MILE POST 7 WEST RIDGE RAILROAD RELOCATION, DAM EXTENSIONS, AND STREAM MITIGATION PROJECT ENVIRONMENTAL ASSESSMENT WORKSHEET (EAW)

RECORD OF DECISION – FINDING OF FACT 28.i
1975 BAKER REPORT

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GEOTECHNICAL EVALUATION
ON-LAND TAILINGS DISPOSAL PLAN
RESERVE MINING COMPANY
Mile Post No. 7 Site

PREPARED FOR

STATE OF MINNESOTA

AUGUST, 1975

PREPARED BY
MICHAEL BAKER, JR., INC.
BEAVER, PENNSYLVANIA

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EXECUTIVE SUMMARY

Introduction

In April of this year, Michael Baker, Jr., Inc., was asked by the State of Minnesota to take a critical look at three important aspects of the on-land taconite tailings disposal system proposed by Reserve Mining Company:

- Geotechnical – Is the plan geotechnically sound? Geotechnology is a new science that brings together civil engineering, soil mechanics, and geology to study – in part – the performance of large man-made structures that modify (or become part of) local terrain. Here, our task was to evaluate the proposed disposal scheme – both its design and function – in light of the character of the terrain, the makeup of the local soil, and the geology of the site.

- Hydraulics – Does the plan anticipate the probable behavior of water that may flow through the soil and the structural elements of the disposal system?

- Hydrology – Have the designers considered the likely flow patterns of surface water from natural and man-made sources?

This Executive Summary is a synopsis of our final report to the State.

The Problem

Taconite tailings are the wastes produced when crude taconite iron ore is processed to extract the iron concentrate for producing iron pellets. Each day, Reserve Mining Company, Silver Bay, Minnesota, discharges some 67,000 tons of taconite tailings into Lake Superior. The Company's processing plant has been in operation since 1955.

Reserve's taconite tailings consist mostly of quartz (a common mineral) and minerals of the cummingtonite-grunerite series (less common mineral). Some minerals of the cummingtonite-grunerite series occur as asbestos or asbestos-like fibers. Fine mineral fibers – those about 1/10,000 inch long, or smaller – are suspected, by some medical authorities, of being able to cause cancer if inhaled or ingested by humans and animals.

Reserve has been ordered to cease the discharge of tailings into Lake Superior. Reserve has proposed an on-land disposal scheme that also includes modifications of the concentrating process that will recycle the water used. Reserve also proposes to install equipment to reduce particulate emissions to the atmosphere from the crushing and pelletizing plants.

The Proposed Solution

Reserve's new process will discard three kinds of taconite tailings:

1. Dry cobbs – gravel-size particles

2. Filtered Tailings – sand-size particles

3. Fine Tailings – silt-size particles

The dry cobbs and filtered tailings are grouped together under the single label: coarse tailings.

Reserve proposes to build a huge basin to hold 40-years production of fine tailings at the Mile Post 7 site, some four miles west of its Silver Bay processing plant. The basin will be constructed by building four large dams around a natural valley; it will have a surface area of about 4.6 square miles.

The primary construction material used to build the four dams will be coarse tailings. In technical terms, the major dams function as rockfill dams without impermeable cores. They are all substantial structures . . . the largest will have a crest length of 12,600 feet and a maximum height of 150 feet; the smallest will be 1,700 feet long and 80 feet high.

The dams will be built progressively, over an eight year period. Reserve's construction schedule is designed so that the dams will grow at a fast enough rate to ensure ample fine-tailings capacity in the basin, but will not exceed the available supply of coarse tailings.

Coarse tailings produced after the dams are finished will be stockpiled on a large open hillside (three square miles in area) that slopes downwards to the west edge of the basin.

Reserve proposes to carry the coarse tailings to the disposal site in railroad cars and to pump the fine tailings (in the form of a slurry) to the site via a pipeline.

What We Did

To prepare our evaluation of Reserve Mining Company's plan for the disposal of taconite tailings at the Mile Post 7 site we:

1. Reviewed reports and other information furnished to the State of Minnesota by Reserve Mining Company.

2. Conducted preliminary subsurface exploration and geotechnical reconnaissance work at the site.

3. Performed laboratory tests on selected soil samples from the site.

4. Critically analyzed the data furnished to us by the State of Minnesota and developed by our investigations.

Our Conclusions

Stable dam structures with adequate factors of safety can be constructed at the proposed sites for Dam 1 and Dam 2-3. Insufficient information is currently available to evaluate the sites of Dam 4 and Dam 5. The design information and geotechnical data that we have received from the State of Minnesota to date (information and data developed by

Reserve Mining Company and its consultants) are not sufficient to support Reserve's belief that its proposed on-land tailings disposal system as a whole will function in the intended manner.

This is our main conclusion; we base it on the fact that our preliminary field investigations indicate that the conditions at the Mile Post 7 site are considerably different – and much more complex – than reported by Reserve's consultants.

We feel that the plans we were asked to review are conceptual rather than ready for implementation . . . as presented, they ignore important geotechnical, hydraulic, and hydrological factors that may profoundly affect construction and performance:

- Seepage out of the fine tailings basin (through the dams and through the soil and rock zones surrounding the basin) may be significantly greater than estimated.
- Further, it is unknown whether seepage from the fine tailings basin will contain significant levels of fine mineral fibers . . . the ability of the dam materials, soil, and rock zones to filter those fibers out of seepage water is unknown (or, at least, has not been communicated to us). We consider this point particularly important because much of the water seeping from the facility will find its way into Lake Superior.
- Reserve and its consultants did not pay sufficient attention to the character of the foundation soils and possible internal hydraulic effects when they evaluated the stability of the proposed dams.
- The available information is insufficient to support Reserve's conclusion that enough "borrow materials" (suitable natural soils) are available at the site to permit initial construction of the dams.
- It is possible that the placement of dry coarse tailings in the dams and other disposal areas may generate airborne dust – possibly rich in fine mineral fibers – that may represent a health hazard to workers and downwind populations.
- After the site is abandoned (40 years hence), a number of effects may cause the surface of the tailings basin to contain a number of bogs (with ponded surface water in low areas) rather than a level, vegetated plateau. Also, seepage from the basin may continue indefinitely.
- The stockpiles of excess coarse tailings (that will accumulate when the dams are finished) may be too steep to permit successful vegetation.

NOTE: The State of Minnesota asked us to consider the possible results of a catastrophic dam failure, however improbable such a failure might be. Catastrophic failure of properly designed and constructed tailings dams is highly improbable. However, we have concluded that the immediate effect would be discharge of the free water and a quantity of fine tailings. The discharge would probably cause loss of life and extensive property damage along the flood route from the dam to, and including, the mouth of the Beaver River. Most of the fine tailings would remain in the vicinity of the Mile Post 7 site.

Our Recommendations

In our opinion, much additional geotechnical, hydrological and hydraulic information is necessary before it would be prudent for the State of Minnesota to grant approval to Reserve Mining Company to develop a taconite tailings disposal facility at the proposed Mile Post 7 site.

We recommend a detailed geologic investigation of the site; careful study of the materials that will be used to build the dams, and of the soils that will be the dams' foundtions; engineering analysis of the proposed dam structures (at several different stages of construction); monitoring of stream flows and rainfall at the site; the development of more detailed construction plans, as well as a more realistic evaluation of the borrow materials available at the site; and, determination of the seriousness of seepage from the fine tailings basin . . . both during the facility's lifetime, and after abandonment.

INTRODUCTION

Reserve Mining Company, Silver Bay, Minnesota, processes crude taconite iron ore to extract and concentrate the iron minerals. The waste products – called tailings – are discharged into Lake Superior . . . approximately 67,000 tons of waste per day. The facility has been in operation since 1955, and during the intervening 20 years has poured millions of tons of taconite tailings into the lake.

The complete disposition of these wastes is unknown. A large portion (probably the bulk of the coarser tailings) have accumulated as a huge delta along the lake shore adjacent to the processing plant. The rest of the tailings are presumably lying elsewhere on the lake bottom or have remained in suspension in the lake water.

Reserve's taconite tailings consist predominantly of:

1. Quartz – a common mineral.

2. Iron Silicates of the Cummingtonite-Grunerite Series – less-common minerals, some of which typically occur as asbestos or asbestos-like fibers.

Fine mineral fibers are considered by some medical authorities to be potentially carcinogenic when ingested or inhaled by humans or animals.

After extensive litigation, Reserve Mining Company has been ordered to cease discharging taconite tailings into Lake Superior. Reserve has proposed the construction of an on-land disposal system to be built at the Mile Post 7 site, located some four miles west of Silver Bay, adjacent to the company's railroad line. Reserve's overall proposed Mile Post 7 plan also includes modifications of the concentrating process with closed circuit recycling of process water used. Reserve also proposes to install equipment to reduce particulate emissions to the atmosphere from the crushing and pelletizing plants.

This new process will produce three classes of tailings:

1. Dry cobbs – predominantly gravel-size particles

2. Filtered tailings – predominantly sand-size particles

3. Fine tailings – predominantly silt-size particles

Under Reserve's proposal, the coarse tailings (dry cobbs and filtered tailings) will be transported in railroad cars to the disposal site, while the fine tailings will be pumped as a slurry through a pipeline. The site will include two disposal facilities: a basin to hold the fine tailings, and a large area to hold the coarse tailings. The disposal area is shown on Figure C-1.

The proposed fine tailings basin will be built by erecting four dams around a natural valley to enclose a surface area of approximately 4.6 square miles:

- o Dam 1, the largest of the four dams, will be built across the south end of the valley. It will have a crest length of 12,600 feet and a maximum height of 150 feet.

- o Dam 2-3, across the north end of the valley, will have a crest length of 5,200 feet and a maximum height of 120 feet.

- o Dam 4 (crest length of 1,700 feet; maximum height of 80 feet) and Dam 5 (crest length of 3,100 feet; maximum height of 130 feet) will each close off one of the two low sections of the rock ridge that forms the east side of the fine tailings disposal valley.

All four dams will be composed, predominantly, of the coarse tailings delivered to the site during the early years of the facility's operation.* Reserve's overall plan calls for progressive construction of the dams according to a schedule that ensures adequate fine tailings disposal capacity and, at the same time, does not exceed the available supply of coarse tailings.

The dams will be completed over an eight year time span; coarse tailings delivered to the site after the dams are finished will be stockpiled in a large open area adjacent to the fine tailings basin. This area encompasses approximately three square miles on a hillside sloping down to the west edge of the basin.

The storage facility has a projected life (in terms of its storage capacity at anticipated taconite processing rates) of 40 years. This is the estimated remaining life of Reserve's taconite mining operation.

Note: The reports and reference materials listed in Appendix A provide more detailed information on the proposed disposal system.

Michael Baker, Jr., Inc., was retained by the State of Minnesota in April 1975 to provide engineering services relative to the evaluation of Reserve Mining Company's plans for on-land tailings disposal and for stabilization of the existing tailings delta in Lake Superior following cessation of tailings discharge into the lake. Most of our work to date has involved evaluation of the on-land disposal scheme. We have reviewed reports and other information furnished to the State of Minnesota by Reserve Mining Company (Appendix A); we have conducted preliminary subsurface exploration and geotechnical reconnaissance work at the site (Appendices B and C); we have performed laboratory tests on selected soil samples (Appendix D); and we have critically analyzed both the information furnished to us and the information developed in our investigation.

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* Dams 1 and 2-3 will have starter dams of glacial till at their upstream toes. Dam 4 and a portion of Dam 5 will have glacial till cores. Dams 1 and 2-3 and the portion of Dam 5 without the glacial till core will function as rockfill dams without impervious cores. Dam 4 and the portion of Dam 5 with a glacial till core will function as zoned earth dams.

This report summarizes our evaluation of the plans that Reserve Mining Company presented to the State of Minnesota in seeking a permit for tailings disposal at the Mile Post 7 site. We understand that this evaluation will be used by the State in public hearings relative to Reserve's permit application. We also understand that the State is currently investigating alternate on-land tailings disposal sites. We have not been involved in engineering or environmental studies for these alternate sites. Moreover, our analysis of the Mile Post 7 site has only considered geotechnical, hydrologic and hydraulic aspects. Environmental and health-hazard aspects have not been studied except where they interface with geotechnical, hydrologic or hydraulic aspects. In these latter cases, we have provided only geotechnical, hydrologic or hydraulic inputs relative to possible enviornmental or health-hazard problems.

The sections of this report that follow present conclusions and recommendations derived from our investigation to date. The general conclusions relate to the feasibility of the proposed Mile Post 7 tailings disposal system as a whole. The specific conclusions focus on individual components of the proposed disposal system. Our recommendations address the technical aspects of the proposed project.

The information upon which our conclusions and recommendations are based is detailed in several appendices to this report. Appendix A contains a list of reports and documents furnished by Reserve Mining Company to the State of Minnesota. Appendices B and C, respectively, present the results of the subsurface exploration and geotechnical reconnaissance studies we conducted at the Mile Post 7 site in June, 1975. Results of our laboratory testing program on soil samples from the Mile Post 7 site are given in Appendix D. Appendix E contains a technical discussion of stability of the proposed tailings dams. Appendix F contains a similar discussion of leakage through the proposed tailings dams. Appendix G deals with significant hydrologic and hydraulic aspects of the proposed tailings disposal system. Finally, Appendix H presents our thoughts regarding stabilization of the tailings delta in Lake Superior.

CONCLUSIONS

General Conclusions

In our view, the two primary geotechnical considerations relative to the feasibility of the proposed Mile Post 7 tailings disposal system and its performance are:

1. Stability (both structural and hydraulic) of the fine tailings basin, and

2. Leakage of potentially carcinogenic mineral fibers from this basin.

Stable dam structures with adequate factors of safety can be constructed at the proposed sites for Dam 1 and Dam 2-3. Our main conclusion is that the information developed by Reserve Mining Company and its consultants, and provided to us by the State of Minnesota as of this date, is not sufficient to support Reserve's contention that the proposed Mile Post 7 tailings disposal system as a whole will function in the manner claimed by its proponents.

We base this conclusion on the fact that our field investigations (conducted in June, 1975 to verify site conditions) indicate that conditions are significantly different, and considerably more complex than indicated by Reserve's consultants.

In our opinion, the plans presented to us for review are conceptual in nature, and they do not reflect adequate cognizance of certain factors of site geology which may have profound effects on project feasibility and ultimate performance. These include:

1. Pervious seams in lacustrine soil deposit blanketing lower portions of proposed fine tailings basin.

2. A pervious to semi-pervious "transition zone" underlying lacustrine soil deposit and overlying glacial till.

3. Pervious to semi-pervious sand and gravel deposits along rock ridge on east side of proposed fine tailings basin (and perhaps elsewhere at the site).

4. Pervious talus deposits along rock ridge on east side of proposed fine tailings basin.

5. Jointing, and other defects and discontinuities in rock ridge, along east side of proposed fine tailings basin (and perhaps in rock masses elsewhere at the site).

6. Groundwater flow pattern(s) at the site, particularly through the soil and rock zones listed above.

7. Abilities of soil and rock materials at the site, and the fine and coarse tailings materials, to filter, chemically absorb, or otherwise remove fine mineral fibers from percolating groundwater.

Most of these geologic factors will exert significant influences on the quantity and quality of leakage from the proposed fine tailings basin. Many of these factors will also influence the water pressures in the foundations of the proposed tailings dams, and, hence, the stability of these dams. More complete discussions of leakage and stability are presented elsewhere in this report.

It is an axiom of geotechnical design (and particularly of the design of dams and facilities for disposal of solid and liquid wastes) that each design must be tailored to site conditions, with special emphasis on conditions of site geology. This does not appear to have been done in Reserve's plans for tailings disposal at the Mile Post 7 site. Although individual components of the proposed system may function more or less as indicated by the designers, we have not as yet seen evidence to indicate that the total system will function in the proposed manner. However, we have reached the following specific conclusions relative to individual system components.

SPECIFIC CONCLUSIONS

Geologic Conditions

As noted above, geologic conditions at the Mile Post 7 site are considerably more complex (and in some respects quite different) than those presented by Reserve's consultants.

The quantity and quality of seepage through pervious and semi-pervious soil and rock zones leading from the proposed fine tailings basin are undetermined. Seepage estimates made by Reserve's consultants do not reflect the soil and rock conditions disclosed by our investigations.

Strength-deformation behavior of the highly plastic lacustrine clay foundation soils, and the possible transmission of uplift water pressures from the rock ridge on the east side of the fine tailings basin and from supernatent water in the basin, have not been adequately considered in evaluating the stability of Dam 1 and Dam 2-3 (Appendices D and E).

Insufficient information is currently available to evaluate the sites of Dam 4 and Dam 5. The assumption that proposed Dam 4 and Dam 5 can be constructed without major problems is unfounded. Because of complex geologic conditions along the east ridge, the potential for major problems exists at the proposed sites of these dams.

Dam Design

The coarse tailings material is suitable for embankment construction. This material can be compacted to a dense, strong, free-draining state, and its component particles are resistant to deterioration from weathering. Comparison of anticipated coarse tailings production rates with proposed construction schedules for the dams indicates that the maximum proportion of filtered tailings in the coarse tailings dam construction material will be about 25 percent.

The coefficient of permeability (4.2×10^{-5} cm./sec.) used by Reserve's consultants in estimating seepage losses through proposed Dam 1, Dam 2-3, and Dam 5 may be too low. Hydraulic deposition of fine tailings from the inside slopes of the dams will result in lateral as well as vertical variations in the permeability of the fine tailings beaches proposed for the inside slopes of the dams. Therefore, seepage losses through the dams could significantly exceed those estimated by Reserve's consultants (Appendix F).

Stable dam structures with adequate factors of safety can be constructed at Dam Sites 1 and 2-3. Vertical sand drains should not be installed in the foundation soils. Sand drain installations will block natural drainage paths, weaken the foundation soils, and increase potential for groundwater contamination. Piezometric heads and soil deformations within the dam foundations must be monitored during construction and operation of the facility.

Hydrology and Hydraulics

Catastrophic failure of properly designed and constructed tailings dams is highly improbable. However, in the unlikely event that such a failure should occur at the Mile Post 7 site, the immediate effect would be the discharge of the free water and a quantity of fine tailings. The discharge would probably cause loss of life, and extensive property damage along the flood route from the dam to and including the mouth of the Beaver River. The majority of the fine tailings would remain in the vicinity of the disposal area. Tailings, including mineral fibers, released by such an event would, for the most part, be carried into Lake Superior with the initial flood crest.

The proposed stream diversions are designed for a 10,000-year recurrence interval storm. The tailings basin, assuming the proposed construction schedules are met, will have adequate storage capacity to retain the probable maximum precipitation (PMP) from its modified drainage area. If the PMP occurs over the entire Beaver River watershed, the diversion dams will be breached. Then flow from upstream portions of the Beaver River watershed would enter the tailings basin and possibly breach the tailings dams.

After construction of the diversions, downstream siltation will occur; from a practical standpoint, this is unavoidable in a project of this type.

The possibility that the estimated quantities of seepage through the dams may be exceeded has not been considered by Reserve's consultants in their hydraulic calculations.

No emergency spillway is required during the active life of the disposal system if the proposed construction schedules are maintained. Any reduction in the proposed rate of construction for the tailings dams will require a reevaluation of the need for an emergency spillway.

Construction

The available information does not support the conclusion that quantities of glacial till borrow material sufficient for construction of Starter Dams 1 and 2-3 exist within the designated borrow areas. The geologic map of Hickock and Associates (January, 1975 report General Geology Mile Post 7 Site), and our field reconnaissance of June, 1975, indicate rock outcrops in the proposed western borrow area for Dam 1. These rock outcrops, plus the substantial boulder content of the till, suggest that the borrow material estimates are unreasonable. Numerous boulders were also encountered in the eastern borrow area for Dam 1. No borings or test pits were made at the borrow area for Dam 2-3. The closest test pits to this borrow area, which were excavated for exploration of Dam Site 2-3, indicate little or no till. Dewatering the borrow areas, and processing till to remove boulders and cobbles, may both present formidable problems.

Placement of relatively dry coarse tailings in the dams and other disposal areas may generate significant quantities of airborne dust. It has not been determined whether this dust may contain mineral fibers, thereby representing a health hazard to construction workers and populations downwind.

Because of severe winter weather conditions in northern Minnesota, construction during part of the year will be difficult. Placement of coarse tailings in the proposed dams and disposal areas can continue throughout the year if ice control and snow removal is practiced to prevent inclusion of ice and snow in the embankments. Earthwork involving glacial till or other non-tailings materials should not be conducted during subfreezing weather.

