/1 0.086mg/1	12.200mg/1 1.240 mg/1 (w/o bottom samples)	0.009mg/1 0.012mg/1	3/12 (25%) of Duluth data and 24/28 (86%) of 1966-67 Lake Survey data exceeds 90% limit of 0.030 mg/1, 9/28 (32%)of 1966-67 Lake Survey exceeds maximum limit of 0.100 mg/1, 1/118 (1%) of 1968 FWPCA Silver Bay surface and mid-depth samples exceed maximum of 0.100 mg/1. 109/118 (92%) of 1968 FWPCA Silver Bay area surface and mid-depth samples exceed 90% limit of 0.030 mg/1
Cadmium	Maximum 0.005 mg/1 90% less than 0.002 mg/1	0.003 mg/1	-	0.007 mg/1	0.001mg/1	-	-	-	0.001mg/1	0.003mg/1	0.001mg/1	8/12 (67%) of Duluth data exceeds 90% limit of 0.002 mg/1, 1/12 (8%) exceeds maximum limit of 0.005 mg/1. 1/31 (3%) of 1968 FWPCA Silver bay area data exceeds 90% limit of 0.002 mg/1.
Chromium	Maximum 0.050 mg/1 90% less than 0.020 mg/1	0.004 mg/1	-	0.020 mg/1	0.001mg/1	-	-	-	0.005mg/1	0.021mg/1	0.001mg/1	Data available less than or equal to proposed standard
Copper	Maximum 0.012 mg/1 90% less than 0.008 mg/1	0.004 mg/1	-	0.006 mg/1	0.003mg/1	-	-	-	0.010mg/1	0.030mg/1	0.003mg/1	35/127 (28%) of 1968 FWPCA Silver Bay Area data exceeds maximum of 0.012 mg/1. 80/127 (63%) of 1968 FWPCA Silver Bay area data exceeds 90% limit of 0.008 mg/1.
Lead	Maximum 0.050 mg/1 90% less than 0.030 mg/1	0.006 mg/1	-	0.020 mg/1	0.001mg/1	0.072mg/1	0.306mg/1	0.015mg/1	0.018mg/1	0.056mg/1	0.001mg/1	5/12 (42%) of 1966-67 Lake Survey data exceed both 90% limit of 0.030 mg/1 & Maximum limit of 0.050 mg/1. 18/147 (12%) of 1968 FWPCA Silver Bay area data exceeds 90% limit of 0.030 mg/1
Nickel	Maximum 0.030 mg/1 90% less than 0.015 mg/1	0.002 mg/1	-	0.003 mg/1	0.001mg/1	0.018mg/1	0.026mg/1	0.008mg/1	0.027mg/1	0.171mg/1	0.001mg/1	31/116 (27%) of 1968 FWPCA Silver Bay area data exceeds maximum of 0.030 mg/1. 67/116 (58%) of 1968 FWPCA Silver Bay area data exceeds 90% limit of 0.015 mg/1 20/21 (95%) of total lake data exceeds 90% limit of 0.015 mg/1.

TABLE 1
(Continued)

Criteria	Recommendation	1964-1968 Duluth Station				1966-1967 FWPCA Lake Survey			1968 FWPCA Silver Bay Area Survey			Comments
		Total Mean	Mean Last 5 Years	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	
Zinc	Maximum 0.015 mg/1 90% less than 0.010 mg/1	0.009 mg/1	-	0.017 mg/1	0.001mg/1	0.048mg/1	0.161mg/1	0.014mg/1	0.021mg/1	0.446mg/1	0.001mg/1	4/12 (33%) of Duluth data and 100% of 1966-67 Lake Survey data exceed 90% limit of 0.010 mg/1. 17/19 (89%) of 1966-67 Lake Survey data exceeds maximum limit of 0.010 mg/1. 35/128 (25%) of 1968 FWPCA Silver Bay Area data exceeds maximum limit of 0.015 mg/1. 51/128 (36%) of 1968 FWPCA Silver Bay area data exceeds 90% limit of 0.010 mg/1.
Cyanide	Maximum 0.004 mg/1 90% less than 0.002 mg/1	-	-	-	-	-	-	-	-	-	-	-
Hydrogen Sulfide	Maximum 0.008 mg/1 90% less than 0.001 mg/1	-	-	-	-	-	-	-	-	-	-	-
Temperature (Surface Waters)	(Jan-Mar) Mean 2°C	-	2.0°C	4.4°C	0.6°C	-	-	-	-	-	-	-
	Maximum 5°C	-										
	(Apr-June) Mean 10°C	-	5.2°C	26.8°C	1.1°C	-	-	-	-	-	-	-
	Maximum 18°C	-										
	(July-Sept) Mean 18°C	-	10.2°C	26.8°C	3.9°C	-	-	-	-	-	-	-
	Maximum 21°C	-										
	(Oct-Dec) Mean 8°C	-	5.5°C	11.1°C	2.2°C	-	-	-	-	-	-	-
	Maximum 15°C											
Phosphorus	90% less than 0.005 mg/1	0.023 mg/1	-	0.076mg/1	0.005mg/1	0.014mg/1	0.104mg/1	0.003mg/1	0.016mg/1	0.499mg/1	0.001mg/1	11/12 (92%) of Duluth data and 65/76 (86%) of 1966-67 Lake Survey data exceed 90% limit of 0.005 mg/1. 74/188 (39%) of 1968 FWPCA Silver Bay area data exceeds 90% limit of 0.005 mg/1

APPENDIX G

PRELIMINARY INVESTIGATIONS OF BOTTOM FAUNA ALONG THE SOUTHWESTERN REGION OF THE NORTH SHORE

BY

DAVID W. ANDERSON
RESERVE MINING COMPANY, SILVER BAY, MINNESOTA

My name is David W. Anderson and I am employed as a Research Biologist for Reserve Mining Company on a full-time basis. I received my Bachelor of Science degree in biology from the University of Minnesota at Duluth, and my Master of Science degree and PhD. degree from the University of North Dakota in the field of limnology.

The following paper was prepared by me in the usual course of my work at Reserve and was not prepared especially for this conference.

Introduction

Reserve Mining Company at Silver Bay, Minnesota, is conducting an extensive limnological study in western Lake Superior. Seasonal bottom fauna sampling is being used to supplement chemical, physical, and other biological investigations concerning the effects of tailings deposition on the aquatic environment.

This lake bottom study, by Reserve, is the first step toward a complete seasonal investigation of bottom fauna along the southwestern portion of the North Shore. Other than two unpublished reports (Burrows, 1950; and Skrypek, Burrows, Bishop and Moyle, 1968), information concerning the seasonal fluctuations and relative numbers of bottom organisms along Minnesota's North Shore is virtually non-existent.

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It is hoped that data from this study, presented now and in the future, will lead to a fundamental understanding of the effects of tailings deposition on the kinds and numbers of bottom organisms.

Methods of Study

Between April 13 and May 2, 1969, 114 bottom fauna samples were collected from 36 stations. Samples were collected on lines 1 through 4 extending from near-shore regions outward into deeper water at right angles to the shore to determine the natural depth distribution of bottom organisms (Figure 1).

In addition, samples were collected on a Northeast-Southwest line (#5), from 9 miles northeast of Reserve's taconite plant to 23 miles southwest to ascertain the effects tailings deposition has on bottom fauna.

Sampling lines and depths from which samples were collected are as follows:

Line 1 - 9.0 miles northeast (upshore) of the plant. Sample collection depths = 50, 100, 150, 200, 250, 300, 350, 400, 500 and 700 feet.

Line 2 - 2.5 miles southwest (downshore) of the plant near the mouth of the Beaver River. Sample collection depths = 100, 150, 200, 250, 300, 350 and 400 feet.

Line 3 - 20.0 miles southwest (downshore) of the plant near the mouth of the Encampment River. Sample collection depths = 50, 100, 150 and 200 feet.

Line 4 - 23.0 miles southwest (downshore) of the plant. Sample collection depths = 50, 100, 150, 200, 250, 300, 350, 400 and 500 feet.

Line 5 - Sample collection points along the Northeast-Southwest line were at 9.0, 5.5, and 2.5 miles northeast of the plant site and at 2.5, 5.0, 10.0, 17.0, 20.0 and 23.0 miles southwest of the plant. All samples were collected at depths of 200 feet.

Field Collection Methods

A modified weighted Petersen dredge[1] was used to collect three samples at each location. Utilizing a Raytheon survey fathometer on the boat, it was possible to accurately collect samples at the specific depth desired and to graphically follow decent of the dredge to the bottom. This latter feature enabled the winch operator to lower the dredge softly onto the bottom. This prevented a hard impact of the dredge on the bottom and the "blow-out" of surface sediments.

Dredge samples were collected in a large pail and then screened through a 30 mesh sieve. Coarse bottom material and organisms remaining on the sieve were transferred into glass jars, preserved with formalin, and taken back to the laboratory for analysis.

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1 Twelve one-half inch holes were drilled into each half of the barrel and covered with 48 mesh sieve cloth. This allows water to percolate upward through the sieve cloth and reduce "blow-out" of organisms when the dredge closes.

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Samples were not collected at the 50 and 500 foot stations on Line 2 or the 250, 300, 350, 400 and 500 foot stations on Line 3 because of a rock and gravel substrate which prevented quantitative collection of samples with the Petersen dredge.

The ratio of tailings versus natural sediments (i.e., per cent tailings) on the lake bottom was determined by a titanium analysis procedure.

Laboratory Methods

In the laboratory, preserved bottom samples were washed in a 48 mesh sieve to remove the formalin solution and any remaining silt. Samples were then placed in white enamel pans and a sugar solution added (Specific Gravity 1.15) to facilitate separation of the organisms from the sediment. Organisms present in each sample were removed with forceps, identified and counted. Bottom organisms found in all samples were preserved in vials and catalogued for future reference.

Results

Small aquatic worms (Oligochaeta), midge larvae and pupae (Chironomidae), fingernail clams (Sphaeriidae), and a scud Pontoporeia (Amphipoda) were the principal bottom dwelling organisms found on the lake bottom in the region studied. Table 1 lists numbers of these organisms (per square meter of lake bottom) found at different depths along Lines 1 through 4. Included also is a physical description of the type bottom found at each depth. Figure 1 graphically presents the data of Table 1.

Table 2 shows the numbers of bottom organisms collected from nine stations at 200 foot depths along Line 5 (Northeast to Southwest) from 9 miles

upshore of the plant to 23 miles downshore. Figure 2 graphically represents the data of Table 2, in addition to per cent tailings in bottom sediments, and a physical description of the bottom along Line 5.

Discussion

The paucity of data collected along Lines 1 through 4(Figure 1) at various depths prevents adequate analysis of the natural depth distribution of bottom fauna. However, from the data collected to date, two features are apparent. First, that total numbers of bottom organisms are greatest in the zone of heavy tailings deposition (Line 2) at 100 to 350 feet of depth. Second, that total numbers of bottom organisms are less in Line 4 (23 miles downshore from the plant) than in either Lines 1 or 2. Causes for this downshore reduction are probably related to the unproductive sand-gravel and rock substrate found in this area. Line 3 (20.0 miles southwest of the plant) could not be adequately sampled because of this type bottom. The low numbers of bottom organisms found in the predominately gravel substrate at the 50 and 100 foot depths on Line 1 reinforces this concept. Also of interest is the reduction of Pontoporeia in the tailing deposition zone (Line 2) and a subsequent increase in oligochaete worms and chironomid larvae in comparison to the upshore Line 1. This may reflect that a bottom composed of tailings and conditions of continual sedimentation provides a more favorable aquatic environmen for oligochaete worms and chironomid larvae than for Pontoporeia. This may enhance a contention that deposition of tailings into the lake creates an environment prohibitive to Pontoporeia. However, it should be noted that the numbers of Pontoporeia within the zone of tailings deposition from 100 to 250 feet are still substantially

greater than numbers found at 23 miles southwest of the plant where there are no tailings.

In sampling the above mentioned lines, it was noted that generally the maximum productivity existed at or near the 200 foot depth. Figure 2 graphically illustrates changes in the quality and quantity of bottom fauna when following Line 5 at the 200 foot depth, through the area of tailings deposition. Line 5 began nine miles upshore (N.E.) of the plant in an area free from tailings. It continued southwest through the area of tailings deposition (from the tailings delta to 17 miles S.W.) and ended, where tailings were no longer evident, 23 miles southwest of the plant.

Sample data collected along Line 5 indicates that the total numbers of bottom dwelling organisms are not materially supressed by the presence of tailings. Qualification of the above statement can be seen by examining the data of Figure 2 which indicates that greatest numbers of bottom dwelling organisms occur in an area where the bottom is composed exclusively of tailings.

It is evident (Figure 2) that in the zone of maximum tailings deposition chironomid larvae and oligochaete worms assume a position of dominance while the Pontoporeia are numerically diminished and the numbers of finernail clams (Sphaeriidae) remain fairly stable. This situation is reversed at a distance further southwest of the plant (from a point 2.5 miles to 10 miles southwest of the plant) where the bottom is still predominately tailings. Over this distance, the numbers of Pontoporeia apparently increase, chironomid larvae decrease, and the numbers of oligochaete worms and fingernail clams remain relatively unchanged. This trend suggests that no definite causal relationship exists

between the frequency in occurrence of Pontoporeia, chironomids, oligochaete worms and sphaerids and a tailings type environment.

The population density of the entire bottom fauna is materially diminished from a point 10 miles southwest to the last sampling station 23 miles southwest from the plant. This phenomenon may be related to the gravel and sand bottom type which become more predominant in the southwestern region of Line 5.

In considering the above mentioned data, it appears that the population densities are related to the bottom type. And that a tailings type bottom is no less productive than natural lake sediments in terms of biological productivity. Future investigations in this study will be directed at confirming this contention.

Summary

1. Based on preliminary data, total bottom fauna densities are not diminished in zones of tailings deposition.
2. Bottom fauna population densities are materially lower southwest of Reserve's taconite plant, where no evidence of tailings deposition was found, than the population densities associated with the tailings type bottom found in the vicinity of the Reserve plant.
3. Based on the data presently available, it is not realistic to draw any conclusions as to the beneficial or detrimental effects of taconite tailings on the bottom fauna along the North Shore of Lake Superior.

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4. This preliminary investigation has focused attention on areas needing further research. Specifically, the causal associations of organisms to bottom type and the seasonal fluctuations in kinds and numbers of bottom organisms.

TABLE

Depth Distribution of Bottom Organisms
Collected Along Sampling Lines 1 Through 4

Sampling Line 1 9 Miles Upshore (N.E.)	N*	Pontoporeia	Oligochaeta	Sphaeriidae	Chironomidae	All	Bottom Type
Depths 50 Feet	3	48	79	20	4	151	Gravel Rocks
100 Feet	3	104	151	133	129	517	Gravel Sand
150 Feet	3	431	165	162	104	866	Sand Silt
200 Feet	3	635	140	122	312	1216	Silt Clay
250 Feet	3	223	162	54	165	604	Silt Clay
300 Feet	3	377	280	50	147	854	Silt Clay
350 Feet	3	291	194	93	144	722	Clay Organic
400 Feet	3	172	237	11	104	524	Clay Organic
500 Feet	3	165	402	18	61	650	Clay Organic
700 Feet	3	14	151	0	11	176	Clay
All depths, all samples combined	30	246	196	66	118	628	

Sampling Line 2 2.5 Miles Downshore (S.W.)	N*	Pontoporeia	Oligochaeta	Sphaeriidae	Chironomidae	All	Bottom Type
Depths 100 Feet	3	560	1834	269	456	3119	Sand Tails
150 Feet	3	345	905	144	524	1918	Tails Organic
200 Feet	3	323	876	50	898	2147	Tails Organic
250 Feet	3	187	485	79	438	1189	Tails Organic
300 Feet	3	68	398	72	320	858	Tails Organic
350 Feet	3	22	57	144	197	420	Tails Clay
400 Feet	3	18	61	97	136	312	Tails Clay
All depths, all samples combined	21	218	659	122	424	1423	

TABLE 1
(Continued)

Sampling Line 3 20 Miles Downshore (S.W.)	N*	Pontoporeia	Oligochaeta	Sphaeriidae	Chironomidae	All	Bottom Type
Depth 50 feet	3	416	535	126	395	1504	sand gravel
100 feet	3	302	370	54	241	978	sand gravel
150 feet	3	427	409	136	140	1112	sand gravel
200 feet	4	133	377	144	101	755	sand gravel
All depths, all samples combined	16	320	423	115	219	1077	

Sampling Line 4 23 Miles Downshore (S.W.)	N*	Pontoporeia	Oligochaeta	Sphaeriidae	Chironomidae	All	Bottom Type
Depth 50 feet	3	370	463	136	75	1044	sand
100 feet	3	147	567	168	11	893	sand
150 feet	3	244	147	126	50	571	sand gravel
200 feet	3	201	90	90	54	435	sand gravel
250 feet	3	151	61	54	172	438	sand gravel
300 feet	3	158	65	25	54	302	sand gravel
350 feet	3	118	108	14	151	391	sand gravel
400 feet	3	86	97	14	83	380	silt organics
500 feet	3	47	36	7	14	104	silt organics
All depths, all samples combined	27	169	182	70	74	495	

*N = Number of Petersen Dredge hauls per sampling station.

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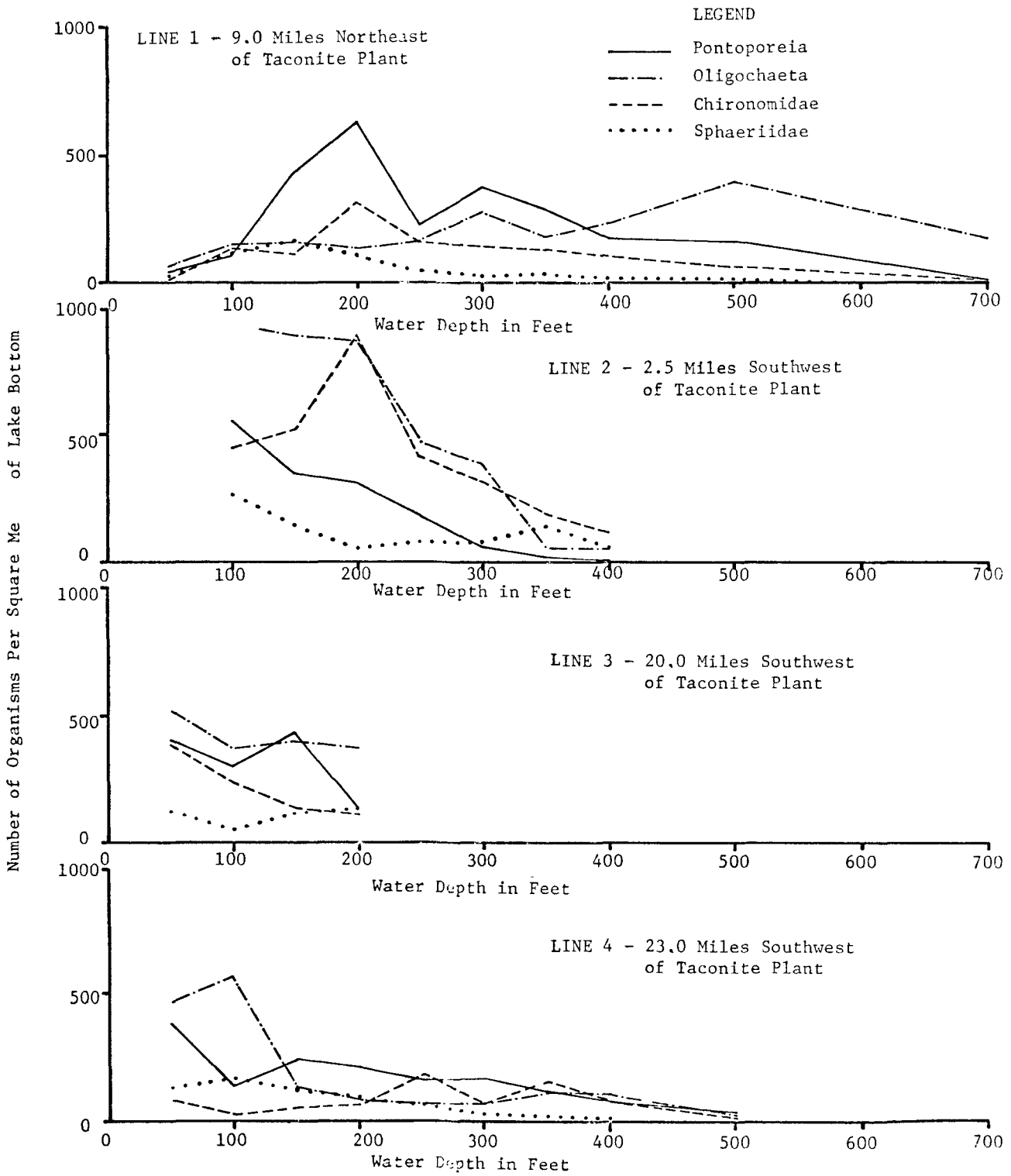
FIGURE 1

Depth of Distribution of Bottom Organisms
Sampling Lines 1 Through 4

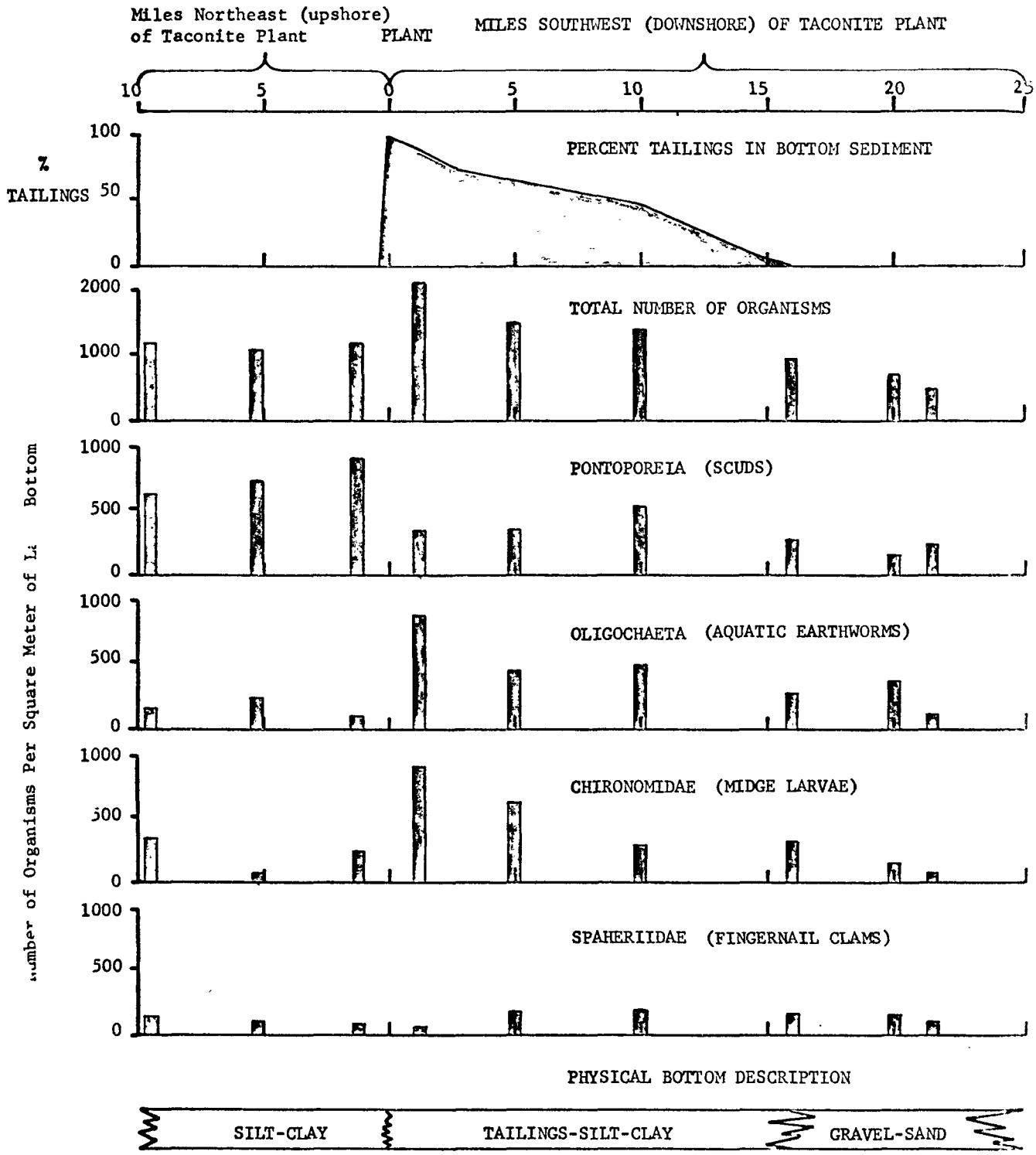


TABLE

Numbers of Bottom Organisms at 200 Foot
Depth Along Sampling Line 5

Miles NE - SW of Plant	9.0 NE	5.5 NE	2.5 NE	2.5 SW	5.0 SW	10.0 SW	17.0 SW	20.0 SW	23.0 SW
Total Organisms #/m^2	1217	1099	1188	2147	1738 1307	1422	948	754 711	434
Pontoporeia #/m^2	635	721	804	323	301 370	510	259	133 140	201
Oligochaeta #/m^2	140	233	93	876	589 259	488	259	377 312	90
Chironomidae #/m^2	312	50	212	898	736 474	273	294	101 129	54
Sphaeriidae #/m^2	129	93	79	50	111 204	151	136	144 119	90
Bottom Type	Silt Clay	Silt Clay	Silt Clay	Tails Organic	Tails Organic	Tailing Silt Clay	Gravel Sand	Gravel Sand	Gravel Sand

FIGURE 2
Bottom Organisms, Percent Tailings and Lake Bottom Description
Sampling Line 5



MR. FRIDE: Mr. Chairman, there were a number of statements that have been filed with the Minnesota conferee and I understand distribution has been made of those. They are for the record.

In addition, I would like to submit at this time a supplemental statement from Dr. G. Fred Lee.

STATEMENT OF DR. G. FRED LEE, PROFESSOR OF WATER CHEMISTRY, UNIVERSITY OF WISCONSIN, MADISON, WISCONSIN

(The above-mentioned statement follows.)

SUPPLEMENTAL STATEMENT

BY

G. FRED LEE

I would like to discuss several points made by speakers in their discussions before this conference.

The first, by Dr. Bartsch, is with regard to the role of temperature in controlling the growth of algae in Lake Superior. He said that temperature is not limiting the growth of algae in Lake Superior. I feel that he is correct in his appraisal since there are many lakes and oceans in the world that are as cold and colder than Lake Superior that have good and in some cases excessive growths of algae. For example, one of the most productive areas of the world's oceans is the Antartic Ocean which is considerably colder than Lake Superior.

The FWPCA report, "An Appraisal of Water Pollution in the Lake Superior Basin," as item seven of the summary and conclusions page 46, states:

> "Lake Superior is an oligotrophic lake. Nutrient values in some areas of the lake have been reported at levels approaching those commonly associated with nuisance algal growths. However, other factors, such as temperature are limiting."

The FWPCA report states that temperature is limiting, yet Dr. Bartsch states that temperature is not limiting the growth of algae. This controversy within the FWPCA provides another example of the numerous statements that are made in the FWPCA report without supporting evidence and that are not accepted by experts in the FWPCA, much less the scientific community as a whole.

In Dr. Mount's discussion at the conference on the proposed water quality criteria, he mentioned that Appendix C contains the supporting evidence for these criteria. I wish to point out that some of the statements made in support of these criteria are incorrect and in some cases inappropriately applied. For example, on page 88 of the FWPCA report, the statement is made that:

> "Turbidity produces in Lake Superior 'colored water' which is not esthetically pleasing.[3]"

They cite page 106 of Odum's book, "Fundamentals of Ecology," as a reference to the statement. Examination of this book will show that no mention is made of colored water in Lake Superior on the page mentioned. They also state that:

> "Increased turbidity requires an increase in available chlorine necessary for chlorination."

This statement would not be accepted for all types of turbidity. It certainly would not be true of many types of inorganic solids that are present in natural waters.

The second point I wish to discuss that was raised in Dr. Bartsch's discussion is the reasonableness of the proposed FWPCA criteria for Lake Superior. Dr. Bartsch said that his review of existing data for phosphorus in Lake Superior shows that the <u>average</u> concentration is about 0.01 mg/l. This number is the same as the FWPCA proposed criteria maximum for the lake. I ask, is it reasonable to propose a standard that is equal to the average concentration naturally occurring in the lake. This means that many samples of Lake Superior will have concentrations in excess of the proposed standard. How does

one enforce such a standard? How does the FWPCA propose to control excessive phosphorus in Lake Superior that is derived from natural sources?

These and other questions raised in my discussion should be resolved before any new criteria are set for Lake Superior.

R. A. Ragotzkie

MR. FRIDE: I also have a statement from Dr. Ragotzkie which I would like to submit for the record.

STATEMENT OF DR. R. A. RAGOTZKIE, DIRECTOR,
MARINE STUDIES CENTER, UNIVERSITY OF
WISCONSIN, MADISON, WISCONSIN

(The above-mentioned statement follows:)

SUPPLEMENTARY STATEMENT

BY

ROBERT A. RAGOTZKIE

UNIVERSITY OF WISCONSIN

I would like to comment briefly on the model studies described by Dr. Baumgartner. Model studies can be useful in that they provide a way to simulate to some degree the nature of water motions such as density currents. However, any model study of a fluid system is limited in application due to the problem of scale. Thus, the qualitative nature of water motions, such as density currents, can be readily demonstrated, but one must be very careful in applying these qualitative results to the real lake or ocean. This is especially true with respect to mixing and turbulence processes which are themselves highly dependent on scale. Therefore, scaling up of mixing processes or eddy sizes from model observations to the real lake is not valid. That turbulence exists along the boundary of density currents can be inferred, but its intensity and magnitude can only be determined from direct observation of the actual phenomenon or calculated from detailed velocity and density gradient data obtained from the real lake system.

A second comment responds to the assertion by Dr. Baumgartner that in 20 years' time the suspended solids load of the "Duluth embayment" will rise sharply due to the disposal of taconite tailings at Silver Bay. This statement, which also mentions the value of 37 p.p.m. as a possible suspended load, is based on several assumptions which are unrealistic when applied to the real Lake Superior. These are:

1. That all of the "fines" from the tailings go into suspension in the epilimnion. (This has not been demonstrated; in fact all available evidence is to contrary.)
2. That the fines, once suspended, remain suspended indefinitely. (This is not true--otherwise all surface waters of all lakes would be highly turbid.)
3. That the circulation and exchange between the "Duluth embayment" and the rest of Lake Superior is weaker than in the lake as a whole. (Current studies by the FWPCA and others do not support this, e.g. the counterclockwise gyre which dominates the entire western half of Lake Superior and possibly the lake as a whole.)

As a final rebuttal to the assertion that the water in the "Duluth embayment" will greatly increase in turbidity over a 20-year period, it is pointed out that during the 13 years that Reserve Mining Company has been disposing of tailings in Lake Superior, no detectable increase in turbidity in the Duluth water intake has been observed.

JAMES K. RICE

MR. FRIDE: May the supplementary statement by James K. Rice be entered into the record?

MR. DOMINICK: Certainly.

STATEMENT OF JAMES K. RICE, PRESIDENT,

CYRUS W. RICE AND COMPANY, PITTSBURGH,

PENNSYLVANIA

(The above-mentioned statement follows.)

SUPPLEMENTARY STATEMENT

BY

JAMES K. RICE

The proposed criteria for Lake Superior open waters greatly reduces the limiting values for many of the quality indicators as well as introduces a measure of the distribution of the values by establishing a lower limit not to be exceeded by more than ten per cent of the data. In this connection, it is interesting to note that in the case of phosphorus the mean of the data by Putnam and Olson and by Beeton (as referenced by FWPCA in Appendix C of the Appraisal Report) is given as 9.6 μg/l while that determined for the 1966-67 Lake Superior survey is 10.5 μg/l with a standard deviation of 5.5μg/l as is shown in Table 30 of my report. Dr. Bartsch in his testimony also cites 10 μg/l as typical of the lake as a whole at the present time and that the lake is presently healthy. While the standard deviation of the data by Bartsch, Putnam, et al. is not given, it is likely that it is similar to that gathered by FWPCA in the report. The proposed maximum criteria is thus set at the mean of the range of concentrations found in the lake and makes no allowance for the actual deviation of the data resulting from sampling and analysis errors.

Dr. Mount, in response to a question from one of the conferees, said that the proposed limit for chlorinated pesticides in fish flesh was set as that equal to the levels found in healthy populations of fish in the lake. Again, presumably the mean of the data was employed as a limit. If Lake Superior is healthy at the present levels for the various quality indicators as has been

stated, there it would seem logical to set any new standards at values no lower than the corresponding existing levels. To set new standards lower than existing levels can literally mean [illegible] a user of [illegible] cooling water could be required to improve the [illegible] water [illegible] before he could return it to the lake.

While the principle proposed by FWPCA of using 90% and [illegible] limit has great merit and is a step forward in standard setting, the usefulness of the step is negated if proper allowance is not given [illegible] variance of the test procedures employed. In addition, it is absolutely necessary that the question of total versus soluble be resolved for each of the parameters involved. FWPCA in Appendix C of the Appraisal Report uses both bases interchangeably in developing support for the proposed criteria and does not give any reasons for their selections. When [illegible] insoluble suspended solids such as the taconite tailings, such [illegible] comply with water quality standards.

MR. FRIDE: And I have a supplement to Mr. Haley's testimony, Appendix H.

MR. DOMINICK: It will be made a part of the record.

(The above-mentioned supplemental statement follows.)

RESERVE MINING COMPANY

MEMORANDUM

TO K. M. Haley DATE April 29, 1969

Revised - May 7, 1969

FROM J. C. Gay

SUBJECT Summary of Statistical Analyses of Chemical Determinations Data in the "Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay"

INTRODUCTION:

"The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior" contains analytical data for the turbidity, phosphorus (total), iron (total), lead, zinc, nickel, ammonia, organic nitrogen, conductivity, pH, alkalinity, dissolved oxygen, $NO_2 + NO_3$, sulfate, chloride, and dissolved solids content of Lake Superior waters in general and also for the Silver Bay area of Lake Superior. In addition, copper, aluminum, and magnesium analyses, and Secchi disc readings for the Silver Bay area only are shown. This data was analyzed statistically by Reserve personnel to determine what conclusions could be made from this data.

Where data for both Lake Superior in total and the Silver Bay area were available, the data was analyzed with the "t-Test." The "t-Test" enables one to determine if the means of two groups of data are the same, or if they are different. The following "t-Tests" comparisons were made:

a. Silver Bay area vs. Lake Superior in total for conductivity, pH, alkalinity, dissolved oxygen, $NO_2 - NO_3$, sulfate, chloride, dissolved solids, turbidity, ammonia, organic N, phosphorus (total), iron (total), lead, zinc, nickel, and magnesium.

b. Silver Bay area vs. United States tributary rivers of Lake Superior for copper and aluminum.

c. Silver Bay area vs. Minnesota North Shore tributary streams of Lake Superior for magnesium.

d. Silver Bay area vs. Wisconsin waters of Lake Superior for phosphorus analyses.

Some of the data required transformation to a normal form before a valid analysis could be made. A square-root transform was used. In these cases, erroneous data was also rejected using Chauvernet's theorem. The Silver Bay area turbidity analyses and Secchi disc readings were compared to those of the Wisconsin area of Lake Superior by inspection.

The data pertaining to the Silver Bay area was also analyzed using analysis of variance. This technique determined if there were differences between surface, mid-depth, and bottom waters in the Silver Bay area. It also determined if differences existed between different areas along the North Shore of Lake Superior.

Confidence limits were calculated for the Silver Bay area data. A confidence limit establishes the range within which the true mean value lies.

A 95% confidence level was selected for all analyses.

Table 1 lists the source of all data used for statistical analyses. Tables 2 through 9 show the statistical analysis results.

RESULTS:

Based on the data shown in the Tables listed in Table 1, the following results were statistically determined:

1. The data for turbidity, ammonia, organic N, phosphorus (total), iron (total), lead, zinc, nickel, and magnesium required transformation and rejection of erroneous data before a valid "t-Test" comparison could be made. This is caused by a very wide scatter of the data resulting from both heavy-density current effects and sampling and analytical error. This creates a large standard deviation with respect to the mean value (Table 2).

2. The quantities conductivity, sulfate, ammonia, lead, zinc, turbidity and total phosphorus are lower in the Silver Bay area than in Lake Superior total (Table 3).

3. No conclusions can be made with respect to alkalinity, dissolved oxygen, and dissolved solids (Table 3).

4. The quantities pH, $NO_2 + NO_3$ and magnesium are higher in the Silver Bay area than in Lake Superior total (Table 3).

5. The magnesium content of the Silver Bay area of Lake Superior is lower than the average magnesium content of Minnesota's North Shore streams which discharge into Lake Superior (Table 4).

6. Iron and turbidity analyses at the bottom of Lake Superior in the Silver Bay area are significantly higher than in the surface and mid-depth waters of the Silver Bay area. This establishes that the heavy-density current is working properly (Table 5).

7. The surface and mid-depth waters of the Silver Bay area have less turbidity than the waters of Lake Superior in total (Table 3).

8. The surface and mid-depth waters of the Silver Bay area are the same as those of Lake Superior in total with respect to total-iron content (Table 3).

9. Secchi disc readings in the Silver Bay area of Lake Superior are higher than those in the Wisconsin waters of Lake Superior (Table 6).

10. Turbidity readings and phosphorus content of the Silver Bay area of Lake Superior are significantly lower than those of the Wisconsin waters of Lake Superior (Table 6 and Table 7).

11. The copper content of the Silver Bay area of Lake Superior is significantly lower than the average copper content of all United States streams discharging into Lake Superior (Table 8).

12. The aluminum content of the Silver Bay area of Lake Superior is higher than the average aluminum content of all United States streams discharging into Lake Superior. However, if the aluminum content of the Silver Bay area of Lake Superior is compared to the aluminum content of those streams along the North Shore of Minnesota, no conclusions can be made (Table 8).

13. There were significantly lower concentrations of copper and lead in the area adjacent to the tailings delta than in some localized areas west of Silver Bay. No reason for this difference is known (Table 5).

14. The mean value estimates for conductivity pH, alkalinity, dissolved oxygen, NO_2 - NO_3, sulfate, chloride, and dissolved solids in the Silver Bay area of Lake Superior are reasonably accurate. This is shown by a confidence limit which is a small percentage of the mean value (Table 9).

15. The mean value estimates for phosphorus (total), iron (total). lead, zinc, nickel, ammonia, and organic nitrogen in the Silver Bay area are highly questionable. This is shown by a confidence limit which is a large percentage of the mean value (Table 9).

J. C. Gay

JCG:mb

TABLE 1

Source of Data on Which Statistical Analyses Was Conducted

Data	Source
Total lake analyses for turbidity, phosphorus (total), iron (total), lead, zinc, nickel, ammonia, organic N, conductivity, pH, alkalinity, dissolved oxygen, $NO_2 + NO_3$, sulfate, chloride, magnesium, and dissolved solids	Table 6 and Table 7 - Section 3, "Investigations by Chicago Program Office" of "The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior."
Silver Bay area analyses for turbidity phosphorus (total), iron (total), lead, zinc, nickel, ammonia, organic N, conductivity, pH, alkalinity dissolved oxygen, $NO_2 + NO_3$, sulfate, chloride, magnesium, and dissolved solids	Table 18 and Table 9 - Section 3, "Investigations by Chicago Program Office" of "The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior."
Lake Superior tributary stream discharge analyses for magnesium, copper, and aluminum	Table 10 - Special Scientific Report, Fisheries No. 559.
Silver Bay area Secchi disc readings	Table 12 and Table 17 - Section 3, "Investigations by Chicago Program Office" of "The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior." Figure 3 - Section 4, "Investigations by National Water Quality Laboratory" of "The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior."
Wisconsin area of Lake Superior analyses for turbidity and phosphorus and Secchi disc readings.	Table II - "Report on the Water Quality Survey in Wisconsin Waters of Lake Superior Made During July, 1968."

TABLE 2

Mean and Standard Deviation of
Chemical Determinations Shown in Tables
6, 7, 18 & 19 of Department of Interior Report

Composite Samples

	Silver Bay Area June			Silver Bay Area July			Total Lake		
Analysis	n	Ave.	Std. Dev.	n	Ave.	Std. Dev.	n	Ave.	Std. Dev.
* Turbidity[1]	91	0.90	1.75	64	0.32	0.25	76	0.36	0.21
Conductivity[2]	91	88.8	2.4	66	93.2	1.5	76	97.4	2.8
pH	91	7.61	0.13	96	7.32	0.13	41	6.86	0.31
Alkalinity[3]	90	41355.6	1756.6	66	43530.3	2444.6	75	42413.3	2557.9
D.O.[3]	84	13544.0	503.6	97	12875.3	198.4	64	12756.2	1212.6
* Ammonia[3]	91	19.7	11.5	97	14.4	8.5	70	27.3	14.2
$NO_2 + NO_3$	88	282.9	30.7	97	274.7	28.5	72	193.2	37.6
* Organic N[3]	42	84.3	79.1	92	76.3	71.4	71	73.1	58.0
Sulfate[3]	91	1858.9	434.8	97	2225.8	433.3	75	2861.3	904.2
Chloride[3]	91	1460.4	163.2	97	1420.6	138.4	76	1438.2	390.9
* Phosphorus (total)	91	23.5	59.6	97	9.9	21.7	76	13.8	13.2
* Iron (total)	89	243.4	378.6	90	244.1	1283.5	28	146.6	247.9
* Lead[3]	68	17.5	12.9	79	17.9	9.8	12	72.3	84.3
* Zinc[3]	31	18.1	16.1	97	22.4	57.8	19	47.6	36.1
* Nickel[3]	29	17.7	11.3	87	30.6	31.2	21	18.5	3.5
Dissolved Solids[4]	90	74.4	13.0	95	60.8	8.5	52	62.6	17.4

* Indicates data not normally distributed

[1] Stated in Hellige units

[2] Stated in µmhos.

[3] Stated in µg/l.

[4] Stated in mg/l.

TABLE 3

Summary and Conclusions of Chemical Determinations
Shown in Tables 6, 7, 18, & 19 of Department of Interior Report

	Composite Samples				Surface and Mid-Depth Samples			
	Silver Bay Area Average		Total Lake Average	Silver Bay Area is	Silver Bay Area Average		Total Lake Average	Silver Bay Area is
	June	July			June	July		
Conductivity[4]	88.8	93.2	97.4	Lower than lake				
pH	7.61	7.32	6.86	Higher than lake				
Alkalinity[5]	41356	43530	42413	Inconclusive[1]				
D.O.[5]	13544	12875	12756	Inconclusive[2]				
$NO_2 - NO_3$[5]	282.9	274.7	193.2	Higher than lake				
Sulfate[5]	1859	2226	2861	Lower than lake				
Chloride[5]	1460	1421	1438	Same as lake				
Dissolved Solids[6]	74.4	60.8	62.6	Inconclusive	74.9	60.3	60.9	Inconclusive
Magnesium[5]	3363	4307	3047	Higher than lake	3364	4302	3054	Higher than lake
*Turbidity[7]	0.28	0.30	0.35	Inconclusive[1]	0.25	0.26	0.35	Lower than lake
*Ammonia[5]	18.6	13.1	27.2	Lower than lake				
*Organic N	76.9	69.2	69.2	Same as lake				
*Phosphorus (Total)[5]	10.4	6.45	12.1	Inconclusive[3]	8.05	5.41	12.1	Lower than lake
*Iron (Total)[5]	97.6	66.1	66.4	Inconclusive[1]	91.6	59.5	66.4	Same as lake
*Lead[5]	17.5	17.9	51.0	Lower than lake	16.8	18.4	51.0	Lower than lake
*Zinc[5]	12.5	9.5	40.2	Lower than lake		11.0	40.2	Lower than lake
*Nickel[5]	14.7	22.5	18.4	Inconclusive[1]		25.9	18.4	Same as lake

[1]Although data must be considered inconclusive, supplementary data indicate the Silver Bay area is the same as the total lake.
[2]Although data must be considered inconclusive, supplementary data indicate the Silver Bay area is higher than the total lake.
[3]Although data must be considered inconclusive, supplementary data indicate the Silver Bay area is lower than the total lake.
[4]Stated in μ mhos
[5]Stated in μ g/l
[6]Stated in mg/l
[7]Stated in Hellige Units

*Indicates data was transformed and erroneous data rejected.

TABLE 4

Statistical Analysis of Magnesium[1]
Data

Composite Samples

Sample Location	n	Average	Standard	't'	Silver Bay Area is
Minnesota Rivers[4]	9	5066.7	2127.8		
Silver Bay Area - June[2]	91	3362.6	82.5	7.51	Lower than rivers
Silver Bay Area - July[3]	97	4307.2	123.5	3.42	Lower than rivers

Surface and Mid-Depth Samples

Minnesota Rivers[4]	9	5066.7	7127.8		
Silver Bay Area - June[2]	61	3363.9	85.7	6.13	Lower than rivers
Silver Bay Area - July[3]	65	4301.5	123.1	282	Lower than rivers

[1]Stated in μg/l

[2]Table 18, U. S. Department of Interior Report

[3]Table 19, U. S. Department of Interior Report

[4]Rivers 93-99, Table 10, Special Scientific Report, Fisheries No. 559.

TABLE 5

Analysis of Variance Results

Analysis	Cruise	Samples	F S-M-B	Significant	F Lines	Significant
Nickel	June	Comp[a]	-	-	<1	No
	July	S-M-B[b]	<1	No	8.35	Yes
Copper	June	Comp	-	-	8.50	Yes
	July	S-M-B	<1	No	5.70	Yes
Suspended Solids	June	S-M-B	<1	No	1.69	No
	July	S-M-B	1.11	No	2.74	Yes
Lead	June	S-M-B	1.00	No	11.40	Yes
	July	S-M-B	<1	No	10.25	Yes
Aluminum	June	S-M-B	<1	No	1.31	No
	July	S-M-B	1.14	No	<1	No
Phosphorus	June	S-M-B	<1	No	1.31	No
	July	S-M-B	1.19	No	<1	No
Turbidity	June	S-M-B	2.70	Yes	<1	No
	July	S-M-B	1.26	No	<1	No
Manganese	July	S-M-B	<1	No	1.46	No
Zinc	June	Comp	-	-	7.02	Yes
	July	S-M-B	1.37	No	1.11	No
Iron	July	S-M-B	3.02	Yes	<1	No

[a]Comp means samples were composite samples

[b]S-M-B means surface, mid-depth and bottom samples

TABLE 6

Secchi Disc Readings and Turbidity Readings in the Silver Bay Area and in the Wisconsin Area of Lake Superior

Location	Measurement	Mean Value	Standard Deviation	Range
Wisconsin Area	Secchi Disc	7.20 ft	4.60	1.0 - 20.0
Silver Bay Area	Secchi Disc	21.5 ft	7.74 ft	6.0 - 39.4 ft
Wisconsin Area	Hach Turbidity*	5.01	8.46	0.08 - 54.0
Silver Bay Area (w/bottom samples)	Hellige Turbidity	0.66	1.38	0.03 - 12.0
Silver Bay Area (w/o bottom samples)	Hellige Turbidity	0.28	0.27	0.03 - 2.7

*One Hach Turbidity reading of 253.0 was deleted from this group of data

TABLE 7

Statistical Analysis[1] of Phosphorus Data

Composite Samples

Sample Location	n	Average[2]	Standard Deviation[2]	Actual[3] Average	't'	Silver Bay Area is
Wisconsin Waters	21	6.50	2.60	42.2		
Silver Bay Area - June	84	3.03	1.14	9.2	9.11	Lower than Wis.Waters
Silver Bay Area - July	93	2.41	0.80	5.8	12.63	Lower than Wis.Waters

Surface and Mid-Depth Samples

Wisconsin Waters	21	6.50	2.60	42.2		
Silver Bay Area - June	56	2.67	0.96	7.1	9.30	Lower than Wis.Waters
Silver Bay Area - July	65	2.24	0.68	5.0	11.88	Lower than Wis.Waters

[1]Analysis conducted on transformed ($\sqrt{}$) data with invalid data discarded.

[2]Average and standard deviation are the average and standard deviation of the square roots

[3]Actual average is the average squared. Stated in $\mu g/l$.

TABLE 8

Summary of Chemical Determinations Shown in Tables
18 & 19 of Department of Interior Report and
Table 10 of Special Scientific Report - Fisheries No. 559

Analysis	Composite Samples				Surface and Mid-Depth Samples			
	Silver Bay Area Ave.		Lake Superior Rivers Ave.	Silver Bay Area is	Silver Bay Area Ave.		Lake Superior Rivers Ave.	Silver Bay Area is
	June	July			June	July		
Copper[1]	6.5	10.7	54.5	Lower than rivers				
Aluminum[1]	133.4	301.4	96.6	Higher than rivers	114.7	305.2	96.6	Inconclusive
			Minnesota North Shore Rivers				Minnesota North Shore Rivers	
Aluminum[1]	133.4	301.4	116.6	Inconclusive	114.7	305.2	116.6	Inconclusive

[1] Stated in μg/l.

TABLE 9

Confidence Limits for Mean Values of FWPCA Chemical Determinations

A. Composite Samples

Determination	Location	Average	Standard Deviation	n	Confidence Limits	95% Confidence Interval	Interval As % of Mean
Conductivity	S.B. Area, June 68	88.8	2.4	91	±0.5	88.3-89.3	1.1
	S.B. Area, July 68	93.2	1.5	66	±0.4	92.8-93.6	0.9
	Total Lake, 66 & 67	97.4	2.8	76	±0.6	96.8-98.0	1.2
pH	S.B. Area, June 68	7.61	0.13	97	±0.03	7.58-7.64	0.8
	S.B. Area, July 68	7.32	1.50	66	±0.37	6.95-7.69	10.1
	Total Lake, 66 & 67	6.86	0.31	41	±0.10	6.76-6.96	2.9
Alkalinity	S.B. Area, June 68	41356	1757	90	±369	40987-41725	1.8
	S.B. Area, July 68	43530	2445	66	±602	42828-44132	2.8
	Total Lake, 66 & 67	42413	2558	75	±591	41822-43004	2.8
Dissolved Oxygen	S.B. Area, June 68	13544	504	84	±109	13435-13653	1.6
	S.B. Area, July 68	12875	198	97	±40	12835-12915	0.6
	Total Lake, 66 & 67	12756	1213	64	±303	12453-13059	4.8
NO_2-NO_3	S.B. Area, June 68	282.9	30.7	88	±6.5	276.4-289.4	4.6
	S.B. Area, July 68	274.7	29.5	97	±6.0	268.7-280.7	4.4
	Total Lake, 66 & 67	193.2	37.6	73	±8.8	184.4-202.0	9.1
Sulfate	S.B. Area, June 68	1859	435	91	±91	1768-1950	9.8
	S.B. Area, July 68	2226	433	97	±88	2138-2314	7.9
	Total Lake, 66 & 67	2861	904	75	±209	2652-3070	14.6
Chloride	S.B. Area, June 68	1460	163.2	91	±34	1426-1494	4.7
	S.B. Area, July 68	1421	138.4	97	±28	1393-1449	3.9
	Total Lake, 66 & 67	1438	390.9	76	±90	1348-1528	12.5
Dissolved Solids	S.B. Area, June 68	74.4	13.0	90	±2.7	71.7-77.1	7.3
	S.B. Area, July 68	60.8	8.5	95	±1.7	59.1-62.5	5.6
	Total Lake, 66 & 67	62.6	17.4	52	±4.8	57.8-67.4	15.3
Turbidity	S.B. Area, June 68	0.26	0.14*	75	±0.03*	0.23-0.29	23.1
	S.B. Area, July 68	0.28	0.16*	63	±0.04*	0.24-0.32	28.6
	Total Lake, 66 & 67	0.32	0.18*	76	±0.04*	0.28-0.37	28.1

TABLE 9
(Continued)

Determination	Location	Average	Standard Deviation	n	Confidence Limits	95% Confidence Interval	Interval as % of Mean
Ammonia	S.B. Area, June 68	17.1	1.23*	91	±0.25‡	15.1-19.3	24.6
	S.B. Area, July 68	12.6	0.70*	93	±0.14‡	11.6-13.6	15.9
	Total Lake, 66 & 67	25.4	1.37*	70	±0.32‡	22.3-28.7	25.2
Organic N	S.B. Area, June 68	63.8	3.55*	41	±1.09‡	47.6-82.4	54.5
	S.B. Area, July 68	60.2	3.00*	90	±0.62‡	51.0-70.2	31.9
	Total Lake, 66 & 67	62.2	2.67*	70	±0.63‡	52.7-62.6	32.0
Phosphorus (Total)	S.B. Area, June 68	9.18	1.14*	84	±0.24‡	7.78-10.69	31.7
	S.B. Area, July 68	5.80	0.80*	93	±0.16‡	5.06-6.60	26.6
	Total Lake, 66 & 67	11.20	1.01*	74	±0.23‡	9.73-12.82	27.6
Iron (Total)	S.B. Area, June 68	91.4	2.52*	73	±0.58‡	80.6-102.8	24.3
	S.B. Area, July 68	60.1	2.47*	80	±0.54‡	52.0-68.7	27.8
	Total Lake, 66 & 67	65.3	2.36*	24	±1.00‡	50.1-82.4	49.5
Lead	S.B. Area, June 68	15.4	1.45*	68	±0.34‡	12.8-18.1	34.4
	S.B. Area, July 68	16.5	1.21*	79	±0.27‡	14.4-18.7	26.1
	Total Lake, 66 & 67	43.7	2.84*	11	±1.91‡	22.1-72.6	116.6
Zinc	S.B. Area, June 68	11.9	0.83*	27	±0.33‡	9.7-14.3	38.7
	S.B. Area, July 68	8.5	1.07*	89	±0.22‡	7.3-9.8	29.4
	Total Lake, 66 & 67	37.8	1.93*	18	±0.96‡	26.9-50.6	62.7
Nickel	S.B. Area, June 68	14.5	0.79*	27	±0.31‡	12.2-17.0	33.1
	S.B. Area, July 68	22.0	1.80*	83	±0.39‡	18.5-25.8	33.2
	Total Lake, 66 & 67	18.3	0.44*	21	±0.20‡	16.6-20.1	19.1
	B. Surface and Mid-Depth Samples						
Dissolved Solids	S.B. Area, June 68	74.9	11.3	61	±2.84	72.1-77.7	7.5
	S.B. Area, July 68	60.3	7.8	63	±1.93	58.4-62.2	6.3
	Total Lake, 66 & 67	60.9	14.7	34	±4.94	56.0-65.8	16.1
Turbidity	S.B. Area, June 68	0.24	0.12*	60	±0.02‡	0.22-0.26	16.7
	S.B. Area, July 68	0.25	0.14*	43	±0.04‡	0.21-0.29	32.0
	Total Lake, 66 & 67	0.31	0.18*	52	±0.05‡	0.26-0.37	35.5

TABLE 9
(Continued)

Determination	Location	Average	Standard Deviation	n	Confidence Limits	95% Confidence Interval	Interval as % of Mean
Phosphorus (total)	S.B. Area, June 68	7.13	0.96*	56	±0.25‡	5.86-8.53	37.4
	S.B. Area, July 68	5.02	0.68*	65	±0.17‡	4.28-5.81	30.5
	Total Lake, 66 & 67	11.40	1.01*	51	±0.28‡	9.55-13.32	33.1
Iron (Total)	S.B. Area, June 68	85.4	2.51*	58	±0.65‡	73.8-97.8	28.1
	S.B. Area, July 68	56.8	1.92*	59	±0.49‡	49.7-64.5	26.1
	Total Lake, 66 & 67	65.3	2.36*	24	±1.00‡	50.1-82.4	49.5
Lead	S.B. Area, June 68	15.3	1.39*	47	±0.40‡	12.3-18.6	41.2
	S.B. Area, July 68	17.2	1.14*	50	±0.32‡	14.7-20.0	30.8
	Total Lake, 66 & 67	43.7	2.84*	11	±1.91‡	22.1-72.6	115.6
Zinc	S.B. Area, July 68	9.06	1.10*	57	±0.41‡	6.76-11.70	54.5
	Total Lake, 66 & 67	37.8	1.93*	18	±0.96‡	26.9-50.6	62.7
Nickel	S.B. Area, July 68	25.2	2.13*	59	±0.54‡	20.1-30.9	42.9
	Total Lake, 66 & 67	18.3	0.44*	21	±0.21‡	16.6-20.2	19.7

*Standard Deviation is the standard deviation of the square roots

‡Confident limits are those of the square root distribution.

