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MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

180 HOWARD STREET
SAN FRANCISCO, CA 94105

MONTANA PROJECT
SANDERS AND LINCOLN COUNTIES, MONTANA
TAILINGS IMPOUNDMENT
PRELIMINARY ENGINEERING REPORT

Noranda Minerals Corp.
Montana Project
101 Woodland Road
P.O. Box A.L.
Libby, MT 59923

by:

Morrison-Knudsen Engineers, Inc.
180 Howard Street
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February 1989

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Noranda Minerals Corp.
Montana Project
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Attention: Mr. Joe Scheuering
Project Manager

Subject: Montana Project
Sanders and Lincoln Counties, Montana
Tailings Impoundment
Preliminary Engineering Report

Gentlemen:

Morrison-Knudsen Engineers, Inc. (MKE) is pleased to submit this preliminary engineering report of the Little Cherry tailings impoundment for the Montana Project.

The purpose of this report is to present the results of preliminary engineering and design studies for the tailings impoundment. The scope of work consisted of (1) hydrologic studies, (2) stability analyses, (3) seepage and contaminant transport analyses, (4) preliminary design of the impoundment and (5) preparation of a conceptual reclamation plan. A companion report, the Geotechnical Report, serves as the geotechnical data base for the tailings impoundment.

The impoundment was designed to store 120 million tons of tailings and will have an operational life of about 16 years. Preliminary plans and sections of the impoundment, a construction schedule and impoundment staging curves are presented. Also, a conceptual plan of the reclaimed impoundment was prepared and construction quantities were estimated.

If you have any questions about this preliminary engineering report, please call me at (415) 442-7573.

Sincerely,

M. P. Forrest

M. P. Forrest
Project Manager

MONTANA PROJECT

TAILINGS IMPOUNDMENT PRELIMINARY ENGINEERING REPORT

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CHAPTER 1
SUMMARY AND CONCLUSIONS

Noranda Minerals Corp. is planning the development of the Montana Project located in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. As part of this project, an impoundment will be required to store tailings from the milling operations. This report presents the results of engineering and design studies performed by Morrison-Knudsen Engineers, Inc. (MKE) for the Little Cherry tailings impoundment. A companion report for this project, the Geotechnical Report, was prepared by MKE and serves as the geotechnical data base for the tailings impoundment.

The scope of work consisted of (1) hydrologic studies, (2) stability analyses, (3) seepage and contaminant transport analyses, (4) preliminary design of the impoundment and (5) preparation of a conceptual reclamation plan.

The tailings production rate will be 20,000 dry tons per day and will total about 120,000,000 tons. This production rate and required storage capacity indicate that the impoundment operational life will be about 16 years.

The tailings impoundment will be developed by constructing a dam across Little Cherry Creek. The watershed area above the proposed tailings dam is 1.78 square miles. A permanent diversion system consisting of a dam at the upstream end of the impoundment and a diversion channel will be required to route the creek around the impoundment and thereby reduce the watershed area by about 50%. The diversion system was designed to route the Probable Maximum Flood (PMF) around the south side of the tailings impoundment. The tailings impoundment was sized to completely contain runoff resulting from 24-hour general storm Probable Maximum Precipitation (PMP) plus snowmelt.

Stability analyses were performed for the starter dam and final dam embankments. Stability was analyzed for (1) end-of-construction for the starter dam, (2) steady-state seepage and seismic loading for both the starter and final dam stages, and (3) flood pool for the final dam stage. The results of the stability analyses indicate that the calculated factors of safety exceed minimum acceptable values for all cases.

Liquefaction potential was evaluated for sandy foundation soils. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking. The design earthquake used for liquefaction analysis was the Maximum Credible Earthquake (MCE). The MCE was determined to be a magnitude 7 event originating on the Bull Hill fault 20 kilometers to the west of the project site. The peak ground acceleration at the site was estimated to be 0.22g. This acceleration was used to estimate the seismically induced shear stresses. Resistance of the soils to liquefaction was estimated from the results of Standard Penetration Tests (SPT's) in borings. The results of the evaluation indicate that the foundation soils are sufficiently dense to preclude liquefaction.