Abandonment

As abandonment is approached, the freewater in the fine tailings basin will be gradually removed. Reduction in buoyancy, plus desiccation by capillary effects, will induce consolidation of the fine tailings (and settlement of the basin surfaces) over a period of years. Because of differences in fine tailings thickness and composition, certain portions of the basin surface will probably settle more than others. The result may be a number of bogs with ponded surface water in low areas rather than a level vegetated plateau.

It is possible that seepage from the abandoned fine tailings basin may continue indefinitely. Ponding of water in low areas on the basin surface would add to such seepage. It has not been determined whether post-abandonment seepage from the basin will be contaminated with fine mineral fibers or other pollutants. If the seepage is contaminated, long-term treatment will be required. Formidable problems are associated with long-term-to-perpetual treatment systems.

Coarse tailings not required for construction of dams and other facilities will be placed in a disposal area northwest of the fine tailings basin. Reserve's proposal calls for placement of tailings in 40-foot-high stages, with slopes of one vertical on 1.3 horizontal. These stages will be separated by benches 27 feet wide, to give an overall slope of approximately one vertical on two horizontal. We doubt that the steep slopes between benches can be successfully vegetated. Furthermore, depending on underlying soil conditions, the overall slope of about 1 on 2 may not be stable.

Geologic events such as uplift of the area are not likely to cause adverse environmental effects relative to the proposed disposal area. Such events will either occur at a rate which is essentially imperceptible and have minimal impact, or they will occur relatively rapidly and have environmental impacts of such magnitude as to render the tailings disposal area insignificant, (reglaciation of North America or a resurgence of volcanic activity, for example).

RECOMMENDATIONS

Geologic Conditions

A detailed geologic investigation should be conducted to develop an accurate representation of geologic conditions at the Mile Post 7 site. All stages of this investigation should be closely coordinated with, and monitored by, the State of Minnesota. As a minimum effort, the geologic investigation should include:

1. Office studies of topographic maps, aerial photographs, and available geologic information to develop rational working hypotheses of the origin and distribution of soil and rock formations.

2. Preliminary field investigation that includes geotechnical reconnaissance work, a limited number of test pits, and standard test borings with continuous undisturbed tube samples.

3. Evaluation of the results of the preliminary field investigation to make possible the planning of a comprehensive exploratory program. This program should identify, within practical limits, those subsurface conditions of significance to the design of the proposed tailings disposal system.

4. A comprehensive exploratory program using whatever techniques are appropriate.

5. Laboratory testing and analysis of samples from the exploratory program, and subsequent interpretation of data, to provide a basis for the reevaluation of the project's design.

To provide meaningful information, these efforts should be conducted independently (sequentially as listed above), with critical reviews following each stage.

Appropriate tests must be conducted to determine the abilities of both natural soils and tailings materials to prevent the migration of mineral fibers.

Dam Design

Coefficients of permeability that reflect the heterogeneity and anisotropy of fine tailings that will be impounded in the basin should be used (with appropriate analytical techniques) to estimate seepage quantities.

Appropriate laboratory tests should be used to determine reasonable peak and residual effective stress shear strength parameters for lacustrine clay soils in dam foundations.

Effective-stress stability analyses using Morgenstern-Price or sliding-wedge methods should be performed to predict performance of:

1. Starter dams at end of construction.

2. Upstream and downstream slopes of tailings dams at end of first construction stage.

3. Upstream and downstream slopes of tailings dams at end of final construction stages.

4. Downstream slopes of tailings dams at end of design life of tailings basin.

For all tailings dams, minimum factors of safety of 1.5 (based on peak shear strength) and 1.2 (based on residual strength) must be arrived at for each potential failure mode, through analyses employing strength and water pressure assumptions acceptable to the State of Minnesota. X

A comprehensive program for monitoring soil deformations and piezometric levels in all tailings dams and their foundations should be developed by Reserve's consultants and approved by the State of Minnesota.

Hydrology and Hydraulics

Diversions 1 and 2 should be designed to accommodate the probable maximum precipitation within the watershed.

Stream-flow and rain gauges should be installed and monitored to develop hydrologic data during operations of the tailings disposal facility. These data will be useful in planning and designing abandonment features.

Immediately prior to abandonment, an overflow spillway must be designed and constructed for the fine tailings basin. Emergency spillways should be provided for all seepage reclaim dams.

Construct a new discharge channel from Bear Lake, either to the south or east, whichever is more economical.

Construction

A more realistic evaluation of sources, types, and quantities of borrow materials should follow the detailed geologic investigation previously recommended.

It must be determined if the dust accompanying the coarse tailings placement is a health hazard. If so, a positive program of dust suppression and personnel protection must be proposed by Reserve and approved by the State of Minnesota.

Programs for monitoring air, surface water, and groundwater quality before, during and after construction should be developed, by Reserve and its consultants, and presented to the State of Minnesota for approval.

Detailed specifications for all phases of construction should be developed, by Reserve and its consultants, and presented to the State of Minnesota for approval.

The State of Minnesota should provide a Resident Engineer, and assistants as required, to ensure quality control during construction.

Abandonment

Studies should determine whether post-abandonment seepage from the fine tailings basin will be contaminated with mineral fibers or other pollutants. If such contamination is probable, or if the question cannot be resolved, Reserve should provide plans for long-term treatment. Alternately, the fine tailings basin should be constructed as an impermeable reservoir.

Slopes in the coarse tailings disposal area should be flattened to inclinations which are demonstrably capable of supporting vegetation.

Monitoring stations established during the active life of the project should be maintained after abandonment in the event that data are desired in the future.

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APPENDICES

APPENDIX A

LIST OF INFORMATION RECEIVED FROM STATE OF MINNESOTA

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Reports

Design Report, On-Land Tailings Disposal Study, Mile Post No. 7 Site, by Klohn Leonoff Consultants Ltd., April 1975.

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Drawings

Drawing No. 292-0003 Revision No. 7	"Mile Post No. 7 Site Tailings Disposal Area: General Plan"
Drawing No. 292-0003 Revision Nos. 7, 8	"Mile Post No. 7 Site Tailings Disposal Area: General Plan"
Drawing No. 292-0016 Revision No. 2	"Mile Post No. 7 Site: Access Roads"
Drawing No. 292-0021	"Mile Post No. 7 Site Tailing Disposal Area: General Layout – Tailings Storage and Diversions"
Drawing No. 292-0022	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Test Hole Location Plan"
Drawing No. 292-0022 Revision No. 1	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Test Hole Location Plan"
Drawing No. 292-0023	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 2-3 – Test Hole Location Plan"
Drawing No. 292-0023 Revision No. 1	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 2-3 – Test Hole Location Plan"
Drawing No. 292-0026	"Mile Post No. 7 Site Tailing Disposal Area: Schedule – Tailing Storage Structure"
Drawing No. 292-0026	"Mile Post No. 7 Site Tailing Disposal Area: Schedule – Tailing Storage Dams"
Drawing No. 292-0027	"Mile Post No. 7 Site Tailing Disposal Area: Volumes – Storage, Reservoir"

Drawing No. 292-0027	"Mile Post No. 7 Site Tailing Disposal Area: Volume Design Curves – Reservoir, Dams, Filling Rates"
Drawing No. 292-0028	"Mile Post No. 7 Site Tailing Disposal Area: Schematic Water Balance"
Drawing No. 292-0030	"Mile Post No. 7 Site Tailing Disposal Area: Soil Design Assumptions"
Drawing No. 292-0030	"Mile Post No. 7 Site Tailing Disposal Area: Summary of Test Data"
Drawing No. 292-0032	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Stability Analysis, Critical Failure Surfaces"
Drawing No. 292-0033	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Settlement Analyses"
Drawing No. 292-0034	"Mile Post No. 7 Site Tailing Disposal Profile: Typical Seepage Analysis"
Drawing No. 292-0035	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Subsoil Profile, Section A-A"
Drawing No. 292-0036	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Subsoil Profile, Section B-B, C-C, D-D"
Drawing No. 292-0037	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 2-3 – Subsoil Profile, Section A-A, B-B"
Drawing No. 292-0038	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 2-3 – Subsoil Profile, Section C-C"
Drawing No. 292-0039	"Mile Post No. 7 Site Tailing Disposal Area: Borrow Pits – Locations and Estimated Volumes"
Drawing No. 292-0041	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – General Arrangement"
Drawing No. 292-0042	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 1 – Starter Dam"
Drawing No. 292-0042	"Mile Post No. 7 Site Tailing Disposal Area: General Arrangement Dam Site No. 1 – Starter Dam"
Drawing No. 292-0044	"Mile Post No. 7 Site Tailing Disposal Area: Starter Dam, Dam Site No. 1 – Sand Drain and Instrumentation Details"

Drawing No. 292-0044	"Mile Post No. 7 Site Tailing Disposal Area: Starter Dam, Dam Site No. 1 – Sand Drain Details"
Drawing No. 292-0048	"Mile Post No. 7 Site Tailing Disposal Area: Typical Seepage Recovery Pumpstation"
Drawing No. 292-0050	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 2-3 – General Arrangement"
Drawing No. 292-0060	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 4 – General Arrangement"
Drawing No. 292-0070	"Mile Post No. 7 Site Tailing Disposal Area: Dam Site No. 5 – General Arrangement"
Drawing No. 292-0081	"Mile Post No. 7 Site Tailing Disposal Area: General Arrangement Diversion Structure No. 1"
Drawing No. 292-0081	"Mile Post No. 7 Site Tailing Disposal Area: Diversion Structure No. 1.
Drawing No. 292-0083	"Mile Post No. 7 Site Tailing Disposal Area: General Arrangement Diversion Structure No. 2"
Drawing No. 292-0083	"Mile Post No. 7 Site Tailing Disposal Area: Diversion Structure No. 2"
Drawing No. 292-0090	"Mile Post No. 7 Site Tailing Disposal Area: Tailing Storage – Discharge and Reclaim Procedure"
Drawing No. 292-0090	"Mile Post No. 7 Site Tailing Disposal Area: Tailing Storage Fine and Coarse Tailings"
Drawing No. 292-0092	"Mile Post No. 7 Site Tailing Disposal Area: Tailing Storage, Detail East Side" Reclaim Facilities Added
Drawing No. 292-0092	"Mile Post No. 7 Site Tailing Disposal Area: Tailing Storage, Detail East Side"
Drawing No. 294-0001 Revision No. 1	"Test Hole Nos. Location and Elevations"
Drawing No. 294-0005	"Mile Post No. 7 Delta Stabilization: Section for Model Studies"
Drawing No. 22-0010-1 Revisions D through N	"Delta Area Launder System, General Arrangement"

Sheet 27	"Topographic Map of Existing Delta"
Drawing No. X-1965-1	"Mile Post No. 7 Site – On-Land Tailings Disposal: General Site Location Plan"
Drawing No. X-1965-2 Revision Nos. 1, 2	"Mile Post No. 7 – On-Land Tailing Disposal: Test Hole Location Plan Showing Plan View of Dam No. 1"
Drawing No. X-1965-3	"Mile Post No. 7 – On-Land Tailings Disposal: Subsoil Profile – Section A-A – Dam Site No. 1"
Drawing No. X-1965-4	"Mile Post No. 7 – On-Land Tailings Disposal: Subsoil Profile – Sections B-B, C-C, D-D – Dam Site No. 1"
Drawing No. D-1965-5	"Mile Post No. 7 – On-Land Tailings Disposal: Section Through Starter Dam and Final Dam, Dam Site No. 1"
Drawing No. D-1965-6	"Mile Post No. 7 – On-Land Tailings Disposal: Stability Analyses – Starter Dam and Ultimate Dam – Dam Site No. 1"
Drawing No. A-1965-7	"Mile Post No. 7 – On-Land Tailings Disposal: Contours of Clay Thickness, Dam Site No. 1"
Drawing No. X-1965-8 Revision No. 1	"Mile Post No. 7 – On-Land Tailings Disposal: Test Hole Location Plan Showing Dam No. 3 Centerline"
Drawing No. B-1965-9	"Mile Post No. 7 – On-Land Tailings Disposal: Tailings Pond Capacity Curve"
Drawing No. X-1965-10 Revision Nos. 1,2,3,4,5,6	"Mile Post No. 7 – On-Land Tailing Disposal: Test Hole Location Plan Showing Plan View of Dam No. 2-3"
Drawing No. X-1965-11	"Mile Post No. 7 – On-Land Tailings Disposal: Subsoil Profile – Section A-A, B-B – Dam Site No. 2-3"
Drawing No. X-1965-12	"Mile Post No. 7 – On-Land Tailings Disposal: Subsoil Profile – Section C-C – Dam Site No. 3"
Drawing No. X-1965-13	"Mile Post No. 7 – On-Land Tailing Disposal: Section Through Starter Dam and Final Dam, Dam Site No. 2-3"
Drawing No. B-1965-14	"Mile Post No. 7 – On-Land Tailings Disposal: Stability Analyses – Starter Dam – Dam Site No. 2-3"
Drawing No. B-1965-15	"Mile Post No. 7 – On-Land Tailing Disposal: Contours Showing Clay Thickness – Dam Site No. 2-3"

Drawing No. X-1965-16 Revision Nos. 1,2,3	"Mile Post No. 7 – On-Land Tailing Disposal: Test Hole Location Plan Showing Plan View of Diversions No. 1 and 2"
Drawing No. B-1965-17	"Mile Post No. 7 – On-Land Tailing Disposal: Typical Sections Diversions No. 1 and 2"
Plaintiff's Exhibit B	"Profile Lake Bottom and Tailings Fill Area – 3 Mile Permit Zone"
Drawing OE A-118 Revision No. 1	"Lake Contours, Delta Area"
Drawing WA-73	"Silver Bay Area Bathymetry"

APPENDIX B

SUBSURFACE INVESTIGATION
BY
MICHAEL BAKER, JR. INC.

APPENDIX B

SUBSURFACE EXPLORATION PROGRAM
BY
MICHAEL BAKER, JR., INC.

Description of June 1975 Boring Program

Six borings were drilled at the Mile Post 7 site from June 10 to June 20, 1975, by Braun Engineering Testing, Inc. of Minneapolis, Minnesota. The locations of borings 2, 4 and 6 at Dam Site 1 are shown on Figure B-1 and the locations of borings 1, 3 and 5 at Dam Site 2-3 are shown on Figure B-2. Drilling work was supervised and inspected by our engineering geologist, and copies of his logs are included in the following section of this appendix. Our engineering geologist established boring locations by taping and/or pacing distances from borings made previously by Reserve's consultants. Ground surface elevations at the locations of our borings were determined by hand leveling from Reserve's borings using ground elevations at the latter borings presented in reports by Reserve's consultants.

During soil drilling operations borings were advanced using 6-1/2 inch outside diameter, 3-1/4 inch inside diameter hollow stem augers. Relatively undisturbed piston-type Shelby tube samples, each having an outside diameter of three inches and a length of approximately two feet, were obtained on a nearly continuous basis where soil conditions permitted. Boreholes were typically advanced in intervals of about one foot between tube samples. Where soil conditions did not permit tube samples to be obtained, representative soil samples were secured using a standard 1-3/8 inch inside diameter split barrel sampler. A standard penetration test was performed in conjunction with the securing of each split barrel sample. These penetration tests employed a 140 pound hammer falling freely through a height of 30 inches. The number of hammer blows required to drive the split barrel sampler each six inch increment for a total penetration of 18 inches was recorded. The standard penetration resistance, as designated in blows per foot, is obtained by adding the number of hammer blows required to drive the sampler the last two six inch increments. This standard penetration resistance provides useful semi-quantitative information on soil density and consistency. Where borings 1, 2 and 4 encountered refusal on rock, NQ wireline drill tools were used to recover continuous cores 1-7/8 inches in diameter.

A total of 337.8 feet of drilling was completed in ten working days. This included 323.8 feet of soil drilling and 14 feet of rock coring. A total of 46 Shelby tube soil samples and 121 jar samples from the split barrel sampling were obtained. Hydraulic pressures used to push Shelby tubes, penetration resistance data from split barrel sampling, rock core recovery, visual classifications of soil and rock strata and other pertinent observations during drilling are presented on the logs in the next section of this appendix.

Groundwater levels were measured in each boring during drilling, upon completion of drilling, and, where possible, at intervals after completion of drilling. Groundwater data are also presented on the logs.

FIELD LOGS OF BORINGS

MICHAEL BAKER, JR., INC. Flextrac Nodwell 160 Tracked Carrier CME 55-Drilling Rig

PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 1 (drilled approx 16' S.W.S. of Boring 3012) Dam 2 - 3 SHEET 1 OF 5

(Approx. 1.3' higher than Boring 3012)

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Disposal Site STATION --- OFFSET --- GROUND ELEV. 1150.4'

WL-6/11/75 - 12.0'

Date Started 6/10/75. 8:00 a.m. Sampler Size 1 3/8" I. D. Wt. of Hammer 140 lbs. Fall 30" Ground Water 0 Hrs. see sheet 5of5

Date Completed 6/12/75 6:00 p.m. Casing Size ------ Wt. of Hammer ---- Fall --- Ground Water 24 Hrs. see sheet 5of5

Core Size ------- Diameter of Auger 61/2" Hollow Stem Weather Cool, cloudy, rain prior to 8:00 a.m. on 6/10/75

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
0.0'-1.2'	red-brn	moist	soft	Clay and silt, w/some small rock (taconite) fragments + PL.	1	0.0'-2.0'	-------	Auger
1.2'-2.0'	red	moist	soft	Clay, some silt, plastic, not varved, +PL.				
2.0'-4.0'	PISTON SHELBY TUBE SAMPLE,			Hydraulically pushed, 500 psi to 700 psi @ 3.0'. Hit rock fragment @3.0' bending tip	2	2.0'-4.0'	-------	piston shelby tube, Recov=1.1' jar sample collected @ tip
@4.0'	red	moist	M. stiff	Clay, some silt, = PL, at tip of shelby tube				
	AUGERED TO 5.0'							
5.0'-7.0'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed 250 psi at top to 650 psi at bottom	3	5.0'-7.0'	-------	piston shelby sample, Recov=1.6' Lost 0.4' recovery at tip. Jar sample collect from bottom of tube
@7.0'	red	moist	M. stiff	Clay & silt, + PL, w/ blocky structure, @tip of shelby tube				
	AUGERED TO 8.0'							
8.0'-10.0'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed pressure=250psi gradually increasing to 800psi	4	8.0'-10.0'	-------	piston shelby sample, Recov=1.8' Jar sample collected from bottom of tube
@10.0'	dk red brn	moist	M. Dense	Silt, tr. of clay, NP, at tip of shelby tube				
	AUGERED TO 11.0'							

DRILLING CO. Braun Engineering, Testing DRILLER Dennis Ruchti Helper-Jim Shearer INSPECTOR J.R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 1 (drilled approx. 16' sws of Boring 3012) Dam Site 2, 3 SHEET 2 OF 5

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Site STATION --- OFFSET --- GROUND ELEV. approx. 1150.4'

Date Started 6/10/75@ 8:00a.m. Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs. ______

Date Completed 6/11/75 Casing Size ---- Wt. of Hammer ---- Fall ---- Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger 6 1/2 Hollow Stem Weather Cool, cloudy, rain prior to 8:00 A.M. on 6/10/75

Description of Each Stratum					Sample		Blows on Sampler	REMARKS
Depth From To	Color	Moisture	Compactness or Consistency	Texture	No.	Depth		
11.0'-13.0'	PISTON	SHELBY	TUBE SAMPLE	hydraulically pushed pressure-250psi gradually increasing to 1000psi	5	11.0'-13.0'		Piston shelby, Recov= 1.7' Jar sample collected at tip of Shelby tube.
@13.0'	dk.red brn.	Mosit	M. dense	SILT, w/tr of clay, tr. of fine sand, NP, at tip of shelby tube				
	AUGERED	D TO 14.0'						
14.0'-16.0'	PISTON	SHELBY	TUBE SAMPLE	hydraulically pushed pressure=250psi increasing to 900psi	6	14.0'-16.0'		Piston shelby, Recov. 1.8' Jar sample collected from end of tube
@16.0'	red	moist	stiff	Clay, some silt, NMC=PL, large pc of gravel at tip of tube, Varves not noticeable				
	AUGERED	D TO 17.0'						
17.0'-19.0'	PISTON	SHELBY	TUBE SAMPLE	hydraulically pushed 300 psi @17.0'- 18.5' 500psi-700psi @18.5'-19.0'	7	17.0'-19.0'		Piston shelby-Recov= 2.0' bottom of tube bent. Jar sample collected from tip.
@19.0'	dk.red brn.	Moist	stiff	Silt, some clay, not varved, NMC=PL Gravel apparently present @18.5'				
	AUGERED	D TO 20.0'						
20.0'-21.0'	PISTON	SHELBY	TUBE SAMPLE	hydraulic pressure 400 psi, 1000 psi @21.0'	8	20.0'-21.0'		Piston shelby, Recov= 0.7' Jar sample collected from tip of tube
@21.0'	dk.red brn.	Moist	stiff	Silt, some clay, little large gravel,=PL, hit cobble @21.0'				