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9. Reserve Mining Company memo of April 25, 1969, to K. M. Haley from J. C. Gay, "Comparison of Secchi Disc Readings and Turbidity Readings Obtained in the Silver Bay Area to Those Obtained Along the Wisconsin Shore of Lake Superior."

10. Reserve Mining Company memo of April 29, 1969, to K. M. Haley from J. C. Gay, "Analysis of Variance of Data Shown in Figures 24 through 95 of 'The Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior," U. S. Department of the Interior, December, 1968.' - Revised."

R. A. Ragotzkie

MR. FRIDE: I think that would help to shorten our presentation if that is satisfactory with you.

Consistent with the policy that Reserve has always had since the beginning of its operation, it has employed not only top scientists on its own payroll but has consulted with leading minds throughout this country.

The next speaker we have, Mr. Chairman, is Professor of the Department of Meterology of the University of Wisconsin. All of these men who follow, as well as those who preceded him have impeccable credentials in their field. I will only refer to their background.

This gentlemen is Director of the Marine Studies Center. He has degrees in biology, sanitation, zoology, and has received his doctorate at the University of Wisconsin. He is Chairman of the Advisory Committee, Division of Environmental Sciences, for the National Science Foundation and a director of the International Association for Great Lakes Research. Interestingly enough, among the many contributions he has made in the scientific field is one report on currents which the FWPCA cited in their appraisal report.

I now call on Dr. Robert Ragotzkie.

R. A. Ragotzkie

STATEMENT OF DR. ROBERT A. RAGOTZKIE,
DIRECTOR, MARINE STUDIES CENTER, UNIVERSITY
OF WISCONSIN, MADISON, WISCONSIN

DR. RAGOTZKIE: My name is Robert A. Ragotzkie and I am from the University of Wisconsin. I am a consultant to Reserve Mining Company on the disposal of taconite tailings in Lake Superior.

I shall abbreviate my statement as much as possible in the interest of time. The full statement is on file with the conferees.

In my capacity as consultant for Reserve I have done the following:

I have reviewed the report "An Appraisal of Water Pollution in the Lake Superior Basin" issued by the FWPCA in April of 1969 and the material contained in the FWPCA reports referred to in the bibliography of the appraisal report.

I have reviewed data on Lake Superior in the vicinity of Silver Bay obtained by Reserve Mining Company in 1968 and 1969.

I have inspected the instruments and research vessel owned and operated by Reserve Mining Company for the purpose of measuring and monitoring the physical properties and the motions of the water of Lake Superior in the vicinity of Silver Bay.

With respect to the second item, I believe the physical data obtained by Reserve is accurate and reliable. With respect to the third item, the instrumentation owned and

used by Reserve are of excellent quality, and they and the company have the capability in terms of a well-equipped research vessel and personnel to use this equipment in an effective manner.

On the subject of density currents:

Density currents can occur in lakes whenever sufficient solid material is suspended or dissolved in the water to increase its density above the density of water at the same temperature. Such currents occur quite frequently in reservoirs and in natural lakes after extremely heavy rainfall.

The decision to dispose of taconite tailings in an aqueous suspension in Lake Superior by Reserve was based on the prediction that this suspension would form a density current and thereby transport the tailings to the bottom in the deep trough paralleling the Minnesota shore in the Silver Bay area. All available evidence indicates that density currents do develop and that the tailings material is being deposited in the deep trough.

The isotach map of tailings prepared by the Reserve Mining Company and issued 20 January 1969, shows that the tailings are being deposited in an elongated pattern oriented parallel to the shore and extending to the southwest. Nearly all of this deposit is located beyond the 400-foot depth contour.

The actual existence of the density current is clearly documented by many observations by FWPCA personnel and by Reserve Mining Company personnel.

R. A. Ragotzkie

I would like to have the first slide, please, and would you dim the lights at the same time?

I must make a few comments on the thermal behavior of Lake Superior in order to put the results here.

The thermal behavior of Lake Superior is an important factor to consider in examining the efficacy of density currents in disposing of taconite tailings to the bottom of the deep trough. In summer, heating occurs at the surface and through the action of the wind a layer of fairly well mixed and relatively warm water develops (the epilimnion). Below this layer is a zone in which the temperature decreases more rapidly with depth (the thermocline). Below this is a zone of cold water (the hypolimnion) which in Lake Superior has a temperature of about 3.8°C, to 3.9° C., the temperature at which water has its maximum density. The thermocline is a layer of great stability, i.e., vertical mixing is sharply inhibited. The significance of this is that the thermocline effectively physically and chemically isolates the deep, dense water (hypolimnion) of the lake from the surface layer.

During the fall season the surface water cools until it reaches the temperature of maximum density (4°C at the surface), and convection caused by the sinking of this cold, dense water, together with wind action results in mixing of the epilimnion (the surface water, that is) and the disappearance of the thermocline. At this time the lake can theoretically mix from top to bottom, but in fact, it may not due to the extreme depth of

the lake and the fact that the bottom water is already at the temperature of maximum density, thus eliminating the convective mechanism for vertical mixing.

Further cooling of the surface below 4°C results in a decrease in density and the development of a cold, but less dense surface layer overlying the deeper hypolimnion which retains the temperature of maximum density. Thus, in winter Lake Superior is stably stratified with a "reverse" thermocline which again functions as a "lid" on the hypolimnion, effectively isolating it from the surface waters. During early summer warming again occurs and the process repeats.

I repeat this statement, due to the great depth of Lake Superior and the existence of maximum density water at all times in the lower layer (probably below 500 to 600 feet) there is good reason to doubt that mixing from top to bottom occurs every year or even every several years. There is not adequate data available to me to prove that mixing does occur. Therefore, the isolation of the bottom layer which exists during the summer and winter stratified periods may also exist during the brief periods in spring and fall when the temperature is at or just below 4°C from top to bottom.

I will now conclude with a presentation of more recent data.

In April, 1969, Reserve Mining Company personnel made additional, more detailed observations of the turbidity and temperature distribution near Silver Bay using an *in situ*

transmissometer. These results are presented in Figure 1969-1. Stations B through F are along a line extending from the delta to the southwest into the trough of deep water. From this vertical section it is clear that the turbid water is descending along the bottom directly into the trough of deep water, reaching a depth of nearly 1,000 feet. There is also a separation of flow with a less dense (less turbid) tongue of water moving away from the delta in the 300-400-foot layer. This tongue is also descending and is apparently associated with an early season vertical thermal gradient which is typical of winter conditions. This stable but weak thermal stratification is apparently sufficient to cause a part of the less turbid water to remain above the bottom and move out along the winter thermocline which still prevailed. From Figure 1969-1 it can be seen that this tongue of the density current is weaker and less turbid than the main, bottom current, and that it is barely identifiable at Station F, which is about 8 miles from the delta.

If can be concluded, therefore, that most of the tailings are being carried directly into the trough where the material is deposited. The other tongue moves downward and dissipates as the suspended material settles out. Once deposited, the tailings material would not be expected to become resuspended because of the sluggishness of currents near the bottom.

The density current mechanism, then, is functioning to rapidly transport the tailings material downslope through the thermocline and into very deep water where it is deposited on the

R. A. Ragotzkie

bottom. Once through the thermocline, the stability of the thermal stratification effectively isolates the material from recirculation into the surface waters.

I would now like to give my conclusions.

1. The FWPCA data and the 1968 Reserve observations strongly indicate and the 1969 Reserve observations prove beyond a doubt that density currents exist and that they are operating effectively to transport the taconite tailings into the deep trough adjacent to the Silver Bay shore line.

2. Once the tailings are transported below the thermocline, both winter and summer, the stability of the water stratification will tend to isolate the material from further recirculation into the surface waters. This isolation certainly exists during the summer and winter stratification and may also prevail during the brief periods when the lake is isothermal.

Thank you, Mr. Chairman. (Applause.)

MR. DOMINICK: Are there any questions?

(No response.)

MR. DOMINICK: No questions. Thank you very much.

(Statement of Dr. Ragotzkie in its entirety follows.)

STATEMENT ON TACONITE TAILINGS DISPOSAL IN LAKE SUPERIOR BY RESERVE MINING COMPANY AT SILVER BAY, MINNESOTA

ROBERT A. RAGOTZKIE
UNIVERSITY OF WISCONSIN

I am a consultant to Reserve Mining Company on the disposal of their taconite tailings in Lake Superior. My professional background and publications are given in the attached vitae.

In this capacity, I have done the following:

1. Reviewed the report summary and appended reports and data contained in "Basic Studies on Environmental Impact of Taconite Waste Disposal in Lake Superior," U. S. Department of Interior and others, December, 1968. I have also reviewed report, "An Appraisal of Water Pollution in the Lake Superior Basin" issued by the FWPCA in April, 1969.
2. Reviewed data on Lake Superior in the vicinity of Silver Bay obtained by Reserve Mining Company in 1968 and 1969.
3. Inspected the instruments and research vessel owned and used by Reserve Mining Company for the purpose of measuring and monitoring the physical properties and motions of the water of Lake Superior in the vicinity of Silver Bay.

With respect to item two, I believe the physical data obtained by Reserve is accurate and reliable. With respect to item three, the instrumen-

tation owned and used by Reserve are of excellent quality, and they have the capability in terms of a well-equipped research vessel and personnel to use this equipment in an effective manner.

Density Currents

Density currents can occur in lakes whenever sufficient solid material is suspended or dissolved in the water to increase its density above the density of water at the same temperature. Such currents occur quite frequently in reservoirs where the inflow contains a high suspended solids load, e.g., Lake Mead (Bell, 1942), Cherokee Reservoir (Lyman, 1944). Density currents have also been observed in natural lakes after the run-off of silt-laden water following heavy rainfall (Bryson and Suomi, 1951).

The decision to dispose of taconite tailings in an aqueous suspension in Lake Superior by Reserve Mining Company was based on the prediction that this suspension would form a density current and thereby transport the tailings to the bottom in the deep trough paralleling the Minnesota shore in the Silver Bay area. All available evidence indicates that density currents do develop and that the tailings material is being deposited in this deep trough.

The isotach map of tailings prepared by the Reserve Mining Company 20 January 1969, shows that the tailings are being deposited in an elongated pattern oriented parallel to the shore and extending toward the southwest. Nearly all of this deposit is located beyond the 400-foot depth contour.

The actual existence of the density current is clearly documented by many observations by FWPCA personnel and by Reserve Mining Company personnel.

FWPCA data on iron concentration (Figs. 24-26 and 49-54), suspended solids (Figs. 42-44 and 89-91), and turbidity (Figs. 45-47 and 92-94) in section three of the December, 1968, Basic Studies Report of the Department of Interior indicate almost without exception that the highest values for these properties occur near the bottom or occasionally in mid-water (depth not defined), but never at the surface. These results are consistent with the presence of density currents.

In 1968 Reserve Mining Company collected three sets of data on the lake in the vicinity of Silver Bay. The first set of observations, 13 June - 11 July, were made before appreciable warming of the surface water had occurred. Water temperatures were between 3° and $5^{o}C$, and almost no thermal stratification was present. The turbidity increased sharply near the bottom at stations 1-5 indicating a density current was present. Stations 6 and 7 were located eastward and offshore respectively and no turbidity stratification was observed. This is as expected in view of the prevailing longshore currents in the Silver Bay area.

The second set of Reserve data was collected in the early fall, 4-12 September, when thermal stratification was present. At this time turbidity at stations 1-4 increased at the level of the thermocline and continued high all the way to the bottom. At station 5 the turbidity increase was located quite close to the bottom while at stations 6 and 7, no well defined turbidity stratification was evident.

The third set of Reserve's 1968 data was obtained during the fall, 29 October - 1 November, when thermal stratification was still present, but

weaker. The thermocline, when present, was deeper and weak, in the vicinity of 100 to 300 feet. Turbidity maxima occurred near the bottom at stations 1 - 3 but was about 100 feet above the bottom at stations 4 and 5. At stations 6 and 7, slight increases in turbidity were found near the bottom.

These data clearly show that density currents were operating in the vicinity of the delta at the Silver Bay plant. In some cases the density current apparently was located some distance above the bottom due to the thermal stratification prevailing at the time. This would occur when the increased density due to the suspended load did not exceed the density of the cold water of the hypolimnion. In most cases, however, the density current was apparently flowing along the bottom, descending as the lake bottom sloped downward.

Thermal Behavior of Lake Superior

The thermal behavior of Lake Superior is an important factor to consider in examining the efficacy of density currents in disposing of taconite tailings to the bottom of the deep trough. In summer, heating occurs at the surface and through the action of the wind a layer of fairly well mixed and relatively warm water develops (the epilimnion). Below this layer is a zone in which the temperature decreases more rapidly with depth (the thermocline). Below this is a zone of cold water (the hypolimnion) which in Lake Superior has a temperature of about 3.8 to 3.9°C, the temperature at which water has its maximum density. The thermocline is a layer of great stability, that is, vertical mixing is sharply inhibited. The significance of this is that the thermocline effectively physically and chemically isolates the deep, dense water (hypolimnion) of the lake from the surface layer.

During the fall season the surface water cools until it reaches the temperature of maximum density ($4^{o}C$ at the surface), and convection caused by the sinking of this cold, dense water, together with wind action results in mixing of the epilimnion and the disappearance of the thermocline. At this time the lake can theoretically mix from top to bottom, but in fact, it may not due to the extreme depth of the lake and the fact that the bottom water is already at the temperature of maximum density, thus eliminating the convective mechanism for vertical mixing.

Further cooling of the surface below $4^{o}C$ results in a decrease in density and the development of a cold, but less dense surface layer overlying the deeper hypolimnion which retains the temperature of maximum density. Thus, in winter Lake Superior is stably stratified with a "reverse" thermocline which again functions as a "lid" on the hypolimnion, effectively isiolating it from the surface waters. During early summer warming again occurs and the process repeats.

Due to the great depth of Lake Superior and the existence of maximum density water at all times in the lower layer (probably below 500 - 600 feet) there is good reason to doubt that mixing from top to bottom occurs every year or even every several years. Therefore, the isolation of the bottom layer which exists during the summer and winter stratified periods may also exist during the brief periods in spring and fall when the temperature is at or just below $4^{o}C$ from top to bottom.

1969 Data on Density Currents

In April, 1969, Reserve Mining Company personnel made additional, more detailed observations of the turbidity and temperature distribution near

Silver Bay using an in situ transmissometer. These results are presented in Fig. 1969-1. Stations B through F are along a line extending from the delta to the southwest into the trough of deep water. From this vertical section it is clear that the turbid water is descending along the bottom directly into the trough of deep water, reaching a depth of nearly 1,000 feet. There is also a separation of flow with a less dense (less turbid) tongue of water moving away from the delta in the 300-400 foot layer. This tongue is also descending and is apparently associated with an early season vertical thermal gradient which is typical of winter conditions. This stable but weak thermal stratification is apparently sufficient to cause a part of the less turbid water to remain above the bottom and move out along the winter thermocline which still prevailed. From Fig. 1969-1 it can be seen that this tongue of the density current is weaker and less turbid than the main, bottom current, and that it is barely identifiable at station F which is about eight miles from the delta.

It can be concluded, therefore, that most of the tailings are being carried directly into the trough where the material is deposited. The other tongue moves downward and dissipates as the suspended material settles out. Once deposited, the tailings material would not be expected to become re-suspended because of the sluggishness of currents near the bottom.

The density current mechanism, then, is functioning to rapidly transport the tailings material downslope through the thermocline and into very deep water where it is deposited on the bottom. Once through the thermocline, the stability of the thermal stratification effectively isolates the material from recirculation into the surface waters.

Conclusions

1. The FWPCA data and the 1968 Reserve observations strongly indicate and the 1969 Reserve observations prove beyond a doubt that density currents exist and that they are operating effectively to transport the taconite tailings into the deep trough adjacent to the Silver Bay shoreline.

2. Once the tailings are transported below the thermocline, both winter and summer, the stability of the water stratification will tend to isolate the material from further re-circulation into the surface waters. This isolation certainly exists during the summer and winter stratification and may also prevail during the brief periods when the lake is isothermal.

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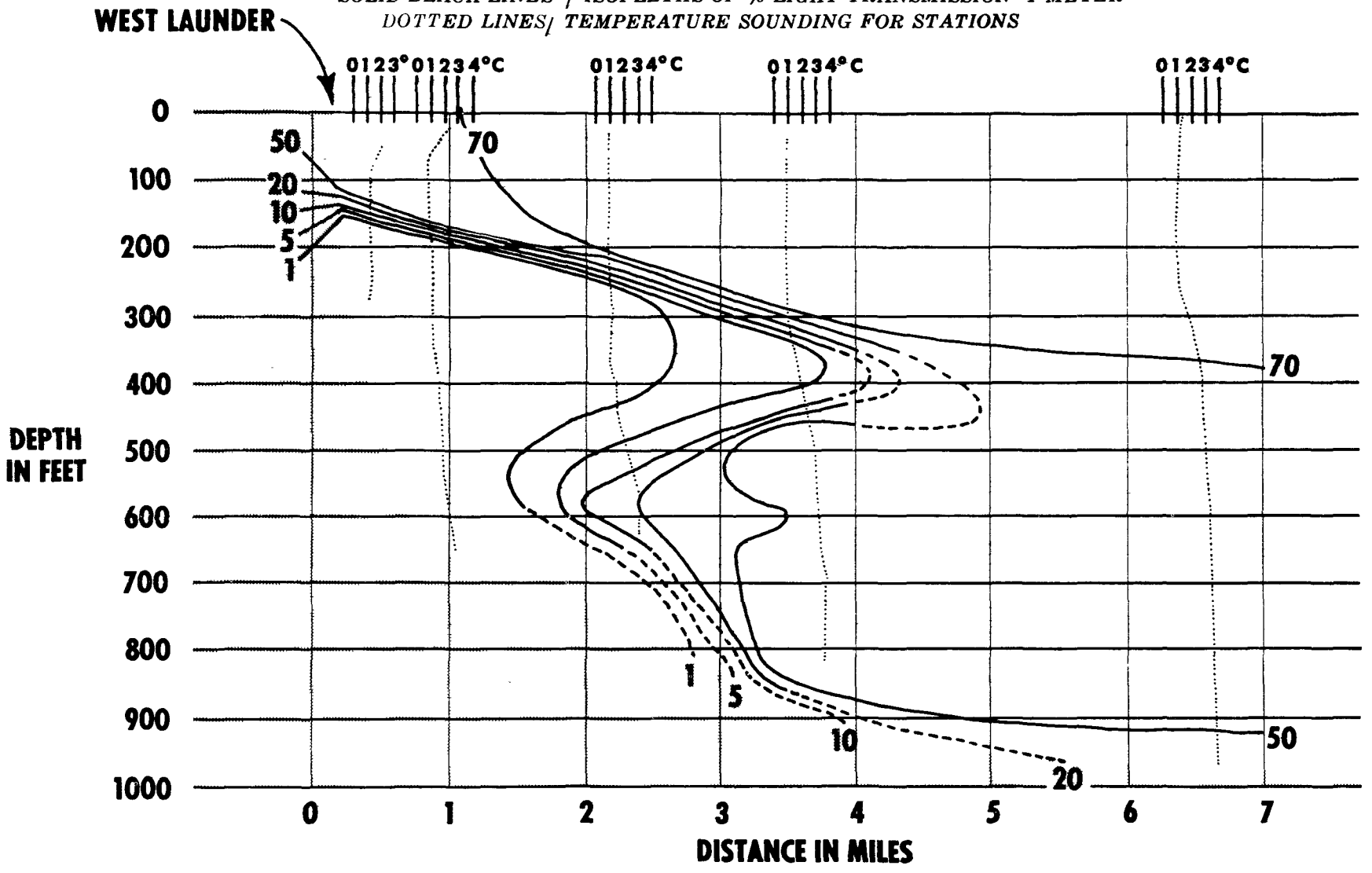
FIGURE 1969 - 1

TURBIDITY SECTION 5 - 11 APRIL 1969

SOLID BLACK LINES / ISOPLETHS OF % LIGHT TRANSMISSION - 1 METER
DOTTED LINES / TEMPERATURE SOUNDING FOR STATIONS



Vitae for Robert A. Ragotzkie

Present Positions: Professor, Department of Meteorology 1964-
Director, Marine Studies Center, UW-Madison
1968 -

Education: B. S. Rutgers University, 1948 (Biology)
M. S. Rutgers University, 1950 (Sanitation)
Ph. D. University of Wisconsin, 1953 (Meteorology-Zoology)

Professional Experience: University of Georgia - 1954 - 57, Assistant Professor of Zoology & Research Coordinator, Marine Biology Laboratory, Sapelo Island, Georgia
1957-59 , Associate Professor of Zoology and Director, University of Georgia Marine Institute, Sapelo Island, Georgia.
University of Wisconsin - 1959 - 61, Assistant Professor of Meteorology
1961 - 64 , Associate Professor of Meteorology
1964 - present Professor of Meteorology
1963 - 67 Chairman, Department of Meteorology
1967 - Present Director, Marine Studies Center

Field of Research: Physical oceanography, remote sensing of the sea surface, Great Lakes Circulations

Society Membership: American Society Limnology and Oceanography
International Association for Great Lakes Research
International Society of Limnology
American Geophysical Union
AAAS (Fellow)
Ecological Society of America
American Meteorological Society

Other Activities: Chairman of Advisory Committee, Division of of Environmental Sciences, National Science Foundation
Environmental Studies Committee, University of Wisconsin
Chairman, Ph. D. Committee, Oceanography and Limnology, University of Wisconsin
CIC Ocean Sciences Conference Group
Member Board of Directors, International Association for Great Lakes Research

Robert A. Ragotzkie
Marine Studies Center
1225 West Dayton Street
University of Wisconsin
Madison, Wisconsin 53706
Phone: (608) 262-1585

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R. C. Bright

MR. FRIDE: The next speaker is Dr. Robert C. Bright. Dr. Bright is Associate Professor of Geology and Ecology at the University of Minnesota. He is a member of the American Society of Limnology & Oceanography and has served as a State Paleontologist from 1963 to 1964. He has degrees from Uppsala University in Sweden and George Washington University and received his doctorate from the University of Minnesota.

Among Dr. Bright's many contributions to scientific studies of Minnesota lakes with respect to water chemistry, his report reflects many months of research, testing, and analysis of limnological effects of tailings in Lake Superior.

Dr. Bright.

STATEMENT OF DR. ROBERT C. BRIGHT,
ASSOCIATE PROFESSOR OF GEOLOGY AND ECOLOGY,
UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MINNESOTA

DR. BRIGHT: Mr. Chairman, conferees, ladies and gentlemen:

My name is Robert Bright. As you heard, I am from the University of Minnesota, Minneapolis, I might add.

I have served as a consultant to the Research and Development Department of Reserve Mining Company in connection with its Lake Superior limnological research program. Limnology is the study of lakes, including physical, chemical, and biological conditions. A resumé of my professional and educational background is appended. My responsibilities in connection with this

program have been (1) to evaluate their research and to determine whether it is being conducted in the most reliable manner, (2) to provide new field and laboratory techniques and to update old ones where advisable, and (3) to evaluate and criticize data obtained from their research, and, more recently (4) to evaluate available State and Federal reports that pertain to disposal of tailings in the lake. As to the first responsibility, it is my judgment that Reserve has, in the past year, produced the most comprehensive data available for Lake Superior and that it is extremely reliable.

Composition of Tailings

An investigation of the mineralogy and chemistry of the tailings deposited in Lake Superior shows that the constituents are quartz (silicon dioxide), cummingtonite (iron, magnesium-silicate), and magnetite (iron oxide), with minor amounts of amphiboles (related to cummingtonite), pyroxenes (iron, magnesium-silicates), fayalite (magnesium silicate), and with trace (much less than one percent of the total) amounts of garnet, feldspar, micas, and "graphite".

The iron, magnesium-silicates and magnetite are known to sometimes contain trace amounts of copper, zinc, nickel, chromium, and lead. To my knowledge, none of those trace metals have been reported in quartz, which is the most abundant mineral in the tailings. Such trace metals are structurally bound and chemically bonded within their various host minerals.

With your permission I will skip a couple of these

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comments in the interest of time.

FWPCA states that "a distinguishing characteristic of tailings discharged by Reserve Mining Company is the presence of large quantities of the amphibole cummingtonite." What they mean by "large quantities" is unknown as they present no quantitative information, although quantity is a critical factor. For example, cummingtonite has been found in the following North Shore streams: Split Rock River, Gooseberry River, French River, Baptism River, and Little Marais River. Under various cond tions those streams are delivering cummingtonite to the lake. Where the material is fine enough, it is suspended in the lake, and X-ray analyses of the suspended load indicate the presence of cummingtonite. It is therefore, possible that the material could be wrongly identified the same as tailings from Reserve's discharge.

Solubility of Tailings in Lake Superior and Toxic Metals

Statements by FWPCA concerning quantities of trace metals delivered to Lake Superior each day via tailings (1969, page 28) and that small increases in such metals (page 46) in the lake could be toxic might lead the unsuspecting reader to believe that trace metals in Reserve's tailings are toxic. In any body of water, metals are toxic only if available to an organism - that is, if it can be assimilated into its system. Long-term, careful studies to determine if trace metels are leached from tailings in

the lake were initiated by Reserve. Experiments consisted of placing tailings in bottles of filtered Lake Superior water, maintaining the samples in darkness and at 4°C to simulate conditions at the lake bottom, and then monitoring any changes in the chemical constituents in the water. Data show that metals such as copper, zinc, and nickel are not leached from the tailings in Lake Superior water so as to become toxic to aquatic life.

That conclusion is further supported by a comparison of the most biologically active form of the metals in question in intake water and discharge water. No significant difference was found.

Chemical Constituents in Western Lake Superior

In order to establish whether or not Reserve's discharge was affecting the lake chemically, several hundred water analyses were accomplished. Samples for water analyses were taken under rigid standards to minimize contamination and to assure accurate location. Laboratory techniques for chemical analyses were the most reliable available, including Atomic Absorption. Three transects across the lake were made to determine any variation in surface-water chemistry. These were located between Taconite Harbor and the South Shore, Silver Bay and Sand Island, and Encampment River and Port Wayne. The surface-water analyses (Figure 2-4) indicate that there were no abnormal concentrations of nutrients or toxic metals either northeast or southwest (prevailing current direction) of Silver

Bay that could be related to Reserve's discharge. It must also be concluded from the surface data that during August 1968 there were higher concentrations of several toxic substances and nutrients along the Wisconsin shore that had no relation to Reserve's tailings.

In deference to time I will forego the slides at this point.

Seven stations on the lake were selected for detailed observations for one year; their location is shown in Figure 1. Figures 5, 6 and 7 show results of the various chemical and physical analyses performed on water at each depth. The quantities of biologically available copper, zinc, and nickel are essentially the same from surface to bottom all summer in 1968 at each station. Even though samples were procured from within the density current or just above the bottom tailings deposit, they did not vary. Such a condition further supports the results of the leaching study to the effect that those metals are not released from the tailings to the water.

Phytoplankton (algae) as Indicators of Effects of Tailings

Since June of 1968, controlled quantitative samples of water have been taken at each of the water-chemistry sites in lake for the purpose of assessing the standing crop of phytoplankters in Lake Superior. One-hundred milliliters of unfiltered water were collected at each site and an algal preservative that

causes minimum cell distortion was added. Samples were kept cool and dark until needed. The algae were counted by the best method possible, under an inverted Wild microscope at a magnification of 500X.

The population structure of the standing crop of algae at the seven permanent stations in June and July of 1968, with the lake nearly homothermal, was remarkably homogenous both vertically and horizontally. The number of cells averaged 2 million per liter, with little variation with depth or between stations. Seventy to 90 percent of those were nannoplankters ($<\mu$). These are forms which are less than 50 microns in size.

Again we will skip the slides.

To further demonstrate the similar ubiquity of all the divisions, the mean proportion of each, throughout the entire water column at each station, is shown in Figure 9. Each species was remarkably evenly distributed both vertically and laterally, 30 to 40 taxa (categories) being identified at each station, even at stations with high turbidity. Such a homogeneous distribution of algae indicates a monotonous environment and that the algae were completely unaffected locally by addition of tailings to the lake.

The September work is not quite complete, but it reflects the effect of thermocline development in the lake (see Figure 6). Above about 100-foot depth there were about 4 million cells per liter, about doubling what we had earlier, and 50 to 70 percent nannoplankters, and below that depth there

R. C. Bright

were about 1.3 million and less per liter. There were 30 to 40 taxa (categories) at each site above the thermocline, equally distributed, and a few less below. Quantitative data from the three surface transects are not yet complete, but preliminary observattions indicate that there was about a two-fold increase in abundance of surface phytoplankton on the Wisconsin South Shore, especially of diatoms. The distribution of algae suggests no effect of tailings within the area of the stations in September.

Summary

Data collected from Reserve Mining Company's limnological geological, and chemical studies of Lake Superior that I have been associated with show (1) that toxic metals are not increased in Lake Superior by disposal of tailings, and (2) that algae in the lake, which are a critical part of the fish-food chain, are not affected by the tailings in the water area studies.

Thank you. (Applause.)

MR. DOMINICK: Thank you, Dr. Bright.

Are there any questions?

Yes.

MR. PURDY: Dr. Bright, in your studies you have mentioned the leaching experiments. Would you comment on the possibility of some of these small, particle-sized substances being toxic to fish and aquatic life in some other fashion other than leaching to the water, i.e., by ingestion or over the gills structure?

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DR. BRIGHT: If these were soluble, for example, in a fish's stomach - I am not that familiar with the fish business - but if this could get in solution, perhaps in the fish's stomach, this may be.

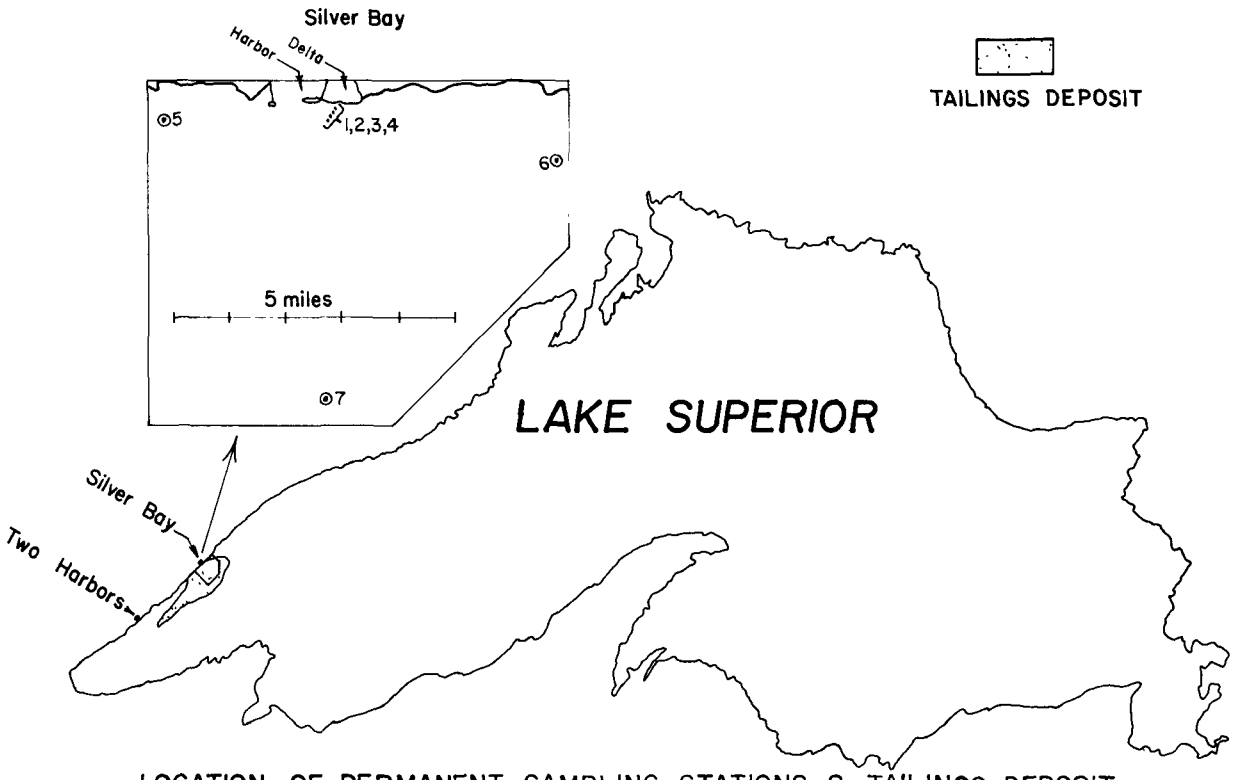
MR. PURDY: Thank you.

MR. DOMINICK: Dr. Bright, you mentioned a number of slides when you went through your presentation. Would vou supply those slides for the record so that they may be placed in the record--

DR. BRIGHT (interrupting): These are the slides of the same appendices you have in your report.

MR. DOMINICK: Fine, we will place those in the record.

(The above-mentioned slides follows.)



LOCATION OF PERMANENT SAMPLING STATIONS & TAILINGS DEPOSIT

Surface Transect, 26 Aug. 68

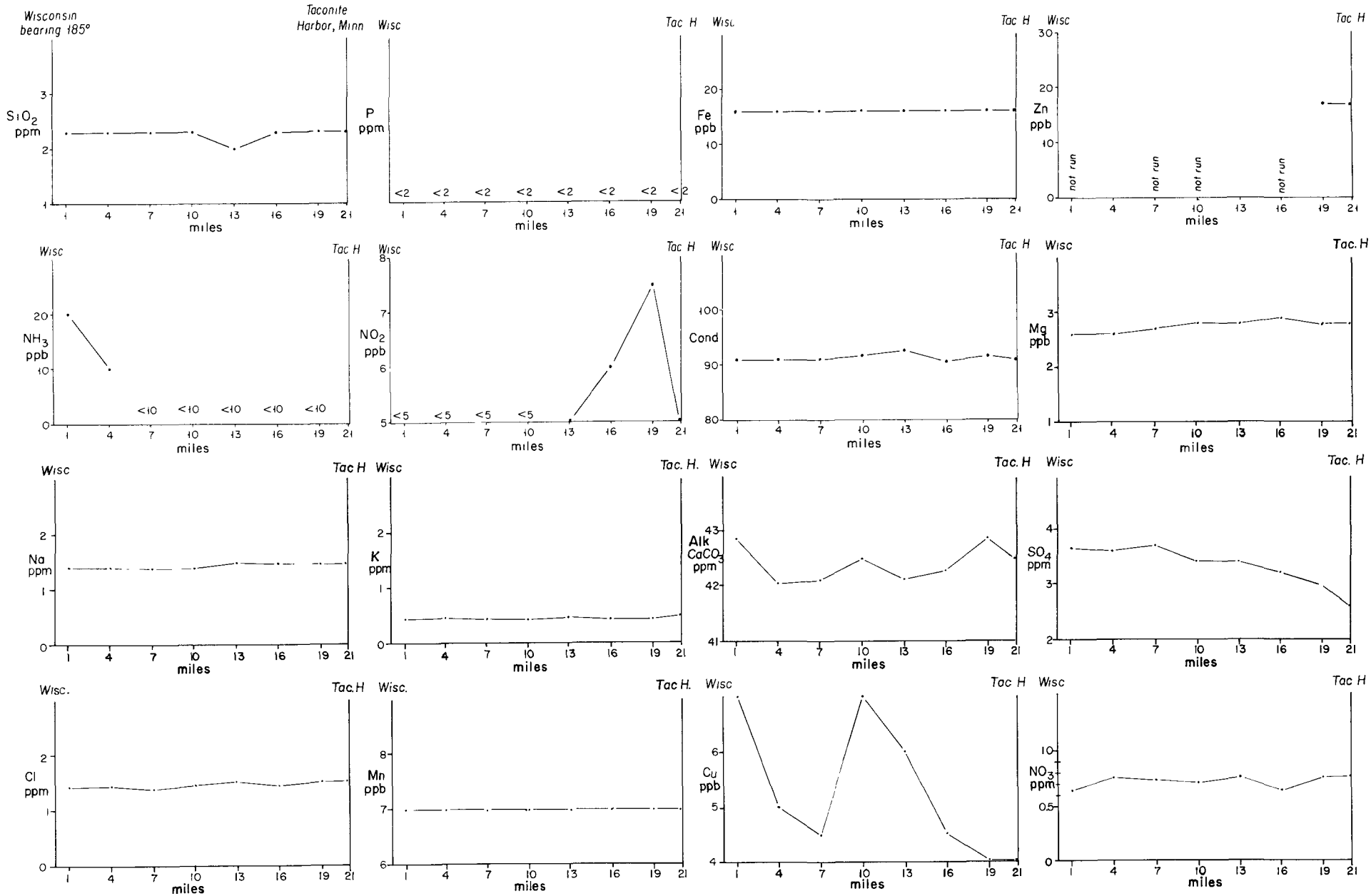
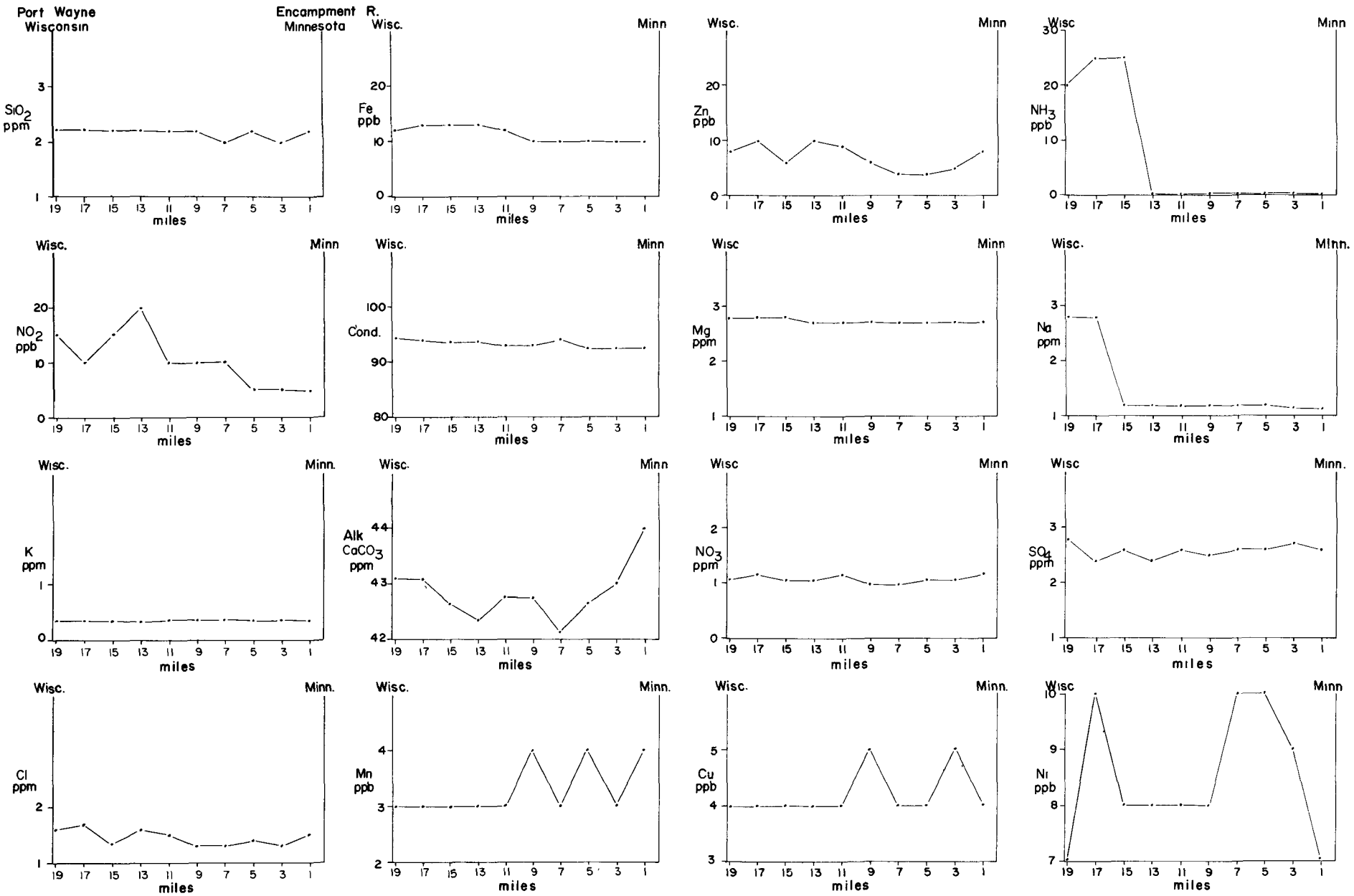
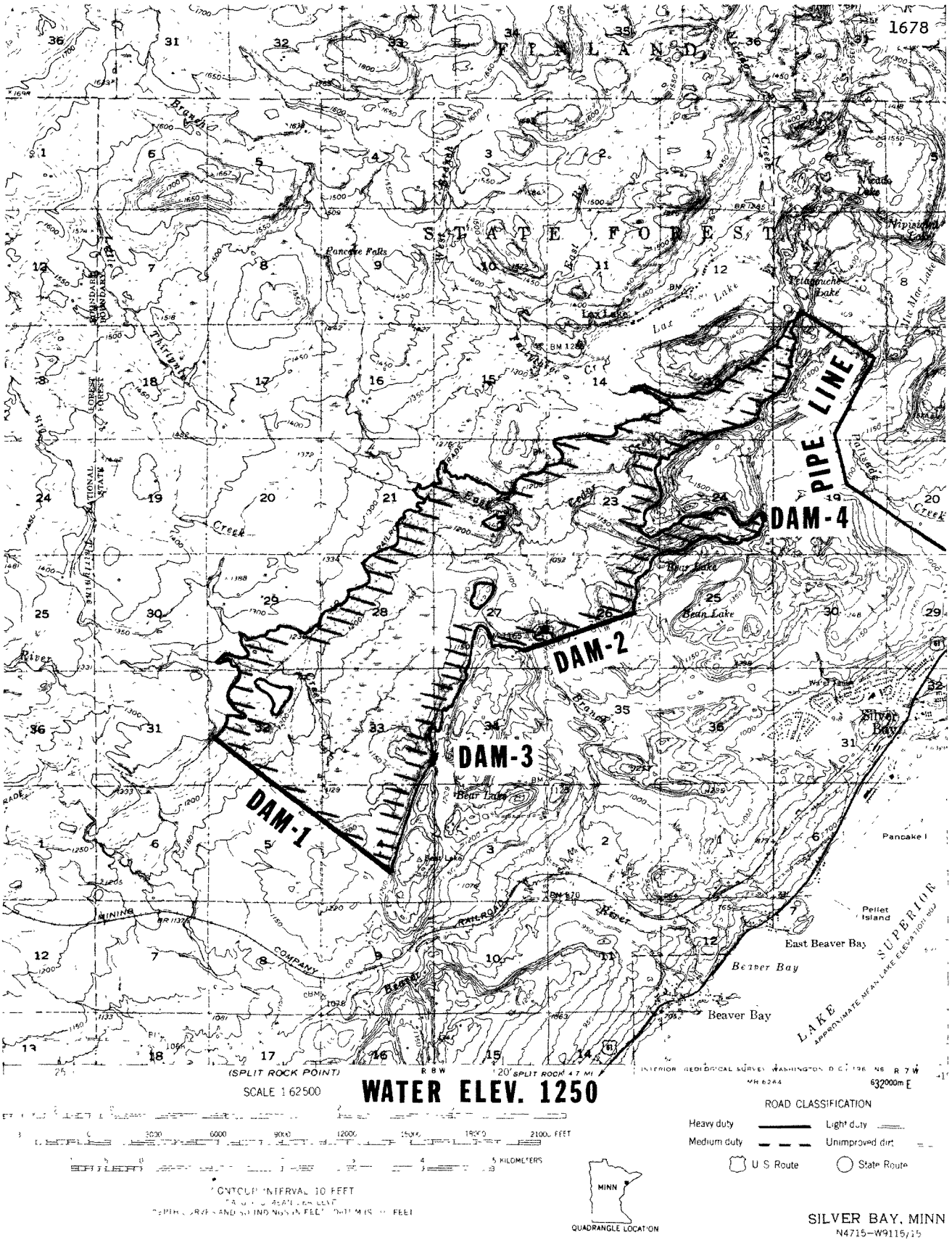


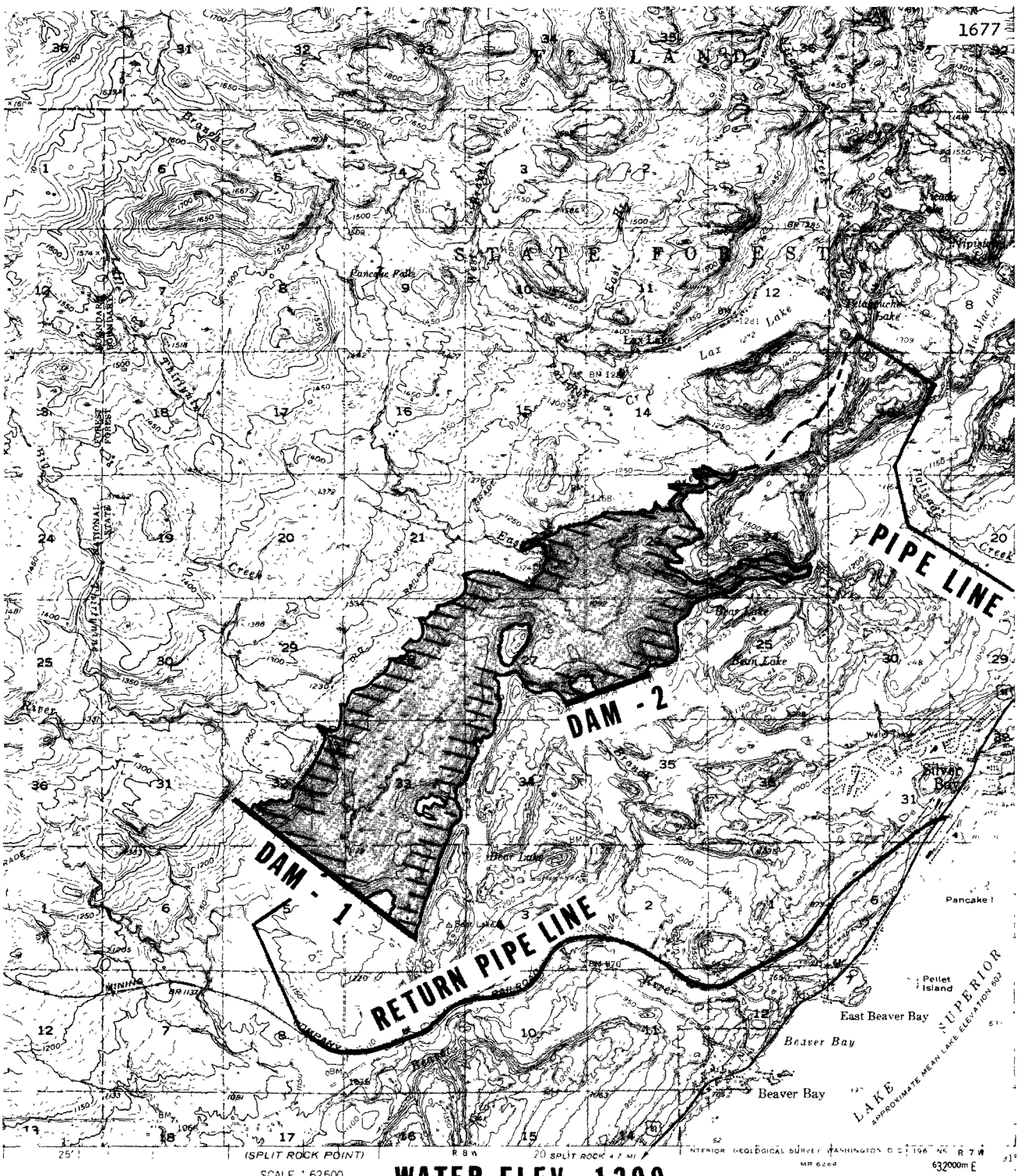
Fig. 2

Surface Water Chemistry, 20 Aug. 68

Fig. 10




1678
DAM-1
DAM-2
DAM-3
DAM-4
PIPE LINE
WATER ELEV. 1250
SCALE 1:62500
Silver Bay
Beaver Bay
East Beaver Bay
Pellet Island
Pancake I
LAKE SUPERIOR
Pancake Falls
Bear Lake
Lax Lake
Nicada Lake
Tettegouche Lake
Nipisiquit Lake
Lic Mor Lake
Silver Bay
(SPLIT ROCK POINT)
SPLIT ROCK 4.7 MI
R 8 W
R 7 W
632000m E
ROAD CLASSIFICATION
Heavy duty
Light duty
Medium duty
Unimproved dirt
U S Route
State Route
CONTOUR INTERVAL 10 FEET
QUADRANGLE LOCATION
MINN
SILVER BAY, MINN
N4715—W9115/15



SILVER BAY, MINN.
N4715–W9115/15

	Quantity	Unit Cost	Total Cost
2. MAINTENANCE AND REPAIR - continued			
7) Classifier Overflow Pumps	4	$ 1,300	$ 5,200
8) Regrind Booster, Sump, and Lub. Pumps	4	250	1,000
9) Thickener Drives	3	10,000	30,000
10) Thickener Underflow Pumps	12	12,000	144,000
11) Thickener Booster, Sump, and Lub. Pumps	9	200	1,800
12) Recycled Water Pumps	8	10 000	80,000
13) Flush Water, Sump and Sewer Pumps	3	300	900
14) Cranes	14	3,000	42,000
15) Flocculant System	L.S.	1,000	1,000
16) Computer, Instrumentation and Sampling	L.S.	24,500	24,500
17) Motorized Gates	8	400	3,200
18) Compressors	10	200	2,000
19) Repair Stl. Tanks	57	800	45,600
c. Pipe Line:			
1) 2 - 5 Man Crews - 8 Hrs./Day, 5 Days/Week Rotate Slurry Lines every 4,400 Hours of Use	20,800 Hours	9.00	187,200
2) Vehicles - 1 Truck and 1 Truck Crane per Crew including Operators	2 080 Hours	86	178,900
3) Replace Slurry Pipes			
a) Replace Pipe (one third annually)	L.S.		3,573,000
b) Replace Expansion Joints (one third annually)	L.S.		1,022,700
d. Launders	L.S.		50,000
e. Liners	L.S.		123,000
f. Misc. Pipe & Fittings	L.S.		50,000
		Total	$ 7,726,000

	Quantity	Unit Cost	Total Cost
B. OPERATING COSTS - ANNUAL			
1. OPERATING (24 hours per day) (7 days per week)			
a. Labor: (10 Men x 24 Hrs. x 365 Days) + (4 Men x 8 Hrs. x 5 Days/Week x 52 Weeks)	95,920	$ 8.00	$ 767,400
b. Transportation	L.S.		5,000
c. Electric Power (Including Lighting)	682,600,000 KWH*	.006	4,095,800
d. Heating	L.S.		79,500
e. Flocculant Consumption 13,000#/Day x 365 Days	4,745,000#	.05	237,300
f. Grinding Rods	1,100 Tons	250	275,000
g. Rod Mill Liner Replacement	1 Mill/Year		50,000
		Total	$ 5,510,000

*After four years, distribution pumping will add ---
86,000,000 x .006 = $516,000

2. MAINTENANCE AND REPAIR			
a. Building, Grounds, Roads, Utilities:			
1) Labor - 13 Men x 24 Hrs. x 365 Days	113,900	$ 9.00	$ 1,025,200
2) Transportation	L.S.		10,000
3) Road Equipment	2,000 Hours	15.00	30,000
4) Material - Road Surface, Paint, Glass, Lights, etc.	L.S.		100,000
b. Process Equipment Repair:			
1) Slurry Pumps (10 Sta. x 5 Pumps)	50	17,000	850,000
2) Booster, Seal & Sump Pumps (10 Sta. x 2 Pumps)	20	500	10,000
3) Hydro Underflow Pumps	2	9,000	18,000
4) Hydro Sump and Booster Pumps	2	200	400
5) Classifiers	4	4,600	18,400
6) Mill Accessories	4	24,500	98,000

II. CONTINUED COSTS

	Quantity	Unit Cost	Total Cost
A. ADDITIONAL DAM CONSTRUCTION			
1. RAISE DAM CRESTS FROM ELEVATION 1225 TO 1275 (Dams #1, 2, 3 and 4)			
a. Common Excavation	504,100 C.Y.	$ 1.50	$ 756,000
b. Rock Fill	8,447,400 C.Y.	2.00	16,894,800
c. Concrete	81,900 C.Y.	38	3,112,200
d. Reinforcing Bars	6,720 Tons	300	2,016,000
e. Grout Base Rock	L.S.		10,000
	Sub-Total	=	$22,789,000
	+ 10% Contingency	=	2,271,000
			$25,060,000
2. RAISE DAM CRESTS FROM ELEVATION 1275 TO 1325			
a. Common Excavation	71,800 C.Y.	$ 1.50	$ 107,700
b. Rock Fill	3,840,300 C.Y.	2.00	7,680,600
c. Concrete	67,800 C.Y.	38	2,576,400
d. Reinforcing Bars	5,700 Tons	300	1,710,000
e. Grout Base Rock	L.S.		5,000
	Sub-Total	=	$12,079,700
	+ 10% Contingency	=	1,208,300
			$13,288,000

	Quantity	Unit Cost	Total Cost
E. RIVER DIVERSION CHANNEL - Requires Dredging 2 miles of river plus Excavation of 3 miles of channel 40' wide and 7' deep.			
1. SITE			
a. Clearing	20 Acres	$ 600	$ 12,000
b. Common Excavation	200,000 C.Y.	1.50	300,000
Sub-Total		=	$ 312,000
+ 10% Contingency		=	31,000
			$ 343,000
F. RETURN WATER PIPE - 10 Miles of 48" Controlled Gravity Flow Pipeline.			
1. DAM #1 TO DELTA			
a. Excavation & Backfill	67,500 C.Y.	$ 3.75	$ 253,100
b. River Crossings	L.S.		125,000
c. 48" Dia. Stl. Pipe	4,850 Ton	550	2,668,000
d. 48" Manual Operated Valve	1 Unit	13,000	13,000
Sub-Total		=	$ 3,059,100
+ 10% Contingency			305,900
			$ 3,365,000
G. FENCE			
1. INLAND BASIN			
a. Clear & Grub	40 Acres	$ 600	$ 24,000
b. 5' Height with 3 Strands Barb Wire	21 Miles	20,000	420,000
Sub-Total		=	$ 444,000
+ 10% Contingency			44,000
			$ 488,000

	Quantity	Unit Cost	Total Cost
C. INLAND BASIN - 7,000 Acre Lake, 2 Major Dams -- one 11,000 feet long x 200 feet high and the other 6,000 feet long x 260 feet high. Several Smaller Dams.			
1. CLEARING			
a. Clearing Dam & Borrow Areas	450 Acres	$ 600	$ 270,000
	+ 10% Contingency		27,000
			$ 297,000
2. DAM CONSTRUCTION TO ELEV. 1225			
a. Dam #1			
1) Common Excavation	3,519,000 C.Y.	$ 1.50	$ 5,279,100
2) Rock Fill	12,703,600 C.Y.	2.00	25,407,200
3) Concrete	79,900 C.Y.	38	3,036,200
4) Reinforcing Bars	6,380 Tons	300	1,914,000
5) Corr. Met. Pipe - Construction Drain	1,200 L.F.	38	46,400
6) Grout Base Rock	L.S.		26,000
b. Dam #2			
1) Common Excavation	1,905,000 C.Y.	1.50	2,857,500
2) Rock Fill	8,114,400 C.Y.	2.00	16,228,800
3) Concrete	60,000 C.Y.	38	2,280,000
4) Reinforcing Bars	4,880 Tons	300	1,464,000
5) Corr. Met. Pipe - Construction Drain	2,400 L.F.	38	91,200
6) Grout Base Rock	L.S.		9,000
c. Dam #3			
1) Common Excavation	82,800 C.Y.	1.50	124,200
2) Rock Fill	109,600 C.Y.	2.00	219,200
3) Concrete	900 C.Y.	38	34,200
4) Reinforcing Bars	70 Tons	300	21,000
5) Grout Base Rock	L.S.		2,000
	Sub-Total	=	$59,040,000
	+ 10% Contingency	=	5,904,000
			$64,944,000
3. UNDERFLOW OUTLET AT DAM #1			
a. Concrete	700 C.Y.	$ 110	$ 77,000
b. 48" Dia. Steel Pipe	63 Tons	550	34,700
c. Traveling Trashrack	L.S.		27,500
d. Hoists - Manual	L.S.		2,500
e. Misc. Steel	10 Tons	625	6,300
f. 48" Manual Oper. Valve	1 Unit	13,000	13,000
	Sub-Total	=	$ 161,000
	+ 10% Contingency	=	16,000
			$ 177,000

	Quantity	Unit Cost	Total Cost
5. **ELECTRICAL** - continued			
9) 250 HP 460 V. Motor & Control	2	$ 10,350	$ 20,700
10) 250 HP 460 V. Motor & Control	4	8,280	33,120
11) 150 HP 460 V. Motor & Control	6	6,210	37,260
12) Crane Motors-20 HP, 460 V.	10	450	4,500
13) Sump Pump - 20 HP, 460 V.	20	445	8,900
14) Heater Motors - 5 HP, 460 V.	60	232	13,920
15) Motor Control Centers	10	5,520	55,200
16) Conduit & Wire for 5 and 20 HP Motors	1,100 HP	75	82,500
17) Conduit & Wire for 1000 HP Motors	10,000 L.F.	15	150,000
18) Conduit & Wire for 2.3 KV Seal Water Motors	1,000 L.F.	15	15,000
19) Conduit & Wire for 460 V. Seal Water Motors	1,100 HP	75	82,500
20) Compressor Motors - 25 HP, 460 V. (20)	500 HP	80	40,000
21) Conduit & Wire for Compressor Motors	500 HP	75	37,500
22) Control Valves, Conduit & Wire	100	620	62,000
23) Booster Seal Pump Motors, Conduit & Wire (20)	400 HP	155	62,000
24) Heaters, Controls, Conduit & Wire for 2.3 KV Motors	110	1,075	118,250
25) 200 KVA, 2.3 KV-480 V. Transformers	10	3,600	36,000
26) Switchgear (2) Units	10	34,500	345,000
27) Grounding	10 Units	5,000	50,000
28) Lighting	10 Units	39,600	396,000
29) Battery Charger & Rack	10	1,150	11,500
30) Communication Systems	L.S.		57,500
31) Spare Parts - Motors, Breakers, Contactors, Brushes, 1 - 7500 KVA Transformer, Armatures, Pole Pieces, Bearings	L.S.		300,000
d. Pump Repair Bldg.:			
1) Misc. 460 V. Motors	500 HP	80	40,000
2) Conduit & Wire for Motors	500 HP	75	37,500
3) Lighting	10,000 S.F.	3	30,000
4) Grounding	L.S.		5,000
	Sub-Total	=	$11,517,170
	+ 10% Contingency	=	1,151,830
			$12,669,000

	Quantity	Unit Cost	Total Cost
4. MECHANICAL SERVICES			
a. Plumbing:			
1) Pump Repair Bldg.	L.S.	$	$ 4,000
2) Pump Station #1	L.S.		4,000
3) Pump Stations #2 thru #10	9	4,000	36,000
b. Heating:			
1) Pump Repair Bldg. (Steam)	L.S.		100,000
2) Pump Station #1 (Steam)	L.S.		124,000
3) Pump Stations #2 thru #10 (Oil)	9	150,000	1,350,000
c. Summer Ventilation:			
1) Pump Repair Bldg. (Gravity)	--	--	--
2) Pump Station #1	L.S.		24,000
3) Pump Stations #2 thru #10	9	21,600	194,000
d. Potable Water	L.S.		250,000
	Sub-Total	=	$ 2,086,000
	+ 10% Contingency	=	209,000
			$ 2,295,000
5. ELECTRICAL			
a. Transmission Line: Inc. Clearing, Steel Towers, Electrical Materials, and Labor from Pump Station #1 to End of Line	5½ miles	$250,000	$ 1,375,000
1) Tower Fdns. - Inc. Excav.	46 each	2,000	92,000
b. Feeder to Delta Plant and Pump Station #1	2,000 L.F.	20	40,000
c. Pumping Stations #1 thru #10:			
1) Pads	10	2,100	21,000
2) 7,500 KVA, 110/KV/2.3 KV Transformer, Inc. Steel Structure, Disconnect, Lightning Arrestors and Grounding	10	80,000	800,000
3) 1000 HP, 2.3 KV Slurry Pump Motors w/Eddy Current Couplings	100	51,750	5,175,000
4) 1000 HP, 2.3 KV Reduced Voltage Starters	100	17,250	1,725,000
5) 450 HP, 2.3 KV Motor with Limitemp Controls	2	18,630	37,260
6) 400 HP, 2.3 KV Motor with Limitemp Controls	4	16,560	66,240
7) 350 HP, 2.3 KV Motor with Limitemp Controls	2	14,490	28,980
8) 300 HP, 2.3 KV Motor with Limitemp Controls	2	12,420	24,840

	Quantity	Unit Cost	Total Cost
3. EQUIPMENT AND PIPING - continued			
2) Compressors	20	$ 12,500	$ 250,000
3) Surge & Accum. Tanks (10 Sta.)	940 Tons	690	649,000
4) Spare Parts			
a) Pipe-16" Dia. Sched. 80	1,000 Tons	200	200,000
b) Exp. Jts. & Guides-16"	20	4,370	87,400
c) Victaulic Couplings-16"	300	40	12,000
d) Valves-48" Manual	1	7,000	7,000
16" Air-Operated	1	1,500	1,500
16" Manual	1	1,300	1,300
e) Pumps-16" (Impellers, Bearings & Seals)	L.S.		86,400
Pumps 14" to 8" (Impellers, Bearings & Seals)	L.S.		7,600
f) Compressor Parts	L.S.		15,000
5) Equip. in Pump Repair Bldg.	L.S.		300,000
6) Instrumentation Incl. Remote Control of 10 Pump Stations from Station #1	100 Pumps	10,000	1,000,000
b. Piping:			
1) Tunnels under Rwy. #61 and at Plant Roads:			
a) Excavation	12,500 C.Y.	2.00	25,000
b) Concrete	4,400 C.Y.	118	519,000
2) Retention Basins at Pump Stas.	L.S.		3,000
3) Pipe Line Piers:			
a) Excavation	21,000 C.Y.	2.00	42,000
b) Concrete	18,000 C.Y.	90	1,620,000
4) Pipe:			
a) 16" Dia. x Sched. 80	19,800 Tons	542	10,720,000
b) 14" Dia. x Sched. 40	276 Tons	502	139,000
c) 12" Dia. x Sched. 40	233 Tons	563	132,000
d) 10" Dia. x Sched. 40	118 Tons	570	67,000
e) 8" Dia. x Sched. 40	84 Tons	810	68,000
f) 3" Dia. x Sched. 40	14 Tons	940	13,000
5) Pipe Fittings:			
a) Saddles & Anchors-16"	15,650 pcs.	34	532,000
Saddles & Anchors-14" to 8"	1,700 pcs.	16	27,000
b) Exp. Jts. & Guides-16"	480 each	6,390	3,068,000
Exp. Jts. & Guides-14" to 8"	48 each	3,980	191,000
c) Victaulic Couplings-16"	7,250 sets	90	653,000
Victaulic Couplings-14" to 8"	720 sets	49	36,000
d) Valves:			
1) 16" Air-Operated	100	2,150	215,000
2) 16" Manual	100	1,990	199,000
3) 8" Plug	100	650	65,000
4) 2" Electrical	100	370	37,000
5) 14" to 8" Air-Operated	40	1,450	58,000
	Sub-Total		= $24,292,200
	+ 10% Contingency		= 2,429,800
			$26,722,000

	Quantity	Unit Cost	Total Cost

B. PUMPING SYSTEM - 10 Pipelines each 5½ miles long, 10 Pumping Stations 60' x 216', total pumping head of 2,100 feet each pipeline, 50' x 200' Pump Repair Building.