Seepage from the pond impoundment was estimated in order to compare its chemistry with groundwater and surface water quality. Based on a one-dimensional seepage analysis for the final impoundment at year 16, the maximum seepage was estimated to be about 475 gpm.

The term "contaminant transport" as referenced in this report is widely used to describe the movement of an effluent through a groundwater system. Contaminant transport analyses were performed by using a model that considers longitudinal dispersion and one dimensional flow through the aquifer. The results of the analyses show that the tailings effluent chemical concentrations generally do not exceed background groundwater concentrations.

It is expected that a portion of the effluent will emerge as seepage in both the Little Cherry Creek and Libby Creek channels. The seepage will be significantly diluted by streamflow. After dilution, the resulting effluent concentrations in the creek would be very low.

The results of the seepage and contaminant transport analyses are presented for the final impoundment, a condition when seepage would be a maximum. After the impoundment has been filled to capacity, the effluent will be evaporated from the tailings surface. Seepage will therefore decrease with time resulting in a diminished migration of effluent from the impoundment.

To control seepage through the tailings embankment, a gravel blanket drain will be placed on the foundation as the dam is being raised. Filter blankets above and below the blanket drain will prevent piping of the tailings and foundation materials into the drain. Seepage will be collected in a pond located downstream of the tailings dam. Water in the pond will be pumped back to the tailings impoundment.

The Little Cherry impoundment will consist of the following structures:

- Diversion Dam
- Diversion Channel
- Tailings Retention Dam that includes a Starter Dam and Toe Dike
- Two Earthfill Saddle Dams
- Seepage Collection Dam
- Collection Ditches

Earthfill materials for embankment dam construction will be obtained from the diversion channel excavation and from a borrow area within the impoundment. Rockfill and riprap will be obtained from mine waste or from a quarry. Blanket drain and filter materials will be obtained by crushing, screening and washing mine waste or quarried rock, or the materials will be imported from a commercial source. A large portion of the embankment dam will be constructed of coarse tailings produced by double cycloning the mill feed. The final dam will be 380 feet high and will have a total volume of 32,971,000 cubic yards of which 27,844,000 cubic yards will consist of cycloned tailings sand with 10% fines (less than 0.074 mm).

Stability monitoring and contingency plans were prepared. The stability monitoring plan includes (1) periodic visual inspections, (2) measurements of seepage through the dam and foundation piezometric pressures and (3) reviews by engineers experienced in tailings dam design and construction. A contingency plan is required to (1) identify the type of incident, (2) formulate the required remedial action and (3) identify the authorities to be contacted.

A conceptual reclamation plan was prepared for the tailings impoundment and diversion channel. The intent of the reclamation plan is to minimize potential long-term erosion and maximize stability of the tailings embankment dam. The basic plan for reclamation consists of (1) stripping soils containing organic matter, (2) depositing cycloned sands into the impoundment during the final year of operation, (3) drying the pond surface by promoting natural desiccation and evaporation, (4) grading the pond surface, (5) replacing soils stripped from the site during construction and (6) seeding the reclaimed pond surface.

The diversion channel slopes will be benched to control surface water runoff and will be covered with 1-foot of soil and seeded with grass to minimize erosion. A 3-foot thick riprap layer will be provided to prevent erosion of the channel during flood flows.

Preliminary plans and sections of the impoundment, a construction schedule and impoundment staging curves were prepared. Also, a conceptual plan and section of the reclaimed tailings impoundment were prepared. Excavation and embankment fill quantities were estimated.

The purpose of this report is to present the results of preliminary engineering and design studies for the Little Cherry tailings impoundment. The scope of the studies was intended to provide sufficient engineering to demonstrate project feasibility. The design has not been optimized and is not final; the design will be developed during subsequent phases. The Geotechnical Report outlines additional field exploration and laboratory testing needed for final design studies.

CHAPTER 2
INTRODUCTION

2.1 BACKGROUND

Noranda Minerals Corp. is planning the development of the Montana Project located in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. The project area is located in the Kootenai and Kaniksu National Forests (Figure 1). An impoundment will be required to store tailings from the milling operations. A site located on Little Cherry Creek, east of the Cabinet Mountains, was determined to be the preferred site for tailings disposal. This preliminary engineering report presents the results of tailings impoundment design studies performed by Morrison-Knudsen Engineers, Inc. (MKE).