AUGERED FROM 21.0'-23.0'

DRILLING CO. Braun Engineering, Testing DRILLER Dennis Ruchti Helper-Jim Shearer INSPECTOR J.R. Rapp

MICHAEL BAKER, JR., INC. — PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 1 (drilled approx 16' SWS of Boring 3012) Dam 2 - 3 SHEET 3 OF 5

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Site STATION --- OFFSET --- GROUND ELEV. approx. 1150.4'

Date Started 6/10/75, 8:00 a.m. Sampler Size 1 3/8ID Wt. of Hammer 140 lbs. Fall 30" Ground Water 0 Hrs. ____

Date Completed 6/11/75 Casing Size ---- Wt. of Hammer ---- Fall ---- Ground Water 24 Hrs. ____

Core Size ____ Diameter of Auger 6 1/2 Hollow ~~Stem~~ Weather ____

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No	Sample Depth	Blows on Sampler	REMARKS
23.0'-23.8'	SHELBY TUBE SAMPLE,		PISTON,	hydraulic pressure 400psi, 1100psi @23.8'-Tip damaged hit large gravel.	9	23.0'-23.8'		Piston shelby, Recov=0.8' Jar Sample collected from tip.
@23.8'	dk red brn	moist	stiff	SILT, some clay, little med. gravel at tip of Shelby tube				
	AUGERED TO	- 25.0'						
25.0'-25.5'	SHELBY TUBE	SAMPLE,	PISTON,	hydraulic pressure-300psi to 1100psi @25.5'	10	25.0'-25.5' HIT WATER @25.0'		Piston shelby, Recov=0.3'
@25.5'	Dk red brn	moist	loose	Silt, tr of clay, NP, w lenses of medium sand. and occ. coarse gravel.				Est. Recov.
25.5'-30.0'	Dk red brn	moist to wet	dense	Silt, tr of clay, tr of sand, little F-M gravel, NP.	11	25.5'-26.3'	40-200/0.3'	Spoon 1.5'
30.0'-32.0'	red brn	wet	stiff	Silt and clay, little gravel, + PL	12	28.0'-29.5'	18-23-29	Spoon 1.5'
					13	31.0'-32.5'	4-5-9	Spoon 1.2'
32.0'-32.5'	red brn	wet	M dense	SAND, medium, tr of silt, tr of clay, NP.	14	32.5'-34.0'	13-20-20	Spoon 1.2'
					15	35.5'-37.0'	18-36-62	Spoon 1.1'
32.5'-33.0'	red brn	wet	stiff	CLAY, and silt, + PL	16	38.5'-40.0'	41-69-90	Spoon 0.1'
33.0'-36.0'	red brn	wet	dense	SAND, medium, little silt, tr of clay little fine gravel., NP.	17	41.5'-42.5'	31-215/0.5'	Spoon 0.7'
						ADVANCED & CLEANED AUGERS AFTER EACH SPOON SAMPLE DRIVE BELOW 25.5'		
36.0'-40.0'	red brn	wet	dense	SILT, and sand, tr. of clay, tr of F-M gravel, NP				
40.0'-44.0'	red brn	wet	V. dense	SAND, F-M, little silt, tr of clay, tr of M-F gravel, NP cobbles present @40.0'&42.0'				

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper - Jim Shearer INSPECTOR J.R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 1 (drilled approx 16' SWS of Boring 3012) Dam Site 2-3 SHEET 4 OF 5

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Disposal Site STATION --- OFFSET --- GROUND ELEV. approx. 1150.4'

Date Started 6/10/75, 8:00 a.m. Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs.

Date Completed 6/12/75 Casing Size ---- Wt. of Hammer --- Fall --- Ground Water 24 Hrs.

Core Size Diameter of Auger 6 1/2 Hollow Stem Weather

Description of Each Stratum					Sample		Blows on Sampler	REMARKS
Depth From To	Color	Moisture	Compactness or Consistency	Texture	No.	Depth		
44.0'-46.0'	red brn	moist	v. Dense	Sand, fine, little silt, tr	18	44.0'-45.5'	25-38-50	Spoon
				of clay, w/a few thin	19	47.0'-48.3'	44-63-105	Spoon 1.2' (Est. Recov.)
				(1/16" - 1/8") silt lenses,	20	48.3'-48.5'		Spoon
				NP	21	50.0'-51.5'	13-18-15	Spoon more than 0.5' (ER)
46.0'-48.3'	red brn	moist	V. Dense	Sand, fine, and silt,	22	53.0'-54.5'	10-13-18	1.0' (Est. Recov.)
				tr of clay, tr of fine	23	56.0'-56.9'	84-250/0.4'	More than 0.5' (ER)
				gravel, NP.	24	58.5'-60.0'	27-56-85	Less than 0.1' (Est. Rec)
48.3'-55.0'	Varved gray	moist	hard to	Clay, varved, 1/4" varves,		@60.0' on	6/10/75	@5:15 p.m.
	brn & red		V. hard	NMC-PL	25	61.5-61.6	200/0.1'	Less than 0.1' (ER)
55.0'-61.6'		moist	V. Dense	SAND, little silt, little Clay, some coarse gravel and cobbles				

REFUSAL ON BOULDER @61.6'

SEE SHEET 5 of 5

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper - Jim Shearer INSPECTOR J.R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BAKER ENGINEERS — WE TRAVERSE THE EARTH

BORING NO. 1 (located approx 16' SWS of Boring 3012)

SHEET 5 OF 5

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Disposal Site

STATION --- OFFSET --- GROUND ELEV. approx. 1150.4

Date Started 6/10/75 Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs. Fall 30" Ground Water 0 Hrs. ______

Date Completed 6/12/75 Casing Size ---- Wt. of Hammer ---- Fall ---- Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger 6 1/2" Hollow Stem Weather cool, cloudy, rain @9:30

Depth From – To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
		REFUSAL	ON BOULDER @	61.6'	25	61.5-61.6'	200/0.1'	Spoon No Recovery
61.6'-64.0	AUGERER THROUGH SMALL BOULDERS AND COBBLES				26	64.0-65.5'	170-115-78	Spoon 0.8' (recov.)
64.0'-69.5	Dk red brn	moist	V. dense	GRAVEL, F+M, and clay, little sand.	27	67.0-68.0'	115-250	Spoon 0.5' (recov.)
					28	69.5-71.0'	86-59-155	Spoon 0.7' (recov.)
69.5'-72.0	Dk red brn	moist	hard	CLAY, and Gravel, F-C, little sand	29	72.5-73.7'	35-146-200/0.2'	Spoon 0.8' (rec)
					30	75.5-75.9'	200/0.4'	Spoon 0.3' (recov.)
72.0-74.0'	Dk red brn	moist	V. dense	GRAVEL, F-C, and sand little clay		REFUSAL @75.9'		
74.0-75.9'	Dk red brn	wet	V. dense	GRAVEL, F-C, and clay		Longyear wireline NQ Core.-1 7/8" diam.		
			REFUSAL @ 75.9'			CORED	Run	Rec. % Rec. RQD
						75.9'-78.9'	3.0	2.7 90% 63% 1.9'
75.9-78.9'	Dark purple brown with white & red amygdules	---	hard	Basalt, amygdaloidal, some small vesicles (1/4") weath 75.9'-76.1' fractured & jointed-76.5' thin joint @76.9 @20° mostly slightly weath, amygdules of calcite and zeolite				
	WATER LEVELS		END OF CORING AT 78.9' on 6/11/75 @6:00 p.m.					
	6/11/75 @7:45 a.m.		12.0'	BORING BACKFIELD WITH CLAY 6/13/75				
	6/11/75 @6:00 p.m.		17.5'					
	6/12/75 @8:00 A.M.		2.0' above top of hole					
	6/12/75 @9:00 A.M.		4.0' after pulling tools					
	6/12/75 @1:00 p.m.		3.0'					
	6/12/75 @5:00 p.m.		2.5'					

DRILLING CO. Braun Engineering, Testing DRILLER Dennis Ruchti INSPECTOR ~~J. R. Rapp~~

Truck Mounted CME-75 Drilling Rig

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD TEST BORING RECORD

BAKER ENGINEERS — WE TRAVERSE THE EARTH

BORING NO. 2 (located 18' west of Test Pit 32) Dam Site #1 SHEET 1 OF 3

Approx. 0.5' higher than T.P. #32

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Site STATION --- OFFSET --- GROUND ELEV. apprx. 1139'

Date Started 6/12/75 @ 1:15 p.m. Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs. Fall 30" Ground Water 0 Hrs. see sheet 3

Date Completed 6/13/75 Casing Size ---- Wt. of Hammer --- Fall --- Ground Water 24 Hrs. see sheet 3

Core Size ______ Diameter of Auger 6 1/2 Auger Hollow Stem Weather 6/12/75 - cool, cloudy, rainy 6/13/75 - cool, sunny

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
0.0'-2.0'	red	moist	soft	CLAY, some silt, +PL,	1	0.0'-2.0'	---	Auger
2.0'-4.0'	PISTON SHELBY TUBE SAMPLE, (hit pc. of gravel @ 3.4')			hydraulically pushed pressure 325 psi increasing to 475 psi	2	2.0'-4.0'	---	Shelby, Recov = 2.0' Jar sample collected from tip of shelby @ 4.0'
@ 4.0'	red	moist	m. stiff	Clay, NMC=PL, CH, AUGERED TO - 5.0'				
5.0'-7.0'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 275 psi increasing to 475 psi	3	5.0'-7.0'	---	Shelby, recov = 2.0' Jar sample collected from tip of shelby @ 7.0'
@ 7.0'	red	moist	m. stiff	Clay, varved, -PL, blocky structure AUGERED TO - 9.0', Hit Boulder @ 8.0'				
9.0'-11.0'	PISTON SHELBY TUBE SAMPLE,			hydrualic pressure - 200 psi increasing to 400 psi HIT WATER @ 9.2'	4	9.0-11.0'	---	Shelby, Recov. = 2.0' Jar sample collected from tip of shelby @ 11.0'
@ 11.0'	red brn.	moist	m. stiff	Clay and silt, tr of fine gravel, NMC = PL AUGERED TO 12.0'				
12.0'-14.0'	PISTON SHELBY TUBE SAMPLE, (hit pc. of gravel bending tip of tube)			hydraulic pressure = 275 increasing to 475 psi	5	12.0'-14.0'	---	Shelby Recov = 1.9' Jar sample collected from tip of shelby @ 14'
@ 14.0'	red brn	moist	stiff	Clay, highly plastic NMC = PL AUGERED TO 15.0'				
15.0'-17.0'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 325 to 400 psi	6	15.0'-17.0'	---	Shelby Recov = 2.0' Jar sample collected from tip of shelby @ 17'
@ 17'	varved red-brn & gray brn	moist	m. stiff	Clay, varved, plastic, NMC=PL, 1/8" gray brown layers - silty clay				

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Ronald Kwilinski Helper - Jim Henning INSPECTOR J.R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 2 cont. (located 18' west of Test Pit 32) Dam Site #1 SHEET 2 OF 3

PROJECT Evaluation of Reserve Mining Company's Proposed Mile Post 7 Site Piston Shelby Tube Samples - 3" O.D. thin wall STATION --- OFFSET --- GROUND ELEV. Aprox 1139' (Approx 0.5' higher than T.P. 32)

Date Started 6/12/74 Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs. see sheet 3

Date Completed 6/13/75 Casing Size --- Wt. of Hammer --- Fall --- Ground Water 24 Hrs. see sheet 3

Core Size Diameter of Auger 6 1/2 Hollow Stem Weather heavy rain @1:35 p.m. 6/13

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No	Sample Depth	Blows on Sampler	REMARKS
				AUGERED TO 18.0'				
18.0'-20.0	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure 325 increasing to 400 psi	7	18.0'-20.0	---	Shelby, Recov=2.0' Jar sample collected at tip of shelby @20.0'
@20.0'	gray	moist	M. Stiff	Clay, highly plastic, +PL				
				AUGERED TO - 21.0'				
21.0'-21.6	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 200 psi to 1000psi @21.6' hit pc of gravel @21.6' bending tube	8	21.0'-21.6	---	Shelby, Recov=0.6' Jar Sample Collected from tip of shelby @21.6'
@21.6'	gray	wet	soft	Silt, some clay, little sand, stratified, +PL				
					9	21.6'-23.1	18-19-18	Spoon 0.1' (Augered between samples)
21.6'-28.0	red brn	wet	dense to very dense	Gravel, F-C, some clay, little silt, tr. of sand.	10	23.1'-24.6	29-31-38	Spoon 1.1'
					11	28.0'-29.5	19-113-94	Spoon 0.8'
		started drilling		6/13/75 @28.0'	12	33.0'-33.7	26-150/0.2'	Spoon 0.7 (washed-out augers to 28',33' 38')
28.0'-43.2	red brn w/occ streaks of white	moist	very dense	Gravel, F+M, some clay, trace of silt.	13	38.0'-39.5	27-138-150	Spoon 1.5'
					14	43.0'-43.2	110/0.2'	Spoon
						REFUSAL @43.2		
				Hit boulder at 35.0' augering				(used chopping bit to clean augers to 43')
				Hit several cobbles @40'-43.0' augering				

SEE SHEET 3 of 3

ADVANCED AUGERS AFTER EACH SPOON SAMPLE DRIVE BELOW 21.6'. WASHED OUT AUGERS PRIOR TO SAMPLING EACH INTERVAL BELOW 24.6'

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Ronald Kwilinski Helper - Jim Henning INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC. — Dam Site #1 — PRELIMINARY FIELD TEST BORING RECORD

BAKER ENGINEERS — WE TRAVERSE THE EARTH

BORING NO. 2 (located 18' west of test pit 32) — SHEET 3 OF 3

PROJECT Reserve Mining Company's Proposed Mile Post 7 Site Study — STATION --- — OFFSET --- — GROUND ELEV. Approx 1139'

Date Started 6/12/75 — Sampler Size 1 3/8" ID — Wt. of Hammer 140 lbs — Fall 30" — Ground Water 0 Hrs.

Date Completed 6/13/75 — Casing Size --- — Wt. of Hammer --- — Fall --- — Ground Water 24 Hrs.

Core Size — Diameter of Auger 6 1/2" Hollow Stem — Weather

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
43.2'-45.5	dk red brn	weathered	M. hard	Basalt, porphyritic, fractured & jointed @ 45°-60°, some thin fracture fillings of calcite.				
45.5'-46.2	dk red brn	weathered	M. hard	Basalt, porphyritic, a few thin joints at 10° to 15°, thin joint filled with clay @46.0' @10°				
46.2'-49.2	dk red brn	weathered	M. hard	Basalt, porphyritic, highly fractured & jointed, some fracture fillings of saponite END OF BORING AT 49.2' Boring backfilled with clay 6/14/75				

Long year NQ wireline core drilling

No.	cored	run	recov.	%rec	RQD	
1	43.2'-44.2	1.0'	0.9	90%	0%	
2	44.2'-45.2	1.0'	1.0	100%	0%	
3	45.2'-46.5	1.3'	1.1	85%	46%	0.6'
4	46.5'-49.2	2.7'	0.7	26%	0%	

NOTE: CORE BARREL BLOCKED UP @44.2', 45.2' and at 46.5'

WATER LEVELS

6/12/75	Hit water at 9.2'
6/13/75	Artesian flow - estimated 1 gpm after core drilling, WL - 2' above hole
6/13/75	4.6' (below top of hole) after pulling hollow stem augers

NOTE: SHELBY TUBE SAMPLES FROM BORING #2 POSSIBLY DISTURBED. TUBES WERE SET ON END (TOPS UP) BEFORE POURING WAX SEAL WHEN ONE TUBE FELL OVER - KNOCKING ALL OTHERS OVER ALSO.

DRILLING CO. Braun Engineering, Testing, Inc. — DRILLER Ronald Kwilinski, Helper, Jim Henning — INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC. Flextrack Nodwell Tracked Carrier CME 55 Rig

PRELIMINARY FIELD
TEST BORING RECORD

Piston Shelby Tube Samples - 3" O.D. thin wall

BORING NO. 3 (located 140' S.W.S. of Boring 3016)

SHEET 1 OF 3

PROJECT Reserve Mining Company's Proposed Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. Approx. 1157'

Date Started 6/15/75 @ 10:30a.m. Sampler Size 1 3/8" ID Wt. of Hammer 140 lbs. Fall 30" Ground Water ~~XXXXX~~ Hit water @ 15.0'; water level @ 11.0' with boring advanced to 16.2'

Date Completed 6/17/75 @8:00 a.m. Casing Size --- Wt. of Hammer --- Fall --- Ground Water ~~XXXXX~~

Core Size Diameter of Auger 6 1/2" Hollow Stem Weather 6/15/75-cool, cloudy, rainy 6/16/75-mild, sunny

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
0.0'-1.0'	red	moist	soft	clay, plastic, tr. of fine gravel, + PL	1	0.0'-1.0'	---	Auger
1.0'-3.0'	PUSHED PISTON SHELBY TUBE SAMPLE			hydraulic pressure= 225 psi increasing to 450psi	2	1.0'-3.0	---	Shelby, Recov=1.7' Lost 0.3' of sample at end of tube Jar sample collected from tip of shelby at 3.0'
@3.0'	red brn	moist	M. stiff	Clay, plastic, blocky structure, + PL				
			AUGERED TO	- 4.0'				
4.0'-6.0'	PUSHED PISTON SHELBY TUBE SAMPLE			hydraulic pressure= 150psi increasing to 600psi	3	4.0'-6.0'	---	Shelby, Recov=2.0' Jar sample collected from tip of shelby at 6.0'
@6.0'	red brn	moist	M. stiff	Clay, plastic, NNC=PL, with thin clayey silt varves.				
			AUGERED TO	7.0'				
7.0'-9.0'	PUSHED PISTON SHELBY TUBE SAMPLE			hydraulic pressure= 200psi - 400psi	4	7.0'-9.0'	---	Shelby, Recov=2.0' Jar sample collected from tip of shelby at 9.0'
@9.0'	red brn	moist	M. stiff	Clay, varved, NMC=PL.				
			AUGERED TO	10.0'				
10.0'-12.0'	PUSHED PISTON SHELBY TUBE SAMPLE			hydraulic pressure= 250psi to 550psi, tip of tube bent, hit pc of gravel at 10.6'	5	10.0'-12.0'	---	Shelby, Recov=2.0' Jar sample collected from tip of shelby sample @12.0'
@12.0'	brn	moist	M. stiff	Clay and silt, with silty clay varves, =PL	6	13.0'-15.0'	---	Shelby, Recov=2.0' Jar sample collected from tip of shelby sample @15.0'
			AUGERED TO	13.0'				
13.0'-15.0'	PUSHED PISTON SHELBY TUBE SAMPLE			hydraulic pressure=200 to 300psi				
@15.0'	brn	moist	M. stiff	Silt and clay, varved, =PL, w/some thin clay lenses				

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper-Jim Shearer INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 3 (located 140' SWS of Boring 3016)

SHEET 2 OF 3

PROJECT Reserve Mining Company's Proposed Mile Post 7 Site Study   STATION ---   OFFSET ____   GROUND ELEV. Approx. 1157'

Date Started 6/15/75 @ 10:30 a.m.   Sampler Size 1 3/8'ID   Wt. of Hammer 140 lbs.   Fall 30"   Ground Water 0 Hrs. ____

Date Completed 6/17/75@ 8:00a.m.   Casing Size ---   Wt. of Hammer ---   Fall ---   Ground Water 24 Hrs. ____

Core Size ____   Diameter of Auger 6 1/2" Hollow Stem   Weather ____

Description of Each Stratum					Sample		Blows	
Depth From To	Color	Moisture	Compactness or Consistency	Texture	No.	Depth	on Sampler	REMARKS
			AUGERED TO 16.0',	HIT WATER AT 15.0'				
16.0'-16.3'	PUSHED SHELBY TUBE TO CLEAN HOLE			WATER LEVEL AT 11.0' WITH BORING ADVANCED TO 16.2', 6/15/75, 12:15 p.m.				
16.0'-16.3'	gray	wet	soft	Silt, some clay, tr of large gravel, tr of fine sand + PL				
16.3'-17.2'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure 250psi increasing to 750psi	7	16.3-17.2	---	Shelby, Recov=0.9' Jar sample collected from tip of shelby @17.2'
@17.2'	red brn	wet	soft	Silt, some clay, some med, gravel, tr of fine sand + PL				
17.2'-18.7'	red brn	moist	soft	Silt, some clay, tr of fine gravel, + PL	8	17.2'-18.7'	8-8-12	Spoon Recov 1.4'
18.7'-20.7'	PUSHED PISTON SHELBY TUBE SAMPLE,			hydraulic pressure 200-300psi - No recovery piston did not lock at top of tube after push.				
18.7'-20.3'	dk red brn	wet	soft to M. stiff	SILT and clay, tr. med. gravel. NMC-PL	9	18.7'-20.2'	3-5-12*	Spoon Recov=1.5
						*NOTE: Spoon driven through disturbed intervals.		
20.7'-21.9'			AUGERED TO 20.7'					
20.7'-21.9'	PUSHED PISTON SHELBY TUBE SAMPLE,			hydraulic pressure 250psi 20.7'-21.6' increasing to 800psi @21.6'-21.9' Hit gravel @21.9'	10	20.7'-21.9'	---	Shelby, Recov=1.1'
@21.9'	dk red brn	moist	V. stiff	Silt, some to little clay, trace fine gravel, - PL				
21.9'-25.0'	dk red brn	moist	hard	Silt, some to little clay trace fine gravel, - PL	11	21.9'-23.4'	18-21-27	Spoon Recov 1.0'

DRILLING CO. Braun Engineering, Testing, Inc.   DRILLER Dennis Ruchti   Helper - Jim Shearer   INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC. — PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 3 (located 140' SWS of Boring 3016) SHEET 3 OF 3

PROJECT Reserve Mining Company's Proposed Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. approx. 1157'

Date Started 6/15/75 @ 10:30a.m. Sampler Size 1 3/8 ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs.