1. SITE

a. Clear & Grub	30 Acres	$ 600	$ 18,000
b. Excavation			
1) Common	250,000 C.Y.	1.90	475,000
2) Rock	709,000 C.Y.	2.00	1,418,000
c. Fill	326,000 C.Y.	.75	244,500
d. Road Surfacing	53,000 C.Y.	6.25	331,300
e. Guard Rail	15,000 L.F.	3.75	56,000
	Sub-Total	=	$ 2,542,800
	+ 10% Contingency	=	254,200
			$ 2,797,000

2. BUILDINGS

a. Pump Stations #2 thru #10:			
1) Excavation	30,000 C.Y.	$ 2.00	$ 60,000
2) Concrete	6,200 C.Y.	110	682,000
3) Building (Frame, Walls & Roof)	119,000 S.F.	25	2,975,000
4) Cranes (15 Ton - Pen. Operation)	9 Units	80,000	720,000
5) Overhead Door - Elec.	9 Each	2,500	22,500
b. Pump Station #1:			
1) Piling (10BP42)	9,600 L.F.	6.25	60,000
2) Bldg. (Inc. Excav., Concr. & Structure)	13,000 S.F.	33	429,000
3) Crane (15 Ton)	1 Unit	80,000	80,000
4) Overhead Door - Elec.	1 Each	2,500	2,500
c. Pump Repair Building:			
1) Bldg. (Inc. Excav., Concr. & Structure)	10,000 S.F.	33	330,000
2) Crane (15 Ton)	1 Each	80,000	80,000
3) Overhead Door - Elec.	1 Each	2,500	2,500
	Sub-Total	=	$ 5,443,500
	+ 10% Contingency	=	544,500
			$ 5,988,000

3. EQUIPMENT AND PIPING

a. Equipment:			
1) Pumps:			
a) 16" Slurry	100	$ 31,720	$ 3,172,000
b) Seal Water Pumps	20	2,100	42,000
c) Seal Water Booster Pumps	20	800	16,000
d) Sump	20	800	16,000

	Quantity	Unit Cost	Total Cost
5. ELECTRICAL - continued			
f. Regrind Building:			
1) Mill Drives - 1200 HP 2.3 KV Motors	5	$ 27,600	$ 138,000
2) Misc. 460 V. Motors	950 HP	80	76,000
3) Conduit & Wire for 460 V. Motors	950 HP	75	71,300
4) 1200 HP 2.3 KV Reduced Voltage Starters	5	20,700	103,500
5) Conduit & Wire for 2.3 KV Motors	500 L.F.	15	7,500
6) Motor Heaters & Controls for 2.3 KV Motors	5	500	2,500
7) Conduit & Wire for Heaters	5	500	2,500
8) Grounding	L.S.		8,000
9) Lighting	17,000 S.F.	3	51,000
g. Transformers & Switchgear:			
1) 10,000 KVA, 110KV/2.3 KV Transformers	3	103,500	310,500
2) 1,500 KVA, 2300/460 V. 3-Phase Transformer	1	18,000	18,000
3) 2,000 KVA, 2300/460 V. 3-Phase Transformer	1	24,000	24,000
4) 1,000 KVA, 2300/460 V. 3-Phase Transformer	1	12,000	12,000
5) Switchgear	4 Units	17,250	69,000
6) Misc. Lighting	L.S.		5,000
7) Grounding	L.S.		10,000
h. Motorized Valves:			
1) Misc. Sizes	42 Units	120	5,000
2) Wire & Conduit	42 Units	500	21,000
i. Spare Parts			
1) Recycled Water Pump Bldg.	L.S.		41,900
2) Thickeners	L.S.		14,400
3) Regrind Bldg.	L.S.		21,000
4) Hydroseparators	L.S.		3,500
5) Sub-Station	L.S.		26,500
	Sub-Total	=	$ 2,285,800
	+ 10% Contingency	=	228,200
			$ 2,514,000

	Quantity	Unit Cost	Total Cost
5. ELECTRICAL			
a. Recycled Water Pump Bldg.			
1) Water Pumps-1500 HP, 2.3 KV	12	$ 34,500	$ 414,000
2) 1500 HP, 2.3 KV Reduced Voltage Starters	12	17,250	207,000
3) Misc. 460 V. Motors	700 HP	80	56,000
4) Conduit & Cable for 460 V. Motors	700 HP	75	52,500
5) Conduit & Cable for 2.3 KV Motors	1,200 L.F.	15	18,000
6) Grounding	L.S.		5,000
7) Lighting	7,225 S.F.	3	21,700
8) Motor Heaters & Controls for 2.3 KV Motors	12	500	6,000
9) Conduit & Wire for Heaters	12	500	6,000
b. Thickeners:			
1) Underflow Pumps-300 HP 2.3 KV	12	6,900	82,800
2) 300 HP 2.3 KV Reduced Voltage Starters	12	5,175	62,100
3) Misc. 460 V. Motors	825 HP	80	66,000
4) Conduit & Wire for 460 V. Motors	825 HP	75	61,900
5) Conduit & Wire for 2.3 KV Motors	1,200 L.F.	15	18,000
6) Motor Heaters & Controls for 2.3 KV Motors	12	575	6,900
7) Conduit & Wire for Motor Heaters	12	500	6,000
8) Grounding	L.S.		5,000
9) Lighting	L.S.		10,000
c. Change House:			
1) Misc. 460 V. Motors	40 HP	80	3,200
2) Conduit & Wire	40 HP	75	3,000
3) Grounding	L.S.		1,500
4) Lighting	480 S.F.	3	1,400
d. Floc. Storage Facility			
1) Power & Light	25	500	12,500
e. Hydroseparators:			
1) Misc. 460 V. Motors	660 HP	80	52,800
2) Conduit & Wire	660	75	49,500
3) Grounding	L.S.		5,000
4) Lighting	L.S.		10,000

	Quantity	Unit Cost	Total Cost
3. EQUIPMENT AND PIPING - continued			
b. Piping:			
1) Recycled Water Piping:			
a) 108" Diameter	185 Tons	$ 565	$ 105,000
b) 90" Diameter	506 Tons	565	285,900
c) 60" Diameter	20 Tons	550	11,000
d) 36" Diameter	10 Tons	525	5,300
e) 16" Diameter	145 Tons	542	78,600
f) 12" Diameter	187 Tons	563	105,300
g) 10" Diameter	43 Tons	570	24,500
2) Hydraulic Piping at Thickener	L.S.		12,000
3) Slurry Piping:			
a) 10" Sched.40-Thickener to Pump Station #1	194 Tons	570	110,600
b) 4" Sched.40-Classifier to Pump Station #1	17 Tons	842	14,300
c) 8" Sched.40 Hydros to Regrind	12 Tons	810	9,700
d) Miscellaneous Valves	L.S.		5,000
e) Launders at Regrind Bldg.	L.S.		5,000
f) Piping on Sumps	L.S.		3,000
g) Hydroseparator Room Piping	2 Units	3,000	6,000
h) Caisson Piping at Thickeners	3 Units	5,000	15,000
Sub-Total		=	$ 6,247,400
+ 10% Contingency			624,600
			$ 6,872,000

4. MECHANICAL SERVICES:			
a. Plumbing:			
1) Change House at Regrind Bldg.	L.S.	$	$ 70,000
b. Heating:			
1) Regrind Bldg. - Includes Steam Main from Power House to Area	L.S.		170,000
2) Recycled Water Bldg.	L.S.		73,000
3) Change House	L.S.		26,000
4) Hydroseparator Pump House	2 Units	13,000	26,000
5) Thickener Caissons	3 Units	10,000	30,000
6) Flocculation Bldg.	L.S.		1,000
c. Fire Protection & Booster Station	L.S.		75,000
d. Summer Ventilation-Powered:			
1) Regrind Bldg.	L.S.		20,000
2) Recycled Water Bldg.	L.S.		65,000
3) Hydroseparator Pump Houses	2 Units	1,600	3,200
4) Thickener Caissons	3 Units	3,500	10,500
e. Potable Water	L.S.		50,000
Sub-Total		=	$ 619,700
+ 10% Contingency			61,300
			$ 680,000

	Quantity	Unit Cost	Total Cost
3. EQUIPMENT AND PIPING			
a. Equipment:			
1) Motorized Gates	8	$ 6,000	$ 48,000
2) Floc. Storage Facility:			
a) Mixer & Feeder	L.S.		20,000
3) Hydroseparators:			
a) Separators	2	30,000	60,000
b) Underflow Pumps	4	13,200	52,800
c) Hydro Water Booster Pumps	2	2,200	4,400
d) Hydro Crane - 10 Ton x 60' -- Includes Runway Supports	1		62,000
e) Sump Pumps	2	2,200	4,400
4) Thickeners:			
a) Thickener	3	492,000	1,476,000
b) Underflow Pumps	12	20,900	250,800
c) Water Booster Pumps	3	2,000	6,000
d) Sump Pumps	3	2,800	8,400
e) Feed Well Hoists (10 Ton)	3	11,000	33,000
5) Regrind Building:			
a) 10½ x 20 Rod Mills	5	245,000	1,225,000
b) 84" Duplex Spiral Classifiers w/Flared Tank & Drive	5	58,900	294,500
c) Classifier Overflow Pumps	5	8,800	44,000
d) Sump Pumps	5	2,200	11,000
e) Mill Water Booster Pumps	2	2,000	4,000
f) Feed Control Valves	10	2,000	20,000
g) Lubrication Systems	5	5,000	25,000
h) Initial Rod Mill Charge	90 Tons x 5	250	112,500
6) Recycled Water Pump Bldg.			
a) Pumps	12	39,400	472,800
b) Motorized Valves	12	6,900	82,800
c) Flush Water Pumps	3	13,200	39,600
d) Sump Pump	1	2,200	2,200
7) Sampling Equipment	L.S.		100,000
8) Instrumentation:			
a) Recycled Water Pumping	L.S.		212,850
b) Regrind Building	L.S.		173,250
c) Hydro Pumps	L.S.		59,400
d) Hydro Water Booster Pumps	L.S.		29,700
e) Hydro Sump Pumps	L.S.		9,900
f) Thickener Pumps	L.S.		174,900
g) Thickener Booster Pumps	L.S.		42,900
h) Thickener Sump Pump	L.S.		16,500
i) Hydro & Thickener Drives	L.S.		6,600
j) Miscellaneous	L.S.		66,000
9) Spare Parts	L.S.		200,000

	Quantity	Unit Cost	Total Cost
2. BUILDINGS - continued			
10) Liner Plates	50 Tons	$ 560	$ 28,000
11) Pipe Supports	100 Tons	750	75,000
12) Regrind Bldg. Sump Tanks	25 Tons	690	17,300
13) Anchor Bolts	L.S.		4,000
14) Overflow Weirs	66.5 Tons	750	49,900
15) Steel Dividing Plates-Launder	6 Tons	750	4,500
16) Drop Box Liners(Reclaimed Steel)	211 Tons	100	21,100
17) Cable & Pipe Bridge	1,070 L.F.	106	113,400
c. Carpentry:			
1) Wood Nailers	16.3 MFBM	340	5,500
d. Moisture Protection:			
1) Built-up Roofing	242 Sq.	50	12,100
2) Flashings, Gravel Stops, etc.	1,500 L.F.	4.40	6,600
3) Gutter	570 L.F.	15	8,600
4) Downspouts	750 L.F.	10	7,500
5) Caulking	L.S.		7,500
6) Insulation:			
a) Roof	242 Sq.	38	9,200
b) Wall	445 Sq.	50	22,300
e. Doors and Windows:			
1) Pedestrian Doors	25	190	4,800
2) Truck Doors-Overhead-Elec.	4 each	2,500	10,000
3) Windows	8 each	80	600
4) Add for Glazing	L.S.		1,200
f. Finishes:			
1) Painting:			
a) Steel	1,600 Tons	40	64,000
b) Other	L.S.		10,000
g. Specialties:			
1) Hardware	25	100	2,500
2) Lockers, Shelving & Toilet Room Accessories	L.S.		6,200
h. Equipment & Furnishings:			
1) Laboratory & Office	L.S.		16,000
i. Conveying Equipment:			
1) Cranes (Incl. Installation)			
a) Regrind Bldg. - 200 Ton	1 each	275,000	275,000
b) Regrind Bldg. - 20 Ton	1 each	116,000	116,000
c) Recycled Water Bldg. - 10 Ton	1 each	75,000	75,000
d) Elec. Hoists	6	5,000	30,000
Sub-Total		=	$ 8,945,200
+ 10% Contingency		=	894,800
			$ 9,840,000

I. INITIAL COST

	Quantity	Unit Cost	Total Cost
A. DELTA PLANT - Requires 2 - 60' dia. Hydroseparators, 3 - 480' dia. Thickeners, 1 - 85' x 85' Recycled Water Pumping Station, 1 - 85' x 200' Regrind Building.			
1. SITE			
a. Divert East Launder	L.S.	$	$ 80,000
b. Divert West Launder	L.S.		63,000
c. Sheet Piling for construction dike	960 Tons	300	288,000
d. Drainage within dike	L.S.		37,000
e. Well Point System	L.S.		88,000
f. Excavation:			
1) Tailings	1,500,000 C.Y.	0.75	1,125,000
2) Overburden	10,200 C.Y.	1.90	19,400
3) Rock	10,200 C.Y.	25.00	255,000
g. Backfill	25,000 C.Y.	1.90	47,500
h. Piling:			
1) 8BP36	927,000 L.F.	5.60	5,191,000
2) 14BP89	4,480 L.F.	11.25	50,400
i. Finish Grading	168,000 S.Y.	0.30	50,400
	Sub-Total	=	$ 7,294,700
	+ 10% Contingency	=	729,300
			$ 8,024,000
2. BUILDINGS			
a. Concrete:			
1) Foundations & Walls	11,350 C.Y.	$ 135	$ 1,532,000
2) Slabs-Incl. Thickener Slab	48,900 C.Y.	105	5,135,000
3) Tac-Crete Linings	2,400 C.Y.	105	252,000
4) 8" Walls around Change House, Office & Elec.Rooms	125 C.Y.	135	16,900
b. Metals:			
1) Launders (Hydro. Feed)	562 Tons	600	337,000
2) Regrind Building	374 Tons	550	206,000
3) Recycled Water Building	75 Tons	550	41,000
4) Misc. Stairs, Ladders, etc.	14 Tons	750	10,500
5) Roof Deck	242 Sq.	105	25,400
6) Siding	445 Sq.	120	53,400
7) Floc. Storage Building	L.S.		52,000
8) Thickener Feed Well	80 Tons	690	55,200
9) Thickener Launder	375 Tons	600	225,000

EFFECT ON PRODUCT COST

Construction Cost - $209,156,000 + $44,100,000 = $253,256,000

Life Expectancy	6 Years	8 Years	13 Years	22 Years
Construction Cost/Year	$42,209,000	$31,657,000	$19,481,000	$11,511,000
Operating Cost/Year	13,236,000	13,236,000	13,236,000	13,236,000
TOTAL	$55,445,000	$44,893,000	$32,717,000	$24,747,000

Assuming 10,000,000 gross ton yearly pellet production

Cost/Ton of Pellets

Construction	$4.22	$3.17	$1.95	$1.15
Operating	1.32	1.32	1.32	1.32
TOTAL	$5.54	$4.49	$3.27	$2.47

ESTIMATED COST SUMMARY (1969 Cost)

II. CONTINUED COSTS (After Pumping Starts)

A. ADDITIONAL DAM CONSTRUCTION

1. Elevation 1225 to 1275	$ 25,060,000
2. Elevation 1275 to 1325	13,288,000
Sub-Total	$ 38,348,000
Engineering & Administration @ 15%	5,752,000
TOTAL	$ 44,100,000

B. OPERATING COSTS - ANNUAL

1. Operating - Labor, Heat, Power & Materials	$ 5,510,000
2. Repair & Maintenance (Labor & Material)	7,726,000
TOTAL	$ 13,236,000

III. ADDITIONAL COSTS (Not covered in this Study)

A. LAND ACQUISITION
B. CLEARING OF BASIN AREA
C. FINANCING AND INTEREST COSTS
D. DISTRIBUTION PUMPING
E. POWER, LIGHTS, COMMUNICATIONS AT DAMS
F. ABANDONMENT OF LAX LAKE ROAD
G. PERMANENT DAM ACCESS ROADS
H. PLANT DEPRECIATION
I. ESCALATION FOR COST INCREASE TO DATE OF CONSTRUCTION
J. COMPUTER RENTAL
K. ADDITIONAL COAL STORAGE & HANDLING FACILITIES

NOTE: Engineering & Administration @ 15% Includes:

A. Engineering - Design, Field Supervision, Inspection	8%
B. Public Liability and Builder's Risk Insurance	1%
C. Transportation and Travel	½%
D. Permits, Licenses, Photos, Scheduling	¼%
E. Material Tests and Soil Analysis	½%
F. Worker Housing and Sanitation	1½%
G. Procurement	¼%
H. Overtime	3%
	15%

ESTIMATED COST SUMMARY (1969 Cost)

I. INITIAL COST

A. DELTA PLANT (Include existing plant tie-in)

1.	Site (Roads, grading, piling, excavation)	$ 8,024,000
2.	Buildings (Tanks, Launders, etc.)	9,840,000
3.	Equipment and Piping	6,872,000
4.	Mechanical Services (Utilities)	680,000
5.	Electrical (Power, Control & Lighting)	2,514,000
	Sub-Total	$ 27,930,000

B. PUMPING SYSTEM

1.	Site (Roads, grading, excavation)	$ 2,797,000
2.	Buildings	5,988,000
3.	Equipment and Piping	26,722,000
4.	Mechanical Services	2,295,000
5.	Electrical (Including Power Line)	12,669,000
	Sub-Total	$ 50,471,000

C. INLAND BASIN

1.	Clearing	$ 297,000
2.	Dam Construction to Elevation 1225	64,944,000
3.	Underflow Outlets Dam #1	177,000
	Sub-Total	$ 65,418,000

D. POWER HOUSE

1.	2 - 75,000 KW Units	$ 33,360,000
2.	Step Up Transformer	500,000
	Sub-Total	$ 33,860,000

E.	RIVER DIVERSION	$ 343,000
F.	RETURN PIPE	3,365,000
G.	FENCE	$ 488,000
	Total of Items "A" through "G"	$181,875,000
	Engineering & Administration @ 15%	27,281,000
	TOTAL	$209,156,000

LIFE EXPECTANCY:

If water is not discharged from the basin into rivers while it is being used as a settling basin for pumped tailings, then the useful life of the basin ceases when the water level reaches elevation 1300. This usable period is:

6 years	if all water is retained
8 years	if some of the rainfall runoff is diverted from entering the basin
13 years	if water is returned to the plant to the extent usable by the plant
22 years	if both runoff diversion and water return to plant are used.

It will take about four to five years for the tailings to build a delta at the discharge end of the pipeline similar to the present delta in Lake Superior. After this period additional pipeline and pumping must be provided to move the discharge end closer to the dams.

The above Life Expectancies could be extended if water could be discharged into the river. There would be ample room for additional tailings after the water reached elevation 1300. By discharging water to the river almost from the beginning, at whatever quality and rate necessary, the rate of accumulation of tailings becomes the more important factor. If we assume there must be at least 10 feet of water above the settled tailings to provide effective settling, the life expectancy could be extended to 66 years.

There is no assurance that outlets to the Beaver River will be tolerated; therefore, the economic feasibility of this project must be based upon the costs distributed over 22 years.

WATER QUALITY:

Past experience with the Babbitt Pilot Plant and other similar processing plants indicates water containing tailings in the range of 250 to 300 ppm can be reused. To obtain this purity in the recycled water is a matter of thickener design and control of operation. There will be very little means of controlling the behavior of the settling in the inland basin, and therefore the quality of water removed from the basin will vary widely.

When the water level in the inland basin reaches its maximum level of 1300 (which will be from six to twenty-two years after pumping starts), the level must be maintained by allowing water to flow from behind the dam into the rivers below the dams regardless of the quality of the water.

It is impossible to return all water that enters the inland basin to the processing plant. As tailings are continually pumped into the basin, while water is being discharged to rivers, the quantity of water behind the dam will become smaller. The quality of water will become progressively poorer until such a time as the solids occupy the entire volume behind the dams and any further water entering will flow through without any retention time for clarification. Obviously the plant will have to cease operation long before this time.

FLOOD CONTROL:

The inland basin must be considered as more than a settling basin for tailings since it is contained within and alters a natural drainage system. It must be planned and used in a way that provides flood control.

After the level in the basin reaches elevation 1300, the quantity of water removed must at least equal the quantity entering to prevent eventual overflow. High rates of inflows from storms must be contained long enough to prevent flooding lower river valleys. Retained water must be released, under control, to prepare for the next inflow surge. This will require continuing daily surveillance and operation of outlet devices, starting as early as six years after pumping starts.

Both underflow (conduit under the dam) and a gated overflow spillway are required if full responsibility for flood control is to be assumed. If a diversion channel is used, storm water in excess of present flows will be directed into the main channel of the Beaver River north of the railroad crossing at mile #7. Since this bridge and space between abutments was designed for present flows, it may be inadequate for these increased flows and may require reconstruction.

RIVER DIVERSION:

The rate of accumulation of water behind the dam can be reduced by intercepting rainfall runoff with an intercepting ditch north of the basin area and conducting the water around the dam. To carry the intercepted runoff, a channel would have to rise in elevation toward the upstream end. Since the shoreline of the inland basin is a level line, the intercepter channel could not be located parallel, but would rather have to taper away from the basin toward the upstream end.

The topography is such that an intercepter channel would prevent 40 square miles of rainfall runoff from entering the basin. The remaining 31 square miles of the total 71 square mile drainage area would still collect in the basin.

The proposed location of the inland basin makes the basin a form of intercepter channel because it lies across the path of the East Branch of the Beaver River. This flow in the East Branch will be reduced to almost nothing. If an intercepter channel is built, much of the runoff that would have traveled the East Branch will enter the Beaver River north of the railroad track.

Diversion of rivers makes possible the longest useful life of the Inland Basin and, therefore, the increased river flow must be provided for.

DAM CONSTRUCTION - continued

Quantities required are: (all dams)

ELEVATION	EXCAVATION C.Y.	ROCK FILL C.Y.
to 1225	5,507,200	20,927,600
1225 to 1275	504,100	8,447,400
1275 to 1325	71,800	3,840,300
TOTAL	6,083,100	33,215,300

This study is based on an examination of ground surface configuration based on U.S.G.S. contour maps only. There has been no on-site exploration either at grade or below the surface. Therefore, there is no assurance that the earth to the south of the basin is suitable to contain the water in the basin without excessive leakage and danger of property damage.

DAM CONSTRUCTION:

Construction quantities were examined for interim stages at 50 foot height intervals for water levels at elevation 1150, 1200, 1250 and 1300 with a freeboard height of dam above water level of 25 feet. Comparing the rate of water and tailing accumulation in the basin with a maximum practical rate of construction, the following was concluded:

1. Slurry pumping could start when the top of the dams reached elevation 1175 provided construction was not halted until the dams reached elevation 1225.
2. An inlet, conduit and outlet must be provided in the initial Dam #1 construction to release water from behind the dam for emergency discharge during construction, for return water to the plant, and for flood control after the basin is filled.

A maximum water level of 1300 and dam top level of 1325 appears to be the ultimate practical height. Even at this level two or three additional small dams will be required to fill in the increasing number of gaps in the south side hills. Any appreciable increase above elevation 1300 would require almost continuous diking along the entire south shore of the basin.

The overburden of organic soils (as much as 25 feet) must be removed at all dam sites to seat the rock fill dam on solid rock. Experience gained during construction of the Reserve Mining Company railroad indicates that the full width dam bases should be built with the first stage.

EMERGENCY SHUTDOWN:

The worst consequences resulting from loss of power are plugging of slurry pipelines and settlement of solids in the thickeners and hydroseparator.

Plugged pipelines will be avoided by providing air operated dump valves, at the low end of all slurry lines, to be operated with air stored in accumulators supplied by compressors in each pump station.

Plugged thickeners and hydroseparator can be avoided only by providing emergency power to keep rakes turning and pumps recirculating the solids. It is assumed that this emergency power will be provided from the existing power house. It does not appear to be practical to provide diesel generators for this large a quantity of power (about 3000 KW).

SYSTEMS STARTUP:

Startup of all equipment, especially pumps, must be on clear water so that full velocity of flows are reached before tailings are introduced. Therefore, mill water piping from the existing flush water pumping station will be required throughout the Delta Plant and to Pump Station #1. Piping must be adequate for full quantity flow to all equipment, but the demand will be of short duration.

Normal shutdown of any equipment or line should likewise be done only after first flushing through all solids. Therefore, when switching flows to standby lines, both the equipment being started and the equipment being stopped must be operating at the same time for a short while. Electrical power supply must accommodate this extra requirement.

Slurry pipelines will not be protected against freezing and therefore must be drained when not operating.

REQUIRED FACILITIES - continued

absolute continuous reliability justify 100% connected standby equipment.

Pumps require clean water under pressure at the shaft seal. A pipeline is required to deliver this seal water to all pumps along the pipeline route. This is another absolutely necessary facility which must be supplemented with standby equipment.

All pumping operations will be controlled from Pump Station #1; instrumentation, telemetering and remote controls, therefore, being required.

All facilities, except for main launders, hydroseparator and thickener, must be housed. An Office and Change House will be required in the Delta Plant. A pump and motor repair shop will be required.

Access roadways will be needed to all facilities and particularly the full length of the pipeline. All pipe sections must be within reach of truck mounted devices designed to rotate the pipe for wear and to replace pipe sections.

REQUIRED FACILITIES - continued

and, since these are subjected to less wear, because the bulk of the solids have been removed, only two standby connected pumps will be provided.

Three concrete tank thickeners will be required, provided flocculation success matches past experience in other known plant processes. No standby thickeners need to be built since it is considered feasible to overload two thickeners 50% while the third is down for repair. This should occur very infrequently. Standby underflow pumps must be provided in each thickener for reliability and so that full pumping capacity exists in any two out of three thickeners.

Preliminary selection of 150 MTPH grinding capacity for the regrind mills necessitates four closed regrind circuits with rake classifiers. Repair and maintenance frequency on mills and classifiers is such as to warrent only one additional standby connected circuit to insure full capacity operation at all times.

Five pipelines have been determined to be the most practical arrangement for pump size and minimum practical standby power requirements. The need for operational flexibility in the Delta Plant precludes any direct associations of specific equipment and specific pump lines. Therefore, all Delta Plant output must be joined and then redivided into five equal controlled parts for delivery to the five operating pump lines, or to five standby pump lines.

The pumping system extends over a 5-1/2 mile route, elevates about 800 feet and requires ten pumping stations. At each pumping station each pipeline terminates in a free surface tank to limit the quantity contained within pipes which must be dumped on emergency shutdown. Pipes and pumps will be subjected to rapid wear due to the highly abrasive character of tailing particles. Frequent repair and replacement and the necessity for

REQUIRED FACILITIES:

The Concentrator process equipment is presently arranged on the concept of gravity launder transportation of tailings throughout the plant and on out to Lake Superior. To process this slurry of tailings and water for overland pumping, the high velocity flows must be recaptured at a location which will require construction, in part, below lake level, within the recently deposited tailings delta. Dewatering the construction areas for building foundations, hydroseparators and thickeners will be difficult and expensive. Anchorage against buoyant uplift of empty tanks must be provided.

A circular concrete tank hydroseparator will be used to separate the oversized particles for regrinding. Only one will be required, but a complete standby hydroseparator must be provided to insure continuous operation while making rake and rake drive repairs. Hydroseparator startup and shutdown will require time and a considerable amount of flush water not absorbable in the recycling water system and, therefore, will be performed as infrequently as possible. Therefore, each hydroseparator must be provided with two underflow pumps, one operating and one standby to use during repair maintenance of the first pump so that pump maintenance does not demand switching hydroseparators.

Hydroseparator overflow must flow by gravity to the thickeners. It would not be practical to pump such a large quantity in order to elevate the thickeners. Thickeners, therefore, will be located with their bottoms considerably below lake level.

The overflow from the thickeners is the large quantity flow and will be gathered into a common well by gravity launders for pumping back to the Concentrator Plant. Thus the recycled water pumping well is also a low level construction problem. Ten recycled water pumps will be required,

SYSTEM DESCRIPTION - continued

Wear of pumps, pipes and launders will necessitate frequent replacement and repair. The only means of maintaining continuous operation is to provide duplicate equipment through which the flow of slurry can be switched to allow maintenance time. In most cases the nature of the duplicate equipment is such as to require its startup before shutdown of the piece requiring maintenance. Consequently electric power requirements will be somewhat higher than the normal function.

SYSTEM DESCRIPTION - continued

4. Return water to the plant and provide river diversion channels.
5. After the water reaches a practical level, water will be drawn off from the basin and discharged to natural drainage at a rate approximately equal to rainfall and runoff entering the basin.

The quantity of water which is removed from the recirculated mill water system to use for pumping the tailings to the Inland Basin is the maximum that can be returned from the Inland Basin to the Plant without upsetting the water balance or causing a discharge to Lake Superior.

The selection of processing and pumping equipment for this report is based upon plant measured and recorded mean high day production rates. Accumulation of water and tailings in the Inland Basin is based on yearly average recorded quantities.

The Concentrator Plant operation is continuous: 24 hours, 365 days per year. Although the quantity of tailings discharged from the plant reduces when sections of the Concentrator Plant are down for repairs, the quantity of water flow in the tailings launders must remain approximately the same to maintain the necessary energy to transport the solids which are being produced. All sections are never shut down at the same time; consequently, there will always be some tailings slurry flow from the plant which must be pumped inland to prevent dumping into Lake Superior.

The new Delta Plant will contain many gravity flow launders in which transportation of solids cannot be maintained if volumes of water flow are reduced. Therefore, the Delta Plant, for processing tailings, and the Inland Pumping System must work continuously and at full capacity at all times.

PURPOSE:

To study the feasibility and costs of disposing of tailings from iron ore concentration in Reserve Mining Company plant at Silver Bay, Minnesota, by overland pumping to an inland settling basin and reusing process water to avoid discharging water or tailings in Lake Superior.

SYSTEM DESCRIPTION:

Tailings slurry presently discharged from the plant will be prepared for pumping by reducing the solids particle size and removing water to concentrate the slurry to reproduce conditions found to be successful for long distance pumping.

The oversize particles (up to 1") will be separated from the slurry, ground to minus #8 sieve size, and returned to the slurry.

Excess water will be removed in thickeners to provide a pumping consistency of 30% solids by weight. Water removed from the slurry will be recycled back to the Concentrator Plant so that no water will be discharged into Lake Superior.

The east branch and other tributaries of the Beaver River will be dammed, at locations already suggested by the Bureau of Mines, with local rock fill to form a basin to retain the water and solids pumped therein. The rate of accumulation of water will be dependent upon which of the following operation modes is used:

1. Allow all inflows to accumulate in the basin.
2. After the water in the basin reaches a certain practical level, it will be returned to the plant at a rate compatible with plant operations.
3. Construct river diversion channels to prevent some of the rainfall runoff from entering the basin, but otherwise allow all inflows to accumulate in the basin.

C O N T E N T S

Purpose . . . . . Page 1

System Description . . . . . Page 1

Required Facilities . . . . . Page 4

Systems Startup . . . . . Page 7

Emergency Shutdown . . . . . Page 8

Dam Construction . . . . . Page 9

River Diversion . . . . . Page 11

Flood Control . . . . . Page 12

Water Quality . . . . . Page 13

Life Expectancy . . . . . Page 14

Estimated Cost . . . . . Page 15

Effect on Product Cost . . . . . Page 17

Detailed Costs . . . . . Page 18

Diagrams

Inland Basin Location Map - Water Elevation 1200

Inland Basin Location Map - Water Elevation 1250

Inland Basin Location Map - Water Elevation 1300

Drawings

RESERVE MINING COMPANY

TAILINGS DISPOSAL REPORT #1

Prepared by

TRYGVE HOFF & ASSOCIATES
1922 East 107th Street
Cleveland, Ohio 44106

April 4, 1969

Hoff Contract #69008

TRYGVE HOFF and ASSOCIATES

CONSULTING ENGINEERS

CLEVELAND OHIO

S. Forssmark

MR. FORSSMARK: Mr. Chairman, conferees, ladies and gentlemen:

I won't read the full report but I will read the basic purpose, which is the study of the feasibility and costs of disposing of tailings from iron ore concentration in the Reserve Mining plant at Silver Bay, by overland pumping to an inland settling basin and reusing process water to avoid discharging water or tailings into Lake Superior.

The estimate of cost that we have come up with for this job is $253,256,000, with an operating cost per year of $13,236,000. This method of operation would be good for 22 years before it would be absolutely necessary to dump water into Beaver River, in which case it would get back into Lake Superior again.

I will be glad to answer any questions anyone might have.

MR. FRIDE: I might say, Mr. Chairman, that a full copy of the report has been submitted to the conferees.

MR. DOMINICK: Are there any questions?

(No response.)

MR. DOMINICK: Thank you.

(Applause.)

(The above-mentioned report follows.)

S. Forssmark

tailings in Lake Superior?"

That is the end of the quote.

So much for the Bureau of Mines report.

However, consistent with the open mind which this company has always sought to bear for any possible solutions to questions that have arisen, we have engaged a nationally prominent consulting firm, Trygve Hoff and Associates of Cleveland. This firm is nationally and internationally recognized as an expert in their field.

This problem was posed to them, and I quote:

"To study the feasibility and costs of disposing of tailings from iron ore concentration in Reserve Mining Company plant at Silver Bay, Minnesota, by overland pumping to an inland settling basin and reusing process water to avoid discharging water or tailings in Lake Superior."

End of quote. That was the question, the problem that was posed to the consulting firm.

Here to tell you that firm's answer to that question is Mr. Stig Forssmark. He is President of Trygve Hoff. He is a registered professional engineer in seven States, including Minnesota.

Mr. Forssmark.

STATEMENT OF STIG FORSSMARK, PRESIDENT,

TRYGVE HOFF & ASSOCIATES, CLEVELAND, OHIO

Ed Fride

MR. FRIDE: Reserve Mining Company has assisted in improvements in technology and the current state of the arts with respect to all phases of its operations. During this conference there have been a few speakers who have alluded to a Bureau of Mines report. They have suggested that in some manner the Bureau of Mines has recommended the piping of taconite tailings to an inland settling basin. On Pages 21 and 24 of that report, I am quoting:

"The second suggestion, to deposit the tailings in a pond on the high ground above the plant, creates many problems. Objectionable effects of a tailings pond would have to be carefully weighed against the effects of depositing the tailings in Lake Superior. The area nearest Reserve is valued as a resort and recreation area; most of the area further removed is in Superior National Forest. A tailings pond could create a serious air pollution problem due to dust unless properly designed and operated."

Continuing with another quote:

"The Bureau of Mines is not recommending this site for tailings disposal, nor can it make recommendations of this or any other site until the quantity and nature of the detrimental material, if any, that Reserve is contributing to Lake Superior is established."

When considering alternates to tailings disposition in Lake Superior, benefits gained should be compared to possible losses; i.e., would a tailings pond and a possible air pollution problem in a particular area by less objectionable than depositing

Rice, James K., "Water Management Reduces Waste and Recovers Water in Plant Effluents," Chemical Engineering, September, 1966

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Rice, James K. and W. E. Bell, "Corrosion From Repeated Acid Cleaning - Citric vs. Hydrochloric," Combustion, April, 1966

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Rice, J. K., "Environmental Pollution Control - The Systems Approach for Industry," Presented at Rice 16th Annual Water Seminar, November, 1967

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Rice, James K., "Measuring Steam Quality," Power, Part I, September, 1962, Part II, November, 1962

Rice, James K., "New Instrumental Methods of Waste Water Analyses," 4th Annual Conference, Texas Water Pollution Control Association, Austin, Texas, January, 1964

Rice, James K., "The Use of Chelating Agents in Industrial Boilers," American Power Conference, Chicago, Illinois, April, 1964

Rice, James K., "Monitoring Water Quality," 2nd TAPPI Water Conference, May, 1964

Rice, James K., "Organic Matter in Industrial Water: Its Measurement and Removal," International Water Conference, The Engineers' Society of Western Pennsylvania, Pittsburgh, Pennsylvania, September, 1964

Rice, James K., "Research on Industrial Water Treatment," Conference of Water Resources Research, Washington, D.C., December, 1965

Rice, James K. and Dr. Charles M. Loucks, "Localized Corrosion During Chemical Cleaning," Materials Protection, February, 1965

Rice, James K., "What the Businessman Can Do to Reduce Pollution," League of Women Voters of Milwaukee, Milwaukee, Wisconsin, September, 1965

Rice, James K. and H. A. Klein, "A Research Study on Internal Corrosion of High Pressure Boilers," Winter Annual Meeting of the American Society of Mechanical Engineers, Chicago, Illinois, November, 1965

Rice, James K., "Corrosion Testing by Measurement of Local Cell Potentials," 9th Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March, 1953

Rice, James K. and H. A. Cohn, "Industrial Waste Treatment - A Manual of Procedure," Plant Engineering, May, 1953

Rice, James K., "Water Treatment - Key Problem in Your Steam System Plant," Journal American Hospitals, January, 1955

Rice, James K., "Use of Coagulation Aids," Proceedings 16th Annual Water Conference, Engineers' Society of Western Pennsylvania, Pittsburgh, Pennsylvania, October, 1955

Rice, James K., "The Use of Organic Flocculants and Flocculating Aids in the Treatment of Industrial Water and Industrial Waste Water," Pacific Area National Meeting of the American Society for Testing and Materials, September, 1956

Rice, James K., "Steam Quality Measurements by Flame Photometer," Combustion, September, 1956

Rice, James K., "Organic Fouling in Anion Exchange," Proceedings 20th Annual Water Conference, Engineers' Society of Western Pennsylvania, Pittsburgh, Pennsylvania, October, 1959

Rice, James K., "Deposit Identification - First Step Toward Understanding a Water Problem," ASTM STP 256, June, 1960

Rice, James K., "Repeated Acid Cleaning of Boilers," Combustion, July, 1961

Rice, James K., D. E. Simon and R. C. Rice, "Determination of Naturally Occurring Organic Acids in Surface Waters," American Chemical Society Meeting, Chicago, Illinois, September, 1961

National Association of Corrosion Engineers
Certified Corrosion Engineer

Engineers' Society of Western Pennsylvania

American Association for the Advancement of Science

BIOGRAPHICAL LISTINGS

Leaders in American Science

Who's Who in the East

World's Who's Who in Commerce and Industry

Who's Who Biographies of Living Notables

Time Magazine 100 Young Men Award, 1953

Who's Who in Consulting

National Engineers Register - Engineers Joint Council

National Register of Scientific and Technical Personnel in the Field of Chemistry

PUBLICATIONS

Rice, James K., "Electroplating Waste Disposal at the Westinghouse Electric Corporation, Beaver Plant," 11th Annual Water Conference, Engineers' Society of Western Pennsylvania, October, 1950

Rice, James K., "Treatment of Recirculated Cooling Water," Corrosion, November, 1952, Vol. 8, No. 11

Rice, James K., "The Rotating Electrode as a Method of Measurement of Local Cell Action Potentials in Corrosion Testing," Houston Chapter of the National Association Corrosion Engineers, Houston, Texas, December, 1952

Mr. Rice began his professional career in 1947 as a Research Engineer working on corrosion processes in water systems. During this period, he specialized in the development of rotary electrodes as a means of studying local corrosion cell action.

HONORS

Tau Beta Pi

Phi Kappa Phi

Sigma Xi

ORGANIZATIONS

American Society for Testing and Materials
- Member Board of Directors
- Member Committee D-19 on Water
- Past Chairman of Subcommittee X - Significance of Water Composition
- Chairman Program Committee ASTM National Forum on Control of Water Quality, May, 1965
- Chairman Symposium on Impurities in Steam, ASTM National Meeting, June, 1961
- Chairman Subcommittee on Corrosivity and Performance Testing

American Society of Mechanical Engineers
- Chairman of ASME Research Committee on Boiler Feedwater Studies
- Chairman Steering Committee Research Studies Internal Boiler Corrosion (Joint ASME-EEI Project)

U.S. Department of the Interior National Technical Advisory Committee on Quality of Industrial Water Supplies
- Chairman of the Committee

American Chemical Society
- Chairman Symposium on Ion Exchange, Annual ACS Meeting, March, 1962

American Water Works Association

coupled with his educational training have elevated him into a position of prominence as a nationally known authority in the field of water management. Related to his background and advancement, he is also recognized as a pioneer in the development of many modern methods of industrial water conservation and reuse, with particular emphasis on the use of systems engineering techniques.

In 1967, Mr. Rice was honored by being appointed the Chairman of the National Technical Advisory Committee on the Quality of Water for Industry by Mr. Stuart Udall, Secretary of the United States Department of the Interior. In this position, he directed and participated in a major program to set water quality criteria for interstate rivers and streams which are utilized for industrial processes. Basic considerations involved the determination of quality and quantity requirements of each process in the various water-using industries, cost analyses to alter quality, determination of minimum and maximum usage requirements, and determination of research needs.

Mr. Rice has served on the American Society for Testing and Materials Research Committee on Boiler Feedwater Studies since 1956. He previously served as the Second then First Vice Chairman, and is now Chairman of the Committee. This Committee is the foremost center for research on Boiler Feedwater Studies in the country. Mr. Rice was Chairman of a Steering Committee appointed jointly by the ASME and EEI to guide a $750,000, four year, research project on high pressure boiler internal corrosion.

In 1952, Mr. Rice was a Senior Engineer with the company. While working in this capacity, he developed expertise in the following areas of interest: corrosion of materials of construction for boilers, effects of chemical cleaning on the susceptibility of materials of construction to corrosion, design of experiments, instrument design and development, methods of measuring and monitoring steam and water quality, determination of the significance of water composition, studies of organic fouling of ion exchange materials, effects of the use of acid cleaning and chelating agents on industrial boilers, development of information retrieval and handling systems, procedures of treating and disposing of industrial wastes, and process evaluation for water and waste water treatment and reuse systems having agricultural, industrial and municipal applications.

PROFESSIONAL RESUME OF

J. K. Rice, President

EDUCATION

1946	B.S., Chemical Engineering, Carnegie Institute of Technology
1947	M.S., Chemical Engineering, Carnegie Institute of Technology

REGISTRATION

Professional Engineer, Pennsylvania and Texas

EMPLOYMENT HISTORY

1947 to date	Cyrus Wm. Rice & Company, Pittsburgh, Pennsylvania, President, Vice-President, Manager of Consulting Services, Treasurer, Director of Research, Research Engineer

EXPERIENCE

Mr. Rice has been the President of Cyrus Wm. Rice & Company since 1959, and is responsible for developing and maintaining its position as one of the nation's leading engineering and research firms specializing in the field of water management. He directs an executive staff in the integral operation of all departments for the continuous performance of essential consulting engineering, research, and testing services to RICE's industrial, municipal, and governmental clients throughout the United States and in a number of foreign countries.