A companion report for this project, the Geotechnical Report, was prepared by MKE and serves as the geotechnical data base for the Little Cherry tailings impoundment site. In addition, that report presents geotechnical data for two other sites considered for tailings impoundments, plant and mine portal sites, and for evaluation adit portal sites. The Geotechnical Report presents the results of the field investigation program and includes discussions of (1) geologic setting, (2) seismicity, including seismic design criteria, (3) field exploration and laboratory testing programs, and (4) site and subsurface conditions.

2.2 PURPOSE AND SCOPE

The purpose of this report is to present the results of preliminary engineering and design studies for the Little Cherry tailings impoundment. The scope of the studies was intended to provide sufficient engineering to demonstrate project feasibility. Designs presented in this report have not been optimized and are not final; the design will be developed in subsequent phases. The approach to the project study is described in the Design Basis Memorandum, Appendix A.

The scope of work for the preliminary engineering tailings impoundment studies consists of the following tasks:

- Conduct a field investigation that includes the following activities:
  - Data review
  - Reconnaissance
  - Geologic mapping
  - Seismicity evaluation
  - Seismic refraction survey
  - Test pit excavations
  - Exploratory drilling
  - Laboratory testing

- Perform the following preliminary tailings impoundment engineering studies:
  - Hydrologic studies
  - Stability analyses
  - Seepage and contaminant transport analyses
  - Conceptual reclamation plan

- Prepare the following technical reports:
  - Geotechnical Report
  - Geotechnical Site Evaluation Report
  - Tailings Impoundment Preliminary Engineering Report

- Attend meetings with Noranda and regulatory agencies.

This report presents the results of preliminary engineering and design studies for the Little Cherry tailings impoundment. The results of the geotechnical investigations, including drilling and test pit logs, seismic refraction results and laboratory test results, are presented in the Geotechnical Report.

2.3 AUTHORIZATION

United States Borax & Chemical Corporation initially authorized the work for this project on 9 May 1988. On 6 September 1988, U.S. Borax transferred its interest to Noranda Minerals Corp.

CHAPTER 3
IMPOUNDMENT SITE SELECTION

The following three impoundment sites were investigated for tailings disposal (Figure 2):

- o Little Cherry
- o Poorman
- o Midas

In the selection of the tailings disposal site, several factors were considered including (1) watershed area and diversion requirements, (2) foundation seepage, (3) impoundment storage capacity and (4) borrow volume requirements. In the following paragraphs, a summary is presented of the impoundment site selection.

The results of studies show that the Little Cherry site is the preferred site for tailings disposal. The site is in a valley that has a relatively small watershed (1.78 square miles). An impoundment could be developed at this site to store 120 million tons of tailings. The site topography is adaptable for construction of a diversion dam and channel on the south side of the impoundment; the channel would discharge into a natural stream channel. This diversion system would reduce the tailings impoundment watershed area by about 50%.

The impoundment at the Poorman site would be formed by a three-sided embankment dam. The site is not large enough to store 120 million tons of tailings. This site would have to be used together with another site to store 120 million tons of tailings. Studies show that to store 70 million tons, an excessive amount of earthfill borrow would be needed for dam construction since insufficient coarse tailings would be produced. The results of geotechnical studies show that artesian groundwater conditions exist at the site. Artesian groundwater indicates that foundation uplift pressures could develop. To control these pressures so that dam stability would not be threatened, a pressure relief well system would be required. The Poorman site is not considered to be an economically feasible site for tailings disposal because of (1) insufficient storage capacity, (2) an excessive volume of earthfill required for dam construction and (3) the necessity for pressure relief wells.

The Midas site would be located in a valley with a watershed area of about 5.16 square miles, about 2.9 times the area of the Little Cherry site. A diversion system at this site would require a channel on both sides of the valley. The channels would be located on hillsides that have ridges extending as much as 2000 feet above the channels. The channels would be subject to blockage by slides and debris. Failure of a diversion channel would lead to failure of the tailings retention dam by overtopping. Because of the potential for obstruction of the diversion channels, the Midas site is not considered to be an economically feasible site for tailings disposal.