Date Completed 6/17/75 @ 8:00a.m. Casing Size --- Wt. of Hammer --- Fall --- Ground Water 24 Hrs.

Core Size Diameter of Auger 6 1/2" Hollow Stem Weather

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
25.0'-28.5'	dk brn	wet	V. dense	SAND, F-M+, little gravel F-M, tr of silt and clay, NP	12	27.0'-28.5'	12-22-33	Recov. Spoon 1.2'
28.5'-42.5'	dk brn	moist	V. dense	GRAVEL, F-M, some clay, little silt, little coarse sand. Numerous cobbles and small boulders present from 38.5'-42.5'	13	33.0'-34.5'	20-58-58	Spoon 1.0'
					14	38.0'-39.0'	18-150	Spoon 0.5'
					15	42.5'-43.1'	130-200/0.1'	Spoon 0.3'
42.5'-50.4'	red brn	moist	V. dense	GRAVEL, F-C, and clay, little silt numerous cobbles from 42.5'-50.4'	16	46.6'-46.9' 6/16/75 WL=9.0'@8:40	200/0.2'	Spoon 0.2'
					17	50.4'-51.4	48-200/0.5'	Spoon 0.8'
50.4'-55.0'	brn	moist	V. dense	GRAVEL, F-C and clay, little silt, little coarse sand. Small Boulder present from 51.4'-52.0'	18	54.9'-56.4'	12-72-74	Spoon 1.2'
					19	60.0'-61.5'	5-25-67	Spoon 1.0'
55.0'-60.0'	brn	wet	V. dense	GRAVEL, M-C, little clay, silt & sand Numerous small boulders and cobbles present from 52'				
60.0'-61.5'	reddish brn	damp	V. dense	GRAVEL and sand, little fines.				

Note: After drilling to 60', boring was reamed with 3-1/8" roller bit from 48' to 60' using "Revert" drilling mud.

Note: Washed out augers w/roller bit or chopping bit below 21.9'

Note: 48' - 60' boring cleaned with 2-7/8" roller bit ahead of augers

Note: END OF BORING @ 61.5' BORING BACKFILLED WITH CLAY 6/18/75

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti INSPECTOR J.R. Rapp to 60.0' A.S. Buangan 60.0'-61.5'

MICHAEL BAKER, JR., INC. Truck Mounted CME-75 Drilling Rig

Dam Site #1

Piston Shelby Tube Samples - 3" O.D. thin wall

PRELIMINARY FIELD TEST BORING RECORD

SHEET 1 OF 4

BORING NO. 4 Boring located 25' north of Boring 1060

PROJECT Reserve Mining Company's, Mile Post 7 Site Study

STATION --- OFFSET --- GROUND ELEV. approx 1130.3'

Date Started 6/17/75 @ 8:35a.m. Sampler Size 1 3/8" ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs. 8.0' 6/18/75@ 5:00

Date Completed 6/18/75@ 5:00p.m. Casing Size --- Wt. of Hammer --- Fall --- Ground Water 24 Hrs. 3.4' 6/19/75

Core Size Diameter of Auger 6 1/2" Hollow Stem Weather 6/17/75 cool, cloudy 6/18/75 warm, sunny

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
0.0'-0.1'	gray	damp	loose	Taconite gravel				
0.1'-2.0'	red	moist	soft-m.stiff	Clay, plastic, + PL	1	0.1'-2.0'	---	Auger
2.0'-4.1'	PISTON SHELBY TUBE SAMPLE			hydraulic pressure= 100psi increasing to 250psi	2	2.0'-4.1'	---	Shelby, Recov=1.6' Jar sample collected from tip of shelby @4.1'
@4.1'	red	moist	soft	Clay, plastic + PL, some minute voids (1/16") present, spongy.				
	AUGERED TO 5.0'							
5.0'-7.0'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure 350 increasing to 500psi	3	5.0'-7.0'	---	Shelby, Recov=2.0' Jar sample collected from tip of shelby @7.0'
@7.0'	varved red&brn	moist	stiff	Clay, varved, = PL				
	AUGERED 7.0'-9.0' - HIT COBBLE AT 7.5'-8.0'							
9.0'-11.0'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 350psi	4	9.0'-11.0'	---	Shelby Recov = 1.8' Jar sample collected from tip of shelby sample @11.C'
@11.0'	red brn	moist	stiff	Clay, plastic, = PL				
	AUGERED TO - 12.0'							
12.0'-14.0'	PISTON SHELBY TUBE SAMPLE			hydraulic pressure = 350psi	5	12.0'-14.0'	---	Shelby, Recov = 2.0' Jar sample collected from tip of Shelby @14.0' Bent tip of shelby @14.0'
@14.0'	brn&red	moist	M.stiff	Clay and silt, w/a few thin red clay varves NMC=PL.				
	AUGERED TO 15.0'							
15.0'-17.1'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 250 to 300 psi	6	15.0'-17.1'	---	Shelby, Recov = 1.8' Jar sample collected from Shelby at 17.1'
@17.1'	red-brn	moist	M. stiff	Clay, plastic, varved, -PL.				

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MICHAEL BAKER, JR., INC.

BAKER ENGINEERS — WE TRAVERSE THE EARTH

PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 4 cont.

SHEET 2 OF 4

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION ______ OFFSET ______ GROUND ELEV. Approx. 1130.3'

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
			AUGERED TO	18.0'				
18.0'-20.1'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure= 250psi increasing to 400psi	7	18.0'-20.1'	---	Shelby, Recov = 1.6' Jar sample collected from tip of shelby
@19.6'	red-brn	moist	stiff	Clay, plastic, = PL				
			AUGERED TO	21.0'				
21.0'-23.0'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 200psi at 21.0'-22.0' increasing to 375 @ 23.0'	8	21.0'-23.0'	---	Shelby, Recov = 2.0' Jar sample collected from tip of shelby.
@23.0'	red-brn	moist	stiff	clay, plastic, = PL				
			AUGERED TO	24.0'				
24.0'-24.9'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure = 200 to +1000psi @24.9'	9	24.0'-24.9'	---	Shelby, Recov = 0.8'
					Tip	of tube bent	at 24.9'	Jar sample collected from tip of shelby
@24.9'	red brn	moist	M. dense	Silt and fine sand, w/ tr of gravel, NP				Spoon Recov.
24.9'-26.4'	brn	wet	M. dense	Sand F-C and gravel, F-M, tr of silt, tr of clay	10	24.9'-26.4'	30-9-17	Spoon 0.9'
					NOTE	: WASHED OUT	AUGERS P	RIOR TO EACH DRIVE BELOW 27.9'
					11	26.4'-27.9'	17-14-23	Spoon 0.6'
26.4'-27.9'	brn	wet	Dense	Sand, F-C, some F-M gravel, little silt, little clay.	12	31.5'-33.0'	34-22-10	Spoon 0.5'
27.9'-34.0'	dk. red brn	moist	hard	Clay, and F-M gravel, little silt, little clay	13	36.5'-37.2'	42-140/0.2'	Spoon 0.5'
		NOTE:	WASHED OUT HOLLOW STEM AUGERS WITH SPOON OR ROLLER BIT BEOFRE SAMPLING BELOW 37.2'		14	41.5'-42.5'	42-143/0.5'	Spoon 0.9'

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Ronald Kwilinski INSPECTOR J. R. RAPP

Helper: Jim Henning

MICHAEL BAKER, JR., INC. — PRELIMINARY FIELD TEST BORING RECORD

BORING NO. ~~4 cont~~ — SHEET 3 OF 4

PROJECT Reserve Mining Company's Mile Post 7 Site Study — STATION ____ OFFSET ____ GROUND ELEV. Approx. 1130.3'

Date Started ____ Sampler Size ____ Wt. of Hammer ____ Fall ____ Ground Water 0 Hrs. ____

Date Completed ____ Casing Size ____ Wt. of Hammer ____ Fall ____ Ground Water 24 Hrs. ____

Core Size ____ Diameter of Auger ____ Weather ____

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
34.0'-40.5'	dk red brn	moist	V. dense	Gravel, F-M+, little clay, little silt NOTE: several cobbles present from 34' to 42.5'	15	46.5'-47.1'	100-75/0.1'	Spoon 0.8' (recov)
					16	51.5'-53.0'	25-50-136	Spoon 1.3' (recov)
40.5'-49.0'	dk red brn	moist	V. dense	SILT, and gravel, F-C, little fine sand, tr of clay. Several cobbles present from 47.5' to 49.5'	17	56.5'-58 0'	68-81-161	Spoon 1.4' (recov)
					18	61.5'-63.0'	23-41-60	Spoon 1.3' (recov)
					19	66.5'-67.0'	145/0.5'	Spoon 0.4' (recov)
49.0'-60.0'	dk red brn	moist	V. dense	GRAVEL, F-C+, some silt, some F. sand, tr of clay.	20	71.5'-71.8'	150/0.3'	Spoon 0.3' (recov)
60.0'-65.0'	dk red brn	moist	V. dense	SAND, fine, and silt, some M. gravel, tr of clay	21	75.0'-75.4'	225/0.4'	Spoon 0.4' (recov)
					22	79.2'-79.4'	180/0.2'	Spoon 0.2' (recov)
65.0'-79.4'	dk red brn	moist to wet	V. dense	GRAVEL, M+-C, and F. sand, some silt, tr of clay. Cobbles present from 74' to 75'		spoon shoe bent on drive 79.2'-79.4' REFUSAL ON ROCK AT 79.4'		
						Longyear NQ wireline Core Drilling		
79.4'-83.0'	dk reddish brown w/ a few lt blue amygdules	sl. weath.	Hard	Basalt, a few small amygdules of calcite and zeolites, a few small vesicles, thin joints at 80.4' & 81.3' at 20° broken from 81.4'-81.6', thin vertical fracture at 82.7'-83.1'		CORED 79.4'-84.4'	RUN 5.0'	RECOV. 4.9' % RECOV. 98% RQD 82%

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Ronald Kwilinski Helper - Jim Henning INSPECTOR J.R. RAPP

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BAKER ENGINEERS — WE TRAVERSE THE EARTH

BORING NO. 4 cont

SHEET 4 OF 4

PROJECT Reserve Mining Company's, Mile Post 7 Site Study STATION ______ OFFSET ______ GROUND ELEV. Approx. 1130.3'

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Description of Each Stratum					Sample		Blows on Sampler	REMARKS
Depth From To	Color	Moisture	Compactness or Consistency	Texture	No.	Depth		
83.0'-84.4'	Dk gray w/ green & white amygdules	sl. weath.	M. hard	Basalt, w/small amygdules of calcite and zeolites, some small vesicles, large (1") amygdule of calcite @ 83.1', joints at 83.6', 84.2', and 84.3', fracture at 83.2'.				

END OF BORING @ 84.4'
BORING BACKFILLED WITH CLAY 6/19/75

NOTE: HIT WATER @24.0'
W.L. @24.0' with boring advanced to 24.9' on 6/17/75 @11:40 a.m.
W.L. @ 7.0' with boring advanced to 61.5' on 6/18/75 @ 8:00a.m.
W.L. @8.0' after completion of boring on 6/18/75 @ 5:00 p.m.
W.L. @3.4' on 6/19/75
BORING BACKFILL WITH CLAYEY SOIL 6/19/75
BREAKDOWN - 6/18/75, 1:25-1:58 p.m. - cat head gear mounting bolts broke

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Ronald Kwilinski INSPECTOR J. R. RAPP
Helper - Jim Henning

CME-55 Drilling Rig Mounted on a Flextrac Nodwell

MICHAEL BAKER, JR., INC. ~~160 Tracked Carrier~~

PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 5 (located 10' NE of Boring 3022)

SHEET 1 OF 3

Estimated 0.3' higher than boring 3022

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. 1161.1'

Date Started 6/19/75 @ 8:00 a.m. Sampler Size 1 3/8" ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs. 4.0' 6/19/75 @1:35

Date Completed 6/19/75@ 1:35 p.m. Casing Size Wt. of Hammer Fall Ground Water 24 Hrs. 1.5' 6/20/75@ 2:05

Core Size Diameter of Auger 6 1/2" Hollow Stem Weather warm, sunny

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No	Sample Depth	Blows on Sampler	REMARKS
0.0'-1.0'	brn	moist	soft	Topsoil, a clayey silt w/tr of root frags, + PL	1	0.0'-1.0'	---	Auger
1.0'-2.0'	red brn	moist	soft	Clay and silt, + PL	2	1.0'-2.0'	---	Auger
2.0'-4.0'	PISTON SHELBY TUBE SAMPLE			hydraulic pressure 200 increasing to 600psi Tip of shelby tube slightly bent as a result of push	3	2.0'-4.0'		Shelby Recov. = 2.0' Jar sample collected from tip of shelby
@4.0'	red brn	moist	stiff	Clay, blocky structure, -PL				
	AUGERED TO 5.0'							
5.0'-6.7'	PISTON SHELBY TUBE SAMPLE,			hydraulic pressure =150 to 700 psi at 6.7' Tip of Shelby tube slightly bent as a result of push.	4	5.0'-6.7'	---	Shelby Recov. = 1.6' Jar sample collected from tip of shelby
@6.7'	brn	moist	stiff	Silt and clay, - PL				
	AUGERED TO 8.0'							
8.0'-10.0'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed hydraulic pressure 150 to 500psi. Tip of shelby tube slightly bent as a result of push.	5	8.0'-10.0'	---	Shelby Recov. = 1.4' Jar sample collected from tip of shelby.
@10.0'	gray	moist	stiff	Silt, little clay, w/ horizontal stratification,-PL				
	AUGERED TO 11.0'							
11.0'-12.2'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed-200 to 600psi hydraulic pressure	6	11.0'-12.2'	---	Shelby Recov. = 0.9' Jar sample collected from tip of shelby.

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti. Helper - Jim Shearer INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC. CME 55 Drilling Rig mounted on a Flextrac Nodwell 160 tracked Carrier

PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 5 (located 10' NE of Boring 3022)

SHEET 2 OF 3

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. Approx. 1161.1'

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
@12.2'	brn	moist	M. stiff	SILT, little clay, w/thin clay varves, =PL				
	AUGERED TO 13.2'							
13.2'-13.4'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed, 200 to 800psi, tube bent	7	13.2'-13.4'	---	Shelby, Recov=0.2' Jar sample collected from from shelby tube.
@13.4'				Sand, fine, and silt, tr. of clay, tr. of fine gravel.				
						NOTE: HIT WATER @13.2'		
	AUGERED TO 14.4'							
14.4'-15.5'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed 100-800psi Tip of tube bent.	8	14.4'-15.5'	---	Shelby, Recov=0.7' Jar sample collected from tip of shelby tube.
@15.5'	brn	wet	loose	Sand, medium, little silt, tr. of gravel.				
	AUGERED TO 16.5'. WITH BORING ADVANCED TO 16.5', WATER LEVEL WAS AT 14.0'							
	WASHED OUT HOLLOW STEM AUGERS TO 16.5'							
16.5'-17.0'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure 200-900psi Tip of tube bent	9	16.5'-17.0'	---	Shelby Recov=0.4' No jar sample collected
@17.0'	brn	wet	loose	SAND, medium, little silt, tr. of gravel.				Recov.
17.0'-24.5'	brn	moist	M. stiff to stiff	SILT and clay, some F-M+ gravel, tr coarse sand	10	17.0'-18.5'	5-30-15	Spoon 1.3'
					11	18.5'-20.0'	8-16-48	Spoon 1.2'
					12	20.0'-21.5'	10-15-19	Spoon 1.0'
					13	21.5'-23.0'	14-17-24	Spoon 1.0'

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper: Jim Shearer INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC. CME 55 Drilling Rig mounted on a Flextrac Nodwell 160 tracked Carrier

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 5 (located 10' NE of Boring 3022)

SHEET 2 OF 3

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. Approx. 1161.1'

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
@12.2'	brn	moist	M. stiff	SILT, little clay, w/thin clay varves, =PL				
	AUGERED TO 13.2'							
13.2'-13.4'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed, 200 to 800psi, tube bent	7	13.2'-13.4'	---	Shelby, Recov=0.2' Jar sample collected from from shelby tube.
@13.4'				Sand, fine, and silt, tr. of clay, tr. of fine gravel.				
						NOTE: HIT WATER @13.2'		
	AUGERED TO 14.4'							
14.4'-15.5'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed 100-800psi Tip of tube bent.	8	14.4'-15.5'	---	Shelby, Recov=0.7' Jar sample collected from tip of shelby tube.
@15.5'	brn	wet	loose	Sand, medium, little silt, tr. of gravel.				
	AUGERED TO 16.5'. WITH BORING ADVANCED TO 16.5', WATER LEVEL WAS AT 14.0'							
	WASHED OUT HOLLOW STEM AUGERS TO 16.5'							
16.5'-17.0'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure 200-900psi Tip of tube bent	9	16.5'-17.0'	---	Shelby Recov=0.4' No jar sample collected
@17.0'	brn	wet	loose	SAND, medium, little silt, tr. of gravel.				Recov.
17.0'-24.5'	brn	moist	M. stiff to stiff	SILT and clay, some F-M+ gravel, tr coarse sand	10	17.0'-18.5'	5-30-15	Spoon 1.3'
					11	18.5'-20.0'	8-16-48	Spoon 1.2'
					12	20.0'-21.5'	10-15-19	Spoon 1.0'
					13	21.5'-23.0'	14-17-24	Spoon 1.0'

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper: Jim Shearer INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 5 cont.

SHEET 3 OF 3 Approx.