Mr. Rice's specialized knowledge, professional interests, and technical specialties have been applied to considerable technical research, consulting projects and research and development studies as he progressed within the company from Research Engineer to President. This valuable experience

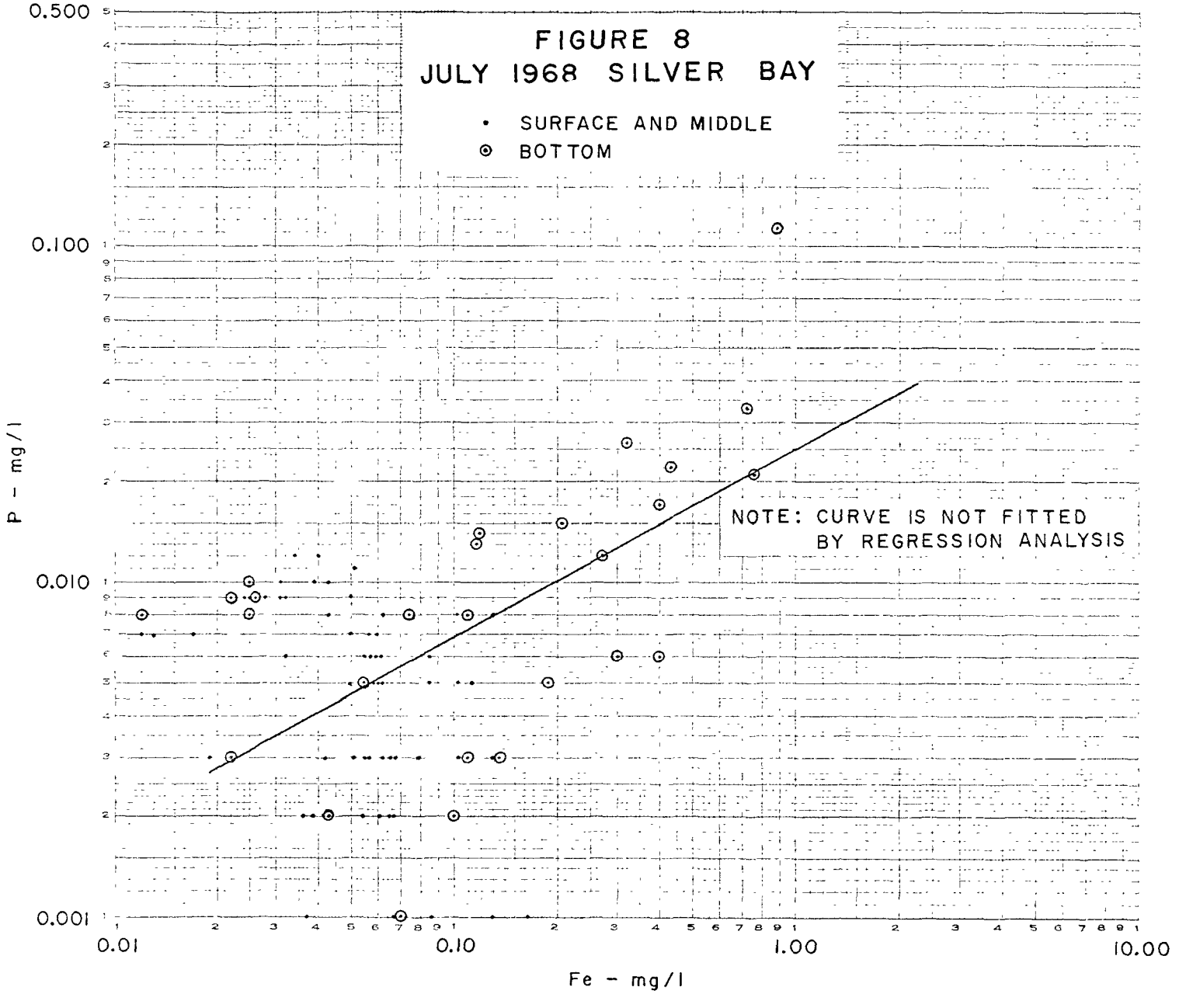
FIGURE 8
JULY 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
NOTE: CURVE IS NOT FITTED BY REGRESSION ANALYSIS
0.500
0.100
0.010
0.001
P - mg/l
0.01
0.10
1.00
10.00
Fe - mg/l

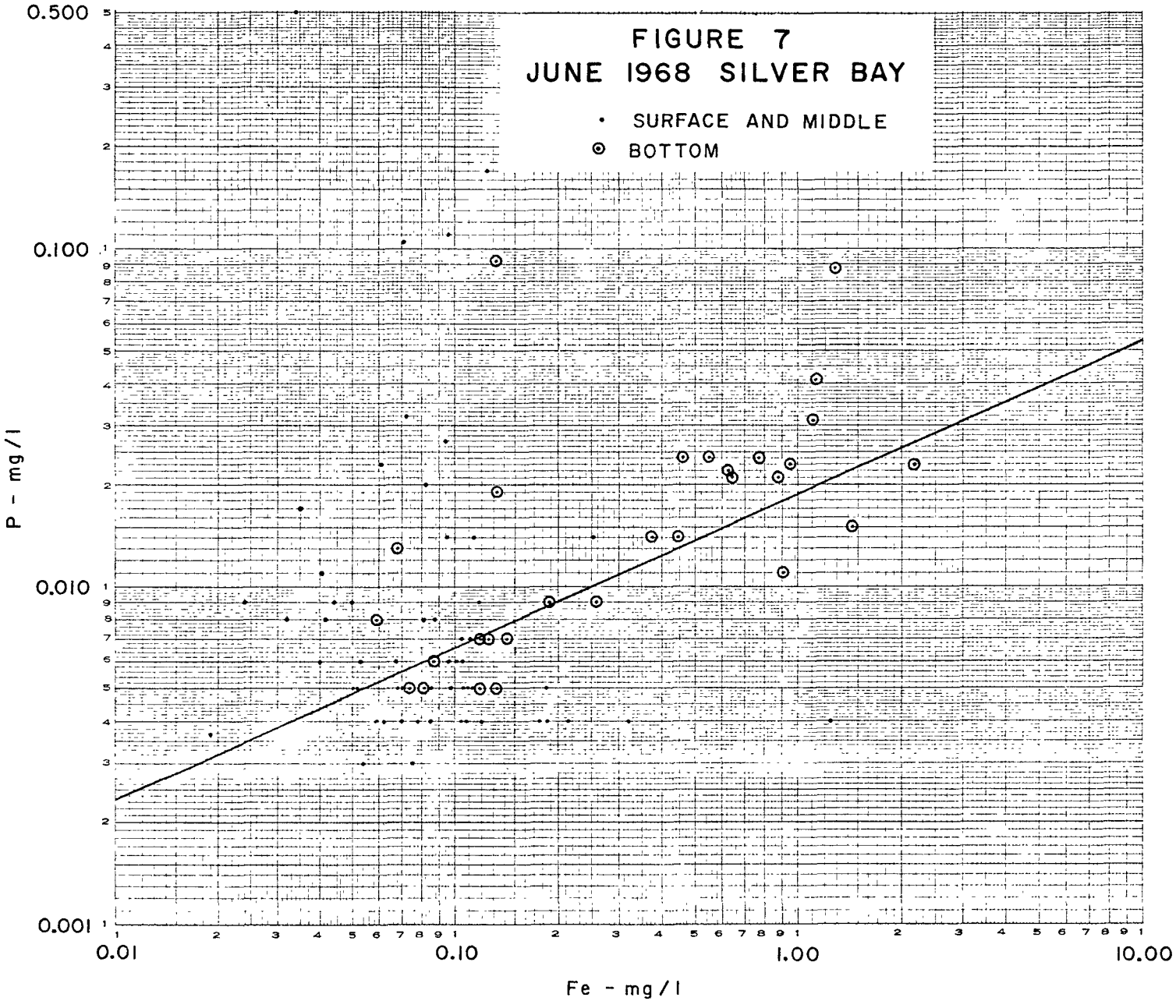
FIGURE 7
JUNE 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
0.500
0.100
0.010
0.001
P - mg/l
0.01
0.10
1.00
10.00
Fe - mg/l

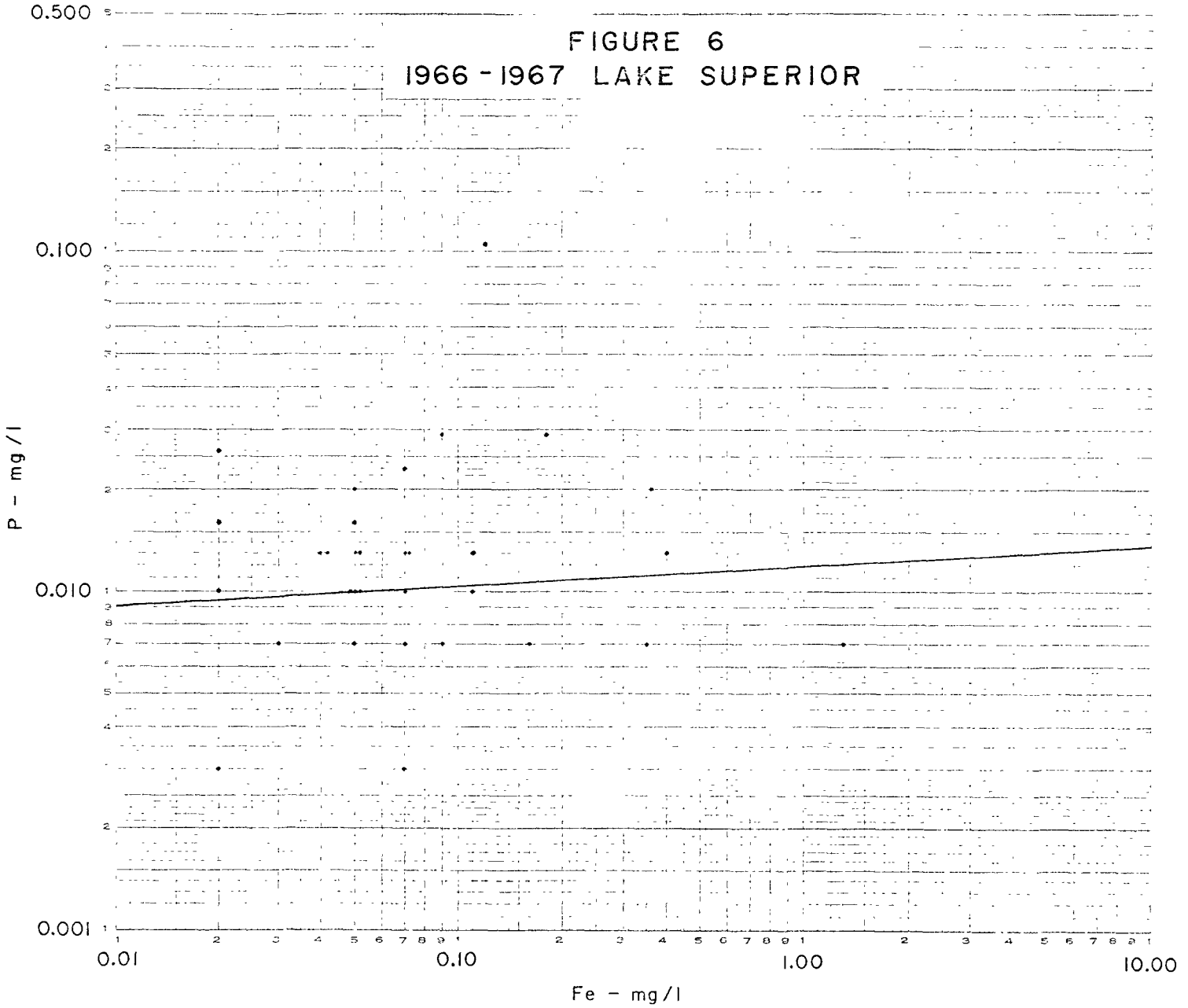
FIGURE 6
1966 - 1967 LAKE SUPERIOR
0.500
0.100
0.010
0.001
P - mg/l
0.01
0.10
1.00
10.00
Fe - mg/l

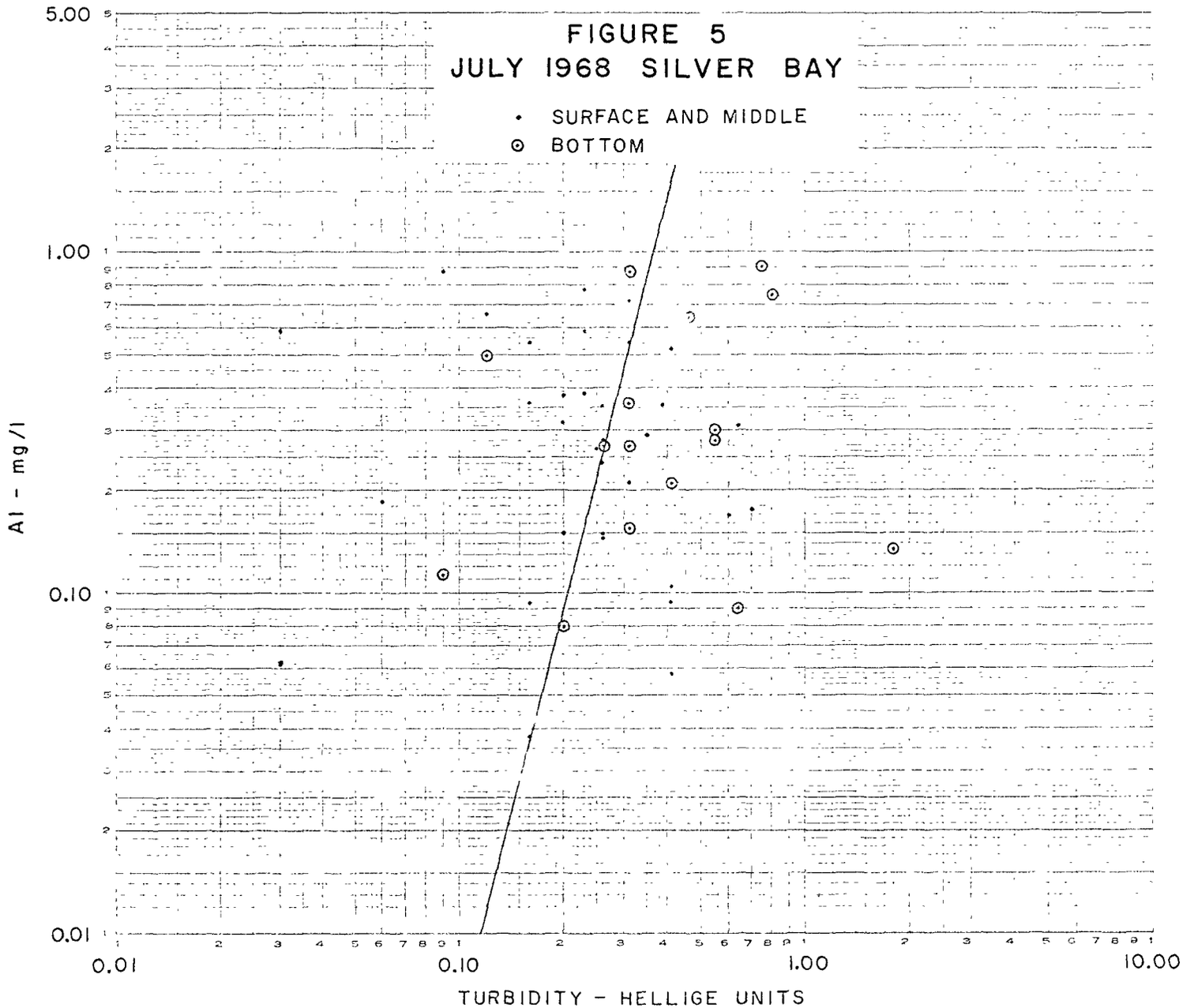
FIGURE 5
JULY 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
5.00
1.00
0.10
0.01
Al - mg/l
0.01
0.10
1.00
10.00
TURBIDITY - HELLIGE UNITS

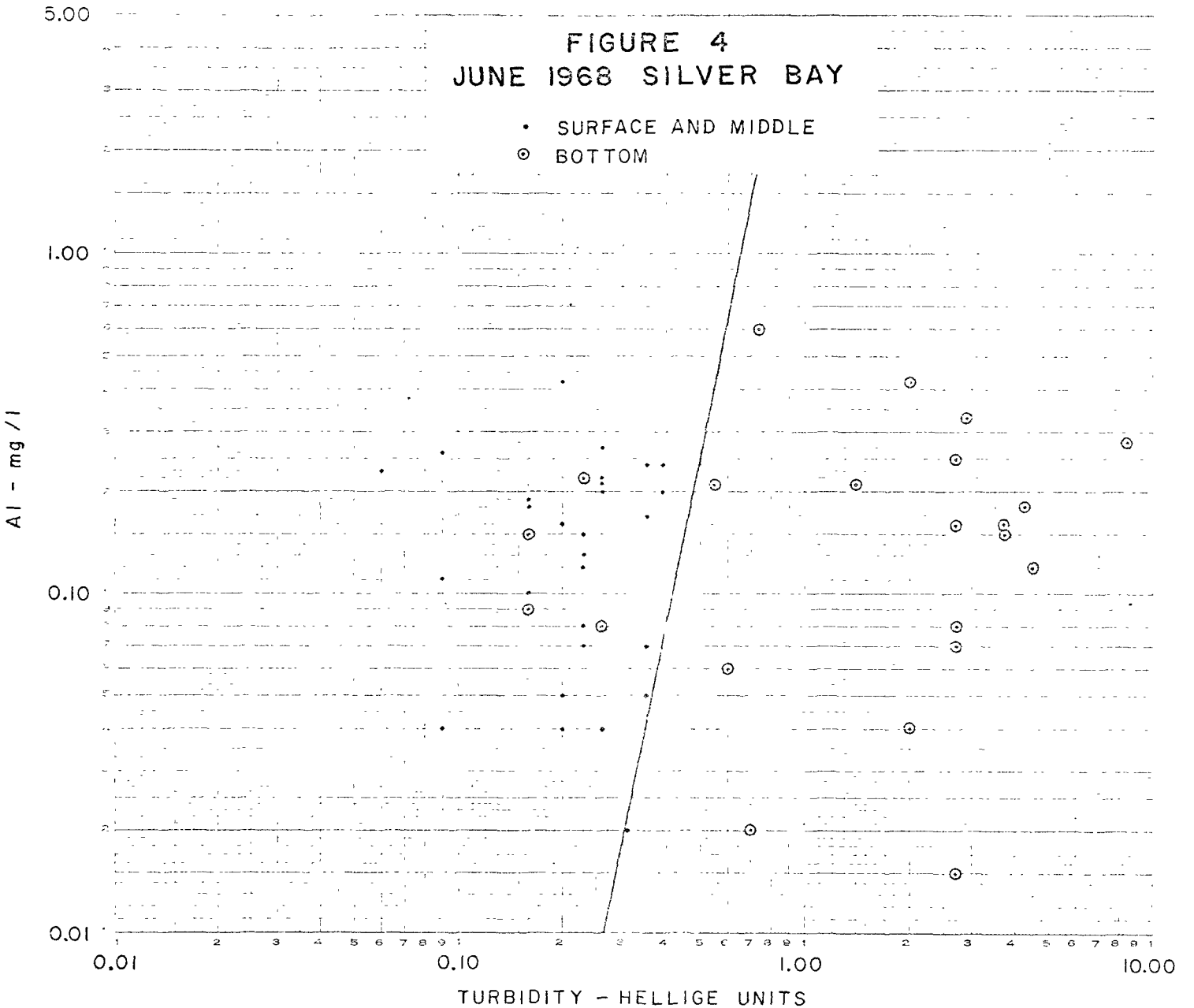
FIGURE 4
JUNE 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
5.00
1.00
0.10
0.01
Al - mg / l
0.01
0.10
1.00
10.00
TURBIDITY - HELLIGE UNITS

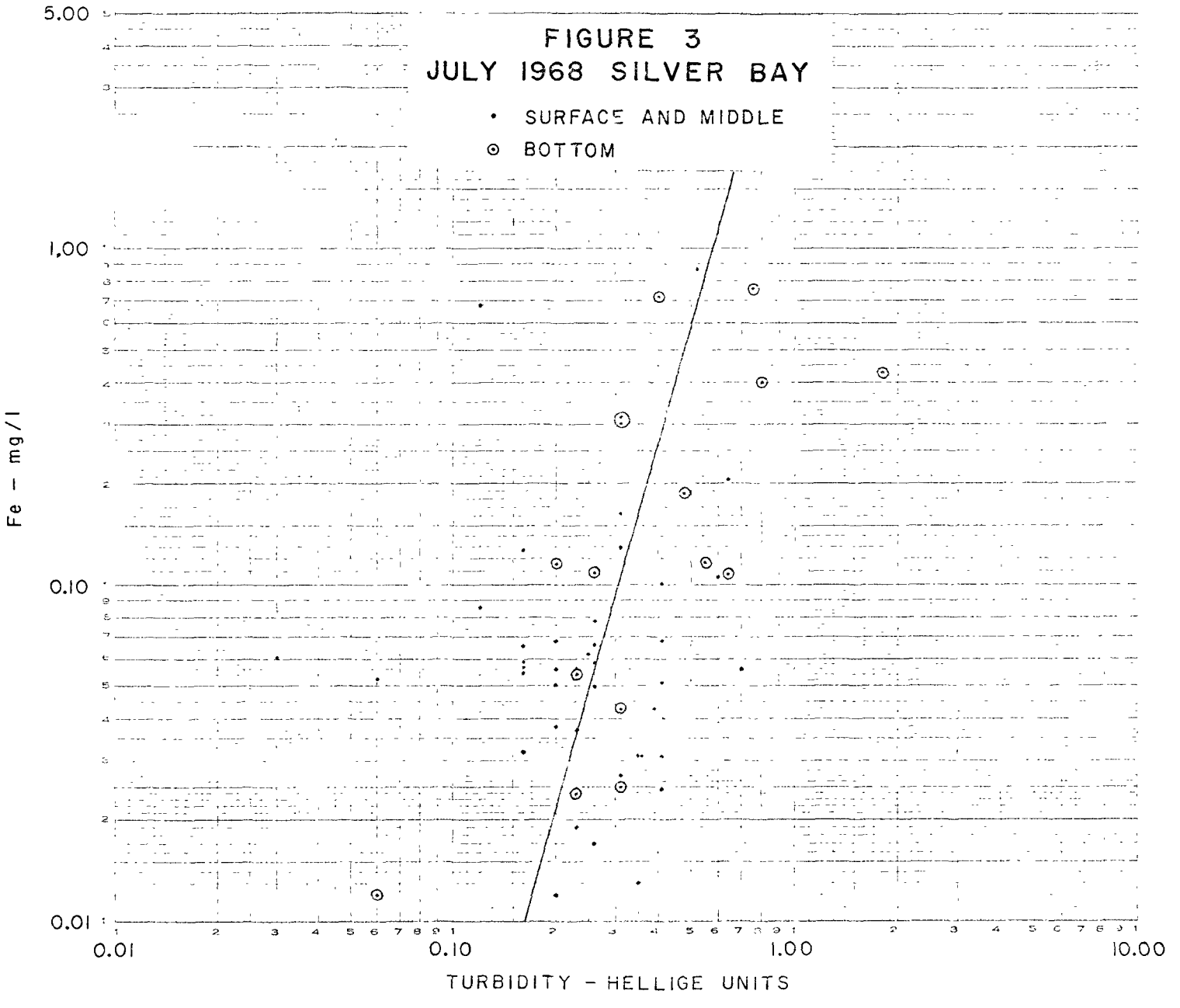
FIGURE 3
JULY 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
5.00
1.00
0.10
0.01
Fe – mg/l
0.01
0.10
1.00
10.00
TURBIDITY – HELLIGE UNITS

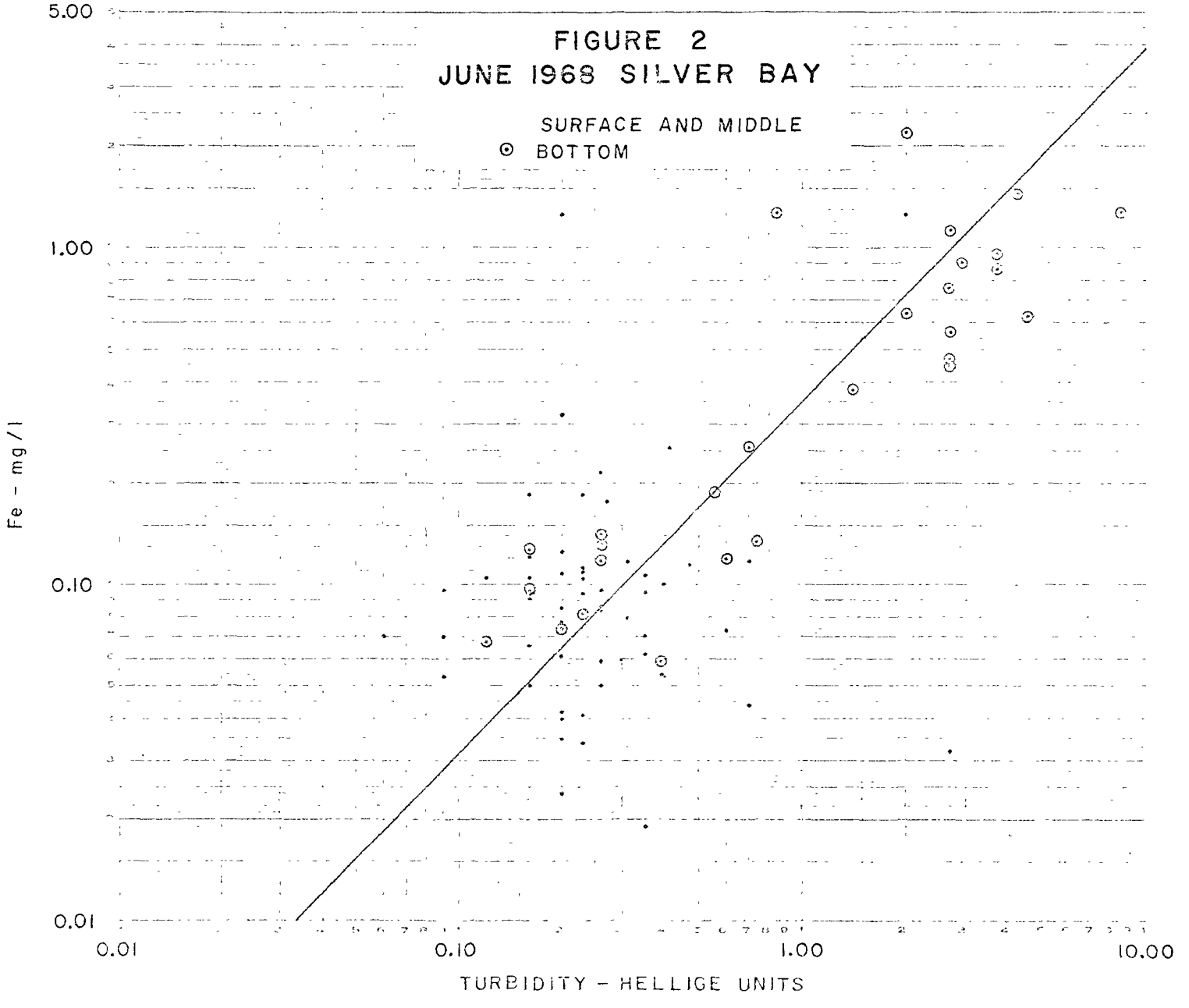
FIGURE 2
JUNE 1968 SILVER BAY
SURFACE AND MIDDLE
BOTTOM
5.00
1.00
0.10
0.01
Fe - mg/l
0.01
0.10
1.00
10.00
TURBIDITY - HELLIGE UNITS

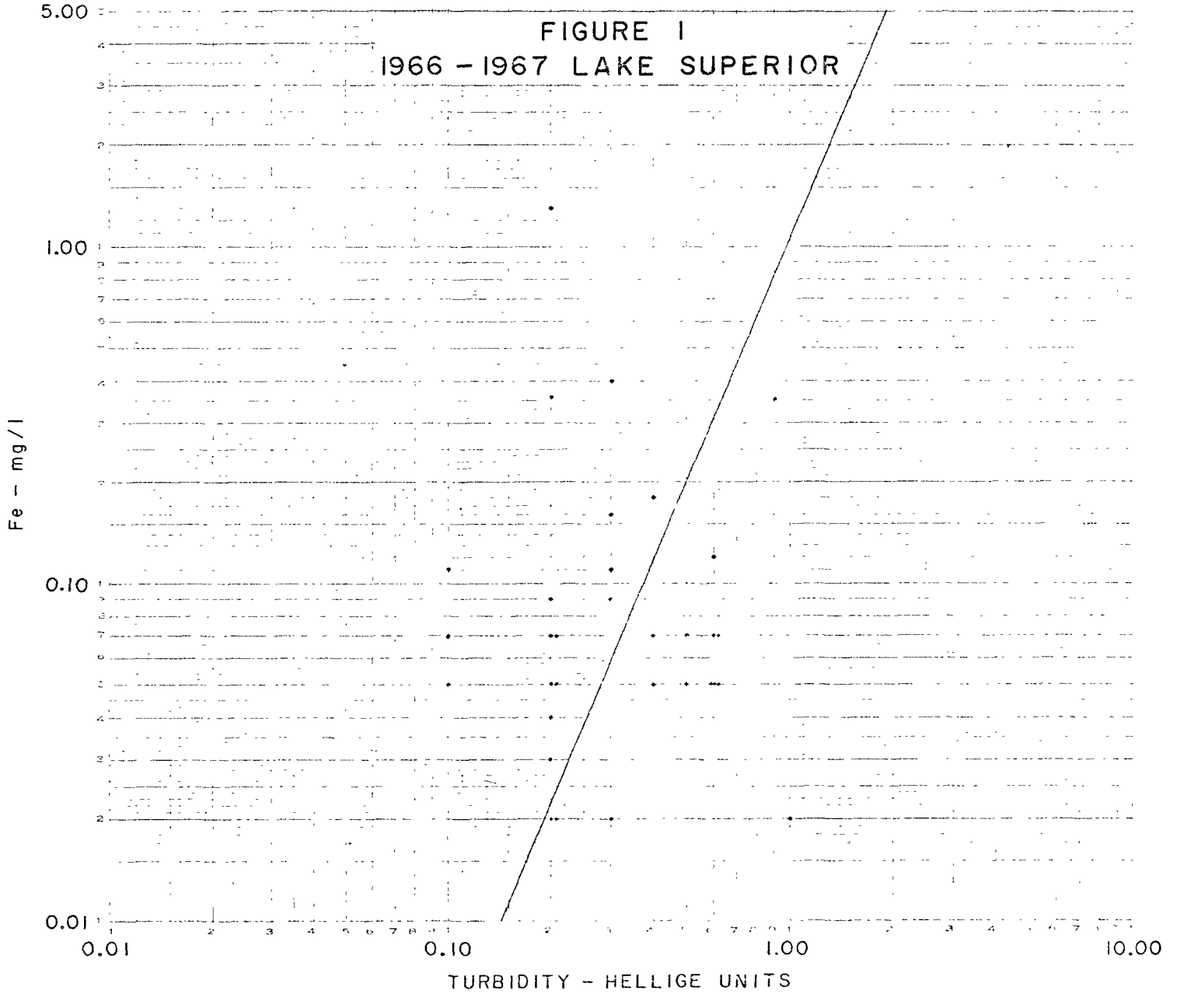
FIGURE I
1966 - 1967 LAKE SUPERIOR
5.00
1.00
0.10
0.01
Fe - mg/l
0.01
0.10
1.00
10.00
TURBIDITY - HELLIGE UNITS

TABLE 30

AVERAGE VALUES OF WATER QUALITY INDICATORS FOR SILVER BAY AND LAKE SUPERIOR
VS.
WATER QUALITY CRITERIA FOR LAKE SUPERIOR OPEN WATERS

Quality Indicator	June 1968 Silver Bay			July 1968 Silver Bay			Lake Superior '66-'67	Present L.Superior Criteria	Proposed L.Superior Criteria	
	Surface	Middle	Bottom	Surface	Middle	Bottom			90%	10%
Turb.[a]	0.23 (0.23)	0.23 (0.21)	1.56 (1.56)	0.27 (0.25)	0.24 (0.25)	0.37 (0.37)	0.38 (0.34)	-	0.5[b]	5.0[b]
P	6.0 (5.4)	5.5 (5.5)	15.3 (14.3)	5.6 (5.6)	5.3 (5.3)	9.3 (7.7)	10.5 (11.9)	-	-	10
Fe	78.6 (78.6)	91.2 (78.0)	462 (462)	60.3 (55.6)	57.0 (49.8)	207 (142)	70.6 (61.5)	300	30	100
Al	107 (107)	161 (146)	192 (143)	337 (310)	350 (292)	342 (342)	-	-	-	-
Pb	14.2 (14.2)	14.3 (14.3)	18.3 (14.5)	18.2 (18.2)	18.8 (18.8)	17.0 (17.0)	51.1 (51.1)	50	30	50
Cu	6.1 (6.1)	-	-	10.5 (10.5)	11.3 (10.9)	10.3 (10.3)	62.0 (62.0)	Trace	8	12
Zn	12.6 (12.6)	-	-	10.0 (9.5)	8.1 (6.9)	8.6 (6.4)	41.3 (39.9)	5000	10	15
Ni	15.4 (14.7)	31.5 (31.5)	33.0 (33.0)	22.9 (21.6)	28.8 (24.7)	23.7 (16.8)	18.5 (18.6)	-	15	30
Cd	1.56	-	-	1.81	1.91	2.36	-	10	2	5
Cr	5.07	-	-	9.23	9.89	9.33	-	Trace	20	50

Notes: 1) All values expressed as (μg/l) except turbidity
2) Turbidity expressed as Hellige Units (a) or as JTU (b)
3) Cd and Cr values based on raw data
4) Values in ( ) are based on data <u>not</u> transformed by square root

TABLE 29

AVERAGE RATIO OF ELEMENT TO IRON IN SELECTED SAMPLES ($R \times 10^5$)

Ratio R	Composite Tails(1)	Tailings Sediment(2)	Natural Sediment(2)	Silver Bay July 1968 Bottom	Silver Bay July 1968 Middle	Silver Bay July 1968 Surface
Cu/Fe	24	21	68	22,600	28,000	24,600
Ni/Fe	8	28	81	17,000	50,700	45,600
Zn/Fe	9	35	135	13,800	22,600	20,500
Pb/Fe	29	14	27	27,100	44,100	39,000
Cr/Fe	39	48	160	-	-	-
P/Fe	260	-	-	17,700	14,500	13,300
Al/Fe	4500	12,500	9600	563,800	563,700	657,000

(1) From Table on page 11 of Summary Report on "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior," by U. S. Department of Interior, December, 1968

(2) Reserve Mining Company Report

TABLE 28

RATIOS OF ELEMENTS
Averages and Standard Deviations
'66-'67 Lake Superior, and
July 1968 Silver Bay

Ratio	'66-'67 Lake Superior		July 1968 Silver Bay Surface		Middle		Bottom	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
P/Fe	0.264	0.273	0.133	0.109	0.145	0.161	0.177	0.213
Al/Fe	-	-	6.570	6.104	5.637	2.822	5.638	8.087
Pb/Fe	0.869	0.737	0.390	0.281	0.441	0.157	0.271	0.315
Cu/Fe	0.336	0.000	0.246	0.163	0.280	0.187	0.226	0.341
Zn/Fe	0.644	0.395	0.205	0.127	0.226	0.212	0.138	0.177
Ni/Fe	0.455	0.286	0.456	0.400	0.507	0.484	0.170	0.193

Note: Ratios calculated from data from which extreme values had been rejected by Chauvernet's Criterion.

TABLE 27

WELCH t-TEST ANALYSIS
June 1968, and July 1968, Silver Bay, vs.
'66-'67 Lake Superior
Extreme Square Root Values Rejected by Chauvernet's Criterion

Quality Indicator	June 1968 Silver Bay vs. '66-'67 Lake Superior				July 1968 Silver Bay vs. '66-'67 Lake Superior			
	Surface is	Middle is	Bottom is	Surface & Middle is	Surface is	Middle is	Bottom is	Surface & Middle is
Turb	Lower	Lower	Higher	Lower	Lower[b]	Lower	Same	Lower
P	Lower	Lower	Higher[a]	Lower	Lower	Lower	Lower[b]	Lower
Fe	Same	Higher[d]	Higher	Higher[g]	Same	Same	Higher	Same
Al	-	-	-	-	-	-	-	-
Pb	Lower	Lower	Lower	Lower	Lower	Lower	Lower	Lower
Cu	Lower[c]	-	-	Lower[c]	Lower[e]	Lower[f]	Lower[e]	Lower[f]
Zn	Lower	-	-	Lower	Lower	Lower	Lower	Lower
Ni	Lower	Same	Same	Same	Same	Higher[d]	Same	Higher

Notes:
a) On a 91% confidence level
b) On a 94% confidence level
c) On a 92% confidence level
d) On a 93% confidence level
e) On a 90% confidence level
f) On a 89% confidence level
g) On a 88% confidence level
h) Test comparisons made on data in square root form

TABLE 26

WELCH t-TEST ANALYSIS
June 1968, and July 1968, Silver Bay, vs.
'66-'67 Lake Superior
Extreme Values Rejected by Chauvernet's Criterion

Quality Indicator	June 1968 Silver Bay vs. '66-'67 Lake Superior				July 1968 Silver Bay vs. '66-'67 Lake Superior			
	Surface is	Middle is	Bottom is	Surface & Middle is	Surface is	Middle is	Bottom is	Surface & Middle is
Turb.	Lower	Lower	Higher	Lower	Lower	Lower	Same	Lower
P	Lower	Lower	Higher	Lower	Lower	Lower	Lower	Lower
Fe	Higher	Higher	Higher	Higher	Same	Lower[c]	Higher	Same
Al	-	-	-	-	-	-	-	-
Pb	Lower	Lower	Lower	Lower	Lower	Lower	Lower	Lower
Cu	Lower[a]	-	-	Lower[a]	Lower[b]	Lower[b]	Lower[b]	Lower[b]
Zn	Lower	-	-	Lower	Lower	Lower	Lower	Lower
Ni	Lower	Same	Same	Same	Same	Higher[d]	Same	Higher

Normal Confidence Level is 95%

Notes:
a) 84% Confidence Level
b) 82% Confidence Level
c) 89% Confidence Level
d) 92% Confidence Level

TABLE 25

COMPARISON OF AVERAGE SAMPLE RESULTS BY LABORATORIES

Laboratory	No. of samples compared	Cu (1)	Ni (1)	Zn (1)	Pb (1)	Cr (1)	Cd (1)	Mn (2)	P (2)	Fe (2)	SiO_2 (2)	Ca (2)	Al (2)
USBM	8	36	19	24	51	50							
Mich. Tech.	8	17	14	10	.8	2.1	1.5						
USBM	17	26	18	19	50	43							
Reserve	17	20	21	15	14	62	.9						
USBM	24							.50	.055	25.83	55.83	1.84	.42
Mich. Tech.	24							.65	.059	26.0	56.0	1.83	.40

(1) Analyses in parts per million

(2) Analyses in percent

(3) Data from Table No. 3 of "Report on Tailings Disposal at Reserve Mining Company's plant, Silver Bay, Minnesota," of "Basic Studies on Environmental Inpacts of Taconite Waste Disposal in Lake Superior," by U. S. Department of Interior, December, 1968

TABLE 24

PRECISION OF ATOMIC ABSORPTION METHODS FOR METALS IN WATER

Metal	Concentration Range Low mg/l	Concentration Range High mg/l	Mean of Determinations[4] Low Range mg/l	Mean of Determinations[4] High Range mg/l	Precision[3] Low Range mg/l	Precision[3] High Range mg/l	Precision % of Amt. Present Low Range %	Precision % of Amt. Present High Range %
Cadmium (Cd)	0.01	0.10	0.0146	0.1075	±0.0086	±0.0149	±86	±15
Chromium (Cr)	0.05	0.20	0.0530	0.1948	±0.0165	±0.0507	±33	±25
Copper (Cu)	0.05	1.0	0.0668	1.0342	±0.0316	±0.1162	±63	±11
Copper (Cu)[2]	0.10	20.0			±0.021	±0.22	±21	±1.1
Iron (Fe)	0.10	0.50	0.1156	0.5203	±0.0527	±0.0480	±53	±10
Lead (Pb)	0.05	0.20	0.0641	0.1892	±0.0452	±0.0657	±90	±33
Zinc (Zn)	0.05	1.0	0.0547	1.0303	±0.0229	±0.1084	±46	±11
Zinc (Zn)[2]	0.02	3.0			±0.005	±0.023	±25	±0.8

Notes:

1) All values from Analytical Reference Service U.S.P.H.S. - Overall Precision
2) ASTM Book of Standards - Part 23 - Single Operator Precision
3) Expressed as Standard Deviation
4) Number of operators participating varied from 19 to 59

TABLE 23

SAMPLES CONTAINING EXTREME VALUES
After Square Root Transformation and Rejection by Chauvernet's Criterion
July 1968, Silver Bay, Bottom

Sample No.	P	Turb.	Fe	Al	Pb	Cu	Zn	Ni
Bottom								
2252	113.0	0.51	880	*	5	7	7	12
2271	15.0	0.64	206	304	37	28	19	12
2289	22.0	1.80	430	134	10	15	1	10
2301	33.0	0.41	724	212	28	6	12	7
2313	186.0	-	12,200	374	39	14	17	35
2316	13.0	0.20	117	80	15	7	9	120
2322	9.0	-	22	228	7	8	6	171

* Not detected at sensitivity of test

Notes: 1) All values expressed as μg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ____ Underscore indicates value rejected as extreme

TABLE 22

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
July 1968, Silver Bay, Bottom

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2252	0.51	113	880	*	5	7	7	12
2261	0.75	21	758	910	13	9	9	20
2271	0.64	15	206	304	37	28	19	12
2274	-	3	220	176	15	13	23	33
2277	0.26	3	109	270	42	18	18	27
2289	1.80	22	430	134	10	15	1	10
2301	0.41	33	724	212	28	6	12	7
2304	0.31	26	314	154	3	9	7	3
2313	-	186	12,200	374	39	14	17	35
2316	0.20	13	117	80	15	7	9	120
2319	0.55	14	118	300	15	11	3	69
2322	-	9	22	228	7	8	6	171
2325	0.09	7	9	114	13	15	7	57
2328	0.06	8	12	*	6	10	5	45
2331	0.31	8	25	360	1	7	26	9
2343	0.23	9	24	*	*	6	5	77
Retained Data:								
Mean	0.37	7.7	142	342	17.0	10.3	6.4	16.8
Std. Dev.	0.22	4.2	131	275	10.6	3.9	3.3	10.2

* Not detected at sensitivity of test

Notes:
1) All values expressed as (μg/l) except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 21

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
July 1968, Silver Bay, Middle

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2251	0.31	8	130	210	*	8	7	13
2254	0.31	1	163	548	10	10	8	15
2257	-	5	112	152	6	12	7	13
2263	0.12	1	86	660	*	15	16	19
2266	-	2	65	790	22	15	6	10
2270	0.20	1	68	314	33	25	16	38
2276	0.16	6	59	364	39	17	49	21
2282	0.03	2	61	588	23	19	11	21
2285	-	3	65	348	35	11	39	13
2291	0.26	7	59	150	10	15	19	2
2294	0.70	7	56	176	*	8	173	14
2297	-	3	67	24	16	20	88	13
2300	0.20	2	38	-	18	8	446	16
2309	-	5	61	348	22	15	132	13
2312	0.26	7	50	*	28	13	84	38
2318	0.35	10	31	292	15	9	8	80
2330	0.26	6	*	356	5	14	7	88
2336	0.09	9	*	880	8	2	2	-
2339	-	8	102	398	14	6	6	53
Retained Data:								
Mean	0.25	5.3	49.8	292	18.8	10.9	6.9	24.7
Std. Dev.	0.08	3.1	18.1	136	9.5	4.1	2.6	17.1

* Not detected at sensitivity of test

Notes:
1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 20

SAMPLES CONTAINING EXTREME VALUES
After Square Root Transformation and Rejection by Chauvernet's Criterion
July 1968, Silver Bay, Surface and Middle

Sample No.	P	Turb.	Fe	Al	Pb	Cu	Zn	Ni
Surface								
2269	2.0	0.26	66	282	29	24	16	45
2272	6.0	-	85	278	32	30	10	40
2296	6.0	-	59	96	11	8	75	22
2302	5.0	0.41	69	*	20	5	298	16
2320	6.0	-	32	410	15	16	7	156
2323	7.0	0.26	*	*	11	11	6	116
Middle								
2254	1.0	0.31	163	548	10	10	8	15
2276	6.0	0.16	59	364	39	17	49	21
2285	3.0	-	65	348	35	11	39	13
2294	7.0	0.70	56	176	*	8	173	14
2297	3.0	-	67	24	16	20	88	13
2300	2.0	0.20	38	-	18	8	446	16
2309	5.0	-	61	348	22	15	132	13
2312	7.0	0.26	50	*	28	13	84	38

* Not detected at sensitivity of test

Notes: 1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 19

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
July 1968, Silver Bay, Surface

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2250	0.31	3	130	712	8	8	8	6
2253	0.16	1	128	*	*	8	8	16
2269	0.26	2	66	282	29	24	16	45
2272	-	6	85	278	32	30	10	40
2278	0.60	3	107	168	23	10	9	40
2290	0.16	3	66	94	10	15	24	10
2296	-	6	59	96	11	8	75	22
2302	0.41	5	69	*	20	5	298	16
2320	-	6	32	410	15	16	7	156
2323	0.26	7	*	*	11	11	6	116
2326	0.03	8	*	62	10	8	6	60
2338	-	10	43	1030	14	9	5	13
Retained Data:								
Mean	0.25	5.6	55.6	309	18.2	10.5	9.5	21.6
Std. Dev.	0.12	2.9	22.7	213	9.4	3.7	5.1	13.1

* Not detected at sensitivity of test

Notes: 1) All values expressed as (μg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 18

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
June 1968, Silver Bay, Bottom

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2046	3.70	23	961	160	52	-	-	-
2049	2.70	24	556	70	56	-	-	-
2059	2.00	23	2160	420	8	-	-	-
2077	0.84	92	131	-	*	-	-	-
2083	2.70	41	1120	250	10	-	-	-
2089	12.00	31	1110	570	5	-	-	-
2092	0.73	5	133	600	31	-	-	-
2104	8.40	87	1280	280	-	-	-	-
Retained Data:								
Mean	1.56	14.3	462	143	14.5	-	-	33.0
Std. Dev.	1.43	7.8	425	89	8.9	-	-	25.3

* Not detected at sensitivity of test

Notes:
1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 17

SAMPLES CONTAINING EXTREME VALUES
After Square Root Transformation and Rejection by Chauvernet's Criterion
June 1968, Silver Bay, Middle and Bottom

Sample No.	P	Turb.	Fe	Al	Pb	Cu	Zn	Ni
Middle								
2045	4	0.12	106	*	47	-	-	-
2048	9	0.20	24	*	52	-	-	-
2058	172	0.20	125	160	12	-	-	-
2070	8	2.70	32	*	-	-	-	7
2073	14	0.41	253	*	14	-	-	15
2085	4	0.20	321	50	7	-	-	-
2121	23	0.20	61	50	14		-	-
2124	27	0.23	94	130	8	-	-	-
Bottom								
2059	23	2.00	2160	420	8	-	-	-
2077	92	0.84	131	-	*	-	-	-
2089	31	12.00	1110	570	5	-	-	-
2104	87	8.40	1280	280	-	-	-	-

* Not detected at sensitivity of test

Notes: 1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 16

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
June 1968, Silver Bay, Middle

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2042	0.20	5	74	420	25	-	-	-
2045	0.12	4	106	*	47	-	-	-
2048	0.20	9	24	*	52	-	-	-
2058	0.20	172	125	160	12	-	-	-
2061	0.39	6	101	200	29	-	-	-
2070	2.70	8	32	*	-	-	-	7
2073	0.41	14	253	*	14	-	-	15
2082	0.23	4	187	150	14	-	-	-
2085	0.20	4	321	50	7	-	-	-
2088	0.47	5	113	*	11	-	-	-
2094	0.16	5	184	90	17	-	-	-
2106	0.26	4	214	210	20	-	-	-
2121	0.20	23	61	50	14	-	-	*
2124	0.23	27	94	130	8	-	-	-
Retained Data:								
Mean	0.21	5.5	78.3	146	14.3	-	-	31.5
Std. Dev.	0.06	1.6	27.4	76	7.4	-	-	24.4

* Not detected at sensitivity of test

Notes:
1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 15

SAMPLES CONTAINING EXTREME VALUES
After Square Root Transformation and Rejection by Chauvernet's Criterion
June 1968, Silver Bay, Surface

Sample No.	P	Turb.	Fe	Al	Pb	Cu	Zn	Ni
Surface								
2041	32	0.60	73	*	14	4	7	10
2044	9	0.70	118	*	45	4	23	16
2047	192	0.35	*	*	52	4	10	28
2050	11	0.23	41	-	-	5	19	54
2053	4	0.20	1240	-	11	5	7	9
2054	105	0.06	71	230	-	6	8	11
2057	110	0.26	97	40	10	7	8	17
2063	9	0.70	44	-	4	8	8	3
2066	499	0.23	34	*	-	110	11	14
2069	17	0.20	35	*	-	4	4	6
2087	4	0.20	78	*	20	15	55	8
2090	5	0.26	50	40	3	21	63	*
2117	14	0.26	113	220	8	4	40	25
2120	37	0.35	19	50	5	8	64	4
2123	20	0.16	82	190	4	6	26	24

* Not detected at sensitivity of test

Notes: 1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 14

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
June 1968, Silver Bay, Surface

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
2038	0.35	5	70	*	23	3	13	32
2041	0.60	32	73	*	14	4	7	10
2044	0.70	9	118	*	45	4	23	16
2047	0.35	192	*	*	52	4	10	28
2050	0.23	11	41	-	-	5	19	54
2053	0.20	4	1240	-	11	5	7	9
2054	0.06	105	71	230	-	6	8	11
2057	0.26	110	97	40	10	7	8	17
2063	0.70	9	44	-	4	8	8	3
2066	0.23	499	34	*	-	110	11	14
2069	0.20	17	35	*	-	4	4	6
2087	0.20	4	78	*	20	15	55	8
2090	0.26	5	50	40	3	21	63	*
2117	0.26	14	113	220	8	4	40	25
2120	0.35	37	19	50	5	8	64	4
2123	0.16	20	82	190	4	6	26	24
Retained Data:								
Mean	0.23	5.4	78.6	107	14.2	6.1	12.6	14.7
Std. Dev.	0.08	1.7	30.2	89	8.1	2.8	6.2	6.3

* Not detected at sensitivity of test

Notes:
1) All values expressed as (µg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 13

SAMPLES CONTAINING EXTREME VALUES
After Square Root Transformation and Rejection by Chauvernet's Criterion
'66-'67 Lake Superior

Sample No.	P	Turb.	Fe	Pb	Cu	Zn	Ni
Surface							
3	(13/13/16)	(0.3/0.2/0.4)	400	*	36	*	*
101	7	0.9	350	118	*	69	*
102	104	0.6	120	27	*	*	*
104	(16/20/26)	(0.5/0.2/0.8)	360	*	*	52	16
106	(7/29/7)	0.4	180	306	113	18	19
112	(3/7/10)	0.2	1300	*	*	161	19
119	33	0.2	20	*	*	14	21
Bottom							
115	46	0.1	70	130	*	31	16

* Not detected at sensitivity of test

Notes: 1) All values expressed as (μg/l), except turbidity
2) Turbidity expressed as Hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 12

SAMPLES CONTAINING EXTREME VALUES
Rejected by Chauvernet's Criterion
'66-'67 Lake Superior

Sample No.	Turb.	P	Fe	Al	Pb	Cu	Zn	Ni
3	(0.3/0.2/0.4)	(13/13/16)	400	-	*	36	*	*
8	0.2	13	40	-	*	*	*	8
10	1.0	10	20	-	*	*	*	*
101	0.9	7	350	-	118	*	69	*
102	0.6	104	120	-	27	*	*	*
104	(0.5/0.2/0.8)	(16/20/26)	360	-	*	*	52	16
105	(0.5/0.3/0.3)	(3/7/7)	160	-	27	*	60	19
106	0.4	(7/29/7)	180	-	306	113	18	19
108	0.5	13	70	-	17	*	69	26
112	0.2	(3/7/10)	1300	-	*	*	161	19
115	0.1	46	70	-	130	*	31	16
119	0.2	33	20	-	*	*	14	21
Remaining Data								
Mean	0.34	11.9	61.5	-	51.1	62.0	39.9	18.6
Std. Devia.	0.19	6.8	28.9	-	43.2	44.2	24.1	2.1

* Not detected at sensitivity of test

Notes:
1) All results in (μg/l), except turbidity
2) Turbidity expressed as hellige units
3) ___ Underscore indicates value rejected as extreme

TABLE 11

AVERAGES AND STANDARD DEVIATIONS
After Square Root Transformation and Rejection of Extreme Values
July 1968, Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean	Std. Devia.	Mean	Std. Devia.	Mean	Std. Devia.
Turb.	0.269	0.135	0.237	0.093	0.371	0.216
P	5.576	2.937	5.344	3.054	9.276	6.221
Fe	60.323	28.614	57.037	27.146	206.633	233.784
Al	336.593	250.815	349.840	207.462	342.154	274.685
Pb	18.185	9.393	18.826	9.485	16.966	10.608
Cu	10.548	3.668	11.344	4.756	10.258	3.932
Zn	9.968	5.654	8.080	4.163	8.625	6.194
Ni	22.929	14.732	28.828	22.523	23.731	19.695

* No Data Taken

Notes:
1) All indicators expressed in (μg/l), except turbidity
2) Turbidity expressed as Hellige Units
3) See Note 3, Table 1, for data source

TABLE 10

AVERAGES AND STANDARD DEVIATIONS
Of Square Roots After Transformation and Rejection of Extreme Values
July 1968, Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean	Std. Devia.	Mean	Std. Devia.	Mean	Std. Devia.
Turb	0.501	0.139	0.475	0.111	0.583	0.183
P	2.273	0.650	2.203	0.710	2.879	1.010
Fe	7.558	1.818	7.338	1.821	12.384	7.424
Al	17.084	6.816	17.897	5.546	17.126	7.127
Pb	4.104	1.182	4.198	1.121	3.911	1.314
Cu	3.201	0.560	3.294	0.713	3.146	0.610
Zn	3.038	0.874	2.759	0.700	2.761	1.017
Ni	4.562	1.480	5.004	1.980	4.492	1.922

TABLE 9

AVERAGES AND STANDARD DEVIATIONS
After Rejection of Extreme Values
July 1968, Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean.	Std. Devia.	Mean.	Std. Devia.	Mean.	Std. Devia.
Turb.	0.254	0.117	0.249	0.081	0.371	0.216
P	5.576	2.937	5.344	3.054	7.692	4.193
Fe	55.586	22.738	49.833	18.115	142.111	131.192
Al	309.923	213.195	291.636	135.829	342.154	274.685
Pb	18.185	9.393	18.826	9.485	16.966	10.608
Cu	10.548	3.668	10.903	4.118	10.258	3.932
Zn	9.500	5.104	6.864	2.569	6.407	3.296
Ni	21.556	13.060	24.741	17.134	16.773	10.202
Cd	1.813	0.981	1.909	0.944	2.364	0.809
Cr	9.231	7.155	9.889	7.821	9.333	10.765

Notes:

1) All indicators expressed in (μg/l), except turbidity
2) Turbidity expressed as Hellige units
3) See Note 3, Table 1, for data source
4) Cd and Cr based on raw data

TABLE 8

AVERAGES AND STANDARD DEVIATIONS
After Square Root Transformation and Rejection of Extreme Values
June 1968, Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean	Std. Devia.	Mean	Std. Devia.	Mean	Std. Devia.
Turb.	0.227	0.083	0.232	0.089	1.561	1.426
P	6.000	2.646	5.500	1.606	15.250	9.139
Fe	78.552	30.159	91.222	45.665	461.759	425.414
Al	107.333	88.839	161.111	98.273	191.667	157.225
Pb	14.208	8.070	14.316	7.372	18.286	14.602
Cu	6.111	2.750	-	-	-	-
Zn	12.593	6.178	-	-	-	-
Ni	15.357	6.956	31.500	24.393	33.000	25.269

* No Data Taken

Notes:
1) All indicators expressed in (μg/l), except turbidity
2) Turbidity expressed as Hellige Units
3) See Note 2, Table 1, of data source

TABLE 7

AVERAGES AND STANDARD DEVIATIONS
Of Square Roots After Transformation and Rejection of Extreme Values
June 1968, Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean	Std. Devia.	Mean	Std. Devia.	Mean	Std. Devia.
Turb	0.468	0.092	0.473	0.090	1.103	0.597
P	2.294	0.355	2.323	0.326	3.738	1.152
Fe	8.678	1.832	9.281	2.300	19.201	9.819
Al	9.472	4.344	12.054	4.092	12.743	5.527
Pb	3.601	1.136	3.659	0.989	3.982	1.596
Cu	2.417	0.527	-	-	-	-
Zn	3.455	0.827	-	-	-	-
Ni	3.810	0.933	5.229	2.354	5.405	2.176

TABLE 6

AVERAGES AND STANDARD DEVIATIONS
After Rejection of Extreme Values
June 1968 Silver Bay

Quality Indicator	Surface		Middle		Bottom	
	Mean.	Std. Devia.	Mean.	Std. Devia.	Mean.	Std. Devia.
Turb.	0.227	0.083	0.210	0.061	1.561	1.426
P	5.381	1.687	5.500	1.606	14.296	7.765
Fe	78.550	30.159	78.250	27.444	461.759	425.414
Al	107.333	88.839	145.882	76.327	143.333	88.738
Pb	14.208	8.070	14.316	7.372	14.526	8.934
Cu	6.111	2.750	*	*	*	*
Zn	12.593	6.178	*	*	*	*
Ni	14.741	6.261	31.500	24.393	33.000	25.269
Cd	1.563	0.513	-	-	-	-
Cr	5.074	3.832	-	-	-	-

* No Data Taken

Notes:

1) All indicators expressed in (µg/l) except turbidity

2) Turbidity expressed as Hellige units

3) See Note 2, Table 1, for data source

4) Cd and Cr based on raw data

TABLE 5

AVERAGES AND STANDARD DEVIATIONS
After Square Root Transformation and Rejection of Extreme Values
1966-67 Lake Superior

Quality Indicator	Mean	Standard Deviation
Turb.	0.375	0.227
P	10.538	5.464
Fe	70.583	41.310
Al	-	-
Pb	51.091	43.214
Cu	62.000	44.170
Zn	41.333	24.076
Ni	18.476	3.487

Notes:

1) All indicators expressed in (μg/l), except turbidity
2) Turbidity expressed as Hellige units
3) See Note 1, Table 1, for data source

TABLE 4

AVERAGES AND STANDARD DEVIATIONS
Of Square Roots After Transformation and Rejection of Extreme Values
1966-67 Lake Superior

Quality Indicator	Mean	Standard Deviation
Turb	0.575	0.214
P	3.133	0.865
Fe	8.076	2.364
Al	-	-
Pb	6.614	2.842
Cu	7.571	2.650
Zn	6.150	1.927
Ni	4.277	0.438

TABLE 3

AVERAGES AND STANDARD DEVIATIONS
After Rejection of Extreme Values
1966-67 Lake Superior

Quality Indicator	Mean	Standard Deviation
Turb.	0.341	0.185
P	11.863	6.773
Fe	61.545	28.856
Al	-	-
Pb	51.091	43.214
Cu	62.000	44.170
Zn	39.947	24.165
Ni	18.632	2.060

Notes:

1) All indicators expressed in (μg/l), except turbidity

2) Turbidity expressed as Hellige units

3) See Note 1, Table 1 for data source

TABLE 2

ANALYSIS OF VARIANCE - Surface plus Middle vs. Bottom, June, July, 1968, Silver Bay; and '66-'67 Lake Superior

Quality Indicator	'66-'67 (Note 1)	June 1968 (Note 2)	July 1968 (Note 3)
	Surf. + Mid. vs. Bot.	Surf. + Mid. vs. Bot.	Surf. + Mid. vs. Bot.
Turb.	S	D	D
P	S	S	D
Fe	-	D	D*
Al	-	S	S
Pb	-	S	S
Cu	-	-	S
Zn	-	-	S
Ni	-	D	S

* Confidence level at 94% - no difference at 95%

S = Same D = Different

Note 1: Chemical Determinations from Table 6 and 7 of Section 3, "Investigations by Chicago Program Office," of "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior," by U. S. Department of Interior, December, 1968

Note 2: Ibid., Table 18

Note 3: Ibid., Table 19

TABLE 1

ANALYSIS OF VARIANCE - Surface, Middle, Bottom, June, July, 1968, Silver Bay, and '66-'67 Lake Superior

Quality Indicator	'66-'67 (Note 1)			June '68 (Note 2)			July '68 (Note 3)		
	Surf.	Mid.	Bot.	Surf.	Mid.	Bot.	Surf.	Mid.	Bot.
Turb.	S	S	S	S	S	D	S	S	D
P	S	S	S	S	S	S	S	S	D
Fe	-	-	-	S	S	D	S	S	D*
Al	-	-	-	D*	S	S	S	S	S
Pb	-	-	-	S	S	S	S	S	S
Cu	-	-	-	-	-	-	S	S	S
Zn	-	-	-	-	-	-	S	S	S
Ni	-	-	-	-	-	-	S	S	S

* Reduced confidence levels below 95% - no difference at 95%

S = Same D = Different

Note 1: Chemical Determinations from Table 6 and 7 of Section 3, "Investigations by Chicago Program Office," of "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior," by U. S. Department of Interior, December, 1968

Note 2: Ibid., Table 18

Note 3: Ibid., Table 19

by Chauvernet's Criterion is the result of analytical error or not. Even for iron, phosphorous, and turbidity, no relationship would be obvious if the data from Silver Bay bottom samples were to be excluded. Without bottom sample analysis, even the Silver Bay iron, phosphorous, and turbidity data scatters sufficiently to prevent a good correlation.

GRAPHICAL RELATIONSHIPS

The taconite tailings have a composition reported as 16.7% Fe and the apparent tailings sediment as reported by Reserve, 14.4%. While the turbidity in the water is a function of suspended clays and algae, as well as any taconite tailings, a plot of iron vs. turbidity could show relationships particularly where the majority component of turbidity is from tailings. In addition, the analysis of variance between surface, middle, and bottom samples showed phosphorous, iron and turbidity values to be significantly different in the bottom data which is known to be affected by the taconite tailings. Since aluminum is a major component of clays, as well as a minor component of taconite tailings (1.8% Al in apparent tailings sediment, 7.1% Al in natural lake sediments by Reserve's analysis,) it was also examined for relationships to turbidity.

Figures 1-8 are plots of all data for the respective quality indicators in Tables 6, 7, 18, and 19 of the FWPCA report. The data for iron vs. turbidity, and phosphorous vs. iron for June and July, 1968, show a reasonable correlation to exist. The curves shown were fitted by regression analysis; some of the data scatters widely, indicating that no significant simple relationships exists. Relationships for iron, phosphorous, and turbidity are useful, however, in examining the analytical data for individual samples to determine if an extreme value found

Except for bottom samples, which were collected 8" from the bottom in the designed density current, it can be seen that iron, lead, zinc, and cadmium values are below the present standards, there being no present numerical standards for turbidity, phosphorous, aluminum, copper, nickel, or chromium. If copper and chromium "trace" limits are construed as the maximum values shown in the proposed criteria, then the average values for copper and chromium in Silver Bay surface and middle samples are less than the present standards. Thus the quality indicators in surface and middle portions of Silver Bay do not exceed the present Federal-State Standards as is contended in the "Basic Studies."

Actually, Lake Superior as a whole exceeds the proposed standards for phosphorous, turbidity, lead, copper, zinc, iron, and nickel, while Silver Bay surface and middle exceed the standards for iron, zinc, copper, and nickel. It is thus apparent that unless Lake Superior as a whole is considered polluted, with respect to these elements, the proposed lake criteria are unrealistic for lead, phosphorous, copper, iron, nickel, and zinc. No standards exist or are proposed for aluminum, which is reasonable, since it is a common component of clay which, in turn, arrives in the lake in the natural streams.

sediments. Since the tailings sediments do not show significant enrichment or depletion of the elements, it is difficult to understand the apparently grossly enriched (other elements with respect to iron) condition of the suspended matter in the water samples, unless one accepts the explanation that most of the other trace metals found in Silver Bay (and the rest of the lake) come from sources independent of the tailings. This latter assumption is substantiated by the great similarity in trace metal values between those for Silver Bay and those for Lake Superior. The analysis of variance tests discussed previously also point to a general source for the trace metals in all Lake Superior water.

SILVER BAY WATER QUALITY

The "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior," presents several conclusions on page 26 of its Summary Report that are based on a comparison of the analytical data with the existing Federal-State Water Quality Standards for Lake Superior. Table 30 presents the results of examination of the analytical data in comparison with the accepted and the proposed criteria[6] for Lake Superior open waters.

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(6) "An Appraisal of Water Pollution in the Lake Superior Basin," by the U. S. Department of the Interior, Federal Water Pollution Control Administration, Great Lakes Region, April, 1969.

as examination of Table 30 will show.

When the surface and middle samples are combined for June, 1968, and also for July, 1968, and the combined data are compared with the Lake Superior composite, the Silver Bay area is lower in the values of all quality indicators, except for iron and nickel.

ELEMENT RATIOS

The taconite tailings, being relatively insoluble and apparently composed mostly of cummingtonite and quartz, would be expected to have reasonably constant ratios of the various elements to iron, the principal constituent. The Reserve Mining Company analysis of bottom sediments shows a reasonably constant composition for the apparent tailings which relates well to similar analysis of the composite tailings by the U. S. Bureau of Mines. On this basis, ratios of selected elements to iron were calculated for the '66-'67 Lake Superior data and for July 1968 Silver Bay surface, middle, and bottom data. These results are shown in Table 28. Inspection of the averages and standard deviations of these ratios shows highly skewed results. It should be pointed out that these ratios do not agree in any way with the ratios in the tailings bottom sediments or with the ratios in the tailings as shown in Table 29. In all cases except aluminum, the water analyses show very high ratios for the elements. These were a thousand times higher than those in the bottom tailings

Considering that these values are reported as obtainable under ideal conditions, it is interesting to note that the "Basic Studies" contains values which are below the published limits of detection for these elements by aqueous atomic absorption.

WELCH t-TEST RESULTS

To determine whether significant differences exist in the mean values of the individual quality indicators for the Silver Bay area, when compared to the Lake Superior composite data, a Welch t-Test was applied. The particular form of the test used allowed for different standard deviations in the two populations being compared. Table 26 shows the results of the comparison. A similar test was applied to the square root transformed data. Essentially, the same results were obtained as shown in Table 27. Since the t-Test is based on normal distribution of the data, the strongest conclusions are those based on the square root transformed data (Table 27).

The tests in Table 27 show, as expected, that the bottom samples are higher in iron and turbidity than is true for the lake as a whole. For all of the remaining parameters (except for one instance for iron and, in one instance, nickel) the average values in Silver Bay, whether surface, middle, or bottom, are lower or the same as in the lake as a whole. The average iron value in June in the middle sample, while higher than that in the lake as a whole, is far below the established standards

It is apparent that there is good agreement in the analyses for manganese, phosphate, iron, silica, calcium, and aluminum between the U. S. Bureau of Mines and Michigan Tech. With the exception of the lead analysis, where the Bureau of Mines value is greater than three times the value reported by Reserve, there is fairly close agreement between these two laboratories on the elements copper, nickel, zinc and chromium. However, when the data reported by the U. S. Bureau of Mines and Michigan Tech is analyzed, there are serious disagreements.

The methods for sampling and preparation of these samples for analysis as detailed in the Bureau of Mines' report were adequate.

If the analysis of the tailings is so imprecise between various laboratories, some doubt is cast over the significance of single sample analyses of lake water.

If the laboratories involved in this study are using atomic absorption spectrometers for the metals analyses, then the detection limits as published by Perkin-Elmer for the Model 303 (without special concentration) are of interest and are as follows:

Aluminum, 100 µg/l
Cadmium, chromium, copper, nickel, 5 µg/l
Lead, 3 ug/l
Manganese and zinc, 2 µg/l

which has been published by the Analytical Reference Service of the U. S. Public Health Service in their publication "Water Metals No. 4, Study No. 30," Publication No. 999-UIH-8, issued in 1968.[5]

Inspection of Table 24 shows that precision values for the higher concentrations are better than those for lower concentrations of metals. The range of overall precision for the metals in this table of the higher concentrations varied from 10 to 25 percent, whereas at the lower concentrations precision varied from 28 percent to 86 percent. Such values for precision are consistent with the standard deviations for the data on Silver Bay and on Lake Superior.

A most revealing comparison of the precision obtained between various laboratories contributing to this report was made in Table 3 of the "Report on Tailings Disposal at Reserve Mining Company's Plant, Silver Bay, Minnesota," by the U. S. Bureau of Mines of the "Basic Studies" report. We have reproduced this table here as Table 25.

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(5) McFarren, Earl F, et al, "Water Metals No. 4, Study Number 30, Analytical Reference Service," Public Health Service, 1968.

On page 14 of the section of the report entitled, "Special Report in the Vicinity of Silver Bay, Minnesota," by the FWPCA Great Lakes Region, there is a review of the chemical methods employed. The metals were analyzed by polarographic techniques through 1967 and by atomic absorption since then.

Meites[3], in his text "Polarographic Techniques," states that relative errors in the order of $\pm$ 2 or 3% can usually be attained by a moderately experienced technician in the range of 1×10^{-5}M to 2×10^{-3}M (1.1 ppm to 220 ppm of cadmium for example). He further states that relative errors of $\pm$ 10% are possible, if interfering substances are absent or can be removed, at the 0.001mM (0.1 ppm) level of cadmium. The relative error can be defined as the standard deviation times 100 divided by the mean.

ASTM Committee D-19 is currently conducting precision studies of various metals by atomic absorption methods, but has published only two such methods, copper and zinc.[4] The results for precision are in Table 24.

Also included in Table 24 is data on aqueous atomic absorption

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(3) Meites, Louis, "Polarographic Techniques," 2nd Ed., John Wiley & Sons, 1965.

(4) 1968 Book of ASTM Standards, Part 23, "Water, Atmospheric Analysis," American Society for Testing and Materials, (ASTM), October, 1968.

respective samples and are probably the result of manipulation or analytical error.

SENSITIVITY AND PRECISION OF WATER QUALITY TESTS

Standard Methods[2] states: "Precision is a measure of the reproducibility of a method when repeated on a homogeneous sample under controlled conditions, regardless of whether or not the observed values are widely displaced from the true value as a result of systematic or constant errors present throughout the measurements. Precision can be expressed by the standard deviation."

For all chemical analyses it is important to present precision statements to lend additional credence to any analytical results reported. No mention is made in the "Basic Studies" of the accuracy and precision of the analytical methods used. One notable exception is the portion of the report prepared by the U. S. Bureau of Mines which does some statistical treatment of the results.

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(2) "Standard Methods for the Examination of Water and Wastewater," 12th Ed., APHA, AWWA, WPCF, 1965.

REJECT DATA FROM JULY 1968 SILVER BAY

The extreme values in Table 19 for surface samples appear to result from manipulative or analytical errors except possibly for sample 2250. The latter is internally consistent insofar as turbidity and iron are concerned, but not consistent in the phosphorous iron relationship. The high aluminum may account for the high turbidity, and if so, the iron analysis may actually be in error. The latter case is in accord with the observations on the June 1968 data.

The analysis of the values in the middle samples in Table 21 is much the same as that for Table 19, except that 3 of 19 samples (2251, 2257, 2339) appear to result from sampling error or reflect discontinuities in the data when compared with the correlation in Figures 1 to 8. Sample 2339 is in very shallow water subject to local disturbance. Samples 2251 and 2257 are at the extreme southwest end of the survey area and in relatively deep water which is puzzling, since samples to the northeast at the same depth show much lower values. These extreme values may result from a local disturbance.

Of the fifteen bottom samples, six (2252, 2261, 2289, 2301, 2304, 2313) contain extreme data, some of which appears to be the result of sampling or of discontinuities in the source. Some, such as the phosphorous in 2252 and the turbidity in 2289, while rejected, appear inconsistent with the associated values in the

picture as the '66-'67 Lake Superior data in Tables 12 and 13 in that, generally there is no apparent relation between the various indicators, as comparison with Figures 1 through 8 will show. Thus the extremes appear to reflect mostly manipulative and analytical error. Of fourteen rejected middle samples, which are shown in Table 16, all but three appear to have extremes of analytical origin. Three samples (2061, 2073, and 2088) have an internal consistency based on the relationship in Figures 1 through 8 that indicates either sampling error or reflects true discontinuities in the data source such as would occur from local clouds of suspended matter. The location of these samples is in accord with this latter possibility, as all three are in a southwesterly line from Silver Bay harbor. It is important to note, however, that these extreme values are lower than the existing standards.

Examination of the reject bottom samples shows four that appear to have extremes resulting from analytical error and four (2059, 2083, 2089, 2104) that reflect sample errors or local discontinuities in the quality. The latter observation probably is correct and is not surprising in view of the inherent discontinuities in the quality of the bottom water resulting from density currents. The extremes (as expected) exceed the values established in the standards.

Bottom sample values, with few exceptions, do not have a normal distribution even after square root transformation. This condition reflects the discontinuous nature of the source where one sample may be in the density current and the next one out of it in clear water.

The values for cadmium and chromium were very few in number and were not subjected to extreme value rejection but were reported as determined on the raw data.

REJECT DATA FROM '66-'67 LAKE SUPERIOR

There does not appear to be any consistent relationship between the various quality indicators in the samples containing extreme values. If, for example, two related variables such as turbidity and iron were both to be high in a sample rejected because of a high iron value, a sampling error could be involved. Since generally this does not appear to be so, the most likely explanation for the reject values is a combination of manipulative and analytical errors. Table 12 shows the samples containing extreme values based on raw data examination. Table 13 based on examination in the square root form has fewer reject values.

REJECT DATA FROM JUNE 1968 SILVER BAY

The surface samples, shown in Tables 14-18, present much the same

To produce as normal a distribution as possible in the pooled values, and to eliminate analytical and manipulative errors, Chauvernet's Criterion[1] was employed. Based upon sample size, this criterion rejects extreme values whose probability of belonging to the general population is less than $\frac{1}{2n}$, where n is the number of samples.

As shown in Table 3, the pooled '66-'67 Lake Superior data, even after rejection of extreme values, does not show a normal distribution except for nickel. A square root transformation and rejection of extreme values was made with the results shown in Table 4 and 5. As will be noted in Table 4, square root transformation produced a more normal distribution. This process also altered slightly the means and standard deviations of the scrubbed data since rejections in the square root transformed condition were fewer than in the raw condition.

Examination of the averages and standard deviations of the June and July 1968 Silver Bay data in Tables 6-11 shows, for surface and middle samples, a normal distribution for turbidity, phosphorous, and cadmium, and nearly normal distributions for iron. The remaining elements do not have a normal distribution. Square root transformation of the data with extreme value rejection again produced more normal distribution and slightly altered the means and standard deviations of the scrubbed data.

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(1) Chazal, Marc de, "How to Discard Invalid Measurements," Chem. Engr., February 13, 1967, p. 182.

It is noted that no differences were significant in surface, middle or bottom for turbidity and phosphorous in the '66-'67 Lake Superior data. Since no bottom flowing density currents are expected in areas other than Silver Bay, this result is not surprising.

The results of this analysis of variance led to the decision to treat the Silver Bay data statistically as three populations, surface, middle, and bottom, and to pool as one population all of the data, surface, middle, and bottom, of the '66-'67 Lake Superior Study.

AVERAGES AND STANDARD DEVIATIONS

The results of the sampling and analysis of the lake water shown in the "Basic Studies" reflect not only normal manipulative and analytical errors, but also normal errors in sampling. In addition, pooling the results for the entire Lake Superior as was done in the statistical analysis, assumes that the quality indicators follow a normal random distribution in value and do not reflect truly different local conditions. This latter assumption is obviously incorrect, but the single sample at each sampling station makes any alternative impossible if comparisons are desired.

ANALYSIS OF VARIANCE

The discharge of taconite tailings to Silver Bay is believed to produce a density current flowing along the bottom down the natural slope. Changes in direction of the density current would produce a shifting pattern of concentration in the bottom samples. This picture leads to the conclusion that the samples of Silver Bay, if pooled as a single population, would produce a highly skewed distribution. Separating the samples into groups of surface, middle, and bottom, would tend to form like populations and thus render the data more susceptible to normal treatment.

Table 1 shows the results of an analysis of variance test run on the raw data compilation from Tables 6, 7, 18, and 19 of Section 3 of the "Basic Studies." The July data, being more complete, demonstrates clearly that at least for turbidity, iron, and phosphorous, the bottom data is from a different population than the surface or middle data. Table 2, which combines surface plus middle and compares them with the bottom samples, simply confirms the fact. The variance within the data for the remaining quality indicators is too great to confirm any significant difference between surface, middle, and bottom. This may indicate that the source of these elements is different from the taconite tailings which appear to constitute the major source of the turbidity, iron and phosphorous in the bottom samples. This point will be discussed later in connection with the ratios of selected elements to iron.

elements to iron in the July, 1968 data, when compared to corresponding ratios in the tailings, and in the apparent tailings sediment from the bottom of the Silver Bay area, demonstrate the point clearly.

Examination of the available sensitivity and precision data shows that for the methods employed, many of the results are below the sensitivity of the published methods. The published precision values are of the same magnitude as the standard deviation for the quality data in the report, and tend to confirm that the statistically rejected extremes were largely the result of analytical errors inherent in the methods of analysis employed.

Comparison of the quality of the water in Silver Bay and in the lake with the existing Federal-State standards for '66-'67 Lake Superior and with the proposed standards, reveal that the Lake Superior data exceeds the proposed standards for turbidity, iron, phosphorous, lead, copper, zinc, and nickel.

The Silver Bay values, even though lower than those for the lake, exceed the proposed standards for iron, copper, zinc, nickel, and cadmium (no cadmium values were available on the '66-'67 Lake Superior data). The Silver Bay surface and middle values, however, do not exceed the present standards.

SUMMARY

The statistical analysis of the quality indicator data shows that the values for turbidity, phosphorous, lead, copper, and zinc are lower in the surface and middle samples of Silver Bay in both June and July than in Lake Superior itself. The values of iron for Silver Bay are higher in June but the same in July as in the lake, while nickel is the same in June but higher in July. Since the surface and middle samples presumably reflect the quality of the bulk of the water in Silver Bay for the period sampled, it appears reasonable to assert that there is no analytical evidence that the taconite tailings discharged have any significant effect on the quality of the water in Silver Bay.

Taconite tailings form a density current that flows along the bottom of the lake. This fact is evident from the chemical determinations on the bottom samples which show that iron, phosphorous, and turbidity are higher in these samples than in either the Lake Superior samples or in the surface and middle samples from Silver Bay. It is important to note that lead, copper, and zinc are lower in the bottom samples than in the lake while nickel is the same.

There are apparently major sources other than the taconite tailings for the trace elements: copper, nickel, zinc, lead, and chromium in the Silver Bay area. The ratios of these

These tables were contained in Section 3, "Investigations by Chicago Program Office," of the subject study.

The Lake Superior data from both the 1966 and 1967 cruises were treated as a whole. The surface, middle, and bottom sample data of the June and July, 1968 cruises were analyzed separately. The averages and standard deviations were calculated and extreme values were rejected by a statistical method known as Chauvernet's Criterion. The Welch "t-Test" was applied to the means to determine whether they were significantly different from each other. Since not all of the quality indicator values had a normal distribution after extreme value rejection, all of the raw data was transformed to the square root form in which the distribution was normalized. The "t-Test" was applied in this transformed condition as well.

The samples having extreme values rejected were examined carefully to determine whether the extremes were the apparent result of sampling or analytical errors. In addition, the respective sensitivity and precision of the tests employed for water analysis were reviewed, as these factors affect the overall variance of the data.

INTRODUCTION

The "Basic Studies On Environmental Impacts of Taconite Waste Disposal on Lake Superior," by the United States Department of the Interior agencies and others, December 1968, presented the results of a series of studies on Lake Superior, Silver Bay, and the tailings discharge of the Reserve Mining Company. This included the results of chemical analysis of samples of water collected from Lake Superior and from Silver Bay during several survey cruises made for this purpose.

The water quality data contained in the subject report was analyzed statistically, as will be described, to determine the significance of quality indicator variations that were observed. Particular attention has been paid in this report to determination of the significant differences for each of the important quality indicators between the Silver Bay area and Lake Superior as a whole. Specifically, the quality data examined were shown in

Table 6 Chemical Determinations
Sample Source: Lake Superior
Study Period: 10/17-11/6/66

Table 7 Chemical Determinations
Sample Source: Lake Superior - Cruise 2
Study Period: May and June, 1967

Table 18 Chemical Determinations
Sample Source: Silver Bay - Lake Superior
Study Period: 6/17-20/68

Table 19 Chemical Determinations
Sample Source: Silver Bay - Lake Superior
Study Period: 7/15-19/68

21. Samples Containing Extreme Values Rejected by Chauvernet's Criterion, July 1968, Silver Bay, Middle

22. Samples Containing Extreme Values Rejected by Chauvernet's Criterion, July 1968, Silver Bay, Bottom

23. Samples Containing Extreme Values After Square Root Transformation and Rejection by Chauvernet's Criterion, July 1968, Silver Bay, Bottom

24. Precision of Atomic Absorption Methods for Metals in Water

25. Comparison of Average Sample Results by Laboratories (U.S. Bureau of Mines Report)

26. Welch t-Test Analysis, June, July, 1968, Silver Bay, vs. '66-'67 Lake Superior

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CYRUS WM. RICE AND COMPANY

STATISTICAL ANALYSIS OF THE CHEMICAL DETERMINATIONS DATA IN THE "BASIC STUDIES ON ENVIRONMENTAL IMPACTS OF TACONITE WASTE DISPOSAL IN LAKE SUPERIOR"

UNITED STATES DEPARTMENT OF THE INTERIOR

AGENCIES AND OTHERS

DECEMBER, 1968

PREPARED FOR

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA

BY

CYRUS WM. RICE AND COMPANY
15 NOBLE AVENUE
PITTSBURGH, PENNSYLVANIA

J. K. Rice, P.E.

1569

CYRUS WM.
RICE AND COMPANY · WATER MANAGEMENT CONSULTANTS

than taconite tailings for the copper, nickel, zinc, lead, and chromium in Silver Bay samples.

MR. DOMINICK: You mentioned that Silver Bay surface and mid-depth analyses were considered in your report. Did you consider any bottom samples?

MR. RICE: Yes, sir, I did, in the surface, mid-depth samples, and bottom samples were all considered separately in the treatment, and the original analysis of the various steps as covered in the report shows that the bottom samples are a distinctly different population of data.

Then we maintain this separate treatment. This difference is expected in view of the fact, and the fact confirms it turns on the bottom.

MR. DOMINICK: Are there any other questions?

(No response.)

MR. DOMINICK: Thank you, Mr. Rice.

MR. RICE: I would like to have the report "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior," which was prepared by Cyrus Wm. Rice & Company, made a part of the record.

MR. DOMINICK: That will be done.

(The above-mentioned report follows.)

James K. Rice

I have shown in Slide 3 the precision for one commonly employed atomic absorption method for several of the trace metals. This data was taken from Analytical Reference Service, U.S. Public Health Service, 1968. Note that in the concentration range of 0.010 mg/l the precision varies from 25 to 90 percent of the average quality data such as we are discussing just from normal analytical error. The standard deviation of the chemical determination data in the report thus reflects the variance from the analytical procedure as well as true variation in the values of the indicators.

Based on this and other considerations, the extreme values found for many of the quality indicators appear to be the result of normal analytical errors.

I have summed up the results of my analysis of the data in the table in Slide 4. Here the average values for the various water quality indicators are shown, as well as the values of the present and proposed criteria for Lake Superior open waters.

Note that Silver Bay surface and middle values do not exceed the present standards. Note also that the values for Lake Superior exceed the proposed criteria for turbidity, iron, phosphorus, lead, copper, zinc, and nickel.

In conclusion, I wish to once again point out that Silver Bay surface and middle values do not exceed the present standards, and in comparison with Lake Superior, Silver Bay's are lower in turbidity, for phosphorus, lead, copper, and zinc.

The data also shows that there are major sources other

Since the surface and middle samples presumably reflect the quality of the bulk of the water in Silver Bay for the period sampled, it is reasonable to assert that there is no chemical, analytical evidence that the taconite tailings discharged have any significant effect on the quality of water in Silver Bay.

One approach to examining the data in Silver Bay was to calculate the ratios of the trace metals to iron as found in the tailings, the apparent tailings sediments, and the natural sediments from the bottom of the Silver Bay area and in the water samples from the surface, middle and bottom of Silver Bay.

Slide 2 shows the results of this approach. Note that in general there are no significant differences in the ratios between tailings and the tailing sediments indicating no selective fractionation. The ratios in the water samples, however, are a thousandfold higher. In my opinion, this large difference can only mean that there are major sources other than taconite tailings for the copper, nickel,zinc, lead, and chromium found in the water of Silver Bay.

Chemical determinations always reflect normal errors in sampling and in analysis itself. Each type of test has its own sensitivity as well. Thus it is expected that results vary over a range of values, even when the true value, if it were known, is constant. The only mention in the subject reports of the methods of analysis employed is that polarigraphic methods were used in obtaining the 1966-1967 trace metal data, while atomic absorption methods were used for the 1968 data.

The exact atomic absorption method is not specified, nor is its sensitivity or its precision.

surface and middle data in Silver Bay were significantly different from the bottom. This fact supported a decision to treat the Silver Bay data in the separate groups -- surface, mid and bottom -- rather than combine them into a single pool of data. This finding was consistent with the presence of a density current along the bottom.

The same analysis applied to the Lake Superior data of 1966-1967, however, showed, as might be expected, no significant differences between surface, mid-depth and bottom, so that I pooled this data and treated it as a single group for comparison purposes.

A comparison of the data from Silver Bay was made versus the data from Lake Superior as a whole in order to determine whether each of the quality indicators, the trace elements, were higher, the same, or lower in Silver Bay versus the lake. This comparison is obviously important as it can indicate whether the taconite tailings are influencing in any detectable way the quality of the lake water as found in Silver Bay.

The results of such a comparison are shown in the first slide. My analysis showed conclusively that the values for turbidity, phosphorus, lead, copper, and zinc are lower in the surface and mid-depth samples of Silver Bay in both June and July than in Lake Superior itself. As expected, the bottom sample values from Silver Bay show iron and turbidity higher than either the surface and middle of the lake.

It is interesting to note that in spite of the presence of tailings in the bottom samples, lead, copper and zinc are lower than in the lake as a whole. Note that the values for iron are higher in June, but the same in July for Silver Bay vs. the lake while the values for nickel are just the reverse.

James K. Rice

gentlemen:

My name is James K. Rice, Consulting Professional Engineer. I am President of Cyrus Wm. Rice & Co. of Pittsburgh, Pennsylvania.

We are a firm specializing in water management. I have 22 years of experience in measuring and controlling quality of water for various uses and for discharge to streams and lakes.

I was appointed by Secretary Udall as Chairman of the National Technical Advisory Committee, Subcommittee for Industrial Supplies, one of five advisory subcommittees, whose combined reports worked up the publication "Quality of Water*" FWPCA.

I am a consultant to Reserve Mining Company. In this capacity I have examined carefully and made an analysis of the chemical determinations found in Section 3 by its Chicago Program office of the report, "Investigation of the Distribution of Taconite Tailings in Lake Superior," USDI, FWPCA, Great Lakes Regional Office, October 1968. These data were collected on Lake Superior during 1966-1967 and on Silver Bay in June and July of 1968.

The statistical procedures employed by me in my analysis of the data are documented in my report. Suffice it to say that the procedures were standard ones applicable to chemical determination data, and they enabled me to draw conclusions that I believe are entirely supportable.

The chemical determination data on the quality of water in Silver Bay and in Lake Superior were obtained from surface, mid-depth, and bottom samples. A statistical procedure known as analysis of variance was applied to these groups of data and showed that the

*Water Quality Criteria

James K. Rice

MR. BADALICH: Mr. Chairman, I believe this covers the presentation of Minnesota and the written statements I have received.

At this time I call upon Mr. Ed Fride who will complete the presentation for Reserve Mining.

MR. DOMINICK: Are there any other public witnesses in the room who would like to testify? If so, would you please come to the front table and we will take your name.

(No response.)

MR. DOMINICK: Mr. Fride.

MR. FRIDE: Mr. Commissioner, we have two witnesses whom we will call to complete the presentation of Reserve Mining Company.

The first is James K. Rice. Mr. Rice has degrees in chemical engineering. He is the President of the Cyrus Wm. Rice Company of Pittsburgh, Pennsylvania, which is one of the Nation's leading water quality research organizations.

Mr. Rice has contributed a great deal of scientific literature and has come to many seminars of monitoring. In 1967 he was honored to be the Chairman of the National Technical Advisory Committee on Water Quality for Industry.

Mr. Rice.

STATEMENT OF JAMES K. RICE, PRESIDENT,
CYRUS WM. RICE & COMPANY, PITTSBURGH,
PENNSYLVANIA

MR. RICE: Mr. Commissioner, conferees, ladies and

mankind with all the forces at our disposal. We cannot, and will not wait until tomorrow to attack problems before us today.

Duluth Conservation Committee

Minnesota Pollution Control Agency to help clean up the St. Louis River. However, the five-year timetable allowed by the agency before the treatment plants are placed in operation, is unrealistic.

Presumably, other industries which are found guilty of polluting our waters in future years, also will be given five-year schedules before halting undesirable practices.

We can no longer wait five years to stop the degradation of our water.

People of this region have a veritable gem in Lake Superior. The lake will prove so valuable to the very existence of this region that its future worth is directly related to its purity.

We residents, who are the working men and women in this beautiful and rich region, have the ability and responsibility to preserve the unsurpassed natural beauty in our corner of the world. On the other hand, we can ignore all warnings, and maybe someday we can see a giant oil slick or some other form of industrial catastrophe because we believed it when a selfish industry talked about the jobs and money and ignored those of us who were talking about environment, pollution, and the future of mankind.

Organized labor, as most of you know, has been in the forefront of fights since its inception. We have attacked our enemies with vigor in the past, and we will continue to fight as doggedly today for causes that are good and just to the working men and women.

We, as union people, are convinced that Lake Superior has pollution problems. We are determined to fight this enemy of

Duluth Conservation Committee

We have heard the emotional, illogical explanation of a company fighting for its profitable life.

The concerning thing is what appears to be a dragging of feet by State Legislatures and Congress, when it come to pollution control. Doesn't the voice of the voter count anymore? Is the voice of business and industry the only voice left?

One of our legislators recently was quoted in the daily press as saying "The truth is that not very much is really known about Lake Superior pollution." He also said "My position has always been you've got to find out more about the causes and effects of pollution. You've got to know more scientifically about what's happening in the lake before you can figure out how to cope with pollution, regardless of what the law is or how good your intentions are."

The same legislator said the Stoddard Report just confused everybody. "It was completely false," he said.

Delegates, we submit that a study undertaken so extensively could not be completely false by any stretch of the imagination. This report, pardon our expression, resulted in getting many people off their dead legs and into action which resulted in this conference today.

While we realize that the primary reasons for this conference are to determine the effects of taconite tailings in Lake Superior, and to prescribe corrective measures, we submit that we cannot ignore the existence of many other sources of pollution in the lake.

We were gratified to learn early this year that two major industries in Cloquet had reached an agreement with the

Duluth Conservation Committee

an algal bloom and a summer stink that rises from the river for miles below the metropolis." These are quotations from The President's Council on Recreation and Natural Beauty, in its 1968 report.

Delegates to this conference, may we remind you that we are well aware of the water pollution problems confronting our heavily industrialized areas in the East.

Our purpose here today is to emphasize our deep and continuing concern for something that for all too long has been taken for granted by too many of our area residents.

Some of this concern has no doubt been prompted by local and national publicity about dying lakes, but probably has received its greatest impetus from the fact that on many lakes--pollution--can be seen by anyone who cares to open his eyes.

Much has been said and written about water pollution in our region, with emphasis on Lake Superior, and the streams and rivers that are its tributaries. Some sense has been made, and also some nonsense.

Much of the controversy centers around a document issued by the U.S. Department of Interior. Most of us here today have heard of or read about the Stoddard report, and of the controversy that erupted when it was first made available to the press.

It was natural that the Reserve Mining Co. reaction was negative, and a vigorous denial of any wrong doing followed the release. In all sincerity we can't fault these people too greatly because they're doing what they do best--making money.

Duluth Conservation Committee

STATEMENT TO THE LAKE SUPERIOR WATER POLLUTION CONFERENCE

By the Conservation Committee

Duluth AFL-CIO Central Body

Concerned delegates to this historic Lake Superior Water Pollution Conference. We represent organized labor in the Duluth Area. We, as members of the Duluth AFL-CIO Central Body's conservation committee, have for many years been deeply concerned with water pollution in our region. The emphasis today is on Lake Superior. And well it should be for our purest water, we believe, is gravely threatened.

To our many visiting officials from Washington, we say welcome to our fair city and would like to call their attention to a few quotations from an article in the Minnesota Engineer issue of March 9, 1969.

It's title is simple, "Of Time and The River" and reads as follows:

"Its waters are so clear, we could see the bottom in several fathoms." (It is fed with) "many sweet rivers and springs" (and filled with) otters, beavers, martins, luswarts, and sables," (and fish so thick that) "we attempted to catch them with a frying pan." "Neither better fish, more plenty or variety, had any of us ever seen in one place." These are quotations from Captain, John Smith on his first view of the Potomac River, in 1607.

"As the Potomac slowly flows through the Nation's capital, its load of silt, filth, and acid from the farms, mills, and mines blends with discharge from overloaded sewers to nourish

We also raise these questions because we have considered the possibility of a horrible mistake in which millions of dollars, if the Company chose to spend them, could be wasted for no good reason, some of which, at least could be spent for the many useful purposes our area needs so badly, such as schools and additional employee benefits.

We firmly believe that Reserve Mining Company employees and the people of Minnesota deserve the right of a complete and unbiased hearing on the one sole issue stipulated - "Does the depositing of these grindings by Reserve Mining Company harm Lake Superior", and that the hearing not be clouded with other matters under consideration, such as dumping of raw sewage, garbage and chemicals.

We are concerned that if this above procedure is not provided, it may resemble an odd court procedure that would bring two accused individuals into the court and the guilt of one would automatically convict the other. Our courts do not operate this way, neither do we believe that any issue be handled in this manner.

We recommend that all opinions and judgments be withheld until such time that this matter be clarified on the basis of facts in procedures as stated.

We further recommend that opinions and judgments on this matter not involve other unrelated matters with all mining companies that must be carried to resolution.

Glenn E. Peterson, Director
United Steelworkers of America

Russell Monson, Staff Representative

Nick Krmpotich, Staff Representative

Clifford Campbell, Staff Representative

Joseph J. Gustin, Staff Representative

Elton J. Kirsch, Staff Representative

TO THE CONFEREES:

Recent publicity and articles probably based on a premature, and as we understand, an unofficial report by an individual of the Department of Interior, have indicated that Reserve Mining Company's by-product of ground rock has a serious effect on Lake Superior.

We write this article only on the basis that a conclusion on a major issue as this cannot be, and should not be reached until such time that due processes which afford all concerned parties ample opportunity to present witnesses and evidence.

We feel that unfounded statements concerning what some individuals may for their own particular purposes label as pollution, can arouse public opinion to the extent that demands can be made on a governamental body to the extent that a cease order could be given, which could have serious repricussions on the future welfare of many people and communities.

We agree with programs that will serve to eliminate actual pollution of the water and air, but cannot agree until undisputed evidence is forthcoming that these grindings do pollute.

Some people on the Mesabi Range mistakenly identify the taconite grindings with the tailings such as come out of the hematitie ore wash plants. These hematite ore tailings do contain soft, sticky paint rock and other materials that do not exist in taconite grindings.

Some people would have us believe that there never had been Federal and State hearings prior to someone giving Reserve the go-ahead on the present method of depositing these grindings. This is not true. Extensive hearings before Federal and State Agencies were held in 1947 and at later dates. Testimony of independent expert witnesses was taken and the same questions were raised as are being raised now. At the conclusion of these hearings Reserve was granted permission to proceed with the present method of depositing the grindings.

Some alternatives have been tossed about, one of which is to deposit the grindings inland from Silver Bay. We wonder if some who claim to be conservationists have considered this alternative which would take up a lare area, including trout streams and lakes, and that the deposits would cover over this area as against the present method which places the material in lake depths up to 900 feet, which lake bottom could never be used even by fish.

UNITED STEELWORKERS of AMERICA (AFL-CIO)

Local 5296

SILVER BAY, MINNESOTA

May 13, 1969

Attention: Minnesota Pollution Control Agency

We of the United Steelworkers at Silver Bay have requested permission to speak at this time. We will not present any scientific facts or data because, like many of us here today, I doubt that we could properly evaluate it.

We do, however, believe that the employees of Reserve Mining Company have more at stake here today than any other single group of people. Fifteen years of our lives and all of the material things which we possess are in the Silver Bay area.

The fact is, whether we like it or not, Silver Bay is a one industry town. Reserve Mining Company is our industry - the only one we have and when you have only one industry you can't stand silent and let somebody destroy it without a good reason.

We are not opposed to a scientific study of Lake Superior or of the rock which is discharged from the plant. Reserve has probably been studied and restudied more than all other areas of Lake Superior put together. There was an extensive study in the late 1940's before Reserve was allowed to build and again in 1960 before the plant expansion. We have to assume that the people who made the studies were honest, sincere and qualified. Now a most extensive study has been completed and up to this point we have not had the official word that the taconite discharge is having the effect on the lake that some people would have us to believe, people we might add, who have not been willing to wait for the completed reports by the authorized agencies.

We would be satisfied to clear away the debris of politics and sentimentality which have tended to crowd scientific data and research into the background.

We would like to have the agencies in charge stick to the cold hard facts and reach their conclusions without outside interference.

United Steelworkers of America (AFL-CIO)

MR. BADALICH: And I have two statements from the United Steelworkers of America, Local 5296, AFL-CIO, Silver Bay, Minnesota; and one from the Conservation Committe, Duluth AFL-CIO Central Body.

(The above-mentioned statements follow.)

During a long life time I have seen nature at work in thousands of lakes in our area which have rock bound shores and the water and waves against the rocks and sand on the shore pulverize it into fines that eventually settle on the bottom of these lakes---and without doing any harm to the aquatic and fish life. This is no different in what is happening at Reserve.

We urge this group to tread carefully and not create a bad business climate for other industry that might be interested in our area, such as the copper-nickel industry.

Taconite has given us payrolls. This is what we want--- not relief rolls such as we experienced in this area prior to the taconite era.

Sincerely,

Jacob L. Pete

Jacob L. Pete

TESTIMONY PREPARED FOR THE
LAKE SUPERIOR WATER QUALITY ENFORCEMENT CONFERENCE
SPONSORED BY THE
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
May 13, 1969
Hotel Duluth

My name is Jacob L. Pete, address 3 West Chapman Street, Ely, Minnesota. I have lived in this lake country for almost three quarters of a century. I have served as the Saint Louis County Commissioner for 16 years and have been very active in civic and conservation work all my life.

I am alarmed at the unwarrented and unjustified publicity Reserve Mining Company has received from sources and reports prematurely issued and have since been proven a misrepresentation of the facts.

Reserve Mining Company, one of our largest employers, pioneered the taconite industry in the State of Minnesota and it is through their successful efforts that we have today a total investment in taconite plants in excess of one billion dollars in Northeastern Minnesota.

Both State and Federal Governments have approved Reserve Mining Company's water permits and disposing excess rock material in Lake Superior. It was after these permits were granted that Reserve Mining Company in good faith invested some 350 million dollars in the future of this area.

It is my belief that after listening to the experts, pro and con, that there is no evidence that Reserve Mining Company is polluting Lake Superior. They are being unjustly critized and I am fearful that this adverse publicity will put its operation in jeopardy.

J. L. Pete

MR. BADALICH: A statement from Mr. Jacob L. Pete of Ely, Minnesota.

(The above-mentioned statement follows.)

open and constructive point of view";

3. Previous evidence produced from Federal and State agencies studies indicated that Reserve Mining Company was not violating State or Federal standards for water quality nor damaging fish life in Lake Superior; and

4. A great deal of unnecessary and prejudicial publicity has been given because of the publication of such a working draft as if it were an official report of the Department of the Interior;

THEREFORE, BE IT RESOLVED that the Committee recommends to the Board of Directors of the Association that any action that might be taken as a result of the publication of this "Report" be delayed or held in abeyance until the final findings of the Federal-State conference scheduled for May 13, 1969 can be studied and appraised by this Committee."

The motion was seconded by Ed Jankowski and unanimously approved by the Committee.

* * * *

CONSERVATION COMMITTEE

MINNESOTA ARROWHEAD ASSOCIATION

Meeting Held Wednesday, 2-5-69

(To the Attention of the Executive Committee)

A motion was made by John Wernham as follows:

"The Conservation Committee expresses its concern over the recent publicity regarding a "Report" prepared by a former member of the U. S. Department of the Interior purporting to establish that Reserve Mining Company is harming the purity and beneficial uses of Lake Superior.

"In view of the facts that:

1. The Assistant Secretary and head of the Water Pollution Control Administration of the Department of the Interior has said that the paper was merely a working draft that had not been approved by that Department, contains errors, and was not an official report of that Department;

2. Stewart L. Udall, the retiring Secretary of the Interior, has called a Federal-State conference on May 13, 1969, which he stated was to be "exploratory and fact-finding in nature" with respect to alleged pollution in Lake Superior and stated that the conference should be not entered into with "preconceived opinions, but with an

However, in view of the gravity of this hearing we wish to make record to this Commission regarding the experience of the M. A. A. with the operation of the Reserve plant at Silver Bay. Our organization promotes and deems as one of the regions greatest assets our pure and crystal clear waters. We recognize the tremendous value this God given resource is to this area. We could not possibly promote or countenance any industry in our area who endangered or destroyed this great asset. For the past ten years the Association has watched the activities of the Reserve plant at Silver Bay and counted this industrial marvel as a great addition to our area. At no time have we had anything but the highest regard for the operation of this plant and the care and concern shown by their management in the treatment of the waters of Lake Superior. Our Association has not to this date been in receipt of any evidence produced from local or state agencies indicating that Reserve was in violation of State or Federal standards for water quality or for damaging fish life in Lake Superior.

The plant at Silver Bay is one of the North Shores and this areas outstanding tourist attractions. During the summer up to 1800 visitors a day witness the taconite processing from the Company observation stands. Far from being a detriment to the North Shore, the plant is an outstanding asset. Their use of the Lake has provoked no objections from visitors on spoiling the beauty of the lake.

In developing an area as widely diversified as Minnesota's Arrowhead country, we must consider all possible assets, industrial development, agriculture and recreation. We consider the taconite operations to be not only a vital economic asset to Northeastern Minnesota, but also an aesthetic tourist attraction as well.

MINNESOTA ARROWHEAD ASSOCIATION

President

MINNESOTA ARROWHEAD ASSOCIATION

Federal Water Pollution Control Hearing

Duluth, Minnesota

May 13, 1969

Gentlemen:

This statement regarding the Reserve Mining Company plant at Silver Bay, Minnesota and how it effects the tourist industry in this area is made on behalf of the Minnesota Arrowhead Association who sincerely appreciates the opportunity to appear at this conference today.

The M. A. A. is in its 45th year of continuous operation. It is the oldest regional association in the State of Minnesota and one of the three oldest in the nation. It enjoys a reputation as one of the nations outstanding tourist promotional groups. Its membership is made up of over 51 member organization representing in excess of 15,000 associate members in the 12-county area of Northeastern Minnesota. Although its primary function is one of promoting the tourist industry it also concerns itself with the commercial and industrial economy of the area. The opinions and positions of its membership therefore on area issues reflects this extremely broad base of support. The Association has over the past 45 years involved itself with the major issues confronting Northeastern Minnesota. Its tenure and its strength today speak for the position it has gained in the eyes of the citizens of Northeastern Minnesota.

It is now greatly concerned and deeply interested in the subject under discussion at this conference. On February 5th of this year its Executive Committee passed a resolution which stated that any decision by the Association regarding the possible pollution of Lake Superior by the Reserve Mining Company be withheld until the findings of this conference were determined. We have not changed our position in this regard and we do await and will abide by decision of the experts on this matter. A copy of our resolution is attached to this statement.

also are proud that we are not a so-called "company town". Reserve does not own our stores, our homes, or run our government. Lest anyone think otherwise, I might point out that our duly elected mayor -- the Honorable Frank Scheuring -- works for Erie Mining Company, not Reserve!

Nevertheless, we feel a close bond of kinship with Reserve. There has always been a spirit of friendly, helpful cooperation between the community and the company. It is a historical fact that Silver Bay did not exist before Reserve Mining Company. It is an equally obvious fact that Silver Bay could not exist without Reserve. We are, therefore, intimately concerned about the future of Reserve -- with which our own individual futures are so closely related.

Thank you.

MR. BADALICH: I have a statement from the Minnesota Arrowhead Association.

(The above-mentioned statement follows.)

and security of the people of this community whose very livelihoods depend on the continued operations of Reserve Mining Company.

The Chamber is made up of individual, independent businessmen who have invested their money and lives in the good faith that Silver Bay will continue to grow and prosper. Any curtailment of Reserve's ability to operate -- produce and ship iron ore pellets from Silver Bay -- would directly affect the welfare of our people.

Before Reserve began construction of its plant in 1951 the area had only one person per square mile. There was no community. Silver Bay was merely a name on a mariner's chart. Today, it is a modern, planned community of about 4,800 persons. From a wilderness area there has been carved out a beautiful, thriving community of nearly 900 homes, chruches, three of the finest schools in the State of Minnesota, and many other fine institutions.

We take pride in our past accomplishments and look forward to future progress confidently. Our citizens left other areas to build new lives as well as a new town. Recently, they passed a bond issue for construction of a new municipal building. The Chamber and the community in general have worked actively to establish a fine recreation program for adults and young people alike. We have developed and recently improved a municipal airport which can accommodate twin-engine aircraft on its 3,200-foot paved runway. We currently are planning to develop a marina on the North Shore of Lake Superior at Silver Bay.

Silver Bay has grown from infancy over the past few years into a well-established self-governing community. Although we are proud of our title as the "Taconite Capital of the World," we

Vernon Larson

Jerry Foster, President
Midway Park Community Club
528 Summit Avenue
Proctor, Minnesota 55810

MR. BADALICH: A statement of Vernon Larson, President of Silver Bay Chamber of Commerce.

STATEMENT OF VERNON LARSON, PRESIDENT,
SILVER BAY CHAMBER OF COMMERCE

MR. LARSON: My name is Vernon Larson. I am a resident of Silver Bay where I am employed as an insurance agent. I appear today as the President of the Silver Bay Chamber of Commerce.

The Silver Bay Chamber, like our entire community, is alarmed and concerned about recent statements and charges against Reserve Mining Company's use of Lake Superior. We feel that many unfounded accusations have caused the general public to form an adverse opinion of this industry's use of the lake. We also feel that these charges have, in some cases, been premature and unfairly made in advance of this Federal conference. We sincerely hope that the issue will be considered on the basis of the facts in an impartial atmosphere without emotional judgements.

As a Chamber of Commerce we do not claim to be experts on water pollution and we do not pretend to make any determination as to whether Reserve Mining Company is or is not polluting Lake Superior. We are, however, qualified to judge what is good for the people of Silver Bay. We can speak as experts on the welfare

natural resources for the use of our children and grandchildren and their children and grandchildren and mobilize all of our forces to solve the problem, and act accordingly.

MR. BADALICH: A statement from Mr. Jerry Foster, President of the Midway Park Community Club of Proctor, Minnesota.

STATEMENT OF JERRY R. FOSTER, PRESIDENT,
MIDWAY PARK COMMUNITY CLUB, PROCTOR,
MINNESOTA

MR. FOSTER:

The Midway Park Community Club in regular assembly does declare:

WHEREAS: Our community is a user of Lake Superior water and

WHEREAS: As a civic organization we are concerned in maintaining clean water and air

WHEREAS: We realize that pollution of air and streams deprive both us and posterity of our rightful heritage of bountiful, clean streams and air and

WHEREAS: We address this resolution particularly to the U. S. Department of the Interior hearings in Duluth, May 13, 1969, and to other kindred organizations having like concern now:

THEREFORE: This assembly of citizens do direct that responsible, expeditious action be implemented to attain and insure antipollution measures.

bad as ever and the piles of sludge to the North of the Plant appeared larger than ever. Those who tried fishing in the Spirit Lake Area have advised me that there is no fish life to speak of in the area.

I realize that there are plans being developed to seek to control this specific pollution problem. The Government Publication entitled "An Appraisal of Water Pollution in the Lake Superior Basin" published by the U. S. Department of the Interior in April 1969, reports this at page 59 under "Status of Industrial Waste Discharges" that: the U. S. Steel Corporation, Duluth Works, is to complete its pollution control system by December 18, 1971. According to the Minnesota Pollution Control Agency the following is the schedule for the Steel Plant for providing adequate treatment facilities:

1.	Engineering Report	--June 18, 1969
2.	Construction Plans	--December 18, 1969
3.	Contracts Awarded	--April 18, 1971
4.	Construction Completed	--December 18, 1971

Now I am pleased that such a program is being developed. I hope that when completed, that it is adequate to control the problem. However, I am wondering if we are not following a "too little and too late" policy. I am wondering if we can afford to drag our feet on this problem.

If America was suddenly attacked by a foreign power similar to the attack on Pearl Harbor, this Nation would at once moblilize all its resources and manpower to repel the enemy. While the pollution of our waters and air and our environment may not appear as dramatic as an armed conflict, it is very real and it may have more far-reaching effects than any war. I believe we should look upon it as a war--as a war to save our precious waters and

"2. The refuse dumped into the river by the Steel Plant includes:

"1) The acid used to wash the scale from the steel.

"2) Oil and oil products used in the lubrication of machines.

"3) The scale from the steel (the men at the plant call this 'slag').

"4) The refuse from the toilets; and

"5) All kinds of miscellaneous waste products."

I understand that my statement disturbed some of the officials at the Morgan Park Plant of the United States Steel Corporation at the time. Their first reaction was a statement by the General Superintendent of the Morgan Park Plant was that "Hargrave didn't know what he was talking about--that there was no pollution at the plant." But it was interesting to note that the next day the Company purchased copies of the aerial photographs taken at my direction which clearly showed the large accumulations of "sludge" being dumped by the company into the river, and which I had introduced into evidence at the April 26, 1967, hearing. I was also pleased to read in the Duluth Tribune about two weeks later that the Steel Plant at Morgan Park had obtained a permit from the Minnesota Water Pollution Control Commission to build a temporary settling pond of about 10 acres in area and about 6 feet deep, to try to somewhat control the problem, and that it was expected to be in operation by the fall of 1967.

Perhaps the Morgan Park Steel Plant is doing something to abate its water pollution activities, but the results are not apparent as yet. The water is not fit for human use--last fall it smelled as

materially changed since then, and secondly, to remind you that the pollution problem in Lake Superior is not limited to the Silver Bay area. We do not have to travel 75 miles up the North Shore to find water pollution. Here is the gist of what I said on April 26, 1967:

"I THINK I CAN SAY WITHOUT FEAR OF CONTRADICTION THAT THE WATER IN THE SPIRIT LAKE AREA OF THE ST. LOUIS RIVER DOES NOT MEET THESE STANDARDS (i.e. good quality industrial which is also fit for swimming and fish life) AT THE PRESENT TIME:

"1. It is common knowledge that the water in the Spirit Lake area is not fit for bathing or swimming--and is not being used as such. The water is dirty, muddy foul-smelling, and few, if any would even think about swimming there.

"2. It is also a matter of common knowledge that the water in the Spirit Lake area is too polluted for fish. The Old Timers will tell you that years ago the Spirit Lake area was one of the finest 'wall-eye' fishing areas in the river. But that is not true today--there are none or few fish in the area, and if there are any, they would not be fit for human consumption.

"IT CAN ALSO BE STATED WITHOUT FEAR OF CONTRADICTION THAT THE PRIMARY SOURCE OF WATER POLLUTION IS THE INDUSTRIAL WASTES BEING DUMPED INTO THE RIVER BY THE MORGAN PARK WORKS OF THE UNITED STATES STEEL CORPORATION.

I have made inquiries among employees of the Steel Plant to determine exactly what the Steel Plant is dumping into the River, and I am told that:

"1. The Steel Plant dumps all of its refuse and waste products into the river except certain slag by-products which are used by the Cement Plant in making cement.

R. J. Hargrave

a tendency on the part of many to single out Reserve Mining Company as the one which is polluting Lake Superior. I am not here to defend Reserve Mining Company, nor to even comment on whether or not the dumping of taconite tailings into the lake is contaminating the lake. I have not studied the problem, nor am I competent to pass judgment. I must admit that I can somewhat sympathize with the situation that Reserve Mining Company has gotten itself into. For if Reserve is indeed polluting our lake, it is only the latest company to start doing so. So let us look at the over-all problem and seek permanent solutions. It is perhaps a little unfair to single out one company (the newest one) as a scapegoat and forget the Morgan Park Steel Plant who has been dumping its refuse into St. Louis River since it built the plant during World War I. I do not believe that the fact that it has been dumping its refuse into the St. Louis River for over 50 years gives the U. S. Steel Corporation any "Grandfathers Rights" to continue to do so, while we direct our fire against Reserve Mining Company.

I now wish to get specific and direct my remarks to one source of water pollution in one area of the Great Lakes region -- that part of the St. Louis River -- St. Louis Bay which is referred to as the SPIRIT LAKE AREA, that is, the part of St. Louis River opposite Morgan Park, Gary and Riverside in Duluth.

On April 26, 1967, I appeared before the State Water Pollution Control Commission hearing held here in Duluth, which was called for the purpose of determining WATER-USE STANDARDS. I would like to summarize what I said then for two reasons -- First because the situation as to the quality of the water in this area has not

and I am advised that other contries throughout the world are having similar problems -- it is not something confined to the United States. Recently I was reading in Newsweek that Russia is having similar problems and that the people in many areas of that country are furious at the National Government for allowing State-owned industries to pollute water supplies. So Apparently water pollution is no respector of ideological frontiers. AND it has become a problem of such proportions that unless checked, it may eventually threaten human life.

THREE: That there is no need for such pollution -- that science and technology has provided us with the technical know-how for controlling water pollution. We have the means at our disposal -- all we need is the WILL to insist on the sollution of the problem.

FOUR: That in seeking to control water pollution, we need not, and I do not believe that there is any intent to destroy or shut down any one industry. I have been at several water pollution meetings in recent months where I heard misguided persons claim that in trying to save our precious waters like Lake Superior from further pollution we are in effect trying to drive some industries out of business. Nothing is further from the truth and to make such claims is a disservice to both industry and the cause of pollution control. I believe that the intent of the Federal Water Pollution Control Act is to establish an environment where both industry and human beings can live in a healthy environment -- to achieve a balance between human health and industrial development.

In recent water pollution control meetings I have noted

and that the fish life had been largely destroyed. What the FWPCA Report has done is to confirm what we already knew and helped crystalize public opinion in support of action to control water pollution. As such it has made a great contribution to the cause of clean water and saving Lake Superior from becoming another Lake Erie.

Perhaps a few generalizations on the subject are in order:

FIRST: as Congressman Blatnik stated at the opening session, water pollution control is divided into two phases -- the policy phase which relates to the making of the political decision as to whether or not we should try to control the pollution of our waters, and the implementation stage, which involves the carrying out of the policy decisions to control pollution by means of the scientific and engineering techniques at our disposal. AND as the Congressman also stated, the political decision has been made -- the passage of the Water Pollution Control Act and its gradual strengthening by amendment, and the passage of similar laws by State Government and the creation of State Water Pollution Control Commissions like we have in Minnesota, is evidence of this decision. Now we are moving to the action stage -- the doing what is necessary to stop pollution.

SECOND: The making of this political decision was late in coming -- the water pollution control problem has been developing for many many years, contaminating our waters, destroying our wildlife, and making human environment less healthy on a national scale. It has become a major problem in virtually every State in the Union,

R. J. Hargrave

MR. BADALICH: A statement from Mr. Roger J. Hargrave, from Duluth, Minnesota.

STATEMENT OF ROGER J. HARGRAVE, MORGAN PARK AREA, DULUTH, MINNESOTA

MR. HARGRAVE: Mr. Chairman, Congressman Blatnik, distinguished conferees, friends:

My name is Roger J. Hargrave, and I am an Attorney at Law who resides in Morgan Park here in Duluth, an area which is in the shadow of and directly affected by an industry which has done much to pollute St. Louis River and Lake Superior, namely, the Duluth Works owned by the United States Steel Corporation located in Morgan Park. I am a member of several conservation and other concerned groups concerned with the problem of water and air pollution, but I speak for none of them today. I prefer to appear before you today as a Committee of one -- as a Morgan Park Homeowner and as a citizen who has had a continuing interest in the control of water and air pollution for many years. As a Committee of one I do not have to worry about the opinions of other members of the organizations, but can speak my mind exactly as I see it.

Let me begin by saying that it would appear from my limited contact with local people -- the Duluth Public -- that a vast majority applaud the Federal Water Pollution Control Commission's Report. In fact, most of us were aware that the St. Louis River and the Duluth Harbor was a polluted cesspool long before the report -- that most of this water area became unfit for swimming years ago,

is a good company. Their interest is in people. We feel that the adverse publicity given them on this pollution matter has been unjust and unfair and are fearful that it might jeopardize the taconite industry in this area.

We have many vacationing travelers that come to Ely after taking the scenic North Shore Drive. Many call their visit to the Reserve Mining Company taconite plant on the North Shore at Silver Bay one of the highlights of their trip. We get many compliments and as yet have never received a complaint on the Reserve operation on the North Shore.