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION ______ OFFSET ______ GROUND ELEV. 1161.1

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS	Recov
24.5'-27.5'	brn	moist	stiff	Silt and clay, little M+F gravel, tr coarse sand.	14	23.0'-24.5'	7-12-22	Spoon	0.8
					15	24.5'-26.0'	14-16-21	Spoon	1.4
					16	26.0'-27.5'	8-11-14	Spoon	1.1
27.5'-31.0'	brn	moist	stiff	Clay and silt, trace coarse sand, varved at 28.5' and at 29.5'-29.6'	17	27.5'-29.0'	7-8-9	Spoon	1.2
					18	29.0'-30.5'	6-6-8	Spoon	1.3
					19	29.5'-29.6'	------	Jar	
	AUGERED TO	31.0'			20	31.0'-31.8'	------	Shelby, Recov=0.4'	
31.0'-31.8'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed 31.0'-31.7' 200psi increasing to 900psi at 31.8'	21	31.8'-33.3'	8-12-33	Spoon	1.5'
					22	33.3'-34.8'	6-13-25	Spoon	1.2'
					23	34.8'-36.3'	30-55-33	Spoon	1.4'
@31.8'	red brn	moist	stiff	SILT and clay, little fine gravel, tr coarse sand.					
31.8'-33.3'	red brn	moist	stiff	SILT and clay, little fine gravel, tr coarse sand.	NOTE: ADVANCED AUGER EVERY 3' AFTER SPOON SAMPLING. WASHED OUT AUGERS AFTER ADVANCING BELOW 17.0'				
33.3'-36.3'	red brn	wet	dense to V. dense	SAND, fine and silt, tr of clay, tr of coarse sand, tr of medium gravel below 35.3'					
			END OF BORING @36.3' BORING BACKFILLED WITH CLAY 6/20/75						

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper - Jim Shearer INSPECTOR J. R. Rapp

CME-55 Drilling rig mounted on a Flextrac

MICHAEL BAKER, JR., INC. Nodwell 160 Tracked Carrier

PRELIMINARY FIELD TEST BORING RECORD

BORING NO. 6 (located 25' S. of Test Pit 1081)

SHEET 1 OF 3

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION --- OFFSET --- GROUND ELEV. Approx. 1122.9'

Date Started 6/19/75@ 4:35 Sampler Size 1 3/8"ID Wt. of Hammer 140 lbs Fall 30" Ground Water 0 Hrs. 5.5' 6/20/75@ 12:05

Date Completed 6/20/75@ 12:05 Casing Size --- Wt. of Hammer --- Fall --- Ground Water 24 Hrs. 4.0' after pulling augers 6/20/75 @1:30

Core Size Diameter of Auger 6 1/2" Hollow Stem Weather warm, sunny 6/19/75 cool, cloudy, rainy 6/20/75

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
0.0'-1.0'	brn	moist	V. soft	Topsoil, a silt w/some clay, + PL	1	0.0'-1.0'	---	Auger
1.0'-3.0'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure 200-300psi SAMPLE DISTURBED PISTON CARRIED DOWNWARD WITH TUBE WHEN PUSHED.	2	1.0'-3.0'	---	Shelby Recov = 0.8' Jar sample collected from tip of shelby sample
@3.0'	red brn	moist	soft	Clay, plastic, little medium sand, + PL				
	AUGERED TO 4.0'							
4.0'-6.0'	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure 150psi to 250psi	3	4.0'-6.0'	---	Shelby, Recov = 2.0' Jar sample collected from tip of shelby sample
@6.0'	brn	wet	soft	SILT, some clay, some M-C sand, + PL				
	AUGERED TO 7.0'							
7.0'-9.0'	PISTON SHELBY TUBE SAMPLE			hydraulic pushed hydraulic pressure - 250 psi increasing to 400 psi	4	7.0'-9.0'	---	Shelby, Recov = 1.8' Jar sample collected from tip of shelby sample
@9.0'	red brn	moist	stiff	Clay, highly plastic = PL.				
	AUGERED TO 10.0'							
10.0'-12.0'	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed hydraulic pressure = 150psi increasing to 300psi	5	10.0'-12.0'	---	Shelby Recov = 2.0' Jar sample collected from tip of shelby sample

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti Helper: Jim Shearer INSPECTOR J. R. Rapp

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 6 cont

SHEET 2 OF 3

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION ____ OFFSET ____ GROUND ELEV. Approx. 1122.9'

Date Started ____ Sampler Size ____ Wt. of Hammer ____ Fall ____ Ground Water 0 Hrs. ____

Date Completed ____ Casing Size ____ Wt. of Hammer ____ Fall ____ Ground Water 24 Hrs. ____

Core Size ____ Diameter of Auger ____ Weather ____

Depth From To	Color	Moisture	Compactness or Consistency	Texture	Sample No.	Sample Depth	Blows on Sampler	REMARKS
@12.0'	red brn	moist	M. stiff	Clay, highly plastic + PL				
	AUGERED TO 13.0'							
13.0'-15.0	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure 250psi-300psi	6	13.0'-15.0'	---	Shelby Recov = 2.0' Jar sample collected from tip of shelby tube
@15.0'	red brn	moist	M. stiff	Clay, 1/8" varves, horizontal, plastic + PL				
	AUGERED TO 16.0'							
16.0'-16.9	PISTON SHELBY TUBE SAMPLE			hydraulically pushed hydraulic pressure = 200 psi increasing to 700psi at 16.9' - Tip of tube bent	7	16.0'-16.9'	---	Shelby, Recov = 0.8' Jar sample collected from tip of shelby tube
@16.9'	brn	wet	---	Silt and fine sand, some clay, tr of fine gravel				
	AUGERED TO 17.9'							
17.9'-19.2	PISTON SHELBY TUBE SAMPLE,			hydraulically pushed hydraulic pressure = 200psi to 700psi @19.2'. Tip of tube bent	8	17.9'-19.2'	---	Shelby, Recov = 0.4' Jar sample collected from tip of shelby tube.
@19.1'	red	moist	M. stiff	Clay, plastic, + PL				
@19.2'	red brn	wet	loose	Gravel, medium, trace of silt, sand, clay				
			HIT WATER AT 19.2'					
19.2'-20.7	---	---	---	Sand or silt (?)	9	19.2'-20.7'	12-11-11	Spoon No Recovery
						redrove spoon w/finger trap		No Recovery
20.7'-22.2	red brn	moist	V. dense	Silt, and coarse gravel little sand, little clay	10	20.7'-22.2'	46-48-80	Spoon Recov. = 1.1"
NOTE:	WATER LEVEL ROSE TO 0.0' AFTER SAMPLING TO 22.2'							

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti INSPECTOR J. R. Rapp
Helper: Jim Shearer

MICHAEL BAKER, JR., INC.

PRELIMINARY FIELD
TEST BORING RECORD

BORING NO. 6 cont

SHEET 3 OF 3

PROJECT Reserve Mining Company's Mile Post 7 Site Study STATION ______ OFFSET ______ GROUND ELEV. ______

Date Started ______ Sampler Size ______ Wt. of Hammer ______ Fall ______ Ground Water 0 Hrs. ______

Date Completed ______ Casing Size ______ Wt. of Hammer ______ Fall ______ Ground Water 24 Hrs. ______

Core Size ______ Diameter of Auger ______ Weather ______

Description of Each Stratum					Sample		Blows	REMARKS	
Depth From To	Color	Moisture	Compactness or Consistency	Texture	No.	Depth	on Sampler		Recovery
22.2'-22.4'	red brn	wet	V. dense	Sand, M-C and gravel, fine, little clay	10	20.7'-22.2	46-48-80	Spoon	1.1'
					11	22.2'-23.1	56-100/0.4'	Spoon	1.0'
22.4'-27.5'	red brn	moist	V. dense	Silt, some M-C gravel, little clay	12	23.1'-24.1	95-100/0.5'	Spoon	0.8'
					13	27.0'-27.5	190/0.5'	Spoon	0.5'

END OF BORING @ 27.5'
BORING BACKFILLED WITH CLAY 6/20/75

ADVANCED AUGERS TO BOTTOM OF
HOLE AFTER EVERY OTHER SPOON
SAMPLE DRIVE BELOW 22.1'
WASHED OUT AUGERS WITH
CHOPPING BIT BELOW 22.1'

DRILLING CO. Braun Engineering, Testing, Inc. DRILLER Dennis Ruchti INSPECTOR J. R. Rapp

Helper - Jim Shearer

Inspection of Soil Samples and Interpretation of Soil Zones

Shelby tube and jar samples of soil obtained from our boring program were inspected at our soils laboratory in Beaver, Pennsylvania in July 1975. Each tube sample was extruded, inspected and visually classified. Nearly every tube sample was split longitudinally so that soil stratification and other details could be observed. The split samples were logged and most were photographed. Approximate unconfined compressive strengths of cohesive, i.e., clay and silt, portions of the tube samples were determined with a pocket penetrometer. Each jar sample was inspected and certain jar samples were photographed. Index properties including natural water contents, specific gravity of soil solids, grain size distributions and liquid and plastic limits were determined for a limited number of specimens selected from the tube and jar samples (Appendix D).

Interpretative logs for each of our six borings were prepared using the results of our detailed inspection of soil samples along with information from the field logs given in the previous section of this appendix. The interpretative logs which are presented in the next section of this appendix were used to develop cross-sections along the lines of our borings at Dam Sites 1 and 2-3. Figures B-1 and B-2 show the plan locations of these cross-sections. The cross-sections for Dam Sites 1 and 2-3 are shown in Figures B-3 and B-4, respectively. Some information from the field log of Boring CASA 3004 (made for Casagrande Consultants and inspected by an engineering geologist from W.A. Wahler and Associates, two other consultants to the State of Minnesota) was used in developing the cross-section in Figure B-4. Otherwise, the soil zones shown in Figures B-3 and B-4 are based entirely on our own boring data. It should be noted, however, that the soil zone boundaries shown in Figures B-3 and B-4 are consistent with our interpretation of information given in the logs of many of the borings made by Reserve's consultants in the vicinities of our two cross-sections.

INTERPRETATIVE LOGS OF BORINGS

INTERPRETATIVE LOG – BAKER BORING 1

LOCATION: DAM SITE 2-3, NEAR KLOHN BORING 3012

Elevation - Ft.	Depth - Ft.	Description
1150-1149±	0-1±	**Topsoil**
1149-1127±	1-23±	**Lacustrine Deposit** Moist, stiff to very stiff, red-brown highly plastic clay with locally a little gravel and silt and traces of sand. Laminated clay (but not varved with silt or sand) El. 1149-1141±. Clay generally varved with thin seams gray silt and brown very fine to fine sand El. 1141-1129±. Varves and laminations crossbedded at about 45° to horizontal El. 1141-1137±. Numerous slickensides in clay (generally parallel to laminations and varves) El. 1141-1131±. Top 4 ft.± of lacustrine deposit appears to have been loosened by plant roots, frost action, and/or seasonal shrinkage and swelling. Pocket penetrometer unconfined compressive strengths of relatively undisturbed tube samples ranged from about 1.0 to 3.5 tsf and averaged 1.5 to 2.0 tsf; the lower individual values corresponded to stiff clay and the higher individual values corresponded to very stiff silt or clay seams.
1127-1114±	23-36±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – interbedded, wet, loose to dense, brown sand, silt, and gravel; some clay seams; crudely stratified. Hit water – apparently under artesian head – at 25.0 ft. (El. 1125±) during drilling.
1114-1106±	36-44±	**Old Alluvium or Young Till** May be denser basal portion of Transition Zone (alluvium) or till deposited in last stage of glaciation. Wet, dense to very dense interbedded brown sand and silt, traces of gravel and clay, a few cobbles at El. 1110 and 1108.
1106-1095±	44-55±	**Old Lacustrine Deposit** May have been deposited in earlier stage of glaciation than upper Lacustrine Deposit, then overridden by glacier. Interbedded, moist, very dense fine brown sand and gray silt with some thin varves of highly plastic red-brown clay.

INTERPRETATIVE LOG – BAKER BORING 1

LOCATION: DAM SITE 2-3, NEAR KLOHN BORING 3012

(Continued)

Elevation - Ft.	Depth - Ft.	Description
1095-1074±	55-76±	**Old Till** Lodgement till – moist very dense brown sand and gravel with a little silt and clay, locally some cobbles and boulders. (There may be a second artesian aquifer at contact between base of Old Till and top of Bedrock – wet, very dense gravel and clay El. 1076-1074±.)
below 1074±	below 76±	**Bedrock** Hard, purple-brown amygdaloidal to vesicular basalt.

INTERPRETATIVE LOG – BAKER BORING 2

LOCATION: DAM SITE 1, NEAR KLOHN BORING 32

Elevation - Ft.	Depth - Ft.	Description
1139-1138±	0-1±	**Topsoil**
1138-1117±	1-22±	**Lacustrine Deposit** Moist, medium stiff to very stiff, red-brown, gray-brown, and gray laminated to varved clay and silt with numerous thin seams or medium dense to dense sand and traces of gravel. Top 4 ft.± of lacustrine deposit appears to have been loosened by plant roots, frost action, and/or seasonal shrinkage and swelling. Some crossbedding at about 30° to horizontal with slickensides generally parallel to crossbedding in highly plastic red-brown clay El. 1133-1122±. Mainly gray (unoxidized and possibly slightly organic) sediments with numerous alternating clay, silt, and sand seams from approximate El. 1120 to 1117 (2-1/8 in. thick red clay varves El. 1117.2±) inferred glacial lake bottom deposits. Moderately sensitive red and gray highly plastic clay El. 1122-1120±. Pocket penetrometer unconfined compressive strengths of relatively undisturbed tube samples ranged from about 0.5 to 2.5 tsf with considerable variation depending on grain size and consistency of individual seams and zones. No definite correlation of stiffness or unconfined strength with depth could be discerned from the tube samples of Boring 2. Water was encountered at approximate El. 1130 in the Lacustrine Deposit during drilling; this is believed to reflect perched water in a silt seam. An artesian aquifer may exist below approximate El. 1119 in a pervious zone at the base of the Lacustrine Deposit and top of the underlying Transition Zone.
1117-1116±	22-23±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – wet loose to dense brown sand and gravel, some silt. (Transition Zone is very thin here and no good samples were obtained; description is based on observed characteristics of Transition Zone in other Baker borings.)

INTERPRETATIVE LOG – BAKER BORING 2

LOCATION: DAM SITE 1, NEAR KLOHN BORING 32

(Continued)

Elevation - Ft.	Depth - Ft.	Description
		From a hydraulic standpoint, Transition Zone should be considered to include lower 1 ft.± of Lacustrine Deposit described above.
1116-1096±	23-43±	**Till** Lodgement Till – moist, very dense gravel, some clay, little silt and sand, occasional cobbles and boulders. There appears to be an artesian aquifer at contact between base of Till and top of Bedrock – El. 1096±.
below 1096±	below 43±	**Bedrock** Medium hard, weathered red-brown basalt.

INTERPRETATIVE LOG – BAKER BORING 3

LOCATION: DAM SITE 2-3, BETWEEN KLOHN BORINGS 3016 AND 3018

Elevation - Ft.	Depth - Ft.	Description
1157-1156±	0-1±	**Topsoil**
1156-1142±	1-15±	**Lacustrine Deposit** Moist, medium stiff to very stiff, red-brown highly plastic clay with laminations and varves of moist, stiff to very stiff gray clay, silt, silty clay, and clayey silt; and damp, medium dense to dense brown fine sand and silty sand (classic varved lacustrine deposit). Numerous crossbedded intervals and slickensides in clay El. 1152-1142± suggest extremely turbulent deposition and/or possible sub-aqueous slumping during or after deposition. Top 3 ft.± of lacustrine deposit appears to have been loosened by plant roots, frost action, and/or seasonal shrinkage and swelling. Pocket penetrometer unconfined compressive strengths of relatively undisturbed tube samples ranged from 0.5 to 3.0 tsf, typically about 1.0 to 1.5 tsf, for clay and about 2.0 tsf for silt.
1142-1135±	15-22±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – interbedded damp to wet, medium dense to dense brown silty sand and gravel, trace of clay; crudely stratified with alternating water bearing seams estimated to have horizontal coefficient of permeability on the order of 10^{-3} to 10^{-4} cm/sec. Hit water under artesian head at 15.0 ft. (El. 1142±) during drilling.
below 1135±	below 22±	**Till** Moist (locally damp or wet very dense brown gravel with locally some cobbles, sand, silt, and clay.

Note: There is a possibility (presently considered fairly remote) that the Transition Zone could extend to a depth of about 29 ft. (El. 1128±).

INTERPRETATIVE LOG – BAKER BORING 4

LOCATION: DAM SITE 1, NEAR KLOHN BORING 1060

Elevation - Ft.	Depth - Ft.	Description
1130-1129±	0-1±	**Topsoil**
1129-1106±	1-24±	**Lacustrine Deposit** Moist, stiff to very stiff red-brown, highly plastic massive to laminated and varved clay, traces of silt, sand, and gravel. Top 6 ft.± appears to have been loosened by plant roots, frost action, and/or seasonal shrinkage and swelling. Varved red clay and gray clayey silt El. 1125-1123± and 1115-1111±. Red and gray clay with laminated to massive and blocky structure El. 1121-1116± and 1111-1107±. Some slickensides in clay El. 1120-1110±. Pocket penetrometer unconfined compressive strengths of relatively undisturbed tube samples ranged from about 1.0 to 2.5 tsf and averaged about 1.3 to 1.5 tsf for the clays with values of 2.0 to 4.0 tsf for very stiff to hard silt seams.
1106-1102±	24-28±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – wet, medium dense to dense, gray to brown sand, some gravel and silt traces of clay; crudely stratified. Hit water – apparently under artesian head – at 24.0 ft (El. 1106) during drilling.
1102-1051±	28-79±	**Till** Lodgement Till – moist, very dense brown gravel and sand, some silt, a little clay, and occasional cobbles.
below 1051±	below 79±	**Bedrock** Medium hard to hard, red-brown to gray, slightly weathered basalt with a few amygdules and vesicles.

INTERPRETATIVE LOG – BAKER BORING 5

LOCATION: DAM SITE 2-3, NEAR KLOHN BORING 3022

Elevation - Ft.	Depth - Ft.	Description
1161-1160±	0-1±	**Topsoil**
1160-1148±	1-13±	**Lacustrine Deposit** Moist, stiff to very stiff, red-brown highly plastic clay with traces of gravel, silt, and sand. Massive to slightly laminated clay (but not varved with silt or sand), very brittle and crumbly with local zones of blocky structure and some slickensides, El. 1158-1154±; no trace of roots – clay may have been loosened by frost action and/or seasonal shrinkage and swelling. Clay varved with thin seams of gray silt and very fine brown sand El. 1152-1148±, with silt laminations apparently predominant below El. 1150±. Lacustrine clay much less slickensided and crossbedded in Boring 5 than in Borings 1 and 3. Pocket Penetrometer unconfined compressive strengths of relatively undisturbed tube samples ranged from about 1.0 to 3.5 tsf and typically averaged about 2.0 tsf for clay as well as silt seams.
1148-1126±	13-35±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – interbedded, moist to wet, loose to dense brown sand (mainly fine to medium grained) and silt with local concentrations of gravel and clay; crudely stratified. Visual observations of split tube samples El. 1148-1144± and 1130-1129± suggest presence of fine horizontal stratification in sand and silt, with estimated horizontal coefficient of permeability on order of 10^{-3} to 10^{-4} cm/sec. for these stratified intervals. Transition Zone generally appears to become less pervious with depth below approximate El. 1144 – appearance is that of silty sand – sandy silt alluvium. Red clay varves in stiff gray silt at approximate El. 1132 suggest older lacustrine deposits near bottom of Transition Zone (perhaps due to water level fluctuation in glacial lake). Hit water under artesian head at approximate El. 1148-1145 during drilling.

INTERPRETATIVE LOG – BAKER BORING 5

LOCATION: DAM SITE 1, NEAR KLOHN BORING 1081

Elevation - Ft.	Depth - Ft.	Description
below 1126±	below 35±	**Till** Lodgement till – wet, very dense brown sand and silt with a little gravel.

INTERPRETATIVE LOG – BAKER BORING 6

LOCATION: DAM SITE 1, NEAR KLOHN BORING 1081

Elevation - Ft.	Depth - Ft.	Description
1123-1122±	0-1±	**Topsoil**
1122-1106±	1-17±	**Lacustrine Deposit** Moist, soft to medium stiff, highly plastic red-brown clay, little silt, trace sand – appears to have been loosened by plant roots, frost action, and/or seasonal shrinkage and swelling – El. 1122-1119±. Moist to wet, soft, gray-brown organic silt with few thin seams of organic clay, twigs, and sand-inferred swamp or stream back channel type deposit – El. 1119-1115±. Moist, medium stiff to stiff red-brown highly plastic clay, traces of silt, gravel and sand – El. 1115-1106±. Portions of clay are laminated to varved with gray silty clay of medium plasticity. Clay contains a few thin silt seams and is moderately sensitive from El. 1110-1106±. Pocket Penetrometer unconfined compressive strengths of relatively undisturbed clay from El. 1115-1111± averaged about 1.0 tsf. No penetrometer data were obtained on clay from El. 1110-1106± due to disturbance in handling samples. Moist, medium dense, brown sand (mainly medium grained) with a little silt and a trace of clay (0.5 in. thick at El. 1106±) believed to mark top of underlying Transition Zone.
1106-1101±	17-22±	**Transition Zone** Alluvium (possibly glacial lake bottom deposit, outwash, and/or somewhat water sorted ablation till) – interbedded, moist to wet, loose to very dense brown sand and gravel, some silt with a few thin seams of soft red clay (based on material in Samples 7, 8 and 10). Hit water at 19.2 ft. (El. 1104±) during drilling and artesian water rose to ground surface after sampling to 22.2 ft. (El. 1101±).
below 1101±	below 22±	**Till** Lodgement Till – moist, very dense brown silt some gravel, little clay.

APPENDIX C

GEOTECHNICAL RECONNAISSANCE
BY
MICHAEL BAKER, JR., INC.

APPENDIX C

GEOTECHNICAL RECONNAISSANCE
BY
MICHAEL BAKER, JR., INC.

General

Geotechnical reconnaissance work at the Mile Post 7 site was conducted intermittently during the period from June 6 to June 21, 1975, by personnel from Michael Baker, Jr., Inc. and by personnel from W.A. Wahler and Associates, another consultant to the State of Minnesota. Unless otherwise noted, all information and interpretations presented in this appendix were derived from the work of our personnel.