We are fearful that the unjust publicity on pollution given Reserve Mining Company through unofficial sources will create a bad business climate for other industry to locate here; specifically, the copper-nickel industry that is at the present time considering locating here.

We urge you to move carefully, slowly, get all the facts. Industry and government should work together, there is no problem so great that can not be settled around a conference table peacefully and with mutual understanding.

Sincerely,

John Buccowich

John Buccowich

STATEMENT PREPARED FOR THE
DEPARTMENT OF INTERIOR
AT THE HEARING IN HOTEL DULUTH
May 13, 1969

My name is John Buccowich. I am manager of the Ely Chamber of Commerce and have lived in this area all my life. I have seen the mining of the high grade ores come and go and witnessed the development of taconite over the years.

The taconite industry has been the backbone of our economy since the three underground mines in Ely closed during the past few years.

We have had the misfortune of losing the underground mining industry in our community because of the depletion of high grade ores. Since this has happened fortunately 600 people from Ely were able to get jobs in Babbitt with Reserve Mining Company. These people work in Babbitt and live in Ely, have their homes in Ely. This year-round employment with Reserve Mining Company means payrolls for families and an opportunity to live in the community that they are raised in and want to be part of. As you know the mine at Babbitt furnishes the taconite for the Reserve Mining Company processing plant at Silver Bay.

We ask you to do everything in your power to see that Reserve Mining Company is given fair and equitable treatment--- that decisions are made on facts and not emotions. Reserve

John Buccowich

MR. BADALICH: A statement from Mr. John Buccowich, manager of the Ely Chamber of Commerce.

STATEMENT OF JOHN BUCCOWICH, MANAGER,

ELY CHAMBER OF COMMERCE, ELY, MINNESOTA

(The above-mentioned statement follows.)

trout in Lake Superior. This happened long before Reserve Mining Company started operation on the North Shore. Trout on the North Shore are now coming back because a real effort was made by Federal and State authorities to clean out the lamphrey and to restock our lake with fish. This is real progress and I am confident that our trout fishing, as well as Coho fishing in Lake Superior in a few years will be a real tourist attraction.

We ask that you continue to study and keep the lake under surveillance. If this is done we can be assured of the continued beauty of the lake for recreational purposes as well as for industrial purposes. We need them both.

Sincerely,

G. F. Kratoska

A STATEMENT PREPARED FOR THE
LAKE SUPERIOR WATER QUALITY ENFORCEMENT CONFERENCE
SPONSORED BY THE
DEPARTMENT OF INTERIOR
HOTEL DULUTH - MAY 13, 1969

My name is G. F. Kratoska, Trout Lake Lodge, Grand Marais, Minnesota. I make these statements representing the Cook County Civic Association, which I have been Executive Secretary of for many years.

We have a keen interest in Lake Superior. We know the aesthetic recreational values and appreciate the God given beauty of Lake Superior. We do not want the lake harmed and want the clean water to remain. We also know and appreciate the important part Reserve Mining Company plant on the shore of Lake Superior is playing in the economy of Northeastern Minnesota and the North Shore

In my many years of participation in civic and conservation programs for the development of our tourist industry in this area and having a lot of personal contact with the vacationing traveler, I have never received any complaints that Reserve Mining Company was polluting the lake, but on the contrary received many fine compliments on the wonderful tourist attraction the plant is on the North Shore.....not only from the taconite heritage, but its educational value as well.

To my knowledge the tailings being disposed of in the lake do not harm fish or aquatic life. To be realistic, it has been our observation that the lamphrey and other predators have harmed the fish life and effected the deep sea fishing for

G. F. Kratoska

MR. BADALICH: I have a statement from Mr. G. F. Kratoska of the Trout Lake Lodge, Grand Marais, Minnesota.

(The above-mentioned statement follows.)

"The fine particles are carried on over the beach by the fast-flowing water and the heavy density current action takes over. The sandy water goes to the bottom and flows along the bottom until it reaches a 1200 foot trough, which is a few miles from shore and is many miles long.

"The settling of the sand is almost instantaneous. Water samples taken only a few feet away from the tailings outflow had a turbidity of something less than 4-parts per million. All other samples taken in the latest study made at depths of 2, 20, 625, and 725 feet from various distances in the 3-square mile area indicated a turbidity of from .15 to .22-parts per million.

"Health officers and medical people have testified that the turbidity of samplings found in the lake in front of the plant site, whether they might be caused by tailings or clays washed in by rivers, has no health significance whatever.

"These turbidity studies made at least twice each year offer further evidence that taconite plants in Minnesota should be located on the shores of Lake Superior. The Emergency Committee has advocated such policy from the very outset of this industrial development.

"Lake Superior is the largest body of fresh water in the world, reaching depths of more than 1300 feet. Taconite beneficiation requires an immense amount of water. The Reserve plant at Silver Bay, operating seven days a week on a 24-hour schedule, utilizes 175,000 gallons of water per minute. By using Lake Superior water, the corporation is not taxing the State's ground water supply, nor utilizing water from our lakes and streams.

"Our inland lakes as receptacles for tailings would soon fill up, and tailings deposited on land surfaces can become unsightly nuisances and fill the air with large volumes of fine dust particles.

"In our estimation, the taconite plant at Silver Bay, from a conservation standpoint, is an asset. It is not befouling the air we breathe nor polluting the water we drink. It is not disturbing the scenic wild character of the region. It is doing its utmost to tune in with Nature."

MINNESOTA EMERGENCY
CONSERVATION COMMITTEE

O. L. Kaupanger, Secretary

OLK:cb

CHARLES L. HORN CHAIRMAN
2700 FOSHAY TOWER
MINNEAPOLIS, MINN

OLIN L. KAUPANGER, SECRETARY
MOUND, MINN.

MINNESOTA
EMERGENCY CONSERVATION COMMITTEE

2700 FOSHAY TOWER
MINNEAPOLIS, MINNESOTA 55402

May 7, 1969

Mr. John P. Badalick
Executive Director
Minnesota Pollution Control Agency
717 Delaware Street S. E.
Minneapolis, Minnesota 55440

Dear Mr. Badalick:

I very much regret my inability to attend the important Lake Superior water hearing to be held at Duluth on May 13. Due to illness it is impossible for me to be present.

At your suggestion I am including a statement of the Minnesota Emergency Conservation Committee which I would like to be introduced into the record of said hearing:

"Lake Superior water is the same good water it has always been. Taconite tailings which have been flowing into the lake from the Reserve Mining Company plant at Silver Bay since 1955 have not altered water conditions.

"Duluth, Two Harbors, and other north shore communities are still using it for domestic purposes--unfiltered. They have been measuring turbidity in the water for more than 20 years and their records reveal there is no difference in the water today than there was prior to 1955.

"As for fishermen and the fishing industry, biologists of the State Department of Conservation have found no evidence for any claim that fishing has been adversely affected by tailings.

"These things we believe to be factual truisms after having observed the extensive studies made of the water taken from samples drawn off at various depths and of the bottom in a 3-square mile area abutting the tailings launder.

"The tailings from the plant, sand from the concentration process, are carried into the lake by water. The coarse particles, because of their weight, settle immediately, forming a sand beach. It can be seen in a small area directly in front of the plant. The delta is firm, retaining more than 50 per cent of the tailings that have been discharged since 1955.

O. L. Kaupanger

MR. BADALICH: A statement from the Minnesota Emergency Conservation Committee, signed by Mr. O. L. Kaupanger.

(The above-mentioned statement follows.)

Edwin Ritchie

MR. BADALICH: I have another letter from Mr. Edwin Ritchie, Secretary, Encampment Forest Association.

(The above-mentioned letter follows.)

EDWIN W. RITCHIE
90 SOUTH SIXTH STREET
MINNEAPOLIS, MINNESOTA 55402

May 7, 1969

To: Department of Interior Water Pollution
Enforcement Conference

Gentlemen:

The worsening condition of Lake Superior waters is a matter of serious concern to members of the Encampment Forest Association, which holds approximately two miles of shoreline on the North Shore some seven miles east of Two Harbors. In our area we have noticed increased cloudiness of the water. Of great importance to us is the effect of pollution on lake ecology. We oppose lake pollution, whether from industrial, municipal or private sources.

Our organization of fifty families has owned the property some forty-five years. We have seen many changes over the years. However, until the last few years we could count on pure lake water. This is not true any more. We strongly support all effective measures to keep Lake Superior clean.

Edwin W. Ritchie
Secretary,
Encampment Forest Association

EWR:mea

James R. Miller
13026 West 3rd. St.
Duluth, Minnesota 55808

April 28, 1969

State of Minnesota
Minnesota Pollution Control Agency
Minnesota Dept. of Health Building
University Campus
Minneapolis, Minnesota 55440

Gentlemen;

Sence 1817, when John Jacob Astor started the trading post in Fond-Du-Lac. The St. Louis river has been used for boating, fishing, or swimming. It is now getting so that it is hardly fit for boating. Eating fish caught in the river is impossible.

I have been boating on the St. Louis river for about 15 years. The ride from Fond-Du-Lac to lake Superior is a very breath-taking ride, on a summy day or a warm evening. The last couple of years. The river has been getting more and more covered with a grease foam. Almost every morning early, we can see large patches of this foam coming down the river. One time last summer, down river from the dam. The foam was high enough to come over the side of a canoe.

The cities and state doesn't seem to have any trouble in passing laws, witch make the home owners put in septic tanks or the boat owners refrain from using toilets open to the lakes or rivers. When it comes to industry, the law makers drag their feet. And inforcement is nill. I there for urge the people from the state of Minnesota to rise up loud and clear. So that our representives in St. Paul and Washington can hear us. And that they see to it, that industry is also made to toe the line. Once again we could use the St. Louis river, as a means of fishing, swimming or boating.

Even if the river, was cleaned up to day. The bottom of the river is covered with a heavy layer of wood product waste. It would still take a long time to make it fit to use.

Sincerely Yours

James R. Miller

James R. Miller

MR. BADALICH: I have a statement from Mr. James R. Miller of Duluth, Minnesota, speaking as an individual.

(The above-mentioned statement follows.)

29 1969
POLLUTION
CONTROL AGENCY

Rule - (for L. Sup. M. file)

James R. Miller
13026 West 3rd. St.
Duluth, Minnesota

April 28, 1969

John P. Badalich
Minnesota Pollution Control Agency
Minneapolis, Minnesota 55440

Dear Sir;

On not being sure if I can attend the meeting of May 13th, In Duluth. Am enclosing a written statement, witch I would like presented. Thank you.

Sincerely Yours

James R. Miller

MINNESOTA Jaycees

MEMBER UNITED STATES JAYCEES JUNIOR CHAMBER INTERNATIONAL

GRIGGS MIDWAY BUILDING 1821 UNIVERSITY AVENUE ST. PAUL, MINNESOTA 55104

STATEMENT TO BE READ INTO THE RECORD OF A CONFERENCE ON POLLUTION OF LAKE SUPERIOR AND TRIBUTARY AREAS, TUESDAY, MAY 13, 1969, AT DULUTH, MINNESOTA

By Bob Dunbar, President, Minnesota Jaycees

Gentlemen:

My statement will be brief. The Minnesota Jaycees meeting at St. Cloud, Minnesota, on March 15 of this year made environmental pollution control a major program area for 1969-1970. It is for this reason that I wish to make a statement.

Being strongly interested in environmental pollution control, I am concerned over any possible threat to the present high quality of the waters of Lake Superior. For this reason, I welcome the opportunity this conference offers to bring together members of private industry and local, state and federal governmental agencies to discuss this matter. Following this conference, the Minnesota Jaycees will support a joint effort by these groups to protect and enhance the water quality of Lake Superior for generations to come.

Bob Dunbar /HCG

BOB DUNBAR
PRESIDENT, MINNESOTA JAYCEES

Entered into the record
on behalf of Bob Dunbar
Harry C. Grounds
By Harry C. Grounds
State Chairman for
Environmental Pollution Control

HCG/jg

MR. BADALICH: I would like to call Mr. William LaFrance, representing the Pickands Mather & Co.

STATEMENT OF WILLIAM LA FRANCE,
PICKANDS MATHER & COMPANY

MR. LA FRANCE: Mr. Chairman, conferees, ladies and gentlemen:

I am William LaFrance of Pickands Mather & Co., which is the managing agent of Erie Mining Company.

I have just a very brief statement of clairfication. It appears that there is an inconsistency in Appendix A of the Federal Water Pollution Control Administration report of April 1969. Specifically, on Page 59, Lake Superior is shown as the place of discharge for the pneumatic ash system of the Erie Mining Company, Taconite Harbor plant. We would like to point out that ash from the plant is not discharged into the lake, but rather that the ash from the plant is deposited on land located away from the lake--shore.

I make this statement merely to clarify the record.

MR. BADALICH: I sould like to introduce for the record written statements that were sent to me to be intoduced. I would like to read these off and so introduce them. I have a statement from Mr. Robert Dunbar, President of the Minnesota Jaycees.

(The above-mentioned letter follows.)

Kenneth Johnson

MR. JOHNSON: The resolution is attached.

(The above-mentioned resolution follows.)

MINNESOTA FEDERATION OF LABOR

AUDITORIUM STREET
ST. PAUL, MINN. 55102

WHEREAS: Pollution of Lake Superior is already far advanced; and

WHEREAS: It would be much cheaper to halt pollution now than restore the water purity later; and

WHEREAS: There is a proposal under consideration to discharge radioactive wastes into the major source of drinking water of the Twin Cities;

THE MINNESOTA AFL-CIO PROPOSES TOTAL PROHIBITION OF DISCHARGE OF RADIOACTIVE WASTES AT ALL TIMES UNDER ALL CONDITIONS FROM LIQUID OR GASEOUS SOURCES;

WE SUPPORT ESTABLISHMENT OF WATER QUALITY STANDARDS AND STRONG ENFORCEMENT PROCEDURES;

WE SUPPORT THE ESTABLISHMENT OF EMISSION STANDARDS GOVERNING THE RELEASE OF POLLUTANTS INTO THE ATMOSPHERE;

AND, WE OPPOSE TAX BENEFITS TO INDUSTRY FOR COSTS OF CONTROLLING WATER AND AIR POLLUTION IN ITS OWN OPERATIONS.

Kenneth Johnson

Wiesinger, Eighth District Vice-President, 202 Insanti Street, Duluth, Minnesota.

(The above-mentioned letter follows.)

MINNESOTA FEDERATION OF LABOR

May 8, 1969

Mr. Joe Wiesinger
8th District Vice President
202 Isanti Street
Duluth, Minnesota 55803

Dear Joe,

Because of the activities of the officers of the Federation at the State Legislature, we will be unable to attend the conference on pollution in Duluth.

Would you, as the Vice President of the 8th District of the Minnesota AFL-CIO, present this resolution on behalf of the Minnesota AFL-CIO?

Fraternally

MINNESOTA AFL-CIO FEDERATION OF LABOR

David K. Roe, President

DKR:b

enc.

Lake Superior has a future.

5. That this conference has the ability to set a precedence, to correct past mistakes and give the people something more than a public relations effort. This conference can illuminate the idea that conservation is the foundation upon which a better society may be built. This conference can be a positive move toward a society which can co-exist with the natural environment in an too frequently characterized by destruction.

RECOMMENDATIONS

1. Lake Superior does not represent a readily recoverable resource and that it is a unique body of water belonging to all the people of the United States. Therefore the regulatory agencies concerned should insure that the private and public users of this water discharge their duty to the community rather than their effluents.

2. Based on a study of the Department of Interior Report of April 1969, we believe that the dumping of Taconite tailings and other pollutnets mentioned in the report constitute a threat to a priceless resource and that the State of Minnesota has grounds to revoke the permit granted to the taconite facilities on 18 Dec. 1948. Further that we would favor the spending of public monies for a disposal system if no other way can be found.

MR. JOHNSON: Mr. Chairman, I would at this time request permission to read a very brief letter and a very brief resolution for inclusion into the record of this conference.

MR. DOMINICK: Very well.

MR. JOHNSON: The letter is addressed to Mr. Joe

allow us to solve some of our more pressing social problems. The failure to bring about economic reform which will make capitalism or socialism compatable with conservation will be costly and perhaps suicidal! Production will not cease, but rather the removal of wastes and the disposal of unwanted refuse must be given equal priority by our economic planners.

SUMMARY AND RECOMMENDATIONS

1. We believe that philosophies, ideas and concepts supported by factual investigations have been translated into political movements, and that such movements have written the laws and furnished the framework for the direction of a society. Conservation is such a movement whose appeal must and will be translated into votes and public decisions.

2. That present practices sanctioned by economic theory and legal support have often resulted in a form of environmental brinkmanship. The defense of past pollution control practices, theory and dogma is justified only if they can be shown to have worked. We believe that they have not. We cannot return to yesterday, but neither can we use yesterday's methods to slow down the pace of today's problems.

3. Without a philosophical base from which to argue and a commitment to a vision based upon choices made today the facts presented will prove inadequate to decide the questions before you. Indeed the studies now and in the future will reveal that the lake is polluted and another resource will be a memory.

4. We represent the age group which will inherit the natural resources of the country and we would like to assure that

Kenneth Johnson

ECONOMICS AND POLLUTION

We are a species which decides the fate of our resources by their ability or lack of ability to earn the currency of the day. Resources which took billions of years to create are appropriated for profit and governed by the laws of economics. Professor Heller has warned us (The Godkin Lectures) that pollution costs and the loss of resources should be reflected in the calculation of the GNP, and that the failure to do so is a serious mistake. The environment has not benefited from the idea that growth and progress are synonomous. Many arguments have been advanced to convince us that pollution is economically justified or necessary. We urge you to reject such a short-term view because it superimposes economic and political considerations over environmental requirements. We believe that a more rational economic direction is needed.

There are alternatives to our dilemma. As an expanding and aging system we must develop our production and consumer oriented economy into more of a decomposer and waste management society. We must concentrate private and government investments in the field of waste management. Decomposition should be developed as an industry as sophisticated as the production end, and it must be done quickly. Such an emphasis on the disposal of the products of the present economy would provide a stable area for investment and employment for the duration of the species. It will still be possible to generate consumer demand which will be more rational and benefit more people because they will be based on a stable economy and a sound environment.

A stable environment and a decomposition technology will

Kenneth Johnson

is growing and that it represents a major problem.

Mr. Fall speaks of a war -- a war which has generated much pro and con, and has presented us with a disturbing visual result -- the dead and wounded. Heretofore any arguments advanced to make that reality more palatable have been unable to relieve the burden of the senses. We hope the same mistake will not be made regarding environmental quality and that we are learning from our experience. Today the evidence of pollution is more and more evident and the concensus grows that something must be done. Yet how ironic and frequently do we hear the disclaimers, "We are for clean water, but we don't pollute it," or we need more facts, it costs too much and if all else fails then we get a myriad of legal arguments and techniques. As with the rationalizations for the dead, the rationalizations offered by the polluter for the degraded environment have not abated public concern because the same senses which can count the dead can see the dirty water and smell the contaminates!. It is no wonder that public relations and other disciplines based on language are sometimes such poor remedies for the senses.

We believe that the viability of a people and their society is a function of its ability to deal with the realities around it. Pollution is a threatning reality and if our society and its government cannot alter that reality, unless the senses can be appeased, and we can point to a cleaner environment then all the hearings you may conduct, all the statements you make, all the profits earned and all the laws written will not make a sound society.

decision, that is nevertheless a value judgement. We submit that the decision to dump something in this or any other lake is also a value judgement not strictly supported by any scientific doctrine or ecological principles. In the past that judgement has gone unchallenged because the political and economic environments were suitable to the despoilation of our natural environment. We submit that the decision to dump is a flagrant value judgement because it runs counter to much of our accumulated knowledge about the biosphere, is dangerous to the species or at least will require a monumental change and adjustment in the quality of life.

We think it better to live with the environment as it is now constituted because it has and does work. We have no guarantee that the gigantic changes being wrought in the environment will meet with success. In fact the evidence grows that this is not the case.

POLLUTION AND PUBLIC RELATIONS

The following is a quote from the late Bernard Fall's Two Viet-Nam's. "Officials concerned with the problem were now caught in the iron logic of their own argument: They could not assert that everything was fine in Viet-Nam and at the same time, ask for higher appropriations and more military and security experts to combat the rising guerrilla threat....In other words, there is very little evidence that the West has learned anything at all in more than two decades." Whether you agree with that statement or not it describes something which is all too common today. Officials, often untrained in the area in question, assure us that everything is fine. Yet recent studies and the visible evidence indicate that pollution

the deadly rivers and lakes and ultimately the "water wars" resulting from population pressure and the failure to practice sound techniques. These problems have their origin in the lack of or an erroneous philosophy. It is in this context that we wish to call your attention to the fact that the disposition of our resources is a philosophical as well as a factual matter.

To speak of conservation requires a definition. We believe that conservation is the preservation of natural ecological relationships between habitat and species. Water is unique in that it serves as a link between the living and the dead. It is exchanged continuously between species and habitat in several of the cycles studied by the scientist. The practical and philosophical problem is whether man is to preserve his natural relationships and whether he is to survive in an environment which will allow him to forsake the plastic bubble existence of a distant planet or such an existence here on earth. We suspect that technology will make existence possible almost anywhere and under most conditions. We may be able to manufacture our water metabolically and insulate the species from his own wastes. Human life will survive, but this raises the question of whether such existence is to be desired. We must ask whether man will co-exist with the natural forces that created him or will he seek to dominate or dictate to them? We believe that your decision on the questions before you requires a choice -- a choice which is not strictly dictated by the facts at hand, but depends on your answer to the questions raised above.

If you decide for co-existence, and much of the biological evidence gathered to date indicates that to be a wise

Kenneth Johnson

Thank you. (Applause.)

MR. BADALICH: I would like to call upon Mr. William Nauha of Two Harbors, Minnesota.

(No response.)

Next would be Mr. Kenneth Johnson of Minneapolis on behalf of the Students for Environmental Defense.

STATEMENT OF KENNETH JOHNSON, STUDENTS FOR ENVIRONMENTAL DEFENSE (SED), MINNEAPOLIS, MINNESOTA

MR. JOHNSON: Some of the points that I am going to cover have already been pretty well covered, so I will try to keep my presentation as short as possible.

Recently on the campus of the University of Minnesota a student group numbering some one hundred people was formed. I represent that organization today because of our interest in environmental problems and a special concern for the quality of the environment which will be passed to us. We would like to make some general remarks concerning conservationist philosophy and then summarize our position.

PHILOSOPHICAL CONSIDERATIONS

Life has evolved in water and with few exceptions it can not be separated from this solvent. The dilemma of maintaining this and other resources in a realistic condition introduces contradicting philosophies, economic theories and value systems. In the background speeding the decision is the expanding population. We can already see or envision the barren lands, population evacuations,

STATEMENT [illegible]

[illegible] C.P., I.O.

to the

[illegible]
[illegible]

May 16, Duluth, Minnesota

[illegible] group of [illegible] citizens, after a lifetime of enjoying the clear, pure water of the Lake Superior area, [illegible] Michigan private recreational [illegible] [illegible], Minnesota.

We feel strongly that the future of the largest fresh water lake in the world must not be jeopardized to serve short term industrial economic benefits. Such a short-sightedness will [illegible] the whole area and cost a great deal more, [illegible] in the long run than [illegible] to reduce pollution.

Federal agency investigation [illegible] limits. This confirms [illegible] color film. [illegible] for legal [illegible] permit agreement.

We also insist that federal water standards that [illegible] the water quality of Lake Superior be enforced strictly by all other industries operating in this watershed. The State of Minnesota should request the co-operation of Canadian authorities in enforcement of rigid pollution control standards.

Submitted by

D. Allen Bruce, President
North Shore Corp, Ltd.

Mrs. Alan Bruce

The skilled people, the skilled men, the men who know how to fish, are rapidly passing from this area. Fishing is a very skilled industry and would take years of hard work by a young man and would require a lot of apprenticeship to be able to do this work. This I am trying to point out, these different factors are reasons why the commerical fishing is not a major factor in the taconite disposal field.

I am happy that my two sons don't have to do the hard work, the danger and the uncertainties that I encountered in this occupation, before Reserve Mining Company ever built its plant.

In conclusion I am wondering, after listening to all this testimony, why the people outside of the area are so concerned about putting out the fire in our kitchen stove when their house at home relatively is on fore from a pollution standpoint.

Thank you very much. (Applause.)

MR. BADALICH: Next I will call upon Mr. Alan Bruce, President of the North Shore Camp, Inc.

STATEMENT OF MRS. ALAN BRUCE, NORTH SHORE CAMP, INC., MINNEAPOLIS, MINNESOTA

MRS. BRUCE: We switched gender, I am Mrs. Alan Bruce. I am presenting this statement from the North Shore Camp, Inc.

(The above-mentioned statement was read and follows.)

A Lorntson

colored water from the Lake Superior-Duluth area to an area just east of Two Harbors. On May 11 there was two patches of green water just off the French River Hatchery.

I do believe that the impact of the mining industry on the fishing industry is of a minor consequence. However, this condition existed prior to the Reserve Mining Company operation at Silver Bay. This also was brought out by commercial fishermen in the hearings held back in 1947. This would occur after heavy storms or sometime in late winter for no particular reason. This condition could exist to such an extent that the lake would take on a greenish color when viewed from the shore. For instance, on April 21, 1969, I observed a very decided green color from Duluth to Two Harbors, but this color declined in intensity from this point east as I drove up the shore toward Beaver Bay. This band of green water extended out into the lake for more than a mile from shore.

I believe the impact that the mining industry has on commercial fishing is of minor consequence.

Commercial fishing has been so severely regulated by the cause of sport fishing that it is not surviving. Isle Royale, Michigan, and the area in and near Bayfield and Cornucopia, Wisconsin, are examples.

The herring market is very limited and, except for herring fillets, will never sustain the heavy fishing of the thirties and forties. The market for animal food for the fishing industry is a thing of the past because the mink farms on the North Shore have all but disappeared.

A. Lorntson

There has been a very decided decline in the herring and trout population over the last 20 years. This is true all over Lake Superior and is not just a local matter. The decline in lake trout was in direct relation to the introduction of deep-sea lamprey. The herring declined with the increasing abundance of smelt. I can see no reason why this decline could be attributed to tailings disposal in the lake.

The North Shore of Lake Superior is not the natural spawning ground for fish. There is only a very narrow band of water shallow enough for fish to spawn in. The bottom is generally boulders and rock not suitable for fish spawning. This fact was brought out by commercial fishermen in the hearings held in 1947 when Reserve Mining sought permission to put tailings into Lake Superior at Silver Bay.

The unanswered problem that has arisen here today, I would just like to kick it around a little bit, and that is the sac fry of lake trout can be affected by taconite tailings. I believe this could happen in a laboratory, but I can't conceivably see how that taconite tailings could go up in a stream where the sac fry exist. This does not exist in Lake Superior.

Cloudy water or high turbidity does cause the herring to move away from shore. This is most noticeable in the spring of the year when the North Shore streams carry a heavy load of sediment. Cloudy water, too, can happen after heavy storms and sometimes it happens in late winter, but for no particular reason at all. On April 21 of this year, 1969, I was coming from Duluth and at that time there was a very, very heavy body of green-

E. Biggins

There are perhaps other reasons why a tailings basin should not be built. We are not experts on water quality, nor are we qualified to determine whether there is a pollution problem posed by Reserve Mining Company's operations with respect to Lake Superior. As residents of this region for some years, however, we do know that we do not want to see this beautiful and historic area despoiled and inundated beneath a vast man-made pond which will become a lasting monument to unfounded panic and ill-advised expediency.

Thank you. (Applause.)

MR. BADALICH: Thank you, Mr. Biggins.

Next I would like to call upon Mr. Arthur Lorntson of Beaver Bay, Minnesota.

STATEMENT OF ARTHUR LORNTSON, BEAVER BAY, MINNESOTA

MR. LORNTSON: I am Arthur Lorntson. I have been a long-time or life-long resident of Beaver Bay, Minnesota. For a number of years I was the Mayor of this village. I am 71 years old. I was engaged in commercial fishing for most of my lifetime, and my father was a commercial fisherman before me.

Considerable discussion has arisen about the effect of taconite tailings disposal in Lake Superior and its possible effect on the fishing industry. I don't believe it has any material adverse effect.

E. Biggins

be necessary. Lax Lake and the Beaver River are popular fishing waters and their setting in nearly pristine woodlands is attractive both to local residents and visiting tourists.

Much of the property in question is privately owned for year-round residences and summer homes. Other lands in the vicinity are conservation lands owned by the State of Minnesota. This region should be preserved for the enjoyment of future generations, not destroyed by a series of dams behind which tailings-laden water would reach alarming depth. Not only would these lands be permanently and irretrievably lost but the surrounding forests, smaller lakes and steams would be constantly imperiled by possible dam rupture.

Since drainage from the region's natural watershed is into the proposed tailings basin area, flash floods would be a constant danger. During periods of heavy rain, runoff water from the reservoir behind the dams would be drawn off. This water, with the finest tailings in it, would have to go into the Beaver River which, in turn, flows into Lake Superior. Therefore, nothing would be gained by adopting a tailings pond except destruction of valuable recreational, residential, and conservation lands and waters.

Also the present Lax Lake road, Lake County Highway No. 4, is undergoing extensive improvement, including widening and resurfacing, to meet the demands of increased traffic. If the proposed tailings basin is adopted, this highway would have to be relocated at great expense.

E. Biggins

deposit its tailings into a diked impoundment which would obliterate our homes, property, and the surrounding woodlands.

We are not convinced that a tailings pond is necessary. We have seen no evidence that Reserve's present tailings disposal method is in any way harmful to Lake Superior. We have seen nothing to indicate that tailings have killed fish or other aquatic life, caused material discoloration or harmed the lake as a source of pure drinking water. We feel, in fact, that the present method of tailings disposal is the only safe and sensible method available to Reserve.

There seems to be no valid reason, therefore, why an alternative method such as a diked tailings pond should be adopted at the expense of thousands of acres of beautiful residential and recreational lands and waters. In this age of national concern for environmental control, the proposal appears to us to be unthinkable.

Our homes and property are on the shores of Lax Lake and the surrounding area. We live here by choice. We would not want our homes taken from us and be forced to establish new homes in less desirable locations. Particularly, we would not want to live in Silver Bay or Beaver Bay in the shadow of a huge dam which might burst and pour millions of tons of water into these communities.

The proposed tailings basin would completely destroy Lax Lake and the surrounding forests and streams. The east branch of the Beaver River would, for practical purposes, cease to exist and rerouting of the course of the Beaver itself might

and the plant, and also between the local people and the new people who have come in and who don't know what the lake looked like before--because there has been them who question you on it--they feel that we ought to up and just close down Reserve. And this is not the case. We need industry and we need Reserve Mining here, but I feel we can have industry and also have clean water, and this should be taken into consideration. They have different methods of doing it, and I sure hope that Reserve Mining will do the right thing and make a good environment here for everybody.

Thank you. (Applause.)

Mr. Chairman, my statement was turned in yesterday along with the Save Lake Superior Association statement.

MR. DOMINICK: Thank you, Mr. Sve. That was a very excellent statement. I had an opportunity to eat lunch with your father this afternoon and hear something about your fishing and I am very glad that you did testify.

Thank you.

MR. BADALICH: Next I would like to call upon Mr. Earl Biggins of Silver Bay, Minnesota.

STATEMENT OF EARL BIGGINS, LAX LAKE
AREA, MINNESOTA

MR. BIGGINS: As residents of the Lax Lake area near Silver Bay, Minnesota, we are seriously concerned about newspaper reports that Reserve Mining Company might be required to

Walter Sve

My dad had three big boats. You could troll around these reefs. You could troll the boat and look around the bottom and look for lake trout. Today you can't do that; you can't see that far. These tailings have certainly done a lot of harm. Before, we had this coloration of the water from the streams in the spring or after a real heavy rainfall, but this was a brown discoloration in the water and this settled out within a few days after a heavy rain or in the spring. You would have it for maybe 2 or 3 weeks and this settled out, and this did not extend out from shore very far.

This grade of discoloration in the water now--what looks green from the reflection in the sky--is a mighty long ways. When I had those nets out there in 1964, 7 miles off the shore, I figured it was 7 miles off because I have a 28 hp. motor and my boat goes 18 to 19 miles per hour and it took me 19 minutes to get out to my nets. When this dirty water was out on these nets, I ran out half an hour from shore, not after my nets, and I never did get out of this discolored water. It extends out a mighty long ways, but that is due to the current.

East of the plant the water is clear out there and it should be clear southwest of the plant also.

With this, gentlemen, I guess that is about all I have to say for now but I sure hope that Reserve Mining will take this all into consideration and do something about this pollution problem, because it would make a much better feeling between the local people that have lived here all of their lives

Walter Sve

I have a friend over in Cornucopia, Wisconsin, who is dependent on the fishing. His name is Albert Premlin, and he has noticed this great discoloration of water over there and seen it on nets, real fine silt, and he is very much concerned. He feels it is definitely taconite tailings and he is concerned about his livelihood. All the fishermen who are southwest of the plant, they have had to find other jobs.

My dad has been affected differently by it because this is one of his means of livelihood. He has cabins, but he is also dependent on the commercial fishing and it has dropped off to nothing, so he has lost part of his livelihood. This, I think, should be considered.

I know Reserve Mining has done a lot for the area, for the people of Babbit and Silver Bay, and I praise them for that, but they should have a little concern for the beautiful Lake Superior and the local people who have lived here all of their lives and who look at this lake and see it discolored now such as it is today. We used to be able to see down into the lake at our place--Split Rock--30 to 35 feet. Today we see 10 feet at the most and sometimes only 2 feet down into the water.

When I was growing up, I just loved to hang over the side of the boat, rowing around, my brother and I, and look down into the water. We would find chains from back in the clipper days--they probably used them out on the ice--laying on the bottom and different things. I now have three children. Today I can't take them out and show them what the lake bottom looks like, the reefs, etc.

Walter Sve

Let me look at my list here a little bit. I had this pretty much down. That is about all I have on here, I guess.

All the commercial fishermen from Silver Bay to Duluth can verify this, that the herring catches have dropped off tremendously. The North Shore is set up in three areas. Area No. 1 extends from Duluth to Encampment River, which is 32 miles. Area No. 2 extends from Encampment River to Cascade River, which is 66 miles. This is the area that we are in; my dad and I, and Reserve Mining is also in this area.

East of the plant where the water is still clear because the current is running in a southwesterly direction they are not getting this dirty water east of the plant and they are still catching nice catches of herring, only their catches drop off when we have a current running in a northeasterly direction, then the herring slack off there. But when the current switches back to the southwesterly direction, then the herring come back. So they are still catching good herring on that side of the plant. That is just immediately off the plant, this isn't miles away, it is right close, because of this current.

As I stated, this definitely proves that the herring cannot tolerate this dirty water.

As for the trout, they can stand dirty water, but I don't think they will come into this discolored water southwest of the plant to spawn because I am afraid it is going to have definite effects on the eggs--the fish eggs.

was looking back in my records. In 1956 the water was still relatively clean. In fact, it was very clean because this fine tailings I noticed that first showed up in August settled out after September, because the current slacks off. September is the month that the current runs its hardest, and when it lets up then they settle out.

At this time the tailings were just falling pretty much along the shore and our nets are set out a half to a mile from shore. In October of 1956 I caught 150 pounds per net per day. By October 1958 this had dropped to 48 pounds per net per day, and by 1959 it had dropped to 11 pounds per net per day.

In 1964 I set nets 7 miles out from shore. We get outside of this discolored water caused by this taconite tailings, and at that time the tailings were extended from shore out approximately 5 miles. Being I was outside of them in the nice, clear water, you could definitely see the difference when you run out. It was just like a line down the lake--like stepping out of a dark room to a light room when you got into the clear water. Out there I caught 92 pounds per net per day, 7 miles off from shore, for 2 weeks. Then the current shifted, dragging this discolored water out to and beyond my nets and then the catch dropped from 92 pounds to 15 pounds the next day. Then the next day after that it dropped down to three herring. This lasted for 5 days. Then the current moved this discolored water in toward shore again and the herring catch resumed to its normal number. This definitely proves that the herring cannot tolerate this dirty water and move away from it.

Walter Sve

pollution meetings since 1956, and each time we have made a statement to tell what has happened to the lake caused by these taconite tailings and the effect on commercial fishing, it always winds up that Reserve gets a permit to dump more and more waste in the lake. So I was wondering what I should say.

Anyhow, I felt it was my patriotic duty to this great country of ours to come and make a statement, as we have this beautiful lake and it is being so wrongfully misused.

Mr. Schmid explained yesterday this density current to us. This was a very good explanation of it and it was right--if this lake was deadly or no current in this lake, but there is a current in the lake and this carries this fine tailings off in the long distance. The tailings will go off the delta and start down at times and will go down a-ways before the current catches ahold of this fine, the finest tailings, and it will carry it beneath the water towards the southwest as far as 2 miles, I noticed, before it shows at the surface. At other times it shows immediately off the delta. So this is why on the slides we saw yesterday it showed blue water directly off from the Reserve's delta. That is because the current isn't running as fast on those days and it isn't picked up until it gets deeper down.

The first we noticed this fine tailings or this discolored water, this so-called green water--but I say it is grey; it is grey water--the first we noticed it at Split Rock was on August 28, 1956. It has had an effect on our fishing. I commercial fished for herring from 1944 until 1964, and I

know-how and ingenuity should be put to full use, driving forward to assure these ends. By the same token the people employed by these industries and supporting businesses should support the industries in this drive for high water quality standards.

The machinery of government is now in motion to help those peoples and industries that are farsighted enough to protect and insure an area that is usable and that will also remain a good place for people to live. All the people familiar with Lake Superior know that the esthetic value of the lake is unmeasurable.

I know that after having lived in Duluth all of my life and having spent the past 13 years working on the Leagues Water Resource Committee, I am convinced that Lake Superior is not only a great resource, but must remain so, for my children, and my children's children if they are to truly prosper anywhere in this Nation.

MR. BADALICH: I would like to call on Walter H. Sve, Two Harbors, Minnesota.

STATEMENT OF WALTER SVE, SPLIT ROCK, MINNESOTA

MR. SVE: Mr. Chairman, conferees, ladies and gentlemen:

I am Walter Sve. I live at Split Rock, 12 miles southwest of Reserve's plant at Silver Bay. I have kind of hesitated to come and make a statement at this conference because my dad and I have been making statements at different water

shortcut to Park Point, wondered how a ship could dock in the bay slips below the railroad tracks. She could only see 4 to 6 inches of water in there. Picking up a stick she poked it in the water. To her surprise what she thought was bottom was sewage. She also saw this same false bottom about 3 feet below the bay water surface, at what we call the "end of the point." A man walking on Michigan Street was bitten by a rat before the correction of this problem became urgent. Ten years later this same girl dove into the bay at the "end of the point" and found the sludge bottom was now about 10 feet under the surface. The slip mentioned before (much clearer now) is the one at the foot of First Avenue West, right next to our beautiful Arena-Auditorium.

This story points out the fact that it took 20 years to stabilize the bay sewage problem, (one of them anyway.) This is the long road of correcting a problem.

Now, projected studies show that within 50 years the bulk of water-using industires will have to locate themselves in the Great Lakes water basin. More industry means more people. These two elements of society should and must work together to set high water quality standards for Lake Superior. Industry must not set a precedent that is detrimental to one of the greatest resources of this area. For our future, industries must have firm guidelines to follow if they are to prosper in this water basin.

Industrial efforts have been made to comply with the regulations of the various States. How much better for all concerned if these efforts were channeled to set and comply with a uniform high code or standard, equally binding upon all users of Lake Superior waters and uniformly enforced. Industrial

Mrs. James Alexander

Conferees:

I am Mrs. James Alexander, Water Resource Chairman of the Duluth League of Women Voters.

We know that since the beginning of this century there has been legislation to protect various waters of this land. These measures were not enough, however, to prevent the pollution problems created by our industrial revolution and the expansion of our population. After many years of debates, hearings, and study the Water Quality Act of 1965 was passed facilitating a major offensive against water pollution in this country.

Recent history and data concerning water cannot be ignored. We have for instance, the hopeless situation on the Eastern seaboard where the great Hudson and Deleware rivers are so polluted that it is costing taxpayers millions of dollars just to keep them at their present undesirable levels.

Three of the five Great Lakes have been studied and only at great cost is it feasible to attempt to clear them out. We could go on and on with examples of this kind throughout our country.

Most studies have shown that Lake Superior with its great size and depth has withstood abuse better than most waterways. This does not mean, however, that it can continue to do so indefinitely.

I would like to tell you a story, back some thirty years ago, about a small girl, who, while taking her usual

Mrs. James Alexander

4. That the precedent-setting nature of the decisions being made at this conference be recognized. Variances permitted now may be multiplied many times as new communities or industries develop.

We wish to reiterate a plea we have made to our Pollution Control Agency at two recent hearings. Minnesota is on a continental divide. Our waters are replenished by rain and we receive most of them pure. Before they leave our borders they have been stamped as sewer or resource. Of all States our water quality should be the easiest to guarantee. Social responsibility demands our sending it on to our neighbors containing as few poisons as possible. (Applause.)

MR. BADALICH: Thank you, Mrs. Brascugli.

Next, I would like to call on a representative of the Lake County Republican Party of Silver Bay, Minnesota.

(No response.)

Next will be Mrs. James Alexander, Water Resources Chairman, League of Women Voters of Duluth.

STATEMENT OF MRS. JAMES ALEXANDER, WATER RESOURCES CHAIRMAN, LEAGUE OF WOMEN VOTERS OF DULUTH, MINNESOTA

(The above-mentioned statement follows.)

Mrs. W. Brascugli

For these reasons we urge:

1. That all industries and municipalities now dumping into Lake Superior be immediately and thoroughly evaluated. And you heard yesterday and today that this is being done for the most part but not for all. We are certainly pleased with the high standards for intrastate and interstate waters that our pollution control agency has set. We certainly hope that when anybody, whether an industry or a municipality, requests a variance of these standards, that it will be denied.

2. That the burden of proof be placed upon the industry or municipality. Discharging should not be allowed to proceed awaiting proof of damage. The dumping should not be permitted unless it is demonstrated to be harmless. Reasonable doubt should be sufficient to stop discharging.

3. That uniform standards should be set for all comparable industries. One industry should not enjoy an economic advantage over another by virtue of its failure to clean up. It has come to our attention that other taconite producers in Minnesota, U. S. Steel at Virginia and Erie Mining Company at Hoyt Lakes, have been required to operate with completely closed systems in order not to pollute nearby lakes. We cite this to demonstrate that tailings are considered pollutants in those instances and also that such a closed system is feasible. It appears to us that the State has established a double standard--one for U. S. Steel and Erie Mining Company and another for Reserve Mining Company.

Mrs. W. Brascugli

When pollution control occasions a greater cost to the consumer, we are prepared to work toward public acceptance of that cost.

We appreciate the value of commitment on the part of local and State governments to set and maintain the highest possible standards. But we also recognize the fact that powerful political and industrial interests may exert strong pressures, making it difficult to enact and carry out pollution abatement programs on the State and local level. For this reason, we believe that the Federal Government has an important role to play in protecting the broadest public interest when State or local efforts fail. Certainly, the quality of the water in Lake Superior should be a matter of interstate and even international concern. How well we take care of Lake Superior, perhaps our most beautiful natural resource, will affect the future of at least three States and Canada.

The economic development of Lake Superior is just beginning. Plans are being made for more extensive tourist business, for increased taconite production, for a gaseous diffusion plant on the Knife River by the Atomic Energy Commission, and for the prospect of extensive copper-nickel production in northern Minnesota. There is even talk of a canal connecting Lake Superior with the Mississippi River. If we do not set and enforce high standards, Lake Superior is certain to be destroyed. Futhermore, because of the low rate of turnover of Lake Superior water (90 percent turnover in 500 years), unlike that of the other Great Lakes, the destruction will be practically irreversible.

Mrs. W. Brascugli

STATEMENT OF MRS. WILLIAM BRASCUGLI, WATER RESOURCES CHAIRMAN, LEAGUE OF WOMEN VOTERS OF MINNESOTA, ST. PAUL, MINNESOTA

MRS. BRASCUGLI: Thank you, Mr. Badalich.

If the ladies could have the last word, this would be well worth waiting for. (Laughter.)

Mr. Badalich, conferees, ladies and gentlemen:

I am Mrs. William Brascugli, Water Resources Chairman of the League of Women Voters of Minnesota. I am also representing Mrs. Thomas Irvine, Water Resources Chairman of the League of Women Voters of Michigan.

The League of Women Voters of the United States has studied the use and preservation of the Nation's water resources since 1956. It is our belief that it is becoming increasingly important for water users to discharge water in as much the same condition as it was withdrawn as is possible. Two years ago local leagues across the country in 1,250 communities expressed to the national board their conviction that the pollution of our waters must be controlled. They agreed 1) that control of wastes should be considered one of the costs of production and 2) that new industrial plants from the beginning of their operation should be required to meet high water quality standards without financial aid from Federal funds. When an industry is unduly penalized with relation to its competitors by undertaking to clean up present operations, we have supported government aid where necessary.

J. G. Marcon

Director and Secretary of our Advisory Board; Clarence Wistrom, Spooner, Northwest Area Fish Management Supervisor; Eugene Hensel, LaCrosse, District Engineer, State Board of Health; citizen members, Ed Bartusch, Eau Claire; Jack Crawford, Superior; Paul Swendby, New Richmond; and myself, John Marcon, Chairman, Rice Lake, are here today.

We have attened past pollution hearings at Duluth and Superior. We have traveled the Silver Bay area by boat. Some of us have flown the entire South Shore of Wisconsin.

While our group can only recommend, we wish to go on record that we are concerned about all the wastes being poured into the most beautiful body of water in this area. We again ask that complete and conclusive studies of needed action be made and that these studies be followed up by immediate plans for action where necessary. We ask that the action needed be carried out as rapidly as is reasonably possible. (Mr. Dominick Continuing)

We will break for 15 or 20 minutes. Be back at a quarter of five, when we will continue with hearing from public witnesses.

(Whereupon a recess was taken.)

MR. DOMINICK: Come to order, please.

Mr. Badalich, will you proceed.

MR. BADALICH: I would like to call on Mrs. William Brascugli for the League of Women Voters for Minnesota.

or in government regulation and assistance, or in all these. One thing is certain. Any "data," "records," etc., cited by those who want to use them in support of continued dumping should be insistently questioned and examined.

I would like to show you a few slides now, if I might.

(A slide presentation was made by Dr. Carson.)

DR. CARSON: If you have any questions --

MR. DOMINICK (interrupting): Are there any questions?

(No response.)

MR. DOMINICK: If not, Dr. Carson, we thank you very much. You have made a very good statement here and we appreciate the fact that you have come to add a good deal of light to the whole discussion.

Thank you. (Applause.)

I would like to have placed in the record at this point a statement by the Region 5, Wisconsin Water Resource Advisory Board, signed by John G. Marcon, Chairman.

STATEMENT OF JOHN G. MARCON, CHAIRMAN,
REGION 5, WISCONSIN WATER RESOURCE ADVISORY
BOARD (read by Mr. Dominick)

We, the members of Region 5, Water Resource Advisory Board, which covers northwestern Wisconsin, are concerned with the future of Lake Superior. Our Board, consisting of Charles Kozel, Eau Claire, Wisconsin, Division of Environmental Protection,

(4), and I leave it to them. It is my conviction, however, that there is a problem and steps should be taken at once to clearly establish the exact parameters of amount, size, and type of sedimentation in the lake. The job should obviously not be left to Reserve or other politically or commercially interested parties, for they can hardly be expected to be unbiased or to police themselves.

The mere enormity of the sedimentation itself suggests a very definite probability of future problems, but it seems to this writer that they may already be here. Few processes in nature, save glacial grinding and faulting, can grind up quartz to the degree of fineness found in the taconite process, and if 22,400 tons per day is smaller than .04 mm in particle diameter, then there is a considerable likelihood that some significant portion of this is colloidal or nearly so. If such is the case, inert colloidal materials are being put into the lake at a fantastic rate, particles which will take an exceedingly long time to settle, if ever. This means an essentially irreversible process and one with entirely unforeseen consequences. It may be argued that the very inertness of quartz renders it nontoxic and harmless -- so in minute amounts is quicksand.

It is my feeling that a thorough understanding of all aspects of this problem is badly needed, and also that a conclusion satisfactory to all concerned can, with effort, be achieved. Perhaps such a solution lies in new commercial uses for tailings

However, it took roughly 10,000 years for them to accumulate, something seldom mentioned. And, although the rate of natural sedimentation on this basis would be roughly twice that for taconite tailings, most of this sedimentation took place relatively early in the history of Lake Superior when enormous quanitities of glacial outwash were swept into the lake by streams draining a recently deglaciated landscape. I doubt very much that modern natural sedimentation of fines in the lake is anything near the 6 inches in less than 20 years that Reserve has accumulated at Silver Bay. Also, it should be remembered that the fines of natural origin on the lake bottom are finer than taconite fines only when considered as discrete clay particles, and not as flocculated clumps.

6. The Department of Interior or Stoddard report suggests that tailings be pumped back over the hill behind Silver Bay and there settled out in basins. It estimates the cost at 3 percent that of the value of the taconite end-products. This possibility should be investigated by neutral parties. No doubt opponents of any such plan will advance many arguments against it, perhaps citing possible damage to the natural environment.

Conclusions

The foregoing statement has concentrated mainly on sedimentation in the lake. Any changes in the biological environment due to taconite tailings would presumably be due to this. The biological area is more competently examined by biologists

C. W. Carson

4. Other statements have been made to the effect that "green water" is a common phenomenon in Lake Superior and elsewhere and therefore no cause for alarm. Green water is, of course, common in the lake at certain localities near the shore and at different times. The causes are multifarious. They may be algal blooms, rock coloration nearby, atmospheric, or taconite tailings. However, when green streaks several hundred feet wide and 15 to 20 miles long are observed to extend directly down the shore from the Reserve operation as this writer has observed them, and when entire broad areas of the lake west of Silver Bay are markedly different in color from water immediately northeast of there, something more than a local phenomenon due to rock color or algae is afoot. To object to the Stoddard report, as some have done, that material clouding of water has not violated State standards from time to time, leaves some interesting questions. Are not these definite streaks downshore from the delta "clouding?" And if, as stated, 6 inches of taconite sediment occur on the bottom 5 miles downshore and .1 inch at 15 miles, how did this material get there? If laid down quickly at odd times and/or by strong currents, there must have been clouding then. Or, if laid down in tiny increments over a considerable time the material must be very near to colloidal size.

5. It has also been stated that natural sediments on the bottom of the lake are far greater in thickness than the 6 inches of taconite tailings in the deep trough in front of Silver Bay. Sometimes these natural sediments are 500 to 600 feet thick.

C. W. Carson

3. A common statement by apologists for tailings dumpage into the lake is that the material is no different than sediment flowing in from streams, especially during flood times when the water is sometimes brown or red from river sediments. This is absolutely false. Not only does the Reserve taconite operation dump as much sediment into the lake in 2 weeks as do all U. S. streams in one year (1-26), but the mineral type of fines is different. Roughly 70 percent of the taconite tailings are silica or quartz, by which we can assume that a similar percentage of fines is of the same mineral. The majority of fines dumped into the lake by streams is clay mineral by contrast. Quartz is far more inert chemically than clays. That is, the covalent bonding of silica or quartz leaves a very low residual charge per unit mass. Clays on the other hand have a different structure with some ionic bonding, and consequently a residual charge on the particles often negative. (2) Positive cations in the water, as well as some positive residual charges on some of the clay particles, will be attracted to the negative particles. (3) The result is a process called flocculation, where clay particles individually too small to settle clump together into larger particles big enough to settle. It is for this reason that the lake doesn't stay red or brown after storms and flood but soon returns to its usual blue, or green -- depending on the location with respect to Silver Bay -- color.

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(2) -- Clay Mineralogy. By Ralph E. Grimm, University of Illinois. McGraw-Hill 1953.

(3) -- Soil Physics. By L. D. Baver. John Wiley & Sons 1956.

C. W. Carson

The Bureau of Mines study (1-10) indicates that 39 percent by weight is smaller than .04 mm (.0017) inches in diameter. This is 22,400 tons per day. While .04 mm sizes are well above the colloidal range, which is 10^{-7} cm -- and what portion of this 22,400 tons is colloidal has apparently not yet been determined -- .04 mm is well within the ability of lake currents to transport some distance before settling. And, should any significant fraction of this 22,400 tons be colloidal, the silica would never settle, but would be kept in suspension by simple molecular motion of even calm water molecules.

The recent FWPCA report indicates that 5,400 long tons per day are discharged at Silver Bay which are less than 4 microns in diameter, thus approaching the colloidal range, although not in it. The study also showed that the currents are capable of transporting particles of this size more than 9 miles a day. Should a significant portion actually be in the colloidal range, fines of this size would be virtually impossible to eliminate by any practical process. Organisms which build their shells from silica, such as diatoms, could then possibly bloom in great numbers in the lake, adding further to changes in the overall ecology, the ultimate results of which can only dimly be envisioned at the present time. It should be stressed that simply because no hard data have apparently shown that a significant colloidal percentage exists it does not mean that such may not exist or that objective studies, unbiased by commercial or political influences, should not be undertaken.

therefore easily subject to dispute, is that the general color of water most of the time in western Lake Superior has become greyer and greener during the last 5 years, especially compared to that northeast of Silver Bay. I conclude that this may very well be due to increased dumping of colloidal and near-colloidal fines at Silver Bay.

2. Composition of taconite tailings is predominantly silicon dioxide or quartz (glass) with a magnesium-iron silicate called cummingtonite in second place (1). Of the 60 or so thousand tons per day dumped into the lake, probably 70 percent is silicon dioxide. According to the December 1968 Department of the Interior report, cummingtonite may well be a cause of the green appearance of the water. This report also states that roughly half of the tailings remain in a delta near the dumping point. and the other half slide, as a density current, into a deep trough in the lake floor. This would imply, then, that no colloidal or near-colloidal or near-colloidal material remains suspended in the water. However, it is also observed that 15 to 18 miles to the southwest, tailings are found on the bottom .1 inch deep. Apparently, then, currents are strong enough, and some fraction of the tailings fine enough, for drifting at least this far.

The question remains, just how much of the 60,000 tons per day is near-colloidal or actually colloidal in size?

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(1) -- Part I Summary Report on Environmental Impacts of Taconite Waste Disposal in Lake Superior. By Charles H. Stoddard. United States Department of the Interior. December 1968.

C. W. Carson

You might make some calculation to see how many gallon lots there are in Lake Superior: 100 miles long, 200 miles wide, up to 1,300 feet deep, maybe averaging 40 feet, at 40 cents per 1,000 gallons, you come up with a considerable number.

The following are comments on data and observations regarding the taconite problem:

1. Circulation in Lake Superior is generally toward the southwest along the North Shore, as many have observed. The most virorous flow is directly along the shore, but even at 30-foot depths approaches .4 miles per hour in mean horizontal flow, (1-12) and equations can be given to give you an estimated flow at most of the time of 40 to 50 centimeters per second in any reasonable wind, say, 15 to 20 miles an hour.

At Duluth, due to the influence of the St. Louis and Nemadji rivers, and some flow along the South Shore, a return spiral to the east occurs. The southwestern flow is largely wind-driven and hence not constant; but prevailing northeasterly winds are sufficient to drive the current system in this pattern for a considerable amount of time. Therefore, it is improper to suggest that since the flow is not continuous it is unimportant. Statistically, it could be shown that the dominant circulation pattern would cause suspended material dumped at Silver Bay to eventually find its way to the Duluth area and even, finally, to other parts of the lake, including, of course, the Wisconsin side.

My own observation, admittedly qualitative and

C. W. Carson

DR. CARSON: The question is, where does cummingtonite come from? It would seem it is probably coming from tailings.

I would like to go to my statement now.

Having lived in Duluth from 1963 until 1968, and being interested in both lakes and conservation, I have been concerned with the apparent changes which have taken place in Lake Superior during the period 1963-1968, and with many reports by both sides regarding the taconite tailings controversy. My qualifications rest on a doctoral dissertation dealing extensively with lake hydrodynamics in Alaska, almost daily observations of the lake during the period 1963-1968, reading of scientific and technical reports on the subject pro and con, and active participation in the Duluth Chapter of the Izaak Walton League and conservation groups in this area.

Gradually I have concluded that Lake Superior, a resource dwarfing Reserve's taconite operation, is in danger of irreversible pollution from taconite tailings. Before detailing the reasons for this conclusion, I would like to point out that I have no wish to see Reserve Mining Company's operation damaged. Surely some solution satisfactory to everyone can be obtained. Further, there has appeared, or so it seems to me, a good deal of deliberate misrepresentation of technical data and qualitative observations not very complimentary to those engaged in it. Sober reflection might suggest that Lake Superior, at a national domestic freshwater rate of 40 cents per 1,000 gallons, is a resource of such vast importance that accuracy of statement and observation is crucial to all.

UNIVERSITY OF Minnesota

INSTITUTE OF TECHNOLOGY • SCHOOL OF EARTH SCIENCES
DEPARTMENT OF GEOLOGY AND GEOPHYSICS • MINNEAPOLIS, MINNESOTA 55455

May 6, 1969

Mr. Dale S. Bryson
Federal Water Pollution Control Administration
East 58th Street and 40th Avenue South
Minneapolis, Minnesota 55450

Dear Mr. Bryson:

In answer to your query concerning the possible sources of cummingtonite which might drain into Lake Superior, I can give you the following information.

1. All of the streams from Duluth northeastward and draining into Lake Superior have their entire courses in rocks which do not contain cummintonite. Most of the bedrock in the area consists of volcanic flows and gabbroic to intermediate igneous rocks none of which are known to contain cummingtonite. The only possible source of any cummingtonite in this area might be from material in the surficial glacial deposits but in all of the studies of this material the rock fragments are essentially all from rock types which do not contain cummingtonite. It would appear essentially impossible to me that this glacial drift could provide a measurable amount of cummingtonite in the streams draining through it.

2. The only known occurrence of cummingtonite in the drainage area within Minnesota leading to Lake Superior is at the eastern end of the Mesabi Range. There is only a small strip of metamorphosed iron-formation from about 3 or 4 miles N.E. of Mesaba to Birch Lake which contains cummingtonite. Most of this area from 3 miles south of Babbitt northeastward to Birch Lake drains through the Dunka River Watershed which drains northward to Birch Lake and Rainy River rather than Lake Superior. Only a small area which drains into the Partridge River could supply any cummingtonite to Lake Superior via the St. Louis River. However, the drainage is so sluggish, with several swamps and lakes occurring between the the cummingtonite source area and the St. Louis River, that it seems unlikely for a significant amount of cummingtonite to reach the St. Louis River, let alone Lake Superior.

Sincerely yours,

Wm C. Phinney

William C. Phinney
Professor of Geology

C. W. Carson

STATEMENT OF CHARLES E. CARSON, ASSOCIATE PROFESSOR, DEPARTMENT OF PLANT & EARTH SCIENCE, WISCONSIN STATE UNIVERSITY

DR. CARSON: Mr. Chairman, conferees, ladies and gentlemen:

My name is Charles Carson. I am Associate Professor of Geology at Wisconsin State University at River Falls.

I have a prepared statement here based on the FWPCA report and the Stoddard report, as well as other information. I would like to read from that statement and then discuss some of the comments that have been made here this afternoon, and, finally, show a few slides.

I would like to start with a letter addressed to Mr. Dale Bryson, FWPC Administration, Minneapolis, Minnesota, from Dr. William Phinney, Professor of Geology, University of Minnesota, Minneapolis. This is relative to the cummingtonite discussion earlier today.

(The above-mentioned letter follows.)

9:drs 1991

ntroduced by Norton, Munger, McFarlin,
Bang, Nolan
March 29, 1969
Ref. to Com. on Land and Water Resources
Reproduced by PHILLIPS LEGISLATIVE SERVICE

H.F. No. 2148
Companion S.F.
Ref. to S.Com.

A bill for an act

prohibiting the deposit of tailings into Lake Superior; providing for a forfeiture and injunctive remedies for violations.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

Section 1. [DEPOSIT OF TAILINGS INTO LAKE SUPERIOR PROHIBITED.] On and after January 1, 1972, no person, firm or corporation shall deposit or permit to be deposited into the waters of Lake Superior any waste materials remaining after the removal of valuable minerals in the processing of the product of a mine, commonly referred to as "tailings." Any person, firm or corporation violating this section shall forfeit the sum of $1,000 for each day which the violation continues, such forfeiture to be recovered and disposed of in the manner prescribed by Minnesota Statutes, Sections 574.33 to 574.35. In addition, a violation of this section may be enjoined upon application of the attorney general or county attorney to the district court of the county in which the violation occurs.

and which violates the standards set by the pollution control agency under the authorization provided by subdivision 1.

Subd. 3. All provisions of this act shall be complied with no later than two years after the passage of this act.

Subd. 4. Violation of any provision of this act by a company shall subject the company to a fine of $500 for each day the violation continues.

T:drs 2050

Introduced by Coombe, Keefe, Chenoweth,
R. L. Pavlak, Bares
February 20, 1969
Ref. to Com. on Land and Water Resources
Reproduced by PHILLIPS LEGISLATIVE SERVICE

H.F. No. 1112
Companion S.F. _____
Ref. to S.Com.

A bill for an act

prohibiting the deposit of tailings into waters of the state; providing a fine.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

Section 1. [DEPOSIT OF TAILINGS INTO WATERS PROHIBITED.] Subdivision 1. No company engaged in the mining of iron ore or other minerals in this state, whether or not such mining is to result in pelletization, shall deposit tailings:

(a) In public lakes and rivers within this state or into Lake Superior; or

(b) In a reservoir maintained by a company, if such reservoir causes pollution of any public lakes or rivers or the air in excess of pollution limits set by the pollution control agency of this state. The pollution allowed by the standards so set shall in no case exceed that allowed under standards applied to other industries in the state.

Subd. 2. Tailings falling within any of the following categories shall be deposited in open pits or other excavations made for the purpose of withdrawing iron ore under regulations established by the state conservation department:

(a) Tailings resulting from the operations of any plant, including tailings resulting from the future expansion of any plant, heretofore deposited in the public lakes or rivers of this state or in Lake Superior, or

(b) Tailings resulting from the operations of any plant, including tailings resulting from the future expansion of any plant, heretofore deposited in a private reservoir

Sec. 3. All of the proceeds of the fee, including interest and penalties in respect thereto, shall be deposited in the state treasury. Refunds shall be paid therefrom. The balance of the proceeds is annually appropriated to the pollution control agency for use in assisting political subdivisions of the state in meeting requirements for obtaining federal assistance for pollution control activities.

Sec. 4. For purposes of this act, "waters of the state" has the meaning ascribed to that term by Minnesota Statutes, Section 115.01, and "taconite" and "iron sulphides" have meanings ascribed to those terms by Minnesota Statutes, Section 298.23.

Introduced by Kozlak, Munger, Bares, Gearty, R. Andersen
April 16, 1969
Ref. to Com. on Land and Water Resources
Reproduced by PHILLIPS LEGISLATIVE SERVICE

H.F. No. 2558
Companion S.F.
Ref. to S.Com.

A bill for an act

relating to fees for the deposit of certain materials in the waters of this state; prescribing a fee in respect thereto; appropriating money.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

Section 1. A fee is hereby imposed upon any person who deposits in the waters of this state residual materials attributable to the production of iron ore concentrate from taconite and iron sulphides. The fee shall be in the amount of 10 cents per gross ton of residual materials so deposited on and after July 1, 1969.

Sec. 2. The fee shall be collected and paid in the same manner and at the same time as provided by law for the payment of the occupation tax imposed by Minnesota Statutes, Chapter 298. Reports shall be made and hearings held upon the determination of the fee at the same times and in the same manner as provided by law for the occupation tax. The commissioner of taxation shall have authority to make reasonable regulations as to the form and manner of filing reports necessary for the determination of the fees hereunder, and by such regulations may require the production of such information as may be reasonably necessary or convenient for the determination of the fee. All the provisions of the occupation tax law with reference to the assessment, determination, and collection of the occupation tax, including all provisions for penalties and for appeals from or review of the orders of the commissioner of taxation relative thereto, are hereby made applicable to the fee imposed by section 1, except insofar as inconsistent herewith.

G. J. Merritt

MR. POSTON: We can send that to Mr. Frangos and the conferees.

MR. DOMINICK: Fine, please do that.

MR. BADALICH: Will Dr. Carson please come forward?

MR. MERRITT: Yes, Dr. Carson.

Before he gets here, I would again ask that the results of Dr. Mount's study be made available during this conference sometime today.

MR. DOMINICK: Thank you very much for your presentation. I think you have done a lot of good, hard work at this conference. It has been constructive work and, although we don't agree on a number of points, I appreciate the effort and the interest that you and others have taken in the proceedings of this conference.

Thank you very much.

MR. MERRITT: I would like to submit for the record copies of three bills concerning pollution which were introduced into the legislature of the State of Minnesota.

MR. DOMINICK: That will be accepted for the record.

(The above-mentioned copies of bills follow.)

G. J. Merritt

other polluters can no longer be accepted in view of the clear and convincing evidence from scientists, commerical fishermen, the firsthand observations of hundreds of persons and the reports, letters, and affidavits introduced as part of this conference record.

We must show the generation attaining majority today that we can preserve our environment now within the framework of our democratic society. Unless we act immediately, we may lose the opportunity forever.

Thank you very much. (Applause.)

Mr. Commissioner, I would ask that Dr. Carson be given an opportunity at this point to proceed with his testimony which has been arranged for by MECCA. I have talked to Mr. Frangos, and Dr. Carson is on the agenda for the State of Wisconsin. He is a professor at the Wisconsin State University at River Falls.

I would be glad to answer any questions you might have if Dr. Carson isn't available.

MR. DOMINICK: Are there any questions?

MR. FRANGOS: I have a question, Mr. Chairman.

In Mr. Merritt's remarks he refers to a report, another report, entitled "Environmental Effects of Pollution and Diversion on the St. Louis River" that was prepared by the Department of the Interior. I am wondering if we could have that sent to Wisconsin. I am not asking that it be placed in the record, but I am not familiar with that report.

MR. DOMINICK: Mr. Poston, are you familiar with that report?

G. J. Merritt

references in the prepared statement and this is a reference to the Duluth Tribune of January 30, 1969.

This report, then, was prepared in accordance with prescribed Interior Department regulations and is an official report in all respects.

Mr. Commissioner, in the telegram that was sent from Senator Mondale, which you did read, you will find reference to the two official reports, the first being the Department of the Interior report, the second the FWPCA report. I would ask the conferees to take an objective look at the facts in this record and compare them with the statements made by Mr. Klein. I have the official copy of that portion of the transcript where Mr. Klein stated as follows:

"The Department of the Interior did not authorize it" -- referring to the so-called Stoddard Report --and is not bound by the report. The only report that was put out officially by the Department of the Interior is this one put out a week ago."

I suggest this is incorrect in view of the evidence.

Finally, gentlemen, we look to this conference to recommend forthwith the necessary action to save the pure water of Lake Superior for future generations. We look to this conference to implement the Department of Interior report without delay. Those of us who are vitally concerned cannot sit by for 5 more years or even 1 more year without action to stop this spoliation and exploitation. The excuses and contentions of Reserve Mining and

G. J. Merritt

MR. MERRITT: All three of these conditions of the State permit are presently being violated by Reserve Mining. The Department of Interior report establishes the direct connection between the Reserve tailings and the green water extending far outside of the 3 mile zone. Material quantities of oil, organic matter, and other wastes are also discharged by Reserve into the lake.

The FWPCA report submitted to this conference, dated April 1969, finds that the tailings have a harmful effect on the ecology of the lake[2]-- this is indeed material and unlawful pollution. This FWPCA report also finds that the tailings have an adverse effect on fish life,[3] which means the third condition above is being violated.

I would like to discuss for just a minute the Department of Interior or so-called "Stoddard Report" because it has been unfairly and incorrectly attacked as a unofficial report submitted to the Corps of Engineers without authority. These charges are false. As Mr. Joe Moore, former Commissioner of the FWPCA, stated after the report was released: "The regional coordinator is charged with the responsiblity of developing the departmental position, which he did in this case.."[4] Moore could find no fault with the regional coordinator's method of preparing the report or in releasing it directly to the Corps of Engineers.[5] I have

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2. FWPCA Report to the Conference, p. 46.
3. Ibid.
4. Duluth News Tribune Jan. 30, 1969, page 1.
5 Ibid.

P. J. Kilian

When I joined Reserve Mining Company, Mr. Ed Furness was my department superintendent. I believe he later progressed to the Presidency of Reserve. With high caliber Management Personnel such as Mr. Furness, it seems they should have been more knowledgeable about the potential polluting dangers.

If there had been as much emphasis on curbing pollution as there was on maintaining full production and on the job safety, Lake Superior would be less polluted today. We probably wouldn't have broken our tonnage output records as often, had we taken a little more time cleaning up and disposing of trash in the proper place.

Reserve Mining Company had a very effective safety program correcting known hazards as soon as possible, weekly safety meetings and safety posters throughout the plant, such as (a clean area is a safe area).

If these facts shed any light on the problem and are corrected, then it will have been well worth the effort it took to get this letter off to you.

Yours truly,

/s/ Paul J. Kilian

Subscribed before Me
May 12, 1969

/s/P. J. Klimek
Notary Public, Wright County, Minn.

My commission expires Jan. 14, 1972.

P. J. Kilian

Gentlemen:

I'm writing this letter in an effort to help find a solution to the pollution problem of Lake Superior.

I was an employee of Reserve Mining Company for 5 years (August '57 to August '62). I was employed in the operation phase (equipment operator) of the crushing section.

In the process of cleaning our equipment and floor areas, Lake Superior was being polluted. We used cleaning solvent (similar to #1 fuel oil) by the gallon to clean off grease and oil from the various machines. At the end of the work shift, this solvent along with a lot of oil and grease filled rags was enroute to Lake Superior. Some people believe this procedure is immaterial because of the furnaces at the end of the production line. However, this is not the case, as only the magnetic iron ore particles go through the furnaces. So I would like to re-emphasize the fact that all this solvent, grease, oil, rags and paper ended up in the Lake. The rags and paper enter the Lake as small particles due to the fine grinding effect of the Ball and Rod Mills. I might also add that the maintenance section was as guilty as we operators were of polluting the Lake. I often witnessed the relining of the fine crushers, which was a greasy job with too much of this grease finding its way to the Lake many times.

P. J. Kilian

Gentlemen, at this time I would like to introduce a statement of a former employee of Reserve Mining, Mr. Kilian, who testified in his statement as to the type of grease and oil and other matter, in addition to the other matters which he saw during the 5-year period he worked for the plant.

I have distributed that statement. May that be made a part of the record?

MR. DOMINICK: Mr. Paul J. Kilian's statement will be made a part of the record.

MR. MERRITT: I am sorry I don't have time to read the statement. It is a very good one.

STATEMENT OF PAUL J. KILIAN,

ST. MICHAEL, MINNESOTA

(The above-mentioned statement follows.)

KILIAN INSULATION
Hagan Cellulose
For Maximum Heating and Cooling Efficiency

St. Michael, Minnesota 55376

PHONE 673-2021 P. J. 'ARCHIE' KILIAN

May 12, 1969

Federal Water Pollution Control Administration
Enforcement Conference
Lake Superior Basin

G. J. Merritt

MR. MERRITT: I would hope that this statement, along with the approximately 100 statements by the Save Lake Superior Association will be read by the conferees, and I assume that will be the case before any further meetings are held by the conferees.

Those of us who have seen this pollution firsthand or have read the reports ask those who are polluting Lake Superior -- and Reserve Mining in particular, since it is the largest single source of discharge -- to cooperate now to reverse this pollution. We ask Reserve to join in abatement, rather than further obfuscation such as referring to the green, turbid water circulating over wide areas of the lake as an "illusion." We ask Reserve Mining -- what right have you to continue this one day longer than is required to build and begin operation of an alternate method of disposal, the type of disposal that has been recommended by the Bureau of Mines? Indeed, under the Minnesota permit -- what right do you have to continue one more day in violation of this permit?

The State of Minnesota permit originally issued in 1947 provides for revocation wherever:

1) Material quantities of matter soluble in water, organic matter, oil, or other wastes are discharged into the lake;

2) There is material clouding or discoloration of the water at the surface outside of the 3 mile zone specified around the plant;

3) The tailings result in any adverse effects on fish life or public water supplies or in any other material unlawful pollution of the waters of the lake.[1]

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1. Permit Issued to Reserve Mining Company, December 18, 1947 by Commissioner of Conservation, Chester S. Wilson.

10. Lake Superior represents a light shining clear and bright in our environment. If we, the public, allow that light to be diminished slowly but surely to the point of irreversible extinction--a dark day will have dawned for us and for our children in our great land.

Lawrence D. Downing

Subscribed and sworn to before me

this 12th day of May, 1969.

Muriel L. Hinrichs
Notary Public, Olmsted County, Minn.
My commission expires Sept. 16, 1971.

7. Over the years I have watched the construction and operation of the Reserve Mining Company's taconite plant at Silver Bay, Minnesota--first with interest, then with growing concern and now with genuine alarm, even panic. I can recall the beautiful little bay and tiny islands that constitute the site of the Reserve Mining Company's taconite plant. I vividly remember the journey past the site after commencement of operation when I first noted a milky green water in the bay instead of the formerly beautifully clear blue. Now the sickening milky green color is spreading out into the body of the lake and for several miles up and down the shore. It has even been reported that tailing residues have been detected across the lake on the Wisconsin shore. I have taken home movies of the area to display to my friends, who remember the former beautiful appearance of the water, the tragedy that is taking place in the name of "good business", "iron ore industry," and "additional tax revenue." I should have liked each and every member attending this conference to have seen the look on my five year old daughter's face as we moved from the mining company's Silver Bay look-out site for tourists to another spot where we could actually see the thousands of tons of tailings spreading out into our--mine and yours--lake.

8. That it would be sad, indeed, for this conference to bog down in questions of jurisdiction, in questions of political expediency, or even in questions of whether taconite tailings are technically pollutants. Even my daughter can recognize this kind of pollution and realize that it must be stopped. Would I permit her to wipe her muddy feet on a clean blue carpet? No more readily will I stand by and allow taconite tailings to soil Lake Superior without protest.

9. The question is not whether Reserve Mining Company can pay the price of disposing taconite tailings in a different manner, but rather is Reserve Mining Company willing to pay the price that an outraged public will exact if the practice continues as it has in the past.

WATER POLLUTION ENFORCEMENT CONFERENCE --

LAKE SUPERIOR BASIN

State of Minnesota)
) ss. Affidavit of Lawrence D. Downing
County of Olmsted)

Lawrence D. Downing, being first duly sworn, deposes and says:

1. That this affidavit is completely voluntary and unsolicited and is being submitted to be made part of the record at the Water Pollution Enforcement Conference--Lake Superior Basin to be held in Duluth, Minnesota commencing May 13, 1969.

2. That I reside on Lake Shady, Oronoco, Olmsted County, Minnesota. That I am an attorney licensed to practice law in the State of Minnesota, having graduated from the University of Minnesota Law School with a J.D. Degree; that I am engaged in the private practice of law with the firm of O'Brien, Ehrick, Wolf, Deaner & Downing in Rochester, Minnesota.

3. That my undergraduate work was completed at Iowa State University at Ames, Iowa with a B.S. Degree in Chemistry.

4. That I have an interest in a cabin on Lake Superior's shore northeast of Grand Marais, Minnesota. I have also camped on the shore of Lake Superior in Isle Royale National Park.

5. That I have traveled the north shore of Lake Superior by highway many, many times and at all times of the year; that I have been on Lake Superior's north shore waters in boats ranging in size from a canoe up to the motor vessel Winonah, which runs daily from Grand Portage, Minnesota to Isle Royale; that I have occasionally even plunged into Lake Superior's frigid waters for a swim following a sauna.

6 I love Lake Superior. Its crystal clear "Lake Superior blue" waters are truly one of the wonders of the world and surely the Creator's gift to man. It alone among large bodies of water in our nation has escaped desecration from man's soiled hands--a unique example from a world that was, but sadly isn't any longer.

his home here in Duluth. This shows the presence of a very murky substance which, according to the recent Federal Water Pollution Control report reported in April of 1969, is taconite tailings. This is not a scientific report, gentlemen, but merely intended to show you what is in the water supply here in Duluth. This was taken this morning. (Laughter.)

By the way, I might interject at this point, for a number of years, my father and a number of people here in Duluth -- and I am also a native Duluthian -- we are from the zenith city of the unsalted seas. But, unfortunately, I don't think we can say that any longer, with the salt and zinc and magnesium and other salts which are present.

At this time, gentlemen, I would like to introduce as part of the MECCA presentation a statement which was sent to me just a few days ago from a Lawyer in Rochester, Minnesota, Mr. Larry Downing, and ask that this be received as a part of this record. I wish I had the time to read it, but I won't take the time.

MR. DOMINICK: This is the affidavit of Lawrence D. Downing?

MR. MERRITT: That is right, Mr. Commissioner.

MR. DOMINICK: Fine, we will be happy to receive that for the record.

STATEMENT OF LAWRENCE D. DOWNING, ROCHESTER, MINNESOTA

(The above-mentioned affidavit follows.)

G. J. Merritt

I had occasion yesterday to talk to Dr. Thomas, who is an observer here from Canada, and I asked him a question on this very point. I said, if a similar situation were to occur in Canada, what would the Canadian Government do with regard to release of this information? He siad, "it would be released. A scientist would be able to stand up and give that information without any question." He was astounded at the withholding of this information by the American Government.

I will now proceed with other matters.

Hundreds of people have observed the turbid or "green water" which stretches from Silver Bay westerly to Duluth. I personally viewed this "green water" off Gooseberry Park along the North Shore several years ago and wondered what it was and where it was coming from. It was completely unlike the runoff from a North Shore stream -- which appears reddish-brown rather than green or gray-green. I have never observed any such "green water" such as this at any time in the waters of Lake Superior at Isle Royale.

Finally, I have seen the filthy waters of the Duluth-Superior Harbor on many occasions. They are filthy, gentlemen. I wish you had an opportunity to see those waters, and you could if you see fit.

At this time I would like to ask my father, Glen J. Merritt, of Duluth, Minnesota, who is in the audience, to bring up a sample which was taken this morning from the flush tanks at

G. J. Merritt

"If the Secretary believes upon the conclusion of the conference or thereafter that effective progress toward abatement of such pollution is not being made and that the health or welfare of any persons is being endangered, he shall recommend the appropriate State water pollution control agency that it take necessary remedial action...."

Later, if necessary, he can convene a public hearing and go forward with the further steps in the statute -- the statute prior to the amendment of 1961. The same amendment I just mentioned said exactly the same as the purpose clause, "of any persons in a State other than that in which the discharge originates,' so the statute has been broadened and that is my interpretation . However, because I know the opinion and the stand which the Federal Water Pollution Control Administration is taking in this conference, I made the demand for the additional information which proves interstate pollution or which at least is the first step towards proving such pollution, and we were refused the report and I am still refused the graphs I asked for until we made a formal request of the Commissioner under the "freedom of information" law.

Mr.Stein stated we must operate under the law. Gentlemen, that is exactly what we are asking for. We ask for the information which is now available and which we were able to inspect at the water lab yesterday, but which we are unable to present to the conferees and have made a part of this record.

G. J. Merritt

We have found through long experience that this is the fastest way to abate pollution. Dealing from a legal and jurisdictional point of view, that is the posture we find ourselves in here.

Thank you.

MR. DOMINICK: Thank you, Mr. Stein.

Mr. Merritt, I am almost as new as you are to this subject of water pollution and jurisdiction and I think we can both agree that this is a highly complex subject and one which we cannot lay out in a matter of a paragraph as to the jurisdictional authority. I think Mr. Stein has done a real service to explain the situation to all of us. I would hope that you will proceed with your statement.

MR. MERRITT: Thank you, Mr. Commissioner.

That is exactly why I have added these remarks to the rather long paragraph in my written statement. It is important. I appreciate and have a great deal of respect for the comments made by Mr. Murray Stein. I, however, differ with his interpretation.

I notice he discussed only Section 10 (d)(1), which I read earlier and won't repeat, but there is no question that Secretary Udall had reason to believe that the interstate pollutio was occurring. Once you pass that hurdle, that is the first question, and you then reach the second question, which is the scope of the jurisdiction of this conference to issue abatement orders. I would refer to Section (e) of the statute which, as with the purpose clause of the statute, states as follows:

G. J. Merritt

with the Government for longer than most of you care to remember. I won't be too definite, but it was before World War II. (Laughter.) I had 4 years off for good behavior to serve in the Service, but other than that I have spent my career with the Government. Let me say, on the basis of my experience, unless the Secretary indicates -- and I know of no Secretary who has -- only the Secretary knows what the basis of his belief is now.

When we look at the record of this case and when we look at the St. Louis River, the Montreal River, and when we look at the undisputed facts here, we get a notion of interstate pollution. In a press release put out at the time we called this conference, Secretary Udall also spoke about the exploratory nature of the conference.

Here is what we do at the conference. When we go out in the conference in any area, we take all sources of pollution -- municipal, industrial, or what-have-you -- however large and however small, because there is no lake cleanup of pollution unless you take all of the sources and not just emphasize one. We also, when the facts will develop, institute an actual program to correct those sources which can be identified.

I think we have heard testimony here on various municipalities and industries where the State has come up with the program of particular remedial facilities and dates. When we do not have it and the situation so develops, we develop the facts and try to move ahead with the States on the basis of these facts.

G. J. Merritt

The other one Mr. Merritt is talking about is the Great Lakes and their tributaries. Since we could deal only with intra- or interstate pollution up to this time, we have not been able to deal with international pollution. We can now deal with international pollution, but we have two restrictions there: 1) We have to have a report of such pollution by a duly constituted international body; 2) We must have the request from the Secretary of State. We have not had any international cases yet.

Of these four kinds of cases -- and this is the point -- we act here solely under the jurisdiction of pollution in one State endangering health or welfare of persons in another State.

We go up every year and are reviewed by Congress on appropriations. The Congress in the Appropriations Committees is fully aware of this interpretation. By their granting the funds again and again, it seems we should have a pretty good indication of what the agreement is, because enforcement is one of the most sensitive things there is, and, if this is not handled right, it will be brought out in a subsequent Committee -- the Government Operations Committee. As many of you in this room know, I have been before these Committees many times to explain the jurisdiction, about which there is no doubt.

There is one other point on the Secretary's calling this conference. "On the basis of the reports, surveys, or studies, he (the Secretary) has reason to believe" -- I have worked for many Secretaries in my time. I am a career man and I have been

G. J. Merritt

First you have to recognize that we must operate under the law and the Federal Government is a Government of limited laws. We can just do what the Congress says we are to do when the law is finally passed. We can't proceed on an interim report as the law is going through. There are many, many amendments. We can now proceed with abatement procedures, such as we have here, when pollution endangers the health or welfare of any person. With these limitations -- and these are the limitations we will have to keep in mind -- we can only proceed on our own initiative, on the Federal initiative, when the Secretary of the Interior, on the basis of reports, surveys, and studies, has reason to believe that pollution in one State endangers -- and here is the key -- the health or welfare of persons in another State.

We can't proceed in an intrastate situation where we find endangerment of health or welfare which doesn't go beyond another State. When the Governor of the State asks us in we may proceed, but we have had no such request from the Governors of any of these States in this situation.

In other cases, such as Detroit, we had a request from the Governor of Michigan. We have not had an intrastate situation here.

We can move on our own initiative against intrastate cases -- and the State request requirement doesn't apply - when pollution affects shellfish areas, so as to prevent the shipments of shellfish in interstate commerce.

G. J. Merritt

jurisdiction of the Federal Government, why we are here and precisely what we are doing.

I would like to agree with Mr. Merritt. As you know, lawyers can differ on any question. However, in a matter of pollution control, enforcement cases and jurisdiction, I have been involved in every one of the pollution control conferences that have been held since the beginning of the Federal program. I also have been, since 1955, called up to testify before the Congress on the enforcement provisions of the Act when they drafted amendments. I have had long discussions with the Chairmen of Committees on a technical basis when they asked them to get technical advice and draft it. The Chairman of the House Committee is a Congressman from this District, Mr. John A. Blatnik, The Chairman of the Senate Committee is Senator Edmund Muskie. These are both very distinguished gentlemen in the field.

On the basis of long discussions, testimony before the Committees and questioning we have had, I might say there is no difference, in my mind, on what they meant by jurisdiction, what the statute means by jurisdiction, what our Federal Water Pollution Control Act means when they talk about jurisdiction. I think there is no question in the Department of Justice mind what is meant by jurisdiction, because I work on a day-to-day basis with them. The Act has been amended several times. Let's now try to get this together so we can understand it and not have this.

G. J. Merritt

MR. MERRITT: Mr. Commissioner, the data I am asking for is not raw data. I am asking for the eight graphs. These graphs have been completed and show the trends of cummingtonite. The further studies that will be taken -- and we learned this in our discussions yesterday morning which you did permit at the water lab -- will try to determine and rule out whether or not this cummingtonite came from sources other than Reserve Mining. That is a further step.

All I am asking is for the graphs, plus the further studies Dr. Mount will undergo and complete this summer, to be made a part of this record.

MR. DOMINICK: I think the procedures are very clear. If they have not been made clear to you, I suggest you do some study on the subject. The procedures are that this conference will consider the evidence properly before us and we will make our recommendations upon that evidence.

The conference will be reconvened for progress meetings at 6-month intervals. As studies are continued, as we gather further evidence, this will be made a part of the progress meeting material which will be considered.

I can see no reason to have any further discussion on this point. I suggest that you proceed, unless Mr. Stein has some remarks with respect to the jurisdictional question.

MR. STEIN: If I might. Would you object, Mr. Merritt, to my statement? I think this is the key point of the conference and something which has led to possible confusion, i.e., the

G. J. Merritt

I would refer to the statement made by the Attorney General in the memorandum outlining the "freedom of information law", which was issued 2 years ago, as follows:

"If government is to be truly of, by, and for the people, the people must know in detail the activities of government. Nothing so diminishes democracy as hypocrisy."

We have not been given the right to use these graphs, to introduce them as part of this record so you conferees might consider them, so that scientists who will later be in this conference can evaluate them and show them on the projector and make other comments.

We would further request, gentlemen, that you incorporate into this record the inclusions which Dr. Mount in the water lab will make, I understand, sometime this summer if they have the manpower and the resources, including the final analyses on these bottom samples.

MR. DOMINICK: Mr. Merritt, I understand that you are a lawyer. If so, you should be aware of rules of evidence; you should be aware of certain procedural requirements. One of the procedural requirements that we have in the conference of this sort is that information which is brought before the conference be fully supportable. Conclusions can be drawn from that information, and the data which was provided to you yesterday, as I indicated yesterday, is raw data. It is not data that has been analyzed or evaluated. And it is not data which is properly subject to our consideration at this time.

G. J. Merritt

the evidence which the water lab in Duluth has taken from bottom samples in Wisconsin waters during the last 2 weeks. We asked for this information under the "freedom of information law." The information was provided at the water lab yesterday morning at 11:00 a.m. and was made public at that time. We were able to inspect the graphs showing the presence of cummingtonite, indicating the presence of cummingtonite and the trace which Dr. Mount mentioned yesterday in 5 of the 6 samples of Wisconsin water.

At this time we request, Mr. Chairman, that those graphs be incorporated into this record. I previously requested that these graphs be published and furnished under the "freedom of information law," but this was denied by the Commissioner. I again request these be made part of the conference record and be considered by the conferees because they do show the presence of cummingtonite in these samples taken in Wisconsin waters last week. I make this request under the "freedom of information law".

MR. DOMINICK: The "freedom of information law" has been fully complied with. This information has been made available to you, to members of the press, at our laboratory. We had a full discussion of that information before this conference yesterday afternoon. I believe that the situation speaks for itself on that point.

You may proceed.

MR. MERRITT: I request the Commissioner provide us with one copy each of the eight samples, the graphs which show the cummingtonite, and that request was denied previously.

G. J. Merritt

I will give the references, as they aren't in my printed statement. 1961 U. S. Code, Congressional Administrative News, Section 2082 through Section 2086, 2098 through 2099, and 2106 through 2107. I would be glad to provide those later for anyone interested.

In the Senate reports the then present law excluded the greater part of the Great Lakes and their tributaries, the implication being, gentlemen, that the amended law includes the Great Lakes. The minority report on this bill contains language supporting the case for strong Federal jurisdiction in this area. The report notes that "this bill removed the interstate requirement that health and welfare of persons be affected in a State other than that in which the discharge occurs," and I again cite the previous section of the U. S. Code, Congressional Administrative News.

After going through the statute a number of times and talking with other lawyers, that is my opinion, but I am not infallible, and I understand there are opinions coming from Washington which apparently state that interstate pollution must be required before you gentlemen have jurisdiction. I think a plain reading of this statute indicates that is not the case. Once the conference is legally convened under Section 10(d)(1) law was broadened to include the enforcement of pollution control in those intrastate waters which are navigable. Anybody knows, of course, that Lake Superior is a navigable water.

Because this may be an erroneous interpretation -- I am not infallible -- we have requested earlier in this conference

G. J. Merritt

The next issue and the issue which you gentlemen have to decide, which has been discussed by a number of people throughout the past 3 days, once the conference is legally convened, the next issue is, what is the jurisdiction or the scope of the conference? This, gentlemen, is a most important question. Must there be interstate pollution or, if there are navigable waters, are you permitted to issue enforcement orders covering intrastate pollution?

Section 10(a) of the statute provides as follows:

"The pollution of interstate or navigable waters in or adjacent to any State or States ... which endangers the health or welfare of any person shall be subject to abatement as ... herein provided."

The former statute, before the Amendment of 1961, gentlemen, read:

"The pollution of interstate waters in or adjacent to any State or States ... which endangers the health or welfare of persons in a State other than that in which the discharge originates, shall be subject to abatement as herein provided."

The statute was broadened in 1961 so as to include enforcement action by a conference such as this, even though it is not occurring.

In 1961 the Senate report accompanying this bill stated as follows:

"By extending the authority for Federal abatement enforcement action to the pollution of any navigable waters which endanger the health or welfare of any person."

G. J. Merritt

Interior may call such a conference when he has "reason to believe" on the basis of reports, surveys, or studies that pollution of interstate or navigable waters is occurring which endangers the health or welfare of persons in other States, in this case other than Minnesota, in which the discharge originates. The Department of the Interior report, which was submitted to the Corps of Engineers early in 1969, the so-called Stoddard Report, he being the Regional Coordinator, gave Secretary Stewart Udall ample justification to call this conference. This report shows that pollution from taconite tailings is occurring in Lake Superior, contrary to Dr. Lee's statement just a few minutes ago, and, in view of the prevailing lake currents, moving from Silver Bay to Wisconsin, this pollution constitutes a definite hazard to the health or welfare of persons in Wisconsin.

In addition to the Department of Interior report forwarded to the Corps of Engineers, Secretary Udall had other reports and studies of Lake Superior pollution available when he decided to call this conference, such as Dr. Louis Williams' paper published in BioScience, Volume 18, No. 1, 1968, and, thirdly, the report of several agencies of the Department of Interior entitled "Environmental Effects of Pollution and Diverson on the St. Louis River," dated October 15, 1968, transmitted to Under Secretary Black in response to his request of November 24, 1967, for a field review of pollution of this interstate tributary. At least Secretary Udall clearly had "reason to believe" that interstate pollution is occurring and legally convened this conference.

G. J. Merritt

calling for an end to dumping of taconite wastes into Lake Superior; public hearings have been held, including one in Duluth on March 15, which attracted over 150 people who spoke out strongly against the pollution of Lake Superior; the very successful Save Lake Superior Association has been organized; a number of TV and radio programs have held discussions on this issue throughout the State a very successful Lake Superior organization has been organized which I am proud to say I belong to; and, finally, the Democratic-Farmer-Labor (DFL) Party of Minnesota, after extensive consideration, adopted the following plank as part of the State Party Platform for 1968-1969:

"The use of Lake Superior as a dumping ground for mining or industrial wastes must be prohibited."

Today we look to you conferees for enforcement -- not control or endless study, but strict enforcement of water quality which will end the pollution of Lake Superior from Reserve Mining Company as well as all other sources. Experience shows that only by strict enforcement will the polluting sources stop their present policies.

Gentlemen, for a few minutes I would like to beg your indulgence to engage in a few legal technicalities to go with the scientific technicalities which are the most important part of this conference.

As an attorney I have examined Section 10(d)(1) 33 U.S.C. 466g of the Federal enforcement statute under which this conference was convened. This section provides that the Secretary of the

already befallen Lake Erie and is seriously threatening Lake Michigan.

For hundreds of years Lake Superior has inspired people, poetry and paintings because of its rugged shoreline and its vast ocean-like expanses, but most of all because of its crystal-clear water, or, as termed by the New York Times, "pristine clarity," -- water which could be drunk directly without fear of ill effects -- pure water unequalled anywhere in the world. It has been our good fortune to inherit this greatest of the Great Lakes. But in our lifetime we have seen the startling and tragic beginning of the degradation of our priceless and irreplaceable resource. Because of our lack of concern, our apathy, and the shortsightedness of certain business interests who would place monetary dividends above natural and human dividends, we now witness the spoilation of the lake in the Duluth-Superior Harbor, the St. Louis River, and along the north and south shores.

Fortunately the public has now been shaken from its apathy. The great interest in the enforcement conference testifies to the public concern that we shall not repeat the series of errors which led to the incredible eutrophication of Lake Erie -- where each industry comforted itself in thinking that it was only contributing a "little more waste" to its waters.

The aroused public has indicated its concern in many ways in the past year. There have been countless letters to the editors of many newspapers and to Congressmen; resolutions have been passed by citizen and conservation groups; three separate bills were introduced in the 1969 Minnesota State Legislature

needing further verification. The on-going studies are near enough to completion so that at the end of a 6-month study period there should be a sufficient corpus of data upon which to make a definitive recommendation as to the question of revocation of the permit granted by the Army Corps of Engineers. To delay this decision beyond the 6-month period would not be advisable considering the fragility of the oligotrophic qualities of Lake Superior which underly its unique and irreplaceable nature.

MR. MERRITT: When I am completed, we will also present the testimony of Dr. Charles Carson who for 5 years has been with the Duluth branch who will discuss Lake Superior pollution.

I want to stress our consultants representing the various citizens and various groups are unpaid consultants. They are not receiving even expense money, with one exception of one who received an airplane ticket. They are here on their own, and I believe their testimony reflects concerned information as objective, interested testimony without anything attached.

The purpose of my statement is to discuss briefly the importance of Lake Superior to Minnesotans. Second, the jurisdiction of this conference over the most immediate and pressing pollution problem -- the dumping of taconite tailings at Silver Bay, the official and authoritative nature of the Department of Interior report submitted to the Corps of Engineers in January 1969 and, four, the critical need for action by this conference. We ask this conference to act quickly to combat the pollution of the greatest of the Great Lakes in order to save it from the fate which has

silt can be found in bottom sediments from 10 miles north of Silver Bay to Duluth and to the Apostle Islands. This material could affect the benthic invertebrates which are important sources of fish food as well as being a source of damage to the demersal types of fish eggs such as those laid by lake herring, whitefish, and lake trout.

Recent unpublished data collected by the National Water Quality Laboratory in Duluth tends to support the findings of Williams that there is interstate transport of taconite tailings silt to the Wisconsin benthic sediments, although additional analyses of the sediments brought into the lake by the South Shore streams are needed to establish whether cummingtonite can be regarded as a specific tracer of taconite tailings.

The document, "An Appraisal of Water Pollution in the Lake Superior Basin, April 1969," Department of the Interior, makes the following recommendation:

"The FWPCA and the States keep the discharge of taconite tailings to Lake Superior from the Reserve Mining Company, E. W. Davis Works, under continuing surveillance and report to the conferees at six month intervals on any findings that interstate pollution is occurring or is likely to occur, and the State of Minnesota is urged to take such regulatory actions as necessary to control the intrastate pollution resulting from these discharges, if any."

It is the view of this investigator that the available evidence is highly suggestive of a serious pollution problem emanating from Silver Bay. However, some of this evidence is incomplete and other evidence is of a preliminary nature, thus

turbidity. This is a high level of turbidity for it exceeds the U.S. Public Health Service Drinking Water Standard of 5 Jackson units by a factor of 42 (Muller and Huver, 1969, unpublished data). The major biological effect of increasing turbidity is to decrease the primary productivity of the lake.

A more serious aspect of the Reserve discharge problem is chemical pollution from the finely ground tailings particles. Analyses of samples collected by the FWPCA from the vicinity of the waste disposal area indicated that copper and zinc were present in concentrations normally considered to be toxic to aquatic life. The FWPCA investigations of June-July 1968 in the Silver Bay area revealed lead and copper levels in excess of Federal-State Water Quality Standards. The Federal report (Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota, December 1968, U.S. Department of the Interior) concluded that aluminum, lead, copper, zinc, cadmium and nickel were "found to be in concentrations in excess of commonly accepted levels for supporting aquatic life." Recent analyses for copper in our laboratory indicate unusually high levels in the vicinity of Silver Bay as compared to other North Shore stations (Muller and Huver, 1969, unpublished data).

Another problem with potentially serious biological consequences is the settling-out of fine grey taconite silt on the bottom of Lake Superior. According to a study entitled, "Should some beneficial uses of public waterways be illegitimate?" by Louis G. Williams in the January 1968 issue of BioScience, taconite

the University of Minnesota. These witnesses testified that fine particles have been carried into Lake Superior for thousands of years by the streams entering the lake. In particular, Dr. Moyle referred to the St. Louis River which flows over the bed of an old glacial lake, and testified that it carried down finer material in larger quantities than would come from Reserve's plant. Recent data from a Department of Interior study, Special Report on Water Quality of Lake Superior in the Vicinity of Silver Bay, Minnesota, December 1968, tends to refute the testimony of Doctors Moyle and Davis in that the FWPCA found that the Reserve tailings were a much more significant source of fine particles than the inlet streams.

Every day the Reserve Mining Company discharges an average of 700 million gallons of water containing some 60,000 long tons of taconite waste solids directly into Lake Superior. Of the waste solids discharged per day, some 5,400 long tons are less than 4 microns in diameter. Particles of this size would stay suspended for considerable lengths of time after discharge. Since the plant went into operation in 1956, more than 190 million tons of taconite tailings have been put into the lake.

An obvious polluting influence of this discharge is the greatly increased turbidity in the water of the Silver Bay area. For photographic evidence of this form of pollution one can refer to a report entitled, Studies on the Productivity and Plankton of Lake Superior, June 1961, published by the School of Public Health, University of Minnesota. Turbidity measurements taken 1/4 mile in front of the Reserve tailings delta reveal 210 Jackson units of

C. W. Huver

(The above-mentioned statement was received and follows.)

PERSPECTIVE ON THE POLLUTION OF LAKE SUPERIOR

BY TACONITE TAILINGS

by

Charles W. Huver

B.S. Michigan State University
M.S. University of Wisconsin
Ph.D. Yale University

Presented to the Conferees of the Federal-State Conference on Pollution of Lake Superior and its Tributary Basin, held at the Hotel Duluth, May 13-15, 1969. The author is Associate Professor of Zoology and Curator of Fishes in the James Ford Bell Museum of Natural History at the University of Minnesota.

The question of possible pollution of Lake Superior by taconite wastes was first brought into public focus during the 1947 hearings before the State Commissioner of Conservation and the Water Pollution Control Commission on a permit application of the Reserve Mining Company to deposit its tailings in Lake Superior at Silver Bay. Considerable concern was expressed about the finer particles that would be part of the tailings deposit and the question of whether they would remain suspended and have any adverse effects on the quality of Lake Superior water.

Testimony paving the way to the granting of the permit was given by Dr. John Moyle of the Minnesota Department of Conservation and by Dr. E. W. Davis of the Mines Experiment Station of

G. J. Merritt

MECCA strongly opposes further discharge of taconite tailings by Reserve Mining Company into Lake Superior at Silver Bay, Minnesota. We urge this conference to recommend necessary remedial action to abate this discharge. We believe the extensive scientific data presently available, and a part of this record by the time this conference closes, proves clearly and convincingly that this dumping of over 60,000 tons of tailings daily, or 20 million tons annually, constitutes pollution of Lake Superior. We also urge the immediate abatement of other forms of pollution in the Lake Superior Basin.

We bear no hostility or malice, gentlemen, toward the Reserve Mining Company. There is an entirely reasonable alternative, as suggested by the Bureau of Mines in the Department of the Interior report to the discharge of tailings at Silver Bay.

MECCA has arranged for the presentation of statements from two outstanding scientists. The first is Dr. Charles Huver of the University of Minnesota. Unfortunately, because of the schedule of this conference, Dr. Huver had to return to the Minneapolis campus last night, and if it is all right with you gentlemen, his statement will be submitted and become part of the record. It will be sent to Mr. Murray Stein.

MR. DOMINICK: That is fine. You don't have the statement here?

MR. MERRITT: No, I don't. He was called this afternoon and it will have to be mailed to the conferees.

MR. DOMINICK: When it is received it will be made a part of the record.

valuable lake. As a native Duluthian, and one who has traveled the North Shore hundreds of times, fished the crystal clear waters of Lake Superior for 30 years, vacationed at Isle Royale National Park in Lake Superior for nearly every one of these past 30 years, I am known as the wolf's eye of the wolf, which is shown on the map behind the conferee at the head of the table. There are a number of people concerned that the wolf no longer will be able to see to the end of his nose if the tailings discharge at Reserve continues much longer, and, furthermore, that the wolf is about ready to gag with the pollution now occurring in the Duluth-Superior Harbor in the river. (Laughter.)

I trust you gentlemen will give close consideration to the very serious problems now occurring in Lake Superior from a number of sources. I am personally concerned that man may destroy this priceless resource --- and sooner than many believe possible, unless we act now to stop the pollution endangering the health or welfare of persons in Minnesota, Wisconsin, and Michigan.

MECCA is a nonprofit Minnesota corporation founded one year ago in the belief that man has passed the time when he can use, exploit, and move on. It is an action group which evaluates problems and then acts to solve these problems in the agency hearings, in the legislative halls, and, if necessary, in the courts. Without much effort to build membership, preferring instead to work for immediate action to abate pollution in a number of areas, the Association has grown to between 500 and 600 members.

G. J. Merritt

MR. BADALICH: Mr. Chairman, I believe Mr. Fride has concluded with the other witnesses.

I will call at this time for other witnesses who want to make an appearance on behalf of the State of Minnesota.

First I would like to call on Mr. Grant J. Merritt, Board of Directors of MECCA, Minneapolis, Minnesota.

Mr. Merritt.

STATEMENT OF GRANT J. MERRITT, DIRECTOR,
MECCA, MINNESOTA ENVIRONMENTAL CONTROL
CITIZENS ASSOCIATION, MINNEAPOLIS, MINNESOTA

MR. MERRITT: Mr. Chairman, conferees, ladies and gentlemen:

My name is Grant Merritt. I am from Minneapolis. It is a pleasure to be here and finally have a chance to make this presentation. I am sorry to hear, however, that Reserve will have a chance to go on after the presentation of the public witnesses. I just learned that from Mr. Badalich.

As a Director of MECCA, Minnesota Environmental Control Citizens Association, and Chairman of the MECCA Task Force on Lake Superior, I am pleased to present this statement to this important conference called by Secretary Stewart L. Udall to enforce pollution control in the Lake Superior Basin. In addition, I am presenting this statement in my own behalf as an individual very interested in the prevention of pollution in this extraordinarily

Author	Degree	Title
Kobayashi, Shigeru	Ph. D.	Aqueous Environmental Chemistry of Arsenic
Peterson, James	Ph. D.	Aqueous Environmental Chemistry of Lead
Plumb, Russell	Ph. D.	Chlorination of Cyanide
Rodel, Max	M. S.	Characterization of Odorous Compounds from Algae
Sanchez, Isaac	Ph. D.	Aqueous Environmental Chemistry of Copper
Shannon, James	Ph. D.	Aqueous Environmental Chemistry of Sulfide
Sherman, Marguerite	M. S.	Use of Algal Pigments to Estimate Eutrophication
Sonzogni, William	M. S.	Chemistry of Plant Nutrients in Farm Ponds
Spear, Richard	Ph. D.	Leaching of Phosphorus from Lake Sediments
Sridharan, Nagalaxmi	Ph. D.	Aqueous Environmental Chemistry of Phosphorus in Lower Green Bay, Wisconsin
Thingvold, Daryle	M. S.	Persistence of TFM in Natural Waters
Veith, Gilman	Ph. D.	Persistence of PCB Compounds in Natural Waters
Walton, Craig	Ph. D.	Algal Nutrition in Lake Wingra
Weimer, Walter	M. S.	The Origin of Meromixis in Lakes
Olson, Donald	M. S.	Effect of Mn Oxides and Sulfate on Release of Phosphate from Lake Sediments

Author	Degree	Date	Title
Boucher, Frank R.	Ph. D.	1967	The Adsorption of Chlorinated Hydrocarbon Pesticides on an Unconsolidated Aquifer Substrate
Tranquillo, James S.	M. S.	1967	Concentration of Dilute Phenolic Solutions Utilizing DMSO
Brezonik, Patrick L.	Ph. D.	1967	The Dynamics of the Nitrogen Cycle in Natural Waters
Bortleson, Gilbert C.	M. S.	1967	Chemistry of Lake Sediment Cores
Wang, Wun-Cheng	Ph. D.	1967	The Effect of the Association of Organic Material with Clays on Parathion and DDT Adsorption
Pfeil, Bernhard, H.	M. S.	1967	Biodegradation of Nitrilotriacetic Acid
Delfino, Joseph J.	Ph. D.	1968	Aqueous Environmental Chemistry of Manganese
Hughes, Robert A.	M. S.	1968	Persistence of Toxaphene in Natural Waters
Plumb, Russell H.	M. S.	1968	The Iron-Organic Complex of Lake Mary
Veith, Gilman D.	M. S.	1968	The Role of Lake Sediments in the Water Chemistry of Toxaphene
Kluesener, John W.	M. S.	1968	Color and Oxygen Characteristics of Petenwell Flowage, Wisconsin River

Theses in progress under the supervision of G. Fred Lee

Name	Degree	Title
Amundson, Rohel	M. S.	Leaching of Nitrogen and Phosphorus from Marsh Sediments
Austin, Elizabeth	M. S.	Leaching of Nitrogen from Lake Sediments
Bentley, Eugene	Ph. D.	Effect of Marshes on Water Quality
Bhatia, Rattan	Ph. D.	Effect of Sanitary Landfills on Water Quality
Bortleson, Gilbert	Ph. D.	Use of Lake Sediment Cores to Estimate Eutrophication
Cowen, William	M. S.	Effect of Natural and Waste Water Organics on the Growth of Algae
Gardner, Wayne	Ph. D.	Aqueous Environmental Chemistry of Amino Acids and Proteins
Hall, Kenneth	Ph. D.	Characterization of Natural Water Organic Matter
Hanson, Arthur	M. S.	Analytical Methods for Fractionation of Organic Nitrogen Compounds in Waste Waters
Hughes, Robert	Ph. D.	Persistence of Toxaphene Isomers in Natural Waters
Kluesener, John	Ph. D.	Release of Nutrients from Lake Sediments

Rai, H., Lee, G. F. and Fruh, E. G. "Plankton of the Madison Lakes" (in preparation).

Sridharan, N. and Lee, G. F. "Coprecipitation of Organics from Lake Waters by Iron" (in preparation).

Veith, G. D. and Lee, G. F. "Water Chemistry of Toxaphene - Role of Lake Sediments" (submitted for publication).

Wang, W., Spyridakis, D. E. and Lee, G. F. "Sorption of Parathion and DDT on Clays" (in preparation).

Wentz, D. E. and Lee, G. F. "Sedimentary Phosphorus in Lake Cores" (in preparation).

Wentz, D. E. and Lee, G. F. "Sedimentary Phosphorus in Lake Cores. Observations of the Depositional Pattern in Lake Mendota, Wisconsin" (in preparation).

Wiersma, J. and Lee, G. F. "Aqueous Chemistry of Selenium" (in preparation).

Wilson, W. and Lee, G. F. "Use of Chemical Composition of Fresh Water Clamshells as Indicators of Paleohydrologic Conditions" (submitted for publication).

WATER CHEMISTRY THESES

Completed under the supervision of G. Fred Lee

Author	Degree	Date	Title
Kobayashi, Shigeru	M. S.	1963	Freeze Concentration of Dilute Aqueous Solutions
Gardner, Wayne S.	M. S.	1964	Oxygenation of Lake Sediments
Brezonik, Patrick L.	M. S.	1965	Sources of Nitrogen Gas in Anaerobic Fermentations
Shannon, James E.	M. S.	1965	Hydrolysis Rates of Condensed Phosphates in Natural Waters
Johnson, W. DeWitt	M. S.	1965	Persistence of Toxaphene in Treated Lakes
Spear, Richard D.	M. S.	1965	Extracellular Glycolic Acid Accumulation in Natural Waters and Laboratory Cultures
Doll, Frederick L.	M. S.	1967	The Effect of Coagulants on the Lime-Soda Softening of Water
Bentley, Eugene M.	M. S.	1967	Determination of Calcium by Atomic Absorption Spectrophotometry
Peterson, James O.	M. S.	1967	Sorption of Rhodamine B on Activated Carbon
Kammerer, Phil A.	M. S.	1967	Freeze Concentration of Organic Compounds in Dilute Aqueous Solutions
Wentz, Dennis A.	M. S.	1967	Available Phosphorus in Lake Sediments
Hawley, John E.	M. S	1967	Calcium Carbonate Equilibrium in Lake Mendota

Boucher, F. R. and Lee, G. F. "The Adsorption of Chlorinated Hydrocarbon Pesticides on an Unconsolidated Aquifer Sand" (submitted for publication).

Delfino, J. J., Bortleson, G. C. and Lee, G. F. "Distribution of Mn, Fe, P, Mg, K, Na, and Ca in Surface Sediments in Lake Mendota, Wisconsin" (submitted for publication).

Delfino, J. J. and Lee, G. F. "Release of Manganese from Lake Mendota Sediments" (submitted for publication).

Delfino, J. J. and Lee, G. F. "Colorimetric Data of Manganese in Lake Waters" (in preparation).

Doll, F. L. and Lee, G. F. "Effect of Coagulants on Lime-Soda Softening of Water" (submitted for publication).

Fitzgerald, G. P. and Lee, G. F. "Use of Tests for Limiting or Surplus Nutrient to Evaluate Sources of Nitrogen and Phosphorus for Algae and Aquatic Weeds" (in preparation).

Fruh, E. G. and Lee, G. F. "Cesium Sorption by Lake Sediments (in preparation).

Fruh, E. G. and Lee, G. F. "Cesium Sorption on Stratified Mica" (in preparation).

Fruh, E. G. and Lee, G. F. "Eutrophication of Madison Lakes" (in preparation).

Fruh, E. G. and Lee, G. F. "Inhibition of Cesium Sorption on Vermiculite" (in preparation).

Gardner, W. and Lee, G. F. "Determination of Amino Acids in Natural Waters by Gas Chromatography" (in preparation).

Hawley, J. E. and Lee, G. F. "Calcium Carbonate Saturation in Lake Mendota" (in preparation).

Hughes, R. A., Veith, G. D. and Lee, G. F. "Analysis of Toxaphene in Lake Water, Sediments, Plankton and Fish" Presented at Applied Spectroscopy Society meeting, Chicago, Illinois, May, 1969.

Kluesener, J. and Lee, G. F. "Deoxygenation of Petenwell Reservoir on the Wisconsin River" (in preparation).

Lee, G. F. "Analytical Methods - Dissolved Substances" Presented at International Symposium on Eutrophication, Madison, Wisconsin, June 11-12, 1967 (in press).

Lee, G. F. "Factors Affecting the Exchange of Materials from Lake Waters and Sediments" to be presented at Amer. Chemical Society meeting, New York City, Sept., 1969.

Peterson, J. O. and Lee, G. F. "Sorption of Rhodamine B on Activated Carbon" (in preparation).

Plumb, R. and Lee, G. F. "Iron Organic Associations in Lake Mary, Wisconsin" (in preparation).

39. Pfeil, B. H. and Lee, G. F. "Biodegradation of Nitrilotriacetic Acid in Aerobic Systems" Environ. Sci. & Tech. 2, 543-45 (1968).

40. Spear, R. D. and Lee, G. F. "Glycolic Acid in Natural Waters and Laboratory Cultures" Environ. Sci. & Tech. 2, 557-58 (1968).