Much of the information resulting from reconnaissance work by Baker and Wahler personnel is shown on Figure C-1, "Map of Preliminary Geologic Reconnaissance". The locations of 23 color polaroid photographs taken by our personnel are indicated on Figure C-1. Prints of these photographs are on file at our office in Beaver, Pennsylvania, and at the Reserve Project Team office in Roseville, Minnesota. More than one hundred 35 mm color slides were taken during our reconnaissance work from June 18 to June 21, 1975. The locations of these slides are not shown on Figure C-1 but labeled copies of the slides are on file at our office and at the Reserve Project Team office.

Our reconnaissance was preliminary in nature and not all portions of the Mile Post 7 site were inspected. Because of time and other limitations, we concentrated our efforts on those areas which we felt were of most immediate concern relative to an evaluation of Reserve's tailings disposal plans. These areas were Dam Sites 1 and 2-3 and the rock ridge along the east side of the proposed fine tailings basin. Our observations in these areas plus the results of our subsurface exploration program (Appendix B) lead to the conclusion that geologic conditions at the Mile Post 7 site are significantly different and considerably more complex than indicated by Reserve's consultants.

Leakage Zones

Our reconnaissance indicated the presence of three potential leakage zones along the rock ridge on the east side of the proposed fine tailings basin:

1. Open joints in ridge rock
2. Talus deposits
3. Sand and gravel deposits

Approximate locations of portions of these zones are shown in Figure C-1. In addition, our reconnaissance plus our boring program (Appendix B) disclosed a "transition zone" of pervious to semi-pervious sandy soil between the relatively impervious lacustrine clay and glacial till deposits on the valley bottom (Figures B-3 and B-4). Based on currently available information it is considered likely that there is some contact and/or connection between the "transition zone" and the three relatively pervious zones on the east ridge. Our present hypothesis regarding such contact and/or connection is shown in Figure C-2, a cross-section sketch through the east abutment of proposed Dam 1.

Open joints and fractures exist in rock exposures on the east ridge within the upper portion of the proposed fine tailings basin (Figures C-1 and C-2). Small seeps and springs were observed at some of the joints, indicating that they transmit groundwater from the ridge. Joint and fracture origins are undetermined at this time. It seems probable that some joints and fractures were formed by past tectonic activity while others resulted from glacial plucking, post-glacial rebound and/or stress relief, and perhaps other causes. The depths to which open joints and fractures continue eastward into the rock ridge could not be determined in our reconnaissance.

Talus deposits consisting of cobble to large boulder size rock fragments with large interstitial voids exist on the east ridge below rock outcrops and within the upper portions of the proposed fine tailings basin (Figures C-1 and C-2). In our opinion, these talus deposits are extremely pervious and they are not amenable to treatment by grouting. We also believe that the coarse tailings fill and fine tailings beach proposed by Reserve's consultants for the east side of the fine tailings basin would be relatively ineffective in preventing leakage through the talus deposits. Upper edges of the talus appear to be in contact with open jointed ridge rock; middle portions of the talus appear to be underlain by glacial till; and lower portions of the talus (at least in the east abutment areas of Dams 1 and 2-3) appear to overlie or interfinger with sand and gravel deposits.

The sand and gravel deposits are inferred to be of glacial ice contact or outwash origin. In the east abutment of Dam 1, the sand and gravel deposits appear to overlie glacial till and extend beneath the lacustrine clays (Figure C-2). It seems likely that the sand and gravel deposits are thus part of or at least connected to the "transition zone" between the lacustrine clay and glacial till on the valley bottom. If this is the case, surface and ground water from the ridge probably flow through the sand and gravel to the "transition zone", thereby creating artesian conditions in the latter zone. The sand and gravel ice contact and/or outwash deposits were observed to extend through the entire east abutment area of Dam 1 to a point south of the proposed east seepage recovery dam (Figure C-1). Limited observations suggest that similar sand and gravel deposits exist in the east abutment area of Dam 2-3 and at the location of previously abandoned Dam 3.

Present information suggests that the "transition zone" between lacustrine clay and glacial till extends downstream from both Dam 1 and Dam 2-3. If this is indeed the case, mineral fibers might leak from the fine tailings basin via the "transition zone" which, as indicated above, is probably hydraulically connected to pervious zones along the east ridge. Even if it is shown that tailings and/or natural soils will prevent migration of mineral fibers, it is highly probable that the "transition zone" would transmit uplift water pressures from the fine tailings basin and/or the east ridge into the dam foundations. Such uplift pressures, which could significantly reduce stability of the dams, do not appear to have been considered by Reserve's consultants in their designs for Dams 1 and 2-3.

Stability Considerations

From June 18 to June 20, 1975, our personnel inspected numerous test pits which had been excavated previously in the lacustrine clay soils at Dam Sites 1 and 2-3 by Reserve's consultants. Most of these test pits were quite fresh (at most a few days old) and they provided an excellent opportunity to observe upper portions of the lacustrine clays on a large scale. Upper portions of the lacustrine clays were generally found to be highly plastic, overconsolidated by desiccation, fissured to blocky in structure, with numerous relatively pervious horizontal to sub-horizontal seams and zones. Vertical permeability of the upper portions of the lacustrine deposits is considered to be very low. Horizontal permeability is considered to be much higher, however, due to sand and silt seams plus fractured and fissured zones. Many of the latter contain slickenslides, i.e., polished surfaces which suggest previous shear displacement. These features observed in the test pits were also observed in tube samples from our boring program (Appendix B).

The pervious seams and zones in the lacustrine clay deposit indicate that vertical sand drains are not necessary to dissipate excess pore water pressures which might be induced by construction of the starter dams and initial coarse tailings portions of Dams 1 and 2-3. Moreover, sand drain installation would have the following detrimental effects:

1. Reduction of lateral continuity of natural drainage layers by smear effects.

2. Reduction of soil strength by remolding effects.

3. Increase of pollution potential by shortening potential leakage paths from the "transition zone".

Pervious seams and zones in the clay deposit which would be beneficial in dissipating excess pore water pressures during initial dam construction might also transmit uplift water pressures from the fine tailings basin in later stages of the proposed project. Such uplift pressures would reach their maximum values near the end of the active life of the tailings basin when supernatent water reached its maximum level above the fine tailings. These uplift water pressures, like those in the "transition zone" discussed above, would tend to reduce dam stability.

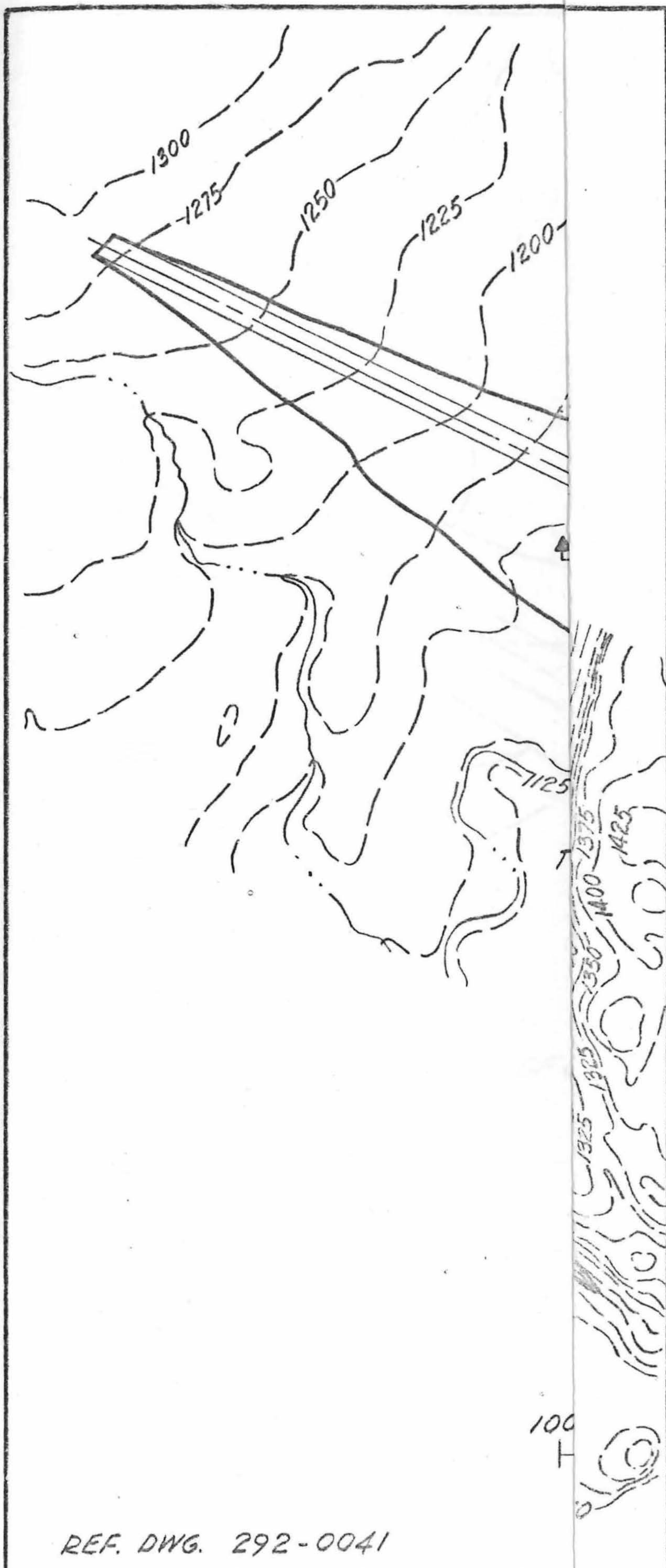
From a strength-deformation-stability standpoint, it seems to us that Reserve's consultants considered the probable behavior of lacustrine foundation soils at Dams 1 and 2-3 to be essentially that of soft to medium stiff clay. Our field observations and boring information indicated the presence of slickensided, fissured and fractured zones, especially in the upper highly plastic and relatively brittle portions of the lacustrine clay. To us, these features suggest that foundation behavior will be more like that of a very stiff clay. This lead to our concern with residual strength of the lacustrine clay (Appendix D) and stability criteria based on residual strength (Appendix E).

Miscellaneous

Our reconnaissance work in June 1975 indicated some aspects of site geology which, while less significant than leakage and stability related aspects, still merit brief mention here.

The glacial till was observed to contain numerous coarse gravel to large boulder size rock fragments. Considerable processing would be required to remove oversize particles from glacial till borrow materials and portions of borrow areas might have to be abandoned because of high boulder content.

Numerous organic silt and clay deposits exist in the valley bottoms at Dam Sites 1 and 2-3. Soft organic deposits would of course have to be removed prior to dam construction.



REF. DWG. 292-0041

FIGURE B-1

PLAN AND LOCATION OF BORINGS
DAM SITE 1

MILE POST NO. 7
DISPOSAL SITE

PREPARED BY
MICHAEL BAKER, JR., INC.
BEAVER PA.

AUG. 1975

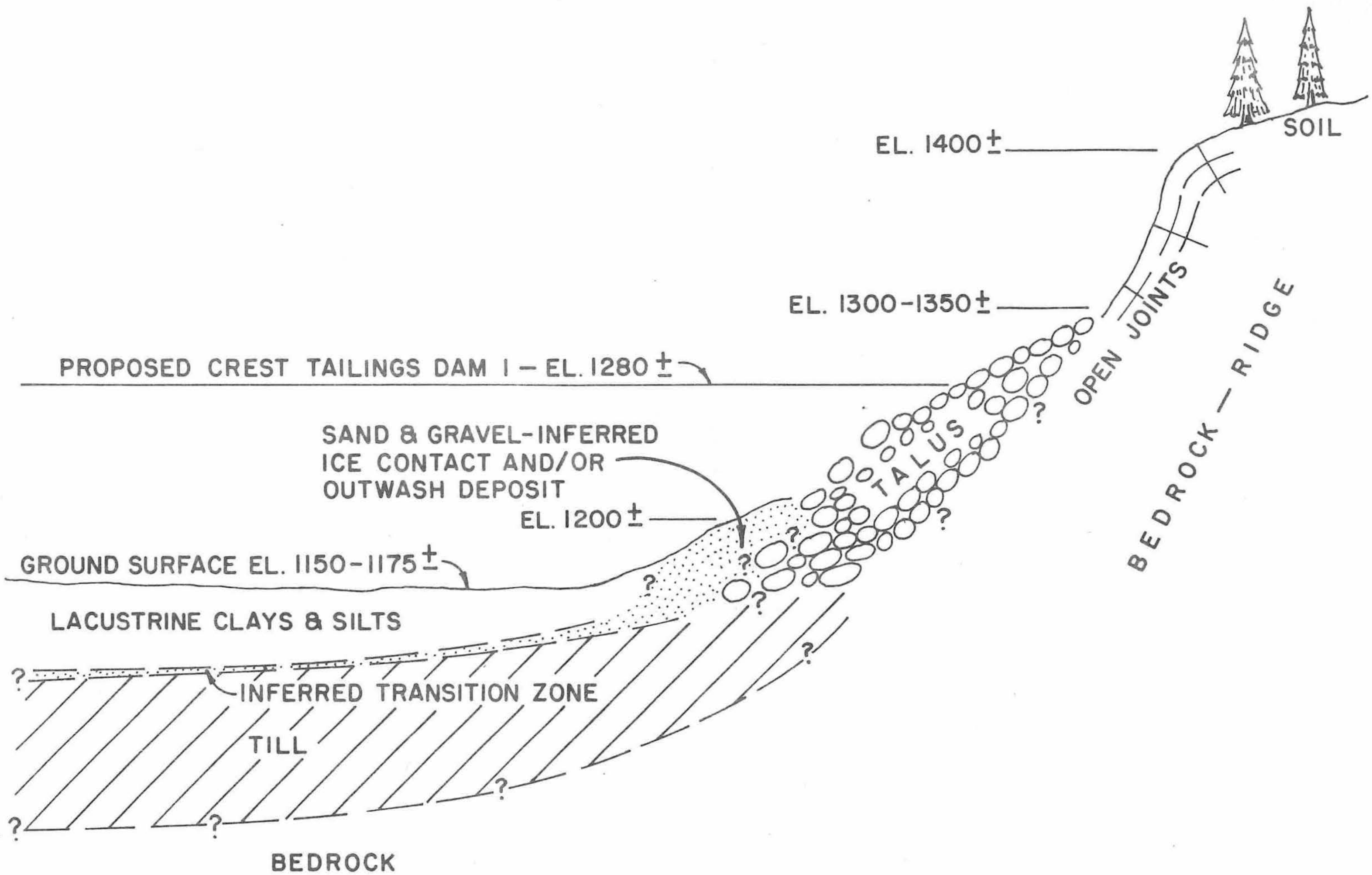


FIGURE C-2

RESERVE MINING CO.
MILE POST 7 SITE

GENERALIZED GEOLOGIC
SECTION THRU EAST
ABUTMENT DAM I-LOOKING NORTH

Not to Scale, Aug. 1975

APPENDIX D

LABORATORY SOIL TESTING
BY
MICHAEL BAKER, JR., INC.

APPENDIX D

LABORATORY SOIL TESTING
BY
MICHAEL BAKER, JR., INC.

Index Properties

As indicated in Appendix B, we performed index properties tests on a limited number of specimens from tube and jar samples obtained in our boring program. Our original intent in performing these tests was to obtain numerical data for comparison with certain results of our visual inspection of soil samples. During the course of our work, however, it became apparent that our standard index properties sampling and testing procedures were inadequate for determination of index properties of those geologic details, e.g., thin pervious seams and minute structural and textural features, which we anticipate will exert significant influences on engineering behavior of the foundation soils at Dam Sites 1 and 2-3. Therefore, we terminated our index properties testing program.

Index properties data obtained in our abbreviated program of tests are summarized in Table D-1. It is our opinion that most of the data in this table are at best of qualitative value in assessing probable engineering behavior of the soils tested. The only exceptions to the preceding statement are the index properties data on the highly plastic clay specimens from 3.5 to 4.0, 6.7 to 6.9, and 6.7 to 7.0 feet depths in Boring 2.

TABLE D-1

INDEX PROPERTIES TEST RESULTS
GEOTECHNICAL EVALUATION OF MILE POST 7 SITE

Boring Number	Depth (Feet)	Liquid Limit %	Moisture Content %	Plastic Limit, %	Soil Type USC
1	14.7	51	–	26	CH
	15.0	52	–	27	CH
	15.8	50	–	26	CH
2	3.5 - 4.0	75	36.9	30	CH
	6.7 - 6.9	75	38.4	33	CH
	6.7 - 7.0	74	41.0	25	CH
	21.0 - 21.6	19	28.6 *	15	ML-CL
	23.1 - 24.6	15	9.1	12	SM
	28.0 - 29.5	21	10.4	16	SM-SC
3	16.3 - 17.2	17	–	14	SM
	21.1 - 21.5	21	–	15	SM-SC
4	24.9 - 26.4	N.O.	8.4	N.P.	SM
	26.4 - 27.9	N.O.	10.0	N.P.	SM
5	6.0 - 6.3	30	–	22	CL
	13.2 - 13.4	20	–	14	ML-CL
	14.6 - 15.0	N.O.	–	N.P.	ML
	31.2 - 31.5	18	–	13	SM-SC
6	16.0 - 16.9	14	15.6 *	10	SM-SC
	20.7 - 22.2	16	9.3	11	SM-SC
	22.2 - 23.1	N.O.	8.8	N.P.	SM

Notes:

USC = United Soil Classification System
N.O. = Not Obtained
N.P. = Non-Plastic

* Moisture content unrealistically high, probably due to testing of wet pervious seam and/or moisture migration in sample prior to testing.

Direct Shear Tests

Our observations of the nature of lacustrine clay soils at the Mile Post 7 site (Appendices B and C) lead to concern about the effective stress strength-deformation behavior of these soils under the loading conditions which might be imposed by Dam 1 and Dam 2-3. Stiff, fissured, highly plastic clays like those in the upper portions of the lacustrine deposit typically exhibit brittle strain-softening behavior under drained loading conditions (e.g., Skempton, 1964). This behavior is characterized by mobilization of the maximum or peak shear resistance at a relatively small shear displacement, then substantial decrease in strength with continuing displacement. The minimum shear strength, termed the ultimate or residual strength, is usually reached after a displacement on the order of one to several inches. Residual strengths for highly plastic clays like those at the Mile Post 7 site are typically equal to or less than about half of the peak strengths for a given effective normal stress. Implications of this type of strength – deformation behavior with regard to dam stability are discussed in Appendix E.

According to Drawing No. 292-0030 of the April 1975 "Design Report" by Reserve's consultants, the lacustrine clays were considered, for design purposes, to have a peak strength characterized by an effective stress Mohr-Coulomb cohesion intercept, $\bar{c}$, of zero and an effective stress Mohr-Coulomb friction angle, $\bar{\phi}$, of 17^o; residual strength parameters were considered to be $\bar{c} = 0$, $\bar{\phi} = 13^o$. We have reviewed soil test data provided to the State of Minnesota by Reserve's consultants and we cannot find sufficient information to support the peak and residual strength values used for design. We have also used empirical correlations between plasticity index (equal to liquid limit minus plastic limit) and peak and residual friction angles given by Kanji (1974) to estimate friction angles for the highly plastic lacustrine clays. Using a typical value of 40 percent for the plasticity index of the clays, Kanji's correlations suggest a peak friction angle equal to or greater than about 16^o and a residual friction angle on the order of 9^o.

In order to obtain data on peak and residual shear strengths as well as strength-deformation behavior of the lacustrine clay, we performed a series of three consolidated-drained direct shear tests using the shear box reversal technique (Skempton, 1964) to obtain residual strengths. Direct shear specimens were taken from a relatively undisturbed tube sample obtained in our Boring 2 at Dam Site 1. The specimens were located at a nominal depth of 6.5 feet (approximately Elevation 1132.5) in moist, very stiff, red brown, highly plastic, thinly laminated clay with traces of sand and silt. This clay had an average liquid limit of 75 percent, an average plastic limit of 29 percent and an average natural water content of 45 percent. A slickenside at 30^o to the horizontal was located at a depth of 6.5 feet. Direct shear Specimen 1 was taken just above the slickenside at a depth of 6.4 feet. Direct shear Specimens 2 and 3 were taken just below the slickenside at depths of 6.5 and 6.6 feet, respectively. Each specimen was 2.0 inches square by 0.7 inches thick. A Soiltest Model D-120 direct shear machine was used for the tests.

Specimen 1 was consolidated under an effective normal stress of 40 psi for 44 hours prior to shear. Figure D-1 is a plot of the ratio of shear stress to effective normal stress, $\tau/\bar{\sigma}$ vs. cumulative shear displacement, δ, for initial shear and three repeated shearings. This plot shows very brittle behavior during initial shear with the peak strength mobilized at a displacement of 0.02 inches. The minimum residual strength characterized by $\overline{\phi} = 10^{\circ}$ was reached at a cumulative shear displacement of about 0.6 inches. The average shear displacement rate was 0.0005 in./min. up to peak strength mobilization and 0.002 in./min. during other portions of the test. These displacement rates are considered slow enough for drained shear.

The failure surface of Specimen 1 was inspected and photographed at the end of the test. This failure surface was very highly slickensided with a slight waviness which was insufficient to influence test results. There was a very thin (approximately 1 mm thick) lamination of intensely remolded clay on each side of the failure surface. Specimen breakdown and extrusion between the shear box halves during the test was minimal. The results of this test are considered reliable.

Specimen 2 was consolidated under an effective normal stress of 20 psi for 63 hours prior to shear. No plot of $\tau/\overline{\sigma}$ vs. δ is included here. The test was stopped after the second repeated shearing because of anomalous data and specimen disintegration and extrusion between the shear box halves. The failure surface was inspected and photographed after the test was stopped. This failure surface had undulations of 1/8 inch maximum amplitude which extended into the shear box halves and interferred with the shearing process. About 1/3 of the failure surface was covered with broken clay fragments while the other 2/3 had slickensides on the undulations. No meaningful data were obtained from this test.

Specimen 3 was consolidated under an effective normal stress of 60 psi for 46 hours prior to shear. Figure D-2 is a plot of $\tau/\overline{\sigma}$ vs. δ for initial shear and three repeated shearings. This plot shows fairly brittle behavior during initial shear with the peak strength mobilized at a displacement of 0.05 inches. The minimum residual strength characterized by $\overline{\phi} = 12^{\circ}$ was reached at a cumulative shear displacement of about 0.6 inches. The average displacement rate was 0.0017 in./min. up to peak strength mobilization and 0.003 in./min. during other portions of the test. These displacement rates are considered slow enough for drained shear.

The failure surface of Specimen 3 was inspected and photographed at the end of the test. This failure surface was highly slickensided with undulations of 1/8 inch maximum amplitude. There was a paste of remolded clay around the specimen edges in the gap between the shear box halves and there appeared to have been some interference of shear box edges in the failure surface. (This interference probably occurred during shear box reversal at the end of each shearing.) Specimen breakdown and extrusion between the shear box halves during the test was noticeable. All of these things taken together suggest that a true residual strength probably was not reached in this test. The peak strength from this test is considered reliable but not quite as reliable as that from the first test.

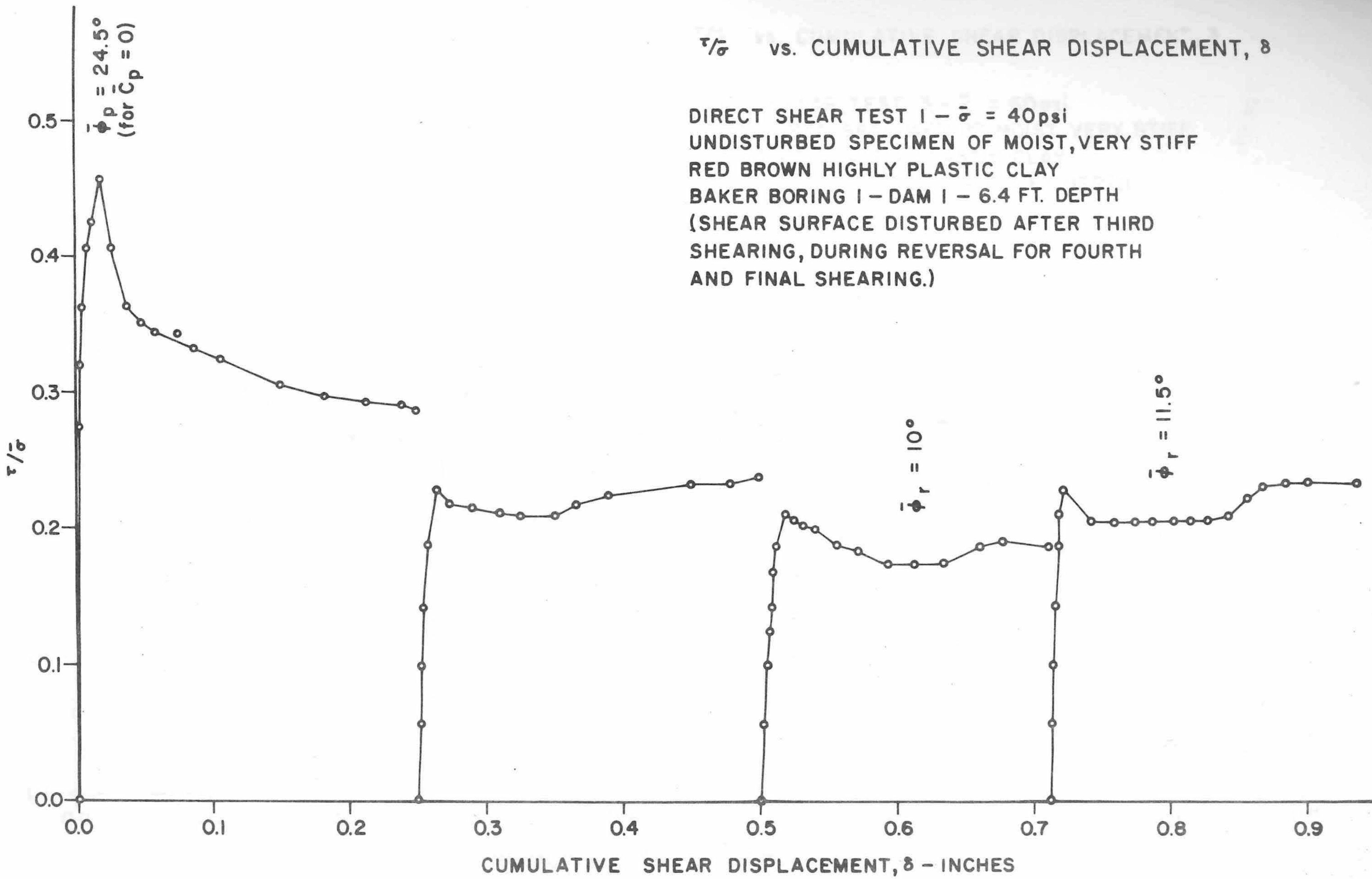
Peak and residual strength data and Mohr-Coulomb failure envelopes from Tests 1 and 3 are plotted in Figure D-3. The peak strength envelope has $\overline{c} = 7.9$ psi = 1140 psf and $\overline{\phi} = 14^{\circ}$. The residual friction angle from Test 1 is 10° and that from Tests 3 is 12°. For the reasons mentioned above, Test 3 probably did not reach a true residual strength. We therefore consider the residual friction angle of the clay tested to be on the order of 10°.

Our direct shear test program was of necessity quite limited. However, based on the information we have seen to date, our test program is considered to be more comprehensive with regard to residual strength than the test program of Reserve's consultants. Data from our most reliable test (Test 1) plus the empirical correlations of Kanji (1974) discussed previously suggest to us that the average residual friction angle of the highly plastic lacustrine clay at the Mile Post 7 site is on the order of 10° or less. More testing is obviously needed to confirm or refute this.

Tailings Materials

Samples of tailings from Reserve's existing ore treatment process and from the proposed new ore treatment process were requested from the State of Minnesota on May 15, 1975. A sample of tailings from Reserve's existing plant was received in late July 1975 but this sample had to be sent to another consultant to the State of Minnesota for his use. Samples of dry cobbs, filtered tailings and fine tailings from Reserve's pilot plant for the new process were received on August 12, 1975 – too late to allow detailed testing for engineering properties in connection with this report.

The dry cobbs and filtered tailings samples were visually examined to confirm their similarity to samples observed in the field during our work in June, 1975. Detailed examination of the fine tailings samples was conducted to qualitatively determine particle size and settling characteristics. Behavior of fine tailings after air and oven drying, as well as in the moist state, was also noted. These examinations confirmed our preliminary conclusions based on field observations, experience with similar materials, and engineering properties data provided by Reserve. The dry cobbs, filtered tailing, and fine tailings samples have been retained in our laboratory for any additional testing as may be required at some future time in conjunction with this project.



τ/σ̄ vs. CUMULATIVE SHEAR DISPLACEMENT, δ
DIRECT SHEAR TEST I – σ̄ = 40psi
UNDISTURBED SPECIMEN OF MOIST, VERY STIFF
RED BROWN HIGHLY PLASTIC CLAY
BAKER BORING I – DAM I – 6.4 FT. DEPTH
(SHEAR SURFACE DISTURBED AFTER THIRD
SHEARING, DURING REVERSAL FOR FOURTH
AND FINAL SHEARING.)
φ̄p = 24.5°
(for C̄p = 0)
φ̄r = 10°
φ̄r = 11.5°
τ/σ̄
0.0
0.1
0.2
0.3
0.4
0.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
CUMULATIVE SHEAR DISPLACEMENT, δ – INCHES

FIGURE D-1

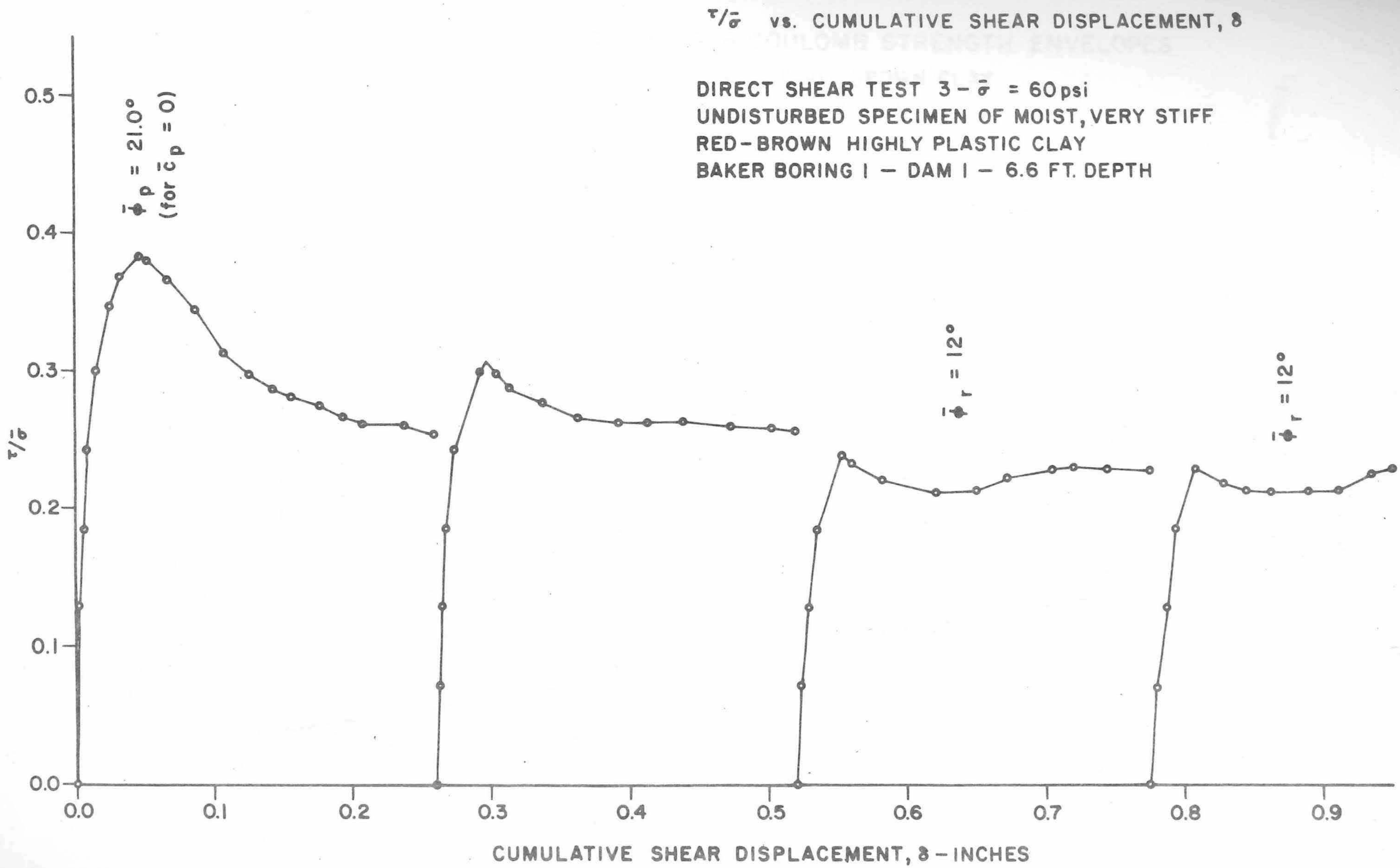

τ/σ̄ vs. CUMULATIVE SHEAR DISPLACEMENT, δ
DIRECT SHEAR TEST 3 - σ̄ = 60 psi
UNDISTURBED SPECIMEN OF MOIST, VERY STIFF
RED-BROWN HIGHLY PLASTIC CLAY
BAKER BORING I — DAM I — 6.6 FT. DEPTH
$\bar{\phi}_p = 21.0°$
(for $\bar{c}_p = 0$)
$\bar{\phi}_r = 12°$
$\bar{\phi}_r = 12°$
τ/σ̄
0.0
0.1
0.2
0.3
0.4
0.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
CUMULATIVE SHEAR DISPLACEMENT, δ - INCHES

FIGURE D-2

PEAK AND RESIDUAL MOHR — COULOMB STRENGTH ENVELOPES

MOIST, VERY STIFF, HIGHLY PLASTIC RED - BROWN CLAY

BAKER BORING 1 — DAM 1 — 6.4 to 6.6 FT. DEPTH

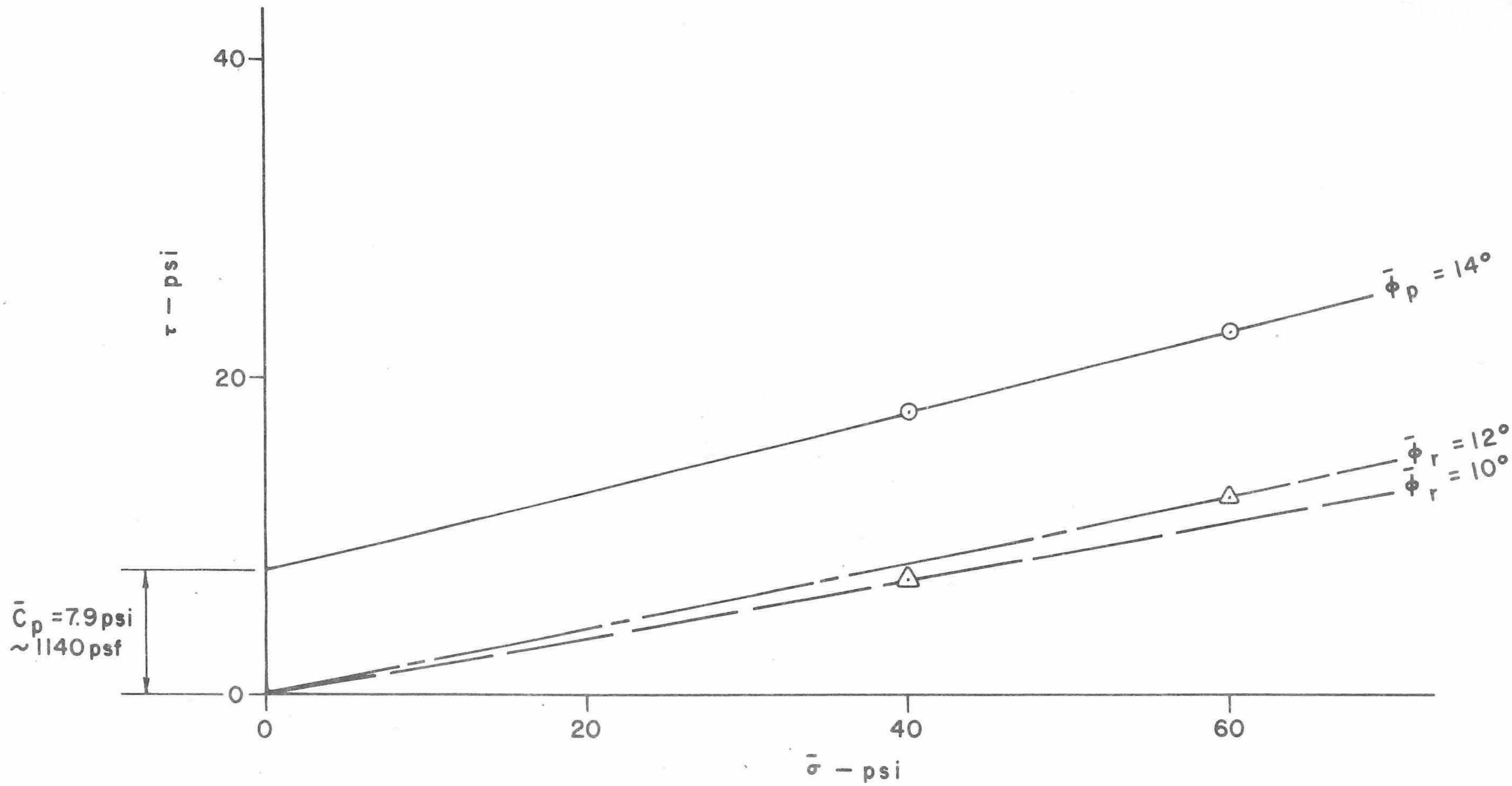


FIGURE D-3

APPENDIX E

DAM STABILITY

APPENDIX E

DAM STABILITY

Stability Considerations

Our investigation disclosed several factors which we believe must be considered in design and evaluation of stability of Dams 1 and 2-3. These factors are:

1. Pervious sand and silt seams in lacustrine clay foundation soils.

2. Pervious to semi-pervious "transition zone" containing artesian water.

3. Highly plastic, stiff, fissured and slickensided nature of portions of lacustrine clay foundation soils.

4. Difficulty of correcting possible dam instability if it should develop.

As indicated in Appendix C, the presence of pervious sand and silt seams in the foundation clays eliminates both the need and the desirability of installing vertical sand drains to dissipate excess pore water pressures induced by dam construction. Even if vertical sand drains were installed, they could not be relied upon to enhance foundation stability because of soil smear and remolding effects which would reduce strength as well as permeability of the lacustrine clays.

Pervious seams in the lacustrine clay and the "transition zone" underlying the lacustrine clay contain water under artesian pressure. This, plus our interpretation of site geology (Appendices B and C) indicates that there is hydraulic communication between the lacustrine soils and permeable zones along the rock ridge on the east side of the proposed fine tailings basin. If the fine tailings basin is filled over a period of about 40 years as planned, the free water surface will eventually reach approximate elevation 1270, some 140 feet higher than its present nominal level (essentially at the ground surface) in the tailings basin. Because of the various pervious seams and zones mentioned above, we expect that artesian water pressures larger than those existing at the present time would develop in portions of the foundations of Dams 1 and 2-3. These artesian pressures would of course tend to reduce dam stability.

Our observations (Appendices B and C) and our laboratory tests (Appendix D) indicate that portions of the lacustrine clay foundation soils are highly plastic, stiff, fissured, and slickensided with brittle, strain-softening, strength – deformation behavior and substantial differences between peak and residual effective stress shear strengths. Experience indicates that the presence of soils with these characteristics tends to increase the potential for progressive failure in dam foundations (Corps of Engineers, 1970, pp. 5-7). The potential for progressive failure with soils of this type also tends to increase with changes in long term loading conditions.

Reserve's plans involve stage construction of Dams 1 and 2-3 over periods of several years. The foundation soils would consolidate and settle under each increment of embankment load but consolidation under a given increment of embankment load would not necessarily be complete prior to placement of the next increment. More importantly, settlement of the relatively stiff upper portions of the lacustrine deposits under embankment loads would involve lateral as well as vertical deformations in the brittle, strain-softening clays. Concurrent with this complex stress – deformation pattern in the foundation clays would be the gradual increase in uplift water pressures in pervious seams and zones of the foundations as the fine tailings and supernatent water levels were raised behind the dams. As noted previously, these uplift water pressures would not reach their maximum values until some 40 years after initial phases of dam construction.

Presently available information is not sufficient to estimate the time interval over which these maximum uplift water pressures might exist in the dam foundations. Uplift water pressures in the dam foundations will eventually dissipate as the freewater level in the tailings basin is drawn down at the end of the period of fine tailings deposition. It seems likely, however, that water pressures greater than those presently existing at the dam sites would exist in the foundation soils for some considerable period of time after the cessation of fine tailings disposal.