41. Morton, S. D. and Lee, G. F. "Calcium Carbonate Equilibria in Lakes" J. Chem. Edu. 45, 511-13 (1968).

42. Morton, S. D. and Lee, G. F. "Calcium Carbonate Equilibrium in the Oceans-Ion Pair Formation" J. Chem. Edu. 45, 513-15 (1968).

43. Delfino, J. J. and Lee, G. F. "Chemistry of Manganese in Lake Mendota, Wisconsin" Environ. Sci. & Tech. 2, 1094-1100 (1968).

44. Lee, G. F. and Delino, J. J. Discussion, "Equilibrium and Kinetics Aspects of Inorganic Chemistry Quality in Reservoirs" Proceedings of Specialty Conference on Current Research into the Effects of Reservoirs on Water Quality, January, 1968, ASCE, Technical Rept. No. 17, Dept. Environ. & Water Resources Engr., Vanderbilt Univ., pp. 51-72 (1969).

45. Tranquillo, J. S. and Lee, G. F. "Concentration of Dilute Aqueous Phenol Solutions Utilizing Methylsulfinylmethane (DMSO)" Environ. Sci. & Tech. 3, 393-6 (1969).

46. Kammerer, P. A. and Lee, G. F. "Freeze Concentration of Organic Compounds in Dilute Aqueous Solutions" Environ. Sci. & Tech. 3, 276-8 (1969).

In addition, G. Fred Lee is a member of committees that prepared the following publications:

_____ "Nutrient Associated Problems in Water Quality and Treatment" Report to AWWA Task Group on Nutrients in Water, J. AWWA, 58, 1337-1355 (1966).

_____ "Sources of Nitrogen and Phosphorus in Water Supplies" Report by AWWA Task Group on Nutrients in Water, J. AWWA, 59, 344-366 (1967).

_____ "Excessive Water Fertilization" Report to Wisconsin Water Subcommittee, Natural Resources Committee of State Agencies (1967) mimeo.

_____ "Required Characteristics and Measurement of Biodegradability" Report to Water Pollution Control Federation Subcommittee on Biodegradability to be published in 1969.

_____ "Chemistry of Nitrogen and Phosphorus in Natural Waters" AWWA Task Group on Nutrients in Water (to be published in J. AWWA, 1969).

Publications in Press and Preparation

Armstrong, D. E., Spyridakis, D. E. and Lee, G. F. "Cycling of Nitrogen and Phosphorus in the Great Lakes" Presented at Amer. Chemical Society meeting, April, 1969, Minneapolis, Minnesota.

Bortleson, G. C. and Lee, G. F. "Chemistry of Lake Sediment Cores" (submitted for publication).

24. Brezonik, P. L. and Lee, G. F. "Sources of Elemental Nitrogen in Fermentation Gases" J. Air Water Poll. 10 145-160 (1966).

25. Johnson, W. D., Lee, G. F. and Spyridakis, D. "Persistence of Toxaphene in Treated Lakes" J. Air Water Poll. 10 555-560 (1966).

26. Brezonik, P. L. and Lee, G. F. "Preservation of Water Samples for Inorganic Nitrogen Analysis with Mercuric Chloride" J. Air Water Poll. 10 549-553 (1966).

27. Shannon, J. E. and Lee, G. F. "Hydrolysis of Condensed Phosphates in Natural Waters" J. Air Water Poll. 10 735-756 (1966).

28. Fruh, E. G., Stewart, K. M., Lee, G. F. and Rohlich, G. A. "Measurement of Eutrophication and Trends" J. WPCF 38 1237-1258 (1966).

29. Lee, G. F. "Chemical Transformations in Self-Purification" National Symposium on Water Quality Standards for Natural Water, Univ. of Michigan, 251-256 (1966).

30. Lee, G. F. "Kinetics of Reactions Between Chlorine and Phenolic Compounds" in Principles and Applications of Water Chemistry, Faust, S. D. and Hunter, J. V. (Eds.), pg. 54-74, Wiley, 1967.

31. Fruh, E. G. and Lee, G. F. "Sorption of Cesium on Stratified Mica" in Principles and Applications of Water Chemistry, Faust, S. D. and Hunter, J. V. (Eds.), pg. 158-215, Wiley, 1967.

32. Kammerer, P. A., Rodel, M. G., Hughes, R. A. and Lee, G. F. "Low Level Kjeldahl Nitrogen Determination on the Technicon AutoAnalyzer" Environ. Sci. & Tech. 1 340-342 (1967).

33. Soltero, F. V. and Lee, G. F. "Apparatus for Automatic pH Control in Algal Cultures" Environ. Sci. & Tech. 1 503-505 (1967).

34. Lee, G. F. and Hoadley, A. F. "Biological Activity in Relation to the Chemical Equilibrium Composition of Natural Water" in Equilibrium Concepts in Natural Water Systems, Gould, R. F. (Ed.), Advances in Chemistry Series No. 67, Amer. Chem. Soc., pg. 319-338 (1967).

35. Gjessing, E. and Lee, G. F. "Fractionation of Organic Matter in Natural Waters on Sephadex Columns" Environ. Sci. & Tech. 1 531-538 (1967).

36. Bentley, E. P. and Lee, G. F. "Determination of Calcium in Natural Waters by Atomic Absorption Spectrophotometry" Environ. Sci. & Tech. 1 721-724 (1967).

37. Brezonik, P. L. and Lee, G. F. "Denitrification as a Nitrogen Sink in Lake Mendota" Environ. Sci. & Tech. 2 120-125 (1968).

38. Lee, G. F. "Automatic Methods for the Analysis of Natural Waters" Proc. IBP Symposium, Nieuwersluis, Oct. 10-16, 1966, pg. 169-180.

8. Lee, G. F. "Studies on the Iron, Manganese, Sulfate, and Silica Balances and Distributions for Lake Mendota, Madison, Wisconsin" Trans. Wisconsin Acad. Science, Arts & Letters LI 141-155 (1962).

9. Shearer, S. D. and Lee, G. F. "Leachability of Radium-226 from Uranium Mill Solids and River Sediments" Health Physics 10 217-227 (1964).

10. Rai, H. and Lee, G. F. "Separation of Planktonic Algal Pigments by Thin Layer Chromatography" Anal. Chem. 36 2208 (1964).

11. Lee, G. F. Discussion of paper "Role of Multivalent Hydrous Metal Oxides on Limnological Transformation" by J. Morgan and W. Stumm, Proc. 2nd Int. Conf. Water Pollution Research, Tokyo, August, 1964, Pergamon Press, 1965.

12. Kobayashi, S. and Lee, G. F. "Freeze Concentration of Dilute Aqueous Solutions" Anal. Chem. 36 2197 (1964).

13. Clesceri, N. L. and Lee, G. F. "Thin Layer Chromatographic Separation of Orthophosphate and Pyrophosphate" Anal. Chem. 36 2207 (1964).

14. Malhotra, S. K., Lee, G. F. and Rohlich, G. A. "Nutrient Removal from Secondary Effluent by Alum Flocculation and Lime Precipitation" J. Air Water Poll. 8 487-500 (1964).

15. Lee, G. F. "Eutrophication of Natural Water" Seminar, Geography Panel Committee on Pollution, National Academy of Science-National Research Council, Washington, D. C., March 1 & 2, 1965.

16. Lee, G. F., Kumke, G. W. and Becker, S. L. "Recovery of Organics from a Eutrophic Lake by the Carbon Adsorption Technique" J. Air Water Poll. 9 69-80 (1965).

17. Lee, G. F. and Harlin, C. C. "Effect of Intake Location on Water Quality" Ind. Water Eng. 2 36-40 (1965).

18. Gardner, W. S. and Lee, G. F. "Oxygenation of Lake Sediments" J. Air Water Poll. 9 553-564 (1965).

19. Clesceri, N. L. and Lee, G. F. "Hydrolysis of Condensed Phosphates. I: Non-Sterile Environment" J. Air Water Poll. 9 723-742 (1965).

20. Clesceri, N. L. and Lee, G. F. "Hydrolysis of Condensed Phosphates. II: Sterile Environment" J. Air Water Poll. 9 743-751 (1965).

21. Lee, G. F., Clesceri, N. L. and Fitzgerald, G. P. "Studies on the Analysis of Phosphates in Algal Cultures" J. Air Water Poll. 9 715-722 (1965).

22. Lee, G. F., Chairman "Report on the Nutrient Sources of Lake Mendota" Nutrient Sources Subcommittee of the Lake Mendota Problems Committee, 37 pp. (January 1966) (mimeo).

23. Lee, G. F. and Fruh, E. G. "The Aging of Lakes" Ind. Water Eng. 3, No. 2, 26-30 (1966).

Summary of Water Chemistry Program

The Water Chemistry Program was initiated in 1962 as an interdepartmental graduate degree program designed to prepare students for careers in the chemical limnology, chemical oceanography, chemical hydrology, biogeochemistry and the chemistry of water supply, water and wastewater treatment and water pollution control. Currently, there are 30 graduate students enrolled in the program, 3 professorial staff, 1 teaching assistant, 1 project associate, and 5 other full-time personnel. The program currently has over 12,000 square feet of teaching and research facilities including a 30 ft. U. S. Naval launch outfitted as a laboratory, a U. S. Army amphibian Dukw used for coring, a panel truck outfitted as a portable laboratory and several other small boats and snowmobiles.

Courses Taught

Water Chemistry
Advanced Water Chemistry
Water Analysis
Advanced Techniques of Water Analysis
Radiochemistry
Colloid and Surface Chemistry
Marine Chemistry
Problems in Oceanography
Organic Water Chemistry

Additional information on the Water Chemistry Program and courses is available upon request.

Publications

1. Granstrom, M. L. and Lee, G. F. "Rate and Mechanisms of Reactions Involving Oxychloro Compounds" Public Works 88 90-2 (1957).

2. Granstrom, L. M. and Lee, G. F. "Generation and Use of Chlorine Dioxide in Water Treatment" J. AWWA 50 1453-66 (1958).

3. Lee, G. F. and Stumm, W. "Determination of Ferrous Iron in the Presence of Ferric Iron with Bathophenanthroline" J. AWWA 52 1567-73 (1960).

4. Stumm, W. and Lee, G. F. "The Chemistry of Aqueous Iron" Schweizerische Zeitschrift für Hydrology XXI 295-319 (1960).

5. Stumm, W. and Lee, G. F. "Oxygenation of Ferrous Iron" Ind. Eng. Chem. 53 143-6 (1961).

6. Lee, G. F. and Morris, J. C. "Kinetics of Chlorination of Phenol-Chlorophenolic Tastes and Odors" Int. J. Air & Water Poll. 6 419-31 (1962).

7. Middleton, F. M., Greenberg, A. E. and Lee, G. F. "Tentative Method for Carbon Chloroform Extract (CCE) in Water" J. AWWA 54 223-7 (1962).

Title	Source	Amount	Period
Use of Lake Sediment Cores to Estimate Eutrophication	FWPCA	$ 12,000	1969

In addition, G. Fred Lee has been sponsor for $300,000 of student research assistantships from Federal agencies in the period 1963-69.

Memberships and Other Activities:

American Water Works Association Committees on Organic Contaminants in Water, Iron and Manganese, Chlorine, Nutrients in Water, and Quality Control in Reservoirs

Water Pollution Control Federation Committees on Biodegradation and Nitrogen and Phosphorus

American Society for Testing Materials Committee on Organics in Water

Water Subcommittee on Excessive Fertilization, Wisconsin Natural Resources Committee of State Agencies

Detergent Advisory Committee, Wisconsin State Board of Health

City of Madison Lake Mendota Problems Committee, Chairman, Nutrient Sources Subcommittee

Abstractor for Chemical Abstracts in areas of water supply and pollution control, limnology and oceanography

Editorial Advisory Board, Environmental Science & Technology, published by American Chemical Society (1966-68)

American Water Works Association, Water Pollution Control Federation, American Chemical Society, American Society for Limnology & Oceanography, American Ecological Society, American Agronomy Society, International Association for Great Lakes Research, Sigma Xi, Delta Omega, Wisconsin Academy of Science, Arts & Letters, Midwest Benthological Society, Societas Internationalie Limnologiae, Soil Science Society of American, American Geochemical Society, International Association of Geochemistry and Cosmochemistry, and International Association for Ecology

Grants and Awards, G. Fred Lee, Principal Investigator:

Title	Source	Amount	Period
Water Chemistry Training Grant	FWPCA	$425,000	1962-67
Water Chemistry Training Grant	FWPCA	402,000	1967-72
Method of Concentrating Organic Solutes	FWPCA	70,000	1964-67
Water Chemistry Research	U. W. Alumni Res. Foundation	18,500	1962-67
Eutrophication of Lakes	U. W. Water Resources Ctr.	12,000	1965-68
Effect of Marshes on Water Quality	Wisconsin Conservation Div.	24,000	1967-69
Persistence of Toxaphene	Wisconsin Conservation Div.	24,000	1966-69
Use of Clamshells as Indicators of Paleohydrologic Conditions	NSF	30,000	1965-68
Contract for no-cost loan of 30 ft. Naval launch and U. S. Army amphibian Dukw	CNR	---	1963-73

RESUME

G. FRED LEE

Current Position: Professor of Water Chemistry and Director of Water Chemistry Program at the University of Wisconsin, Madison, Wisconsin

Business Address: Water Chemistry Laboratory, University of Wisconsin
Madison, Wisconsin 53706 Telephone: 608 262-2470

Home Address: 122 East Gilman, Apt. 505
Madison, Wisconsin 53703 Telephone: 608 251-1437

Date and Place of Birth: July 27, 1933 Delano, California U. S. citizen

Education:	B. S.	San Jose State College	1955
	M. S.	University of North Carolina	1957
	Ph. D.	Harvard University (Division of Engineering & Applied Physics)	1960

Experience: Assistant Professor of Water Chemistry, University of Pittsburgh, 1960-61
Assistant Professor of Water Chemistry, University of Wisconsin, 1961-63
Associate Professor of Water Chemistry, University of Wisconsin, 1963-65
Professor of Water Chemistry, University of Wisconsin, 1965-present

Health: Good Marital Status: Married Military Service: None
Honors: Sigma Xi, Delta Omega, Phi Lambda Upsilon

Consultant: Bettis Atomic Power Laboratory, Pittsburgh, Pennsylvania, 1960-61
(Environmental monitoring of radioactivity)

Lake County Illinois Health Department, 1962-63
(Lake fertilization problems)

U. S. Public Health Service (Federal Water Pollution Control Administration)
(Great Lakes studies, 1964-67)

Automated Environmental Systems, Inc., Long Island, New York, present
(Design environmental monitoring system)

Procter & Gamble Corporation, Cincinnati, Ohio, present
(Water fertilization by detergents)

Reserve Mining Company, Silver Bay, Minnesota, present
(Taconite tailings waste disposal)

James McHugh Construction Company, Chicago, Illinois, present
(Control of algae and weeds in lakes)

Martin-Marietta Corporation, Colorado Division, present
(Environmental pollution)

Various consulting engineering and industrial firms on water supply, water and wastewater treatment, lake and stream problems.

Summary

As a consultant to Reserve Mining Company, I have found the following:

1. Reserve Mining Company has the capability to do and is doing, an excellent job in the collection and analysis of water quality data in Lake Superior.

2. Water chemistry studies conducted at my request by Reserve personnel show that trace metals, such as Cu, Zn, and Cd present in taconite tailings do not enter into solution and, therefore, are probably non-toxic to aquatic organisms, nor would they be expected to have any detrimental effect on drinking water and other beneficial uses of the lake.

3. Many of the trace metals of interest are removed from Lake Superior water and carried to the sediments by taconite tailings.

4. There is insufficient information available at the present time to support the FWPCA proposed water quality criteria for Lake Superior.

5. No evidence is presented in the several FWPCA reports which reflects reasonable support for the use of the proposed criteria. Much information in the reports demonstrates the impossibility of meeting the criteria since the lake for years has already exceeded such.

the Brule River water and FWPCA Duluth National Water Quality Laboratory water. Evidently an appreciable part of the copper present in the Brule River is not available to aquatic organisms, i.e., non-toxic. However, this would probably not be the case in FWPCA laboratory studies. This example points out the need to take into account the particular forms of the elements that are present in a sample of water in setting water quality criteria at or near the levels proposed by the FWPCA for Lake Superior. The total copper in a sample may be of little or no significance in the toxicity of these elements to aquatic organisms. As explained above, only that part of the element that becomes available is of significance.

Another very important problem in establishing water quality criteria at or near the proposed criteria is that the analytical methods used to measure the amounts of the element present do not distinguish between that part of the total element that is inert and that part that is available to aquatic organisms. For taconite tailings, the problem is even more complicated since as stated in the FWPCA report:

> "The chemical state of these metals was not assessed and it would be presumptuous at this time to say what portion of the elements enter into solution."

It is easily possible that the total copper or some other elements may enter the water from many sources and exceed FWPCA proposed criteria and yet be non-toxic to aquatic life in the water. Any standards that are established for Lake Superior must take this kind of information into account. The FWPCA proposed criteria do not take this kind of information into account and, therefore, I feel are unrealistic.

to the general scientific community for their review. It seems to me totally unrealistic to set very strict water quality standards based on information that apparently has only been reviewed by FWPCA. All interested individuals should review all available data prior to setting any radically different water quality criteria for Lake Superior.

There are many problems in justifying the FWPCA proposed water quality criteria for Lake Superior. For example, some of the proposed criteria are less than the natural concentrations of the elements found in Lake Superior water by the FWPCA. Water quality criteria are not precise numbers in which there is no question about their magnitude. Usually water quality criteria are based on years of experience in which the concentrations of chemicals in the water are compared to the reproduction, growth and survival of organisms in the water. In the case of the proposed criteria, there is essentially no environmental experience which demonstrates the significance of trace metals and other substances in Lake Superior water at the proposed limits. Some of their proposed criteria are based on very limited laboratory studies which have not been reviewed by the scientific community as a whole. In fact, experience shows that some of the criteria may be too strict for conditions that are naturally encountered in the Lake Superior drainage basin. For example, the Brule River in Wisconsin, which empties into Lake Superior, is a renowned trout stream. People come from all over the midwest to fish in this stream. U. S. Department of Interior studies have shown that the copper content of this river greatly exceeds the FWPCA proposed criteria for this element. This discrepancy can be explained by differences in the water chemistry of copper in

I have paid particular attention to the question: Do the available data support the state conclusions? Also, is the technical evidence present the best available evidence? I have attempted to point out some of those "statements of fact" that are, in reality, merely opinions which are not supported by experimental fact.

For example, on page 21 of the FWPCA report, "An Appraisal of Water Pollution in the Lake Superior Basin," the statement is made:

> "For example, an increase in five units in turbidity will result in a reduction of many feet in light penetration and a significant loss of fish food organisms."

This is presented as a fact yet neither this report nor any of the supporting documents provide evidence that a reduced light penetration of the magnitude that would be associated with a small increase in turbidity will decrease fish production. It is certainly not a generally recognized fact among aquatic scientists that this statement is true.

The proposed criteria for many of the elements listed in the FWPCA report, "An Appraisal of Water Pollution in the Lake Superior Basin, April, 1969," are unrealistic in terms of existing knowledge concerning the aqueous environmental chemistry of most pollutants in natural waters. The report states:

> "Additional data concerning water quality criteria for Lake Superior are now available as a result of recently completed research at the FWPCA National Water Quality Laboratory of Duluth, Minnesota."

This additional information has not been presented in any of the reports or supporting documents to these reports. To my knowledge, this "additional data" concerning water quality specific for Lake Superior has not been released

sorption tests consisted of adding taconite tailings to Lake Superior water that contained small amounts of trace metals. The solutions were mixed for a period of time and amounts of metals present in the water that would be suspected to be readily available to organisms, were determined. The results of the studies are preliminary in nature but do show that based on the leaching tests, the copper and several other metals present in tailings are not released to the water.

The sorption test showed that the taconite tailings would tend to remove trace metals from Lake Superior water and indicate that some of the toxic metals such as copper present in the surface waters of Lake Superior in areas of taconite tailings discharged would be removed from the water and carried to the sediments by the tailings.

In summary, the studies on the water chemistry of taconite tailings in Lake Superior water show that the trace metals such as copper, zinc and cadmium, cited by the FWPCA as having "a lasting deleterious effect upon the lake" are not released to the water from taconite tailings and in fact any of these metals present in the immediate vicinity of the discharge of taconite tailings will be removed from the water and carried to the sediments (bottom) of the lake by the tailings.

Technical Accuracy of FWPCA Reports

One of my primary responsibilities as a consultant to Reserve has been to review all released state and federal agency reports that are pertinent to the disposal of taconite tailings in Lake Superior for their technical accuracy. Also, I have reviewed each of Reserve's reports in this area. In this review,

These statements may lead some readers of this report to believe that Reserve is discharging large quantities of trace metals that might be toxic in Lake Superior water. Careful examination of these reports and their supporting documents shows that they have no evidence to support their implications. There is no question that taconite tailings contain trace metals. The question is one of whether the trace metals such as copper present in taconite tailings, are toxic in Lake Superior water. It is well known that an important parameter in the toxicity of metals is their availability to organisms. The criteria for the critical concentrations must be based not on the total metal present in a solid but on that part of it which is available to the test organisms. The availability is directly controlled by the aqueous environmental chemistry of the solids in the water under study. In the case of taconite tailings, the solids are silicate minerals. These solids will likely behave in a markedly different way than other solids normally present in natural waters. At the present time, very little is known about the availability of copper and other metals in taconite tailings to aquatic organisms. Reserve has initiated an experimental program to determine the water chemistry of taconite tailings in Lake Superior water. I have acted as a consultant in these studies by helping to establish experimental procedures and in the interpretation of data.

Both trace metal release (leaching) and trace metal uptake (sorption) studies have been conducted. The leaching tests consisted of placing known amounts of tailings in a bottle containing Lake Superior water and determining the amount of trace metals released over a period of several months. The

studies to determine the aqueous environmental chemistry of tailings in Lake Superior water. These investigations have included leaching (metal release) and sorption (metal removal) studies of trace metals in Lake Superior water. Also studies have been made to determine the actual chemical species of the elements present in Lake Superior water.

The effect of the discharge of taconite tailings on water quality is dependent on their water chemistry in Lake Superior water. These tailings could be chemically inert or chemically active in the environment. If the taconite tailings are chemically active, then consideration must be given to their chemistry in the Lake Superior environment. It should be pointed out that FWPCA implications in their report on the possible significance of the trace metals in the taconite tailings have a direct bearing on this topic. For example, the FWPCA states as conclusion ten, page 28 of their report "An Appraisal of Water Pollution in the Lake Superior Basin," April, 1969:

> "Chemical analysis projected to the probable daily discharge, measured in pounds of certain parameters: copper, 4,100; nickel, 2,500; zinc, 2,500; lead, 6,100; chromium, 6,200; phosphorus, 51,500; and manganese, 629,000. Other elements in the discharge include silica, arsenic, and substantial quantities of iron. The chemical state of these metals was not assessed and it would be presumptuous at this time to say what portion of the elements enter in solution."

They further state in Item 3 of their summary and conclusions from this report:

> "Because of the low mineral content of Lake Superior's water, increases in the range of 2 to 50 parts per billion of heavy metals such as copper, chromium, zinc and cadmium will have lasting deleterious effects upon the lake."

A summary of my findings is presented below:

Analytical Chemistry

The chemical analyses conducted by Reserve's analytical chemistry group are in general of superior quality to those normally produced by federal and state agencies that must analyze large numbers of samples with limited equipment and personnel. In my opinion, Reserve is conducting analyses with the best available analytical techniques and has taken all reasonable steps to insure these analytical procedures yield precise and accurate results. It should be pointed out that the analysis of trace elements in Lake Superior water is a very difficult task due to the extremely low levels of these elements present in the water. Procedures that are normally used for routine chemical analysis in other waters will likely yield incorrect results in Lake Superior water. The Reserve analytical chemistry group is producing data that are of the quality normally associated with high quality research projects. This same level of approach also prevails in their sampling of lake waters and sediments. They are taking all reasonable steps to collect samples that are representative of the water and sediments. In summary, I am very favorably impressed with the analytical chemistry capabilities of the analytical chemistry group at Reserve Mining Company.

Water Chemistry of Taconite Tailings

Reserve is making extensive, high quality field studies to determine the location of tailings deposits, chemical composition of tailings, leaching and sorption characteristics of the tailings and alleged water quality problems that are said to be caused by them. At my suggestion, they are conducting laboratory

AN APPRAISAL OF RESERVE MINING COMPANY ANALYTICAL AND WATER CHEMISTRY CAPABILITIES AS ASSOCIATED WITH THE DISPOSAL OF TACONITE TAILINGS INTO LAKE SUPERIOR

BY

G. FRED LEE

PROFESSOR OF WATER CHEMISTRY
DIRECTOR OF THE WATER CHEMISTRY PROGRAM
UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

For the past several months, I have acted as a technical consultant to Reserve Mining Company on the water chemistry aspects of the disposal of taconite tailings in Lake Superior. A resume of my professional education and experience is attached.

My primary responsibity has been to review the current analytical chemistry capabilities of Reserve's analytical chemistry group in the analysis of taconite tailings, Lake Superior water and sediments. I have advised Reserve on the laboratory and field studies that should be conducted to determine the aqueous environmental chemistry of taconite tailings in Lake Superior water and have reviewed "Basic Studies on Environmental Impacts of Taconite Waste Disposal in Lake Superior" by the U. S. Department of Interior, December, 1968, and "An Appraisal of Water Pollution in the Lake Superior Basin," U. S. Department of Interior, April, 1969. Also, I have reviewed data supplied by Reserve Mining Company.

In accord with these activities, I have visited the Reserve plant at Silver Bay, Minnesota, on several occasions in the past two months. During these visits I have observed the operations of the analytical chemistry group and field sampling techniques. I have spent several days discussing the results of their analyses and the pertinent reports.

G. F. Lee

With regard to standard methods, I feel that at least some of the materials -- and I would have to look at them individually -- could not be analyzed by the standard method procedure as it exists now. Remember, the new standards for measuring will come out in 1970 and the methods which come out in 1970 will enable us to get down to these levels.

MR. PURDY: Thank you.

MR. DOMINICK: Thank you, doctor.

(The above-mentioned statement of Dr. Lee in its entirety follows.)

G. F. Lee

DR. LEE: First, on the leaching test we really don't know anything about the solubility of the species. In other words, we have copper tied up in some kind of silicate mineral. We can't talk about copper sulfide or copper silicate, we really don't know. It is included within the minerals, so it is not a question of solubility at all.

To answer your question, I don't think that is pertinent to this discussion.

MR. FRANGOS: Thank you. That is all I have.

MR. DOMINICK: Mr. Purdy?

MR. PURDY: Dr. Lee, you addressed yourself to the water quality criteria. I assume that you are acquainted with the so-called standard methods of testing water. Would you comment as to whether, in your opinion, the standard techniques for testing water are capable of testing in the accuracies that would be necessary if the proposed Water Quality Criteria were adopted?

DR. LEE: You really asked two things, I think, 1) whether we can test for these things, and 2) what is the accuracy needed in terms of adoption.

This is another point that I think has to be spelled out when we discuss criteria. What kinds of accuracy do we want? What is the number of 12 micrograms per liter, what does it mean, 12.1, 12.5, what could we accept? Any time you get above 12 for copper, this kind of thing should be specified in any type of proposed criteria.

these numbers have to be answered. I think, as an important part of this, the States are faced with the question of how to enforce numbers such as proposed criteria. How do you enforce a number that is less than the normal concentrations? This kind of thing has to come into any discussion of proposed criteria, and, as I see it, the proposed criteria do not contain this kind of discussion. Therefore, I feel they are unrealistic.

Thank you. (Applause.)

MR. DOMINICK: Are there any questions?

MR. FRANGOS: Dr. Lee, I might ask you to comment briefly on this. This morning I received a statement which indicated it is an established fact that when large masses of material are reduced to particulate size, their rates of solubility increase exponentially. That seems to be contrary to the testimony that you just presented as I understood your testimony with respect to the leaching test.

Is my assessment correct?

DR. LEE: No. To be a college professor for a minute, the statement this morning I think, is based on chemistry in which as you go to very finely divided particles, solubility of the material increases. There is no question about this. With time, though, particles tend to grow and become larger particles and the solubility decreases. It is a natural phenomenon; it happens in the laboratory all the time.

MR. FRANGOS: What is the relationship between this thing and what has happened in the leaching test?

elements listed in the criteria. The criteria makes no mention of the forms of the elements that are important. They simply state, for example, that copper should be less than 12 micrograms per liter. There is no discussion as to what forms of copper are important. Do they mean by this that the copper present in taconite tailings or in other inside-the-forms, which is clearly shown to be non-toxic, that they should not exceed 12 micrograms per liter? Do they mean only soluble? These are the kind of questions that should be asked before those kinds of criteria are adopted.

The second point I want to come to is the question of the levels of some of the proposed criteria, in particular phosphorus.

The FWPCA data, Dr. Bartsch in his discussion here, and the State of Wisconsin in their presentation, have all said the average phosphorus concentration in Lake Superior is about 0.01 milligrams per liter, 0.01. The proposed criteria for phosphorus in Lake Superior is also 0.01, the same value. This means if you go out from Lake Superior, away from the shore so there is no question about pollution, and you grab a sample and bring it back, probably half the time or something you are going to get a sample that exceeds the proposed criteria. What do you do? You ask, is it reasonable to set a number or criteria, for example, phosphorus in the lake that is equal to or less than the natural occurring concentration of the elements?

I feel that questions such as the reasonableness of

simply no data to support them. I think it is unfortunate that the conservation groups here have used the information provided in the early reports as the basis for their operation. If you go into this data and look at it, you see it is not supported.

We now come to this final report of April 1969 and ask, is it a good report? I have to state that I feel it is much improved over the other reports, but yet it does contain numerous errors that I feel are significant.

Let's take one example, and I can cite many.

Dr. Bartsch, in his discussion of the eutrophication of Lake Superior stated the other day that temperature is not a factor controlling the growth of algae in Lake Superior. If we look on Page 46, Item 7, of the summary and conclusions of the FWPCA report, you see this report states that temperature has limited algae growth in the lake.

I think everyone would agree that Dr. Bartsch is an eminent authority in eutrophication. There is no question, I think, that he is. If you go to Alaska, you will find many lakes in Alaska that are colder than Lake Superior and that have excessive algae. If you go to the Antarctic, it is colder than Lake Superior and it is one of the most productive areas. So temperature limiting it is not based on any fact.

Let's look now to the question of water quality criteria.

There are two questions to this aspect which I feel are important. The first deals with the water chemistry of the

G. F. Lee

Another aspect of the water chemistry studies I have been actively involved in is the metal uptake or sorption studies. At my request I have taken some Lake Superior water and added very small amounts of the various trace metals cited by the FWPCA and waited to see what happened. Our sorption studies have clearly shown that these toxic metals such as copper and cadmium and so forth are removed from Lake Superior water by taconite tailings. This you would expect. Anyone doing any work in the area of chemistry of natural waters would expect any time you have a solid like taconite tailings you would remove these metals from the water. This is certainly the case here. This also applies to phosphorus.

I think these sorption tests, the leaching tests, the various reports we have heard over the last few days all clearly point to the fact that at the present time there is no evidence to support the contention that the discharge of taconite tailings into Lake Superior water has any significant deleterious effect on water quality.

Let's turn now to another aspect of this discussion which I feel is important, that of the technical quality of the FWPCA report.

Having reviewed all of the reports that have been released over the past 6 months or more, I have noted that in each one there has been an upgrading of quality. I think it is very easy to understand why the earlier reports were never officially released, although, unfortunately, leaked out. You can see the conclusions stated in these earlier reports are simply unfounded,

G. F. Lee

and the personnel to do a good job in this area and they are doing it.

Let's come to the question of the chemistry of taconite tailings. We can look at them from two points of view. One, you consider them chemically inert. You could say they are like bees wax, nothing happens to them when you put them in the water. The other view is that they are chemically active, the trace things that are in taconite could be released in the water and, therefore, affect the various kinds of organisms that are in the water.

There is no question that taconite tailings contain small amounts of taconite. They contain copper and zinc and so forth. However, the question is one, as raised by Dr. Bright, of whether or not the metals present in taconite tailings are released to the water. As a consultant I have worked with them in the area of water chemistry studies to investigate these studies. We have to admit that our results are preliminary, but I think our conclusions, our studies have gone far enough that our conclusions are reasonable, based on data.

As you heard from Dr. Bright, so-called static leaching tests in so many months, we find the metals by the FWPCA being important to Lake Superior water are not released. I have examined this data and I support it completely.

In addition, I want to point out that phosphorus which is often cited as being a key element here in the beneficiation which is present in tailings, is also not released to the water.

G. F. Lee

STATEMENT OF DR. G. FRED LEE, PROFESSOR OF WATER CHEMISTRY, DIRECTOR OF THE WATER CHEMISTRY PROGRAM, UNIVERSITY OF WISCONSIN

DR. LEE: Conferees, ladies and gentlemen:

I have acted as a technical consultant to Reserve Mining Company on the water chemistry aspects of the disposal of taconite tailings in Lake Superior for the past couple of months. I have also assisted Reserve in planning water chemistry studies on the effects of taconite tailings on Lake Superior water and I have reviewed all the reports that have been released, even those that haven't been released, that are concerned with the discharge of taconite tailings in Lake Superior water.

In the few minutes that I am allowed to present my results, I will briefly summarize just the three aspects.

First, I want to look briefly into this question of the water chemistry of taconite tailings.

Second, I want to look at the question of the technical quality of the FWPCA report.

Third, I want to briefly touch base on this question of the reasonableness of the FWPCA-proposed water quality criteria for Lake Superior.

First, I want to preface my remarks by stating that I feel that Reserve has the capability and is doing a very good job in the area of studying that past history of taconite tailings. As you heard from other speakers, they have the instrumentation

G. F. Lee

MR. DOMINICK: As Reserve Mining goes along with its presentation, if you omit any slides which would be helpful in establishing continuity of your testimony, please submit those for the record.

MR. BADALICH: Mr. Chairman, Reserve Mining would like to continue with one more witness at this particular time, and then we will yield to those who want to be heard. I certainly appreciate the cooperation of the company and their willingness to abbreviate their testimony.

MR. FRIDE: The next witness for Reserve Mining Company is Dr. G. Fred Lee. Dr. Lee is Professor of Water Chemistry and Director of Water Chemistry programs at the University of Wisconsin. He has degrees from the University of North Carolina and he received his doctorate from Harvard. He has been a consultant to many governmental agencies, including the U. S. Public Health Service and has conducted a great many studies in the Great Lakes for the FWPCA.

He is a member of the International Association for Great Lakes Research. He has conducted studies for the University of Wisconsin Water Resource Center and the Wisconsin Conservation Division. He has conducted studies for the National Science Foundation and is the author of some 80 scientific papers. We are very happy to have him here today.

Dr. Lee.

Publications, continued:

In manuscript, Pleistocene Lakes Thatcher and Bonneville and related volcanism in Southeastern Idaho.

Pollen and Seed analyses of Swan Lake, outlet of Lake Bonneville, Southeastern Idaho: (1967) Tebiwa, Jour. Idaho State University.

Surface Water Chemistry of Some Minnesota Lakes with Notes on the Diatoms: Interim Report No. 3, Limnological Research Center, University of Minnesota, 1968.

ROBERT C. BRIGHT

Born: December 28, 1927, Salt Lake City, Utah

Education:

Univ. of Idaho	1947-49
Univ. of Utah	1949-53 B. S. 1952
George Wash. U.	1953
Univ. of Utah	1955-57 M. S.
Univ. of Minn.	1957-63 Ph. D. June, 1963

Positions held:

Instructor - University of Minnesota - 1959
Assistant Professor of Geology - University of Minnesota - 1965 - 69
State Paleontologist - 1963-64
Curator of Paleontology, Museum of Natural History, Univ. of Minn. -1965
Research Assoc., Limnological Research Center, Univ. of Minn. - 1963-64
Assoc. Professor of Geology & Ecology - Univ. of Minn. - 1969 -

Honors Received:

National Science Foundation Postdoctoral Fellow, 1963-64, Uppsala University, Sweden
Fellow, Geological Society of America

Memberships in Societies:

American Society of Limnology & Oceanography
American Association for Advancement of Science
Geological Society of America
American Association of Petroleum Geologists
Paleontological Society
Sigma Xi

Other Activities:

Consultant: Lithium Corporation of America
Director, CIC. Geology Field Station

PUBLICATIONS: (Partial List)

1957, New look at Elrathia Kingii (Trilobita): G. S. Amer. Bull., (Abs.), V. 68

1959, A paleoecologic and biometric study of the Middle Cambrian trilobite Elrathia Kingii (Meek): Jour. Paleo., V. 33.

1963, Pleistocene Lakes Thatcher and Bonneville, Southeastern Idaho; G. S. A. Bull., (Abs.)

1963, (with Zoltai, T., and Papike, J.) Chrystal Sphere orienter: Rev. Sci. Instr., V. 32, P. 23-24.

Watts, W. A., & Bright, R. C., Pollen, Seed, and Mollusk analyses from Pickerel Lake, Day County, South Dakota: Bull. Geol. Soc. America

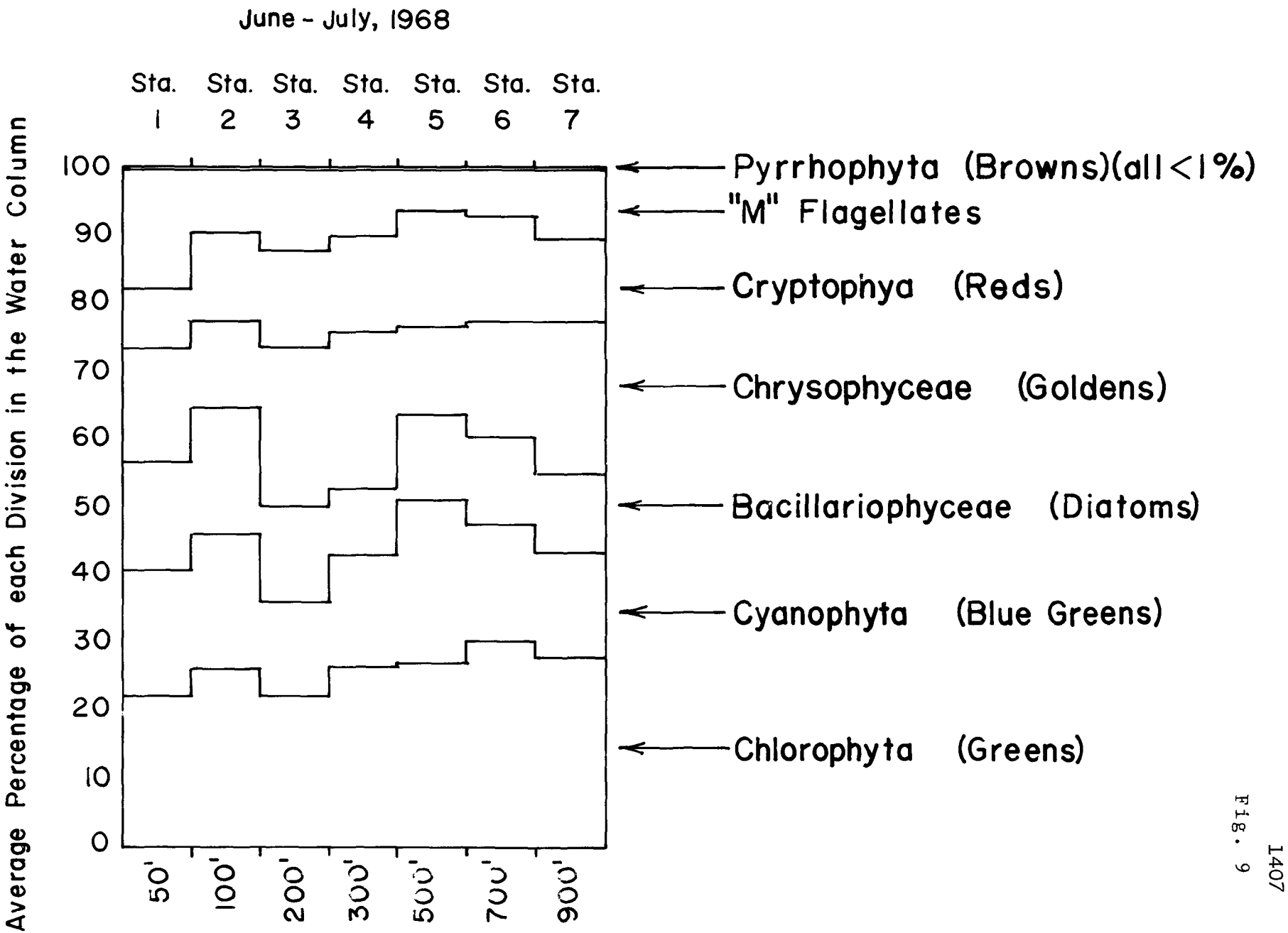
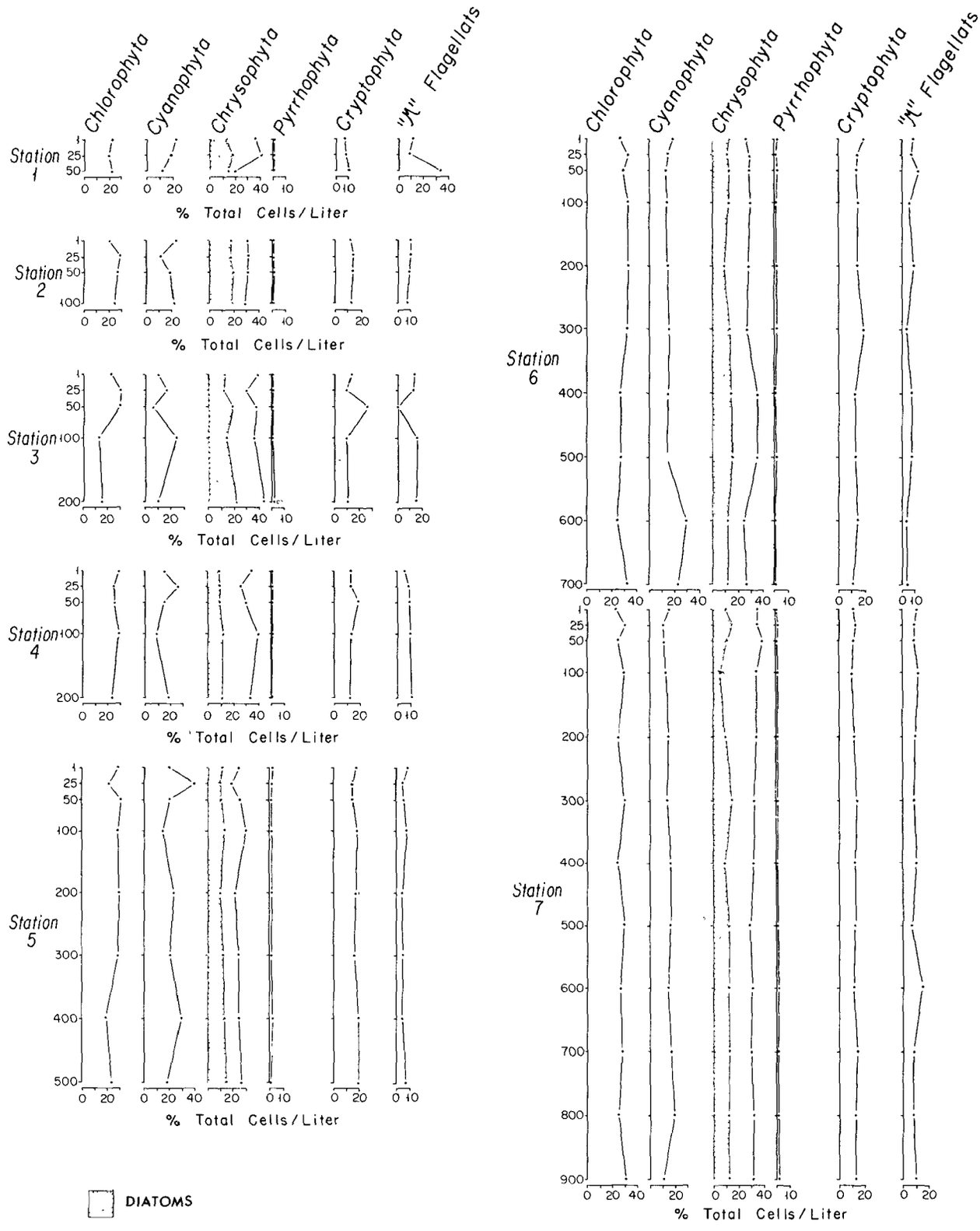

June - July, 1968
Sta. 1
Sta. 2
Sta. 3
Sta. 4
Sta. 5
Sta. 6
Sta. 7
Average Percentage of each Division in the Water Column
100
90
80
70
60
50
40
30
20
10
0
50'
100'
200'
300'
500'
700'
900'
Pyrrhophyta (Browns)(all<1%)
"M" Flagellates
Cryptophya (Reds)
Chrysophyceae (Goldens)
Bacillariophyceae (Diatoms)
Cyanophyta (Blue Greens)
Chlorophyta (Greens)

Fig. 9

Fig. 8

Composition of Standing Crop of Phytoplankton



Ed Fride

MR. DOMINICK: Before we proceed to another matter, I would say the Bure u of Mines report is before the conference. It is referenced in our FWPCA report and we will certainly be looking at that report in its entirety.

The mandate which you gave to the consulting firm would appear to me to be quite specific in nature, namely; to investigate one alternate method of disposal. Have you investigated any other alternate methods which might show a lesser cost in the long run?

MR. FRIDE: The method that was suggested by several speakers was, of course, the inland settling basin, and it was that method that Mr. Forssmark addressed himself to.

I am not a technician. I can say this,to my knowledge, so far as I know, there has been no realistic economic means determined for the deposition of tailings other than the one that is expressly being utilized.

I can suggest that at the original hearings in 1947 and subsequently, scientists, not only from Reserve Mining Company but from the State of Minnesota and from numerous other agencies, examined all kinds of different possibilities of tailings deposition long before the plant commenced operation. The common consensus that was established at that time was the one that Reserve followed and is the one that takes advantage of the density current, placing the material at the bottom of the Great Trough in Lake Superior.

MR. DOMINICK: I think that a judgment made in 1947 is really the basis for the entire problem here. A different judgment might be arrived at in 1969. I only point out that if additional

technology is available and if other methods in addition to the one which you have investigated are available, this might be worthy of your consideration as well as ours.

MR. FRIDE: I didn't mean to suggest at all, Mr. Commissioner, that the only consideration to the question that you pose ended in 1947. It started before then and is continuing today. But insofar as the existence of any reasonable, practical, economic means of depositing tailings -- from studies continued right to today -- I have no knowledge that any such means exists.

You have to start, too, I think, with the premise of solving the problem, so to speak, that really perhaps does not exist in the sense of whether or not there is any need or reason to get into that area at all. It seems to me that with the evidence that has been submitted, when the conferees have an opportunity to review it in depth, I think that the conclusion would be well established that the deposition of tailings in Lake Superior is having no deleterious effect in the lake quality.

I would also suggest, Mr. Commissioner, if I may, that the statement of April 1, 1969, which I have submitted to the conferees, does contain something of a summation of Reserve, and we have tried to be very mindful of the clock in connection without presentation here. If one will refer to that summary, I think it contains sufficient information on most of the points that I considered here.

I would suggest this, too, if I might, to the conference, that there have been some photographs shown, some pictures shown. Frankly, I have spent some time in Silver Bay and I have never seen

John C. Green

some of the scenes that were depicted.

Be that as it may, I am extending to the conference on behalf of the President an invitation to come to the plant, to inspect it and look at it.

That is all the evidence we have. We are deeply grateful for the opportunity to be heard.

MR. DOMINICK: Are there any questions?

(No response.)

MR. DOMINICK: Mr. Badalich, do you have anything further?

MR. BADALICH: I think I missed a written statement. This is a statement from Mr. John C. Green, Professor of Geology at the University of Duluth. Have it entered into the record.

MR. DOMINICK: Fine.

(The above-mentioned statement follows.)

[On the subject of cummingtonite] and its geologic occurrence in Minn

Statement to be submitted for the record of the Lake Superior Pollution Enforcement Conference, Duluth, Minnesota, May 13-15, 1969

by

John C. Green
Professor of Geology, University of Minnesota, Duluth

Since 1962 I have spent most of each summer engaged in field studies of the rocks of northeastern Minnesota, as a geologist for the Minnesota Geological Survey. I am well acquainted with the geologic structure and rock types of the area, and have visited the Reserve and Erie Mining Companies' pits at the east end of the Mesabi Range.

Both from my own experience and from my acquaintance with published geological reports I know of no significant body of rock in northern Minnesota, except for the metamorphosed iron formations, that contain the iron silicates cummingtonite or grunerite. Of these iron formations, only very minor amounts of cummingtonite are found in the Soudan Iron Formation and related strata of the Vermilion District (Ely to Tower): only in the east end of the Biwabik Iron Formation in the vicinity of the Reserve and Erie mines are these minerals found in appreciable quantities.

The Vermilion District rocks lie entirely in the Rainy Lake Hudson Bay watershed and could supply no cummingtonite to Lake Superior. Only a small area of the cummingtonite-bearing Biwabik is within the Lake Superior watershed: it is drained via the Partridge River, a tributary to the Saint Louis. In the 10,000 years or so since the last glaciation, essentially no bedrock erosion has occurred in the Saint Louis River drainage above Cloquet: the river meanders for most of the 115 miles from the source of the Partridge at Babbitt sluggishly through the flat "100 Mile Swamp" on its way toward the steeper drop from Cloquet to Fond du Lac. Thus no cummingtonite could have been eroded from the Biwabik Iron Formation, even by this one of the many tributaries to the St. Louis River; and if it had been, it would have had ample opportunity to settle out or be drastically diluted with normal glacial-clay particles during its passage toward the lake.

The glacial deposits that cover the bedrock in most of northeastern Minnesota were deposited, according to the most recent research of Prof. H. Wright, University of Minnesota, by two main lobes of ice, one flowing southwest in the Lake Superior basin (the Lake Superior Lobe) and another, to the west, moving generally south (the Rainy Lobe). Work to date indicates that the ice that moved across the cummingtonite-bearing Mesabi Range (Rainy Lobe) did not enter the Lake Superior basin proper, but was prevented from doing so by topography and by the contemporaneous existence of the Lake Superior lobe filling the basin. However, the Rainy Lobe did cover, and deposit sediment, in much of the drainage basin of the Saint Louis River. This sediment should be tested for cummingtonite content, especially relative to other minerals, but it can be confidently predicted that only trace amounts are present because of the wide variety of other rocks eroded by the glaciers and mixed with that from the iron formation.

Amounts of cummingtonite in the glacial drift of the Rainy Lobe in the drainage of the Saint Louis River are estimated to be well below 0.01%. In

contrast, the taconite mined by Reserve is estimated to contain from 10 to 20% cummingtonite, and after removal of magnetite at Silver Bay this proportion would rise. The U.S. Geological Survey (in its Lake Superior study in preparation for this conference) estimates a yearly inflow of about 60,000 long tons of sediment per year by all the North Shore streams; 0.01% of this would be about 6 tons of cummingtonite per year. Reserve deposits roughly 20% x 60,000 or 1,200 T of cummingtonite per day into the lake at Silver Bay.

In conclusion, geologic relations in northeastern Minnesota indicate that (1) the only concentration of cummingtonite is in the general area of the Reserve Mining Company's mine; (2) Mining, crushing, and separation of cummingtonite by the mining operation must be the greatest source of this mineral in western Lake Superior by several orders of magnitude.

Closing Statement

MR. DOMINICK: Thank you, Mr. Fride, for your presentation and those connected with Reserve Mining.

Are there any other statements to be made at this time?

(No response.)

MR. DOMINICK: Are there any other submissions for the record at this time?

(No response.)

MR. DOMINICK: If not, I would like to take this opportunity to thank all of those who have prepared and presented statements at the conference.

I also wish to thank those who stayed with us through this proceeding during this past week.

I give a special word of thanks to the conferees who have been extremely diligent in their attention and in their interest in the proceedings of this conference.

The presentations reflect a considerable amount of work, and I think we have achieved a gathering of the full spectrum of data, together with the views, analyses, and evaluations of Federal, State, and local agencies, industries, and citizens groups.

The record which has been made here, I believe, will provide a complete compendium of the information relating to water quality of Lake Superior available at this time. It should prove to be a useful reference tool for all interested parties.

Those of you who have listened to the testimony will appreciate the fact that the issues involved are complicated, indeed. Differing views have been presented concerning the physical plants and the course for future actions. Many of these views have been brought together for the first time at this quorum.

Closing Statement

In the interest of developing the State-Federal program for the protection of the quality of the waters of Lake Superior in an orderly manner, the conferees will be given an opprotunity to analyze and evaluate the material placed before them. We will have a transcript prepared and sent to all conferees, together with supporting exhibits that have been presented.

We will, therefore, stand in recess for about a month to examine this material. Following that examination, the conferees will be called together for an Executive Session where we will develop a Conference Summary as required by law.

At the conclusion of the Executive Session, the Chairman will reconvene the Lake Superior Conference for the presentation to the public of the conclusions and recommendations agreed to by the conferees.

If there are no further statements, we will stand in recess at this time.

I want to thank you very much for your excellent cooperation and participation.

(Applause.)

(Whereupon, at 6:30 p.m., the conference adjourned sine die.)

DEFENDERS OF SOIL, WOODS WATERS AND WILDLIFE

1689

The Izaak Walton League of America
INCORPORATED
BUILDING A BETTER OUTDOOR AMERICA

NATIONAL OFFICES · 1326 WAUKEGAN ROAD · GLENVIEW, ILLINOIS 60025 · PHONE 312-724-3880

WASHINGTON OFFICE · ROOM 509 · 719-13TH STREET, N W · WASHINGTON, D C 20005 · PHONE 202-347-5880

May 23, 1969

Federal Water Pollution Control Administration
Department of the Interior
Washington, D. C.

Subject: Enforcement Conference
Lake Superior

Gentlemen:

This letter is on behalf of the Indiana Division of the Izaak Walton League, and is for the record of the recent pollution abatement enforcement conference on Lake Superior.

It is true, as most witnesses appeared to observe, that Lake Superior is presently the last Great Lakes stronghold of relatively clean water. Some of the research on relative concentrations of pesticides in fish tissue from Lake Superior specimens compared to that of Lake Michigan specimens would be one indicator which bears this out.

However, it is equally true that pollution levels are nonetheless rising alarmingly in Lake Superior, and that this great body of water is being threatened with ruin by the same array of sources as Lake Michigan, Lake Erie and other long-raped Great Lakes waters--industrial wastes, untreated municipal waste, paper and mining firm wastes, and other effluents and dumpings.

The Indiana Division of the League vigorously supports the position and the detailed observations offered to the conference by the Duluth, Minnesota Chapter and the Wisconsin Division of our national organization; and there is little need to reiterate the splendid analyses offered by these units of the League in this letter.

The Izaak Walton League strongly supports the non-degradation principle, and we apply this to thermal as well as to all other forms of environmental contamination. Prevention of pollution is difficult enough; but elimination of situations, or reversal, such as we face in Lake Michigan, are infinitely more difficult.

This is the time for Federal, state and local governments to strike their greatest blows for clean Lake Superior waters. It will never be easier to do than it is today. The awesome lessons of inaction in Lakes Erie

and Michigan should allow no other choice. If we continue to permit the degradation of Lake Superior--a body of water of which we can still be relatively proud--then there would seem no prospect at all that we can come to grips with the infinitely more complex problem in the more southerly waters.

The Indiana Division has testified at every known public hearing and abatement conference on Lake Michigan, and its representatives will once again speak out next week with regard to the Corps of Engineers practice of dumping lethal dredgings from Indiana Harbor into the outer waters of Lake Michigan.

If Federal authorities can not or will not throw down the gauntlet to Lake Superior polluters, then can there really be any hope that it will respond to the far graver threats to all usefulness of Lake Michigan waters? With that question lingering on our minds, we feel sure the FWPCA will understand the intensity of our interest in what is done about Lake Superior.

Sincerely yours,

Thomas E. Dustin, Executive Secretary
Indiana Division
The Izaak Walton League of America, Inc.
106 West Wildwood
Fort Wayne, Indiana 46807

c: President, Wisconsin Division, IWLA
President, Duluth Chapter, IWLA
Executive Director, IWLA
State President and State Secretary, Indiana Division, IWLA

U.S. GOVERNMENT PRINTING OFFICE 1970 O - 430-853 (Vol. 4)