In addition to the geologic and operational features outlined above, we have also considered measures which might be taken to correct dam instability if it should develop. The combination of site conditions and tailings disposal plans, as we understand them, suggests that foundation instability at Dam 1 or Dam 2-3, e.g., sliding of a portion of either dam along a weak foundation seam, would be difficult to correct. During the 40 year period of fine tailings deposition, it would be difficult if not impossible to:

1. Cease fine tailings deposition in the basin.

2. Remove supernatent water above the fine tailings.

3. Lower the crests of the two dams.

Flattening or buttressing upstream slopes of the dams would be difficult because of fine tailings and water in the basin. Flattening or buttressing downstream slopes of the dams would also be difficult, especially at Dam 2-3, because of the proximity of seepage reclaim facilities which would have to be kept operational.

If it were determined during design or operation that uplift water pressures in the dam foundations were tending to reduce stability below acceptable levels, consideration might be given to installation of a system of relief wells. Such relief wells would have many of the limitations discussed previously in connection with vertical sand drains and it is not certain at this time whether relief wells would necessarily be effective in reducing uplift pressures over sufficient distances to significantly improve stability of the dam foundations.

Design Approach

Our assessment of site geology and especially of foundation conditions lead to the conclusion that stable dam structures with adequate factors of safety can be constructed at Dam Sites 1 and 2-3. However, as indicated in the previous section of this appendix, many stability considerations are complex and interrelated with various aspects of site geology, dam design and construction, tailings basin operation, etc. Because of these complexities and interrelationships as well as the possible consequences of dam instability or failure, we believe that a conservative approach to dam stability is warranted. Our recommended design approach is outlined in the following paragraphs.

A detailed geologic investigation of the Mile Post 7 site must be conducted in order to develop an accurate representation of geologic conditions affecting dam stability as well as other aspects of the proposed tailings disposal system. Information presently available is sufficient, however, to indicate that vertical sand drains should not be used in the foundations of Dams 1 and 2-3. Future dam design and stability evaluation efforts should involve consideration of uplift water pressures in the dam foundations due to filling of the tailings basin.

A carefully planned and executed program of laboratory tests is necessary to determine reasonable peak and residual effective stress shear strength parameters for highly plastic lacustrine clay soils in the dam foundations.

A comprehensive program of foundation sliding stability analyses should be conducted for each tailings dam using the sliding wedge method (e.g., Corps of Engineers, 1970, Appendix VII) or the Morgenstern-Price (1965) method of analysis. These analyses should be based on the effective stress rather than the total stress approach. Conservative values of shear strength parameters and water pressures should be employed in all stability analyses but it is not necessary to consider earthquake loading.

Stability analyses should be performed for the following cases:

1. Starter dams at end of construction.

2. Upstream and downstream slopes of each tailings dam at end of first construction stage.

3. Upstream and downstream slope of each tailings dam at end of final construction stage.

4. Downstream slope of each tailings dam at or near end of active life of tailings basin when supernatent water over fine tailings has maximum elevation.

Final dam designs should be such as to give, for each of the cases cited above, a minimum factor of safety against foundation sliding of 1.5 based on peak strength and a minimum factor of safety against foundation sliding of 1.2 based on residual strength. It should be noted that these minimum factors of safety are consistent with those recommended in several manuals and design guides for situations of comparable complexity and consequences of failure (Corps of Engineers, 1970; Mines Branch, 1972; National Coal Board, 1970).

A comprehensive program for monitoring soil deformations and piezometric levels in each tailings dam and its foundation during the active life of the disposal facility should be developed. The purpose of the monitoring program is to provide information on deviations, if any, from design assumptions in sufficient time so that contingency plans can be implemented to deal with such deviations. The monitoring program should therefore include timely review of field observations and reasonable contingency plans for correction of stability or other problems if, despite conservative design criteria, such problems develop. Simple, rugged devices of proven long term reliability, e.g., settlement plates, surface survey monuments, and open standpipe piezometers, should be included in the field instrumentation used in the monitoring program.

APPENDIX F

SEEPAGE THROUGH DAMS

APPENDIX F

SEEPAGE THROUGH DAMS

Reserve's consultants have proposed construction of spigotted fine tailings beaches on the upstream or inside slopes of Dam 1, Dam 2-3 and Dam 5 in order to reduce seepage losses through the coarse tailings portions of these dams. (An impervious core of compacted glacial till has been proposed for Dam 4.) Graphical (flow net) and numerical (finite element) techniques were used by Reserve's consultants to estimate maximum seepage rates through Dam 1, Dam 2-3 and Dam 5. In their seepage studies, compacted glacial till starter dams (at Dam 1 and Dam 2-3) and underlying lacustrine soils were assumed to be impervious and coarse-tailings in the dams were assumed to be free-draining or infinitely pervious. Fine tailings inside the dams were assumed to extend up to their ultimate level of elevation 1270 and to be homogeneous and isotropic with an average coefficient of permeability of 8×10^{-5} ft./min. The water level in the tailings basin was assumed to coincide with the top of fine tailings, elevation 1270, but the free water surface in the basin was assumed not to intersect the inside slopes of the coarse tailings portions of the dams. Steady flow was assumed and maximum seepage rates were calculated using the techniques and assumptions outlined above.

In our opinion, hydraulic deposition of fine tailings from the inside slopes of the dams will result in both lateral and vertical variations in the permeability of the fine tailings beaches. At a given elevation, we expect that the coarser fraction of the fine tailings would be deposited adjacent to the dams and tailings gradation would generally become finer with distance away from the dams. This depositional pattern would be repeated vertically as the fine tailings beaches were built upward. The end result, however, would probably be a zone of the coarser and more permeable portion of the fine tailings along the inside slope of each dam.

We understand that the average coefficient of permeability of 8×10^{-5} ft./min. or 4×10^{-5} cm./sec. used by Reserve's consultants in their seepage estimates was determined by them from laboratory permeability tests on settled fine tailings. The details of these permeability tests are unkown to us at this time. It should be noted, however, that laboratory settling of soil containing silt and clay size particles usually involves deposition of progressively finer particles with the settled specimen having its finest particles in a "skin" at the top. Both theory and experience indicate that the coefficient of permeability measured in a test involving vertical flow through such a specimen will depend very significantly on the thickness and gradation of the finer upper portions and particularly on the properties of the "skin", if any, at the top of the specimen.

If the laboratory permeability tests performed on fine tailings by Reserve's consultants were conducted in such a manner as to measure the average permeability of a homogeneous specimen or the average vertical permeability of a non-homogeneous sedimented specimen, it seems probable to us that they did not measure a coefficient of permeability appropriate for estimating seepage through the coarser portions of the fine tailings beaches. We believe that estimates of seepage through the fine tailings beaches should be based on coefficients of permeability measured for the coarser particles of the fine tailings which, we anticipate, would be deposited adjacent to the inside slopes of the tailings dam. These materials might have an average coefficient of permeability several times greater than that used by Reserve's consultants in their seepage analyses. Therefore, the maximum seepage rates through the dams could be several times those estimated by Reserve's consultants.

This possibility has several implications. If the seepage reclaim systems were to be used as planned, extra pumping and/or storage capacity would be necessary. Some of the additional pumping capacity could be added as required during the life of the facility but seepage reclaim ponds would probably have to be built to their maximum sizes during initial construction. Perhaps more important than seepage during the operating life would be residual seepage after abandonment. It is not clear to us at this time what provisions would be made to handle residual seepage nor is it clear whether such seepage would be contaminated with fine mineral fibers. Additional studies of seepage and fine mineral fiber migration, if any, from the fine tailings basin are needed.

APPENDIX G

HYDRAULICS

APPENDIX G

HYDROLOGY AND HYDRAULICS

Summary

Our review of the Design Report indicates that disposal of tailings on land at the Mile Post 7 site is hydrologically feasible. The review also indicates that final design of this facility should consider hydrologic design based on rainfall frequencies of a considerably higher magnitude (less percent chance of recurrence).

Recommendations

It is recommended that the Design Report be accepted hydrologically subject to the following considerations:

1. Design Diversion No. 2 channel to pass the storm runoff occurring from a probable maximum precipitation (PMP) rainfall or assuming Diversion No. 2 is breached include sufficient surplus storage together with adequate freeboard within the reservoir area at all times to accept the PMP runoff from that drainage area above Diversion No. 2 plus PMP that occurs within the reservoir area.

2. Provide emergency spillways over or through all seepage reclaim dams.

3. Install a recording stream gauge at Diversion No. 2 and no fewer than three rain gauges (non-recording) throughout the reservoir area; the recommended location being at Diversion No. 2 and seepage reclaim facilities at Dam Site 1 and Dam Site 2-3. These gauges should be maintained for the life of the project.

4. Periodically review gauged data and compare the data with empirical values used to hydrologically design the facility.

Michael Baker, Jr., Inc. Hydrologic Review Procedures

Hydrologic computations presented in the reports by Reserve's consultants are insufficient to determine their accuracy. Further, past experience indicates that an independent preliminary hydrologic design by the reviewer is an economical checking procedure. Therefore, the results indicated herein by Michael Baker, Jr., Inc. have been derived independently from those presented in the design reports. Since our results have been derived from published data without benefit of direct input from local historical data and factors used to determine these results are necessarily based on average conditions over large areas, it is important that these data be used for comparison purposes only. Numerical values have been included on this basis.

A comparison of the results, even though different procedures were used in some cases, indicates consistency and they are well within the anticipated range of agreement. This comparison indicates that Reserve's results are slightly more conservative than Baker's results when the same design storm is analyzed. This is due to using slightly different rainfall-runoff coefficients. Refinement of these coefficients requires considerable study of local historical data and/or drainage area soil classification which is not warranted under this review.

Beaver River Hydrology

We consider the analysis of the watershed as presented by Reserve to be a reasonable estimate of the watersheds peak discharges. We suggest that a hydrograph analysis (Chow, 1964) of the nearby gauging records be made using frequency rainfall data. The results should then be compared to the theoretical flows developed in this report.

Main Tailings Storage Area

Based on proposed dam construction schedules, we consider the fine tailings basin to have adequate capacity to retain the probable maximum precipitations (PMP) at any level of construction. The value of PMP for this area is 22.5 inches and when applied to the watershed area of 8.7 square miles, yields a volume of approximately 16.5 million cubic yards. The volume computed assumes the worst possible conditions including 100 percent runoff. It will be necessary to maintain this storage at all phases of the operation. The construction schedule (Drawing No. 292-0026), if followed, will maintain sufficient dam levels at all times.

The conclusions, as stated above, were derived by comparing the construction schedule (Drawing No. 202-0026) and the tailings reservoir capacity curve (Drawing No. 292-0027).

The main reservoir will be of sufficient capacity, upon completion, to store the PMP volume. We recommend, however, that an overflow spillway be installed upon project completion.

Diversion No. 1

Our results generally concur with Reserve's estimated flood flows due to routing of a 10,000 year recurrence interval design flood. We note that if the embankment diverting the flow were breached, all flow would enter the reservoir area. However, our computations indicate the available reservoir storage is sufficient to store the PMP storm runoff without endangering the facility.

A comparison of the results is as follows:

Reserve:

Design Recurrence Interval = 10,000 yr., 48 hour storm

Flood Flow = 4,000 cfs.

Michael Baker, Jr., Inc.:

Design Recurrence Interval = 10,000 yr., 6 hour storm (U.S. Weather Bureau, 1961)

Flood Flow = 3,300 cfs.

Design Recurrence Interval = PMP Storm

Flood Flow = 20,600 cfs.

Flood Volume = 8.9 million cubic yards

Diversion No. 2

Our results generally concur with Reserve's estimate for flood flows due to routing of a 10,000 year recurrence interval design flood. However, we note that if the embankment diverting the flow were breached, all flow would enter the reservoir. Further, if the diversion embankment were breached due to the PMP runoff, this volume of storm water added to the volume occurring within the reservoir due to a PMP rainfall would approach the available reservoir storage capacity for storm runoff and could result in breaching one of the tailings dams.

Therefore, we recommend that Diversion No. 2 be designed to contain the runoff from a PMP storm.

A comparison of the results is as follows:

Reserve:

Design Recurrence Interval = 10,000 year – 48 hour storm

Flood Flow = 10,000 cfs.

Michael Baker, Jr., Inc.:

Design Recurrence Interval = 10,000 year – 6 hour storm (U.S. Weather Bureau 1961)

Flood Flow = 9,200 cfs.

Design Recurrence Interval = PMP Storm

Flood Flow = 59,000 cfs.

Flood Volume = 33 million cubic yards

Seepage Recovery Ponds

We consider the 500 year recurrence interval design adequate for these facilities providing (1) that an emergency spillway be constructed for each seepage recovery pond sized to pass the PMP storm runoff and (2) that discharge from these emergency spillways, if this remote possibility does occur, is acceptable to the State of Minnesota. It is noted that a 500 year recurrence interval has a 0.2 percent chance of occurring in any year.

Seepage rates are difficult to estimate and considerable error in selection of pumping rates could result in estimating low seepage rates. However, if the seepage rates were twice the amount estimated by Reserve and the pumping rate remained the same, the design storm frequency would be reduced from 500 to approximately 300 year recurrence interval (0.2 to 0.3 percent chance of occurrence).

Alternately, if the proposed storage and design interval were retained, maximum pumping rates would have to be increased in accordance with the following table when seepage increases as noted:

	Est. Seepage	2 Times Est. Seepage	5 Times Est. Seepage	10 Times Est. Seepage
Dam No. 1A	2,500 gpm	2,800 gpm	4,900 gpm	8,000 gpm
Dam No. 1B	1,000 gpm	1,300 gpm	2,200 gpm	3,700 gpm
Dam No. 2-3	1,250 gpm	1,700 gpm	3,000 gpm	4,400 gpm
Dam No. 5	500 gpm	1,150 gpm	2,300 gpm	4,600 gpm

Bear Lake

We believe that there are only two methods of permanently correcting the effects on Bear Lake due to the installation of the proposed facility. These are (1) construct a new discharge channel from Bear Lake, either to the south or east whichever is most econmical (we consider the channel, if sized for a 500 year frequency storm runoff more than adequate) and (2) permit the lake to rise to a new normal water surface as required to provide a new location for the natural discharge from the lake. This second alternate would probably flood existing structures and require purchase of the Bear Lake property. It would also require that the area between existing normal pool and proposed normal pool be cleared of all trees in order to maintain a natural lake. Additional consideration must be given to the effect on Dam 5, which will be partially below lake level.

We do not recommend consideration of any alternate which would require perpetual maintenance.

Reclamation

It is recommended that plans for reclamation include a permanent spillway in Dam 1, otherwise, we anticipate that stream flow over one of the dams would occur in 2 to 5 years after termination of the facility operations. We further anticipate that normal erosion would soon expose both the material in the dam and the fine tailings in the reservoir if the dams were permitted to erode due to channelized flow.

It is recommended that the permanent spillway consist of two structures, a normal spillway designed to pass a 10,000 year frequency flood and an emergency spillway which, when combined with the normal spillway, will give capacity to pass the total flow from a PMP flood. It is expected that discharge from the emergency spillway would cause considerable erosion if the emergency spillway ever became operational (due to normal spillway flow being exceeded). Erosion due to emergency spillway discharge is usually permissible in the design of earth dams as long as this erosion is repairable.

Drought Occurrences

We do not consider drought occurrences as affecting the feasibility of the proposed installation. Long term droughts in Minnesota are unusual and any effects on the tailing ponds could easily be corrected by decreasing the plant make-up water obtained from the tailings pond.

Dam Failure

Determining the catastrophic effects that would occur if either Dam 1 or Dam 2-3 were breached and all impounded water were suddenly released into the Beaver River basin is considerably beyond the scope of this review. The costs and time consumed to yield a reliable estimate of these effects rules out an in-depth study. However, the volume of water stored within the tailings pond together with that impounded within the reservoir due to rainfall would approximate the volume of storm water obtained from a PMP flood over the entire Beaver River drainage basin. Further, and of most critical importance, the maximum rate of discharge along the Beaver River drainage course from dam failure would be many times that which would occur due to the runoff from a PMP over the entire Beaver River basin.

It becomes apparent that failure of either of these dams due to overtopping would be a catastrophe causing major property damage and probable loss of life.

Therefore, design parameters and operational procedures must include use of safety factors which would essentially eliminate the possibility of dam failures. Hydrologically and hydraulically, this could be obtained by allowing sufficient freeboard storage within the impoundment to provide for the maximum probable condition of rainfall and runoff and proper operating procedures. We note that considerable latitude is permitted in operating procedures as presently proposed and except for several very short periods of time near the beginning of operation of the facility, proposed operating procedures would not effect the integrity of the facility. Even if the facility were abandoned prior to its estimated life, considerable time would be available (probably several years) to correct deficiencies due to non-operation.

APPENDIX H

TAILINGS DELTA IN LAKE SUPERIOR

APPENDIX H

TAILINGS DELTA IN LAKE SUPERIOR

As indicated in the Introduction of this report, most of our work to date has been directed toward evaluation of plans for the Mile Post 7 site. It seems appropriate, however, to include in this report a brief summary of our thoughts regarding stabilization of the tailings delta in Lake Superior.

The tailings delta adjacent to Reserve's ore processing plant at Silver Bay extends about 1/2 mile out from the original lake shore and about 1 mile along the shore. The surface of the delta slopes down from about Elevation 640 near the original shore line to about Elevation 602 at the present shore line. Detailed geometric data on the delta have not been provided to us. The available information indicated, however, that the thickness of the delta is on the order of 250 feet at the outer edge and that the outer edge extends downward at a slope of approximately 2.5 horizontal to 1 vertical to the lake bottom some 450 feet below the lake level.

Reserve wishes to convert to on-land tailings disposal and then stabilize the delta so that it will provide maximum useable land surface with minimum adverse environmental effects. Reserve's consultants have proposed a delta stabilization plan whereby the delta edge would be converted to a more stable beach-type configuration by controlled erosion and then permanently stabilized with rock armor material. Hydraulic model studies of this stabilization plan are currently in progress.

In our view, the main consideration relative to delta stabilization is the amount of potentially health hazardous mineral fibers which might be released from the delta if it is allowed to erode to a stable configuration under either controlled or uncontrolled conditions. As far as we know, there are at present no data available on mineral fiber content of the delta. Efforts should be made to obtain such data as expeditiously as possible in order to assess the public health implications of delta erosion.

Observations by our personnel during visits to the delta on May 3 and June 20, 1975, plus basic principles of fluvial processes and sedimentation suggest that the delta is composed mainly of fine gravel through silt size tailings particles with sand and gravel sizes dominant. This does not, however, rule out the possibility of localized zones of the delta containing concentrations of finer tailings particles including mineral fibers.

It seems probable to us that most of the silt and clay size particles in the tailings discharge wash directly into Lake Superior. However, we can envision several processes which would cause some finer silt and clay size tailings particles to remain in the delta:

1. Seepage of tailings discharge water through the upper portions of the delta with fine tailings particles, possibly including mineral fibers, filtered from tailings water seeping toward the lake.

2. Mineral fibers may adhere to coarse tailings particles deposited on the delta through some combination of physical, chemical and/or electro-static attraction processes.

3. Flocculation of mineral fibers, e.g., as a result of mutual chemical and/or electro-static attraction, and concentration of fiber flocs in relatively calm water pools or back channels on the delta surfaces.

If it is determined that the delta does not contain potentially health hazardous amounts of mineral fibers, and if there is little potential for physical breakdown of larger particles in the delta to liberate fibers, we can at this time see no reason to attempt to stabilize the delta. Alternatively, if the delta does contain potentially health hazardous amounts of mineral fibers or if there is potential for physical breakdown of larger particles to liberate fibers, there appear to be two options available:

1. Let the delta erode into the lake until a stable shoreline is achieved.

2. Attempt to stabilize the delta.

Considerable additional study of delta composition appears to be necessary in any event. We recommend that specialists in fluvial processes and physico-chemical behavior of mineral fibers be retained to assess the first aspect of the problem, i.e., whether there are significant amounts of fibers in the existing delta. Depending on the results of such study, a decision will have to be made on possible attempts to stabilize the delta. If delta stabilization is contemplated, specialists on shoreline protection and stabilization should be retained to advise on such matters.

We have not yet received the results of hydraulic model tests conducted by Reserve's consultants on their proposed delta stabilization plan. Based on our understanding of this plan, we do not believe that it would prevent long term erosion of fine particles from the delta. Moreover, we do not at this time believe that it would be feasible to totally prevent long term erosion of fine particles from the delta. This has relatively little consequence, however, unless fine particles in the delta include significant numbers of potentially health hazardous mineral fibers.

In any event, the surface of the delta should be vegetated after Reserve ceases discharge of tailings onto it. We anticipate no major problems with establishment of vegetation on the delta. If Reserve wishes to construct any facilities on the delta, the possibility of foundation instability or distress must be considered.