CHAPTER 4

HYDROLOGIC STUDIES

4.1 DESIGN FLOOD CRITERIA

The design flood criteria are based on the U. S. Forest Service and U.S. Corps of Engineers (1977) criteria (see Design Basis Memorandum, Appendix A). The designation of the tailings impoundment design flood is based on size and hazard potential classifications. The tailings retention dam will be raised incrementally to increase impoundment storage capacity. Size classification is determined by either storage or dam stage height, whichever gives the larger size category. For this project, dam stage heights control the size classification.

U. S. Highway 2 is located about 5.7 river miles downstream of the Little Cherry damsite; the nearest dwelling is located about 5.4 miles downstream of the site. Libby is the closest town to the impoundment site and is located about 14 miles downstream (north) of the site. Because of the potential for downstream damage and resulting clean-up, the U. S. Forest Service and the Montana Department of State Lands consider the impoundment site to have moderate to high hazard potentials (see Design Basis Memorandum, Appendix A).

Based on dam stage size and hazard potential classifications, the Forest Service and Department of State Lands designated the following design flood criteria:

- For containment: 24-hour general storm
  Probable Maximum Precipitation (PMP)

- For diversion: 72-hour general storm
  Probable Maximum Flood (PMF)

The PMF is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region (U. S. Corps of Engineers, 1977). The PMF is derived from the PMP, which is defined as theoretically the depth of precipitation for a given duration that approaches the upper limit of what the atmosphere can produce over a given storm area at a particular geographic location at a certain time of the year (U. S. Department of Commerce, Hydrometeorological Report No. 43, 1966).

Because thunderstorm events should also be considered for small watersheds, the local storm PMF (resulting from the 6-hour PMP) was also considered for diversion. The more critical of the two diversion floods was used for diversion system design.

Based on engineering practice, the minimum embankment dam freeboard (above the peak flood water surface) was taken to be 3 feet (U.S. Bureau of Reclamation, "Design of Small Dams," 1987).

4.2 METHODOLOGY

The Corps of Engineers' "HEC-1 Flood Hydrograph Package" computer program was used for the hydrologic studies. The "Hydrometeorological Report No. 43, Probable Maximum Precipitation - Northwest States" (Hydromet 43), developed by the U. S. Department of Commerce, Weather Bureau (1966) was used as the basis for estimating the local storm and general storm PMP's.

An unlimited snowpack was assumed to be available for snowmelt during the 24-hour and 72-hour general storm PMP's. Data on snowpack and snow-water equivalents are not available, thus, snowmelt estimates were based on the Corps of Engineers' "Runoff from Snowmelt" (1960). Since forest cover is less than 80 percent of the watershed, the snowmelt equation developed for open and partly forested areas was used. Percent forest cover was estimated from July 1988 aerial photographs. Dew point temperatures and wind speeds during the PMP were developed from procedures described in Hydromet 43.

The general storm PMF was based on the general-storm type 24-hour and 72-hour PMP plus snowmelt; the local storm PMF was based on the 6-hour local storm PMP. Unit hydrographs were developed following the Soil Conservation Service (SCS) method, as described in the U. S. Bureau of Reclamation "Design of Small Dams" (1987). Infiltration and retention losses were also estimated following SCS hydrologic soil group and curve number (CN) procedures. These estimates were based on soil conditions and vegetal cover as determined from the aerial photographs and information provided in available reports (U. S. Department of Agriculture, 1984). Hydrologic Soil Group B was used in the analysis. Basin lag time was calculated by using procedures described in "Design of Small Dams". The antecedent moisture conditions (AMC) for the PMF estimates were based on AMC III conditions.

A diversion dam and diversion channel are required to divert the watershed runoff around the Little Cherry tailings impoundment. To determine the size of the channel and diversion dam height, the design flood (described in Section 4.1) was routed through the diversion pond by using HEC-1 procedures.

4.3 WATERSHED CHARACTERISTICS

The Little Cherry watershed, tailings impoundment and diversion system are shown on Figure 3. The tailings retention dam will be constructed across Little Cherry Creek. A diversion dam will be constructed at the upstream end of the tailings impoundment and a channel will divert runoff around the south side of the impoundment.

Table 4.1 summarizes the drainage area characteristics of the Little Cherry watershed.

TABLE 4.1

DRAINAGE AREA CHARACTERISTICS

Tailings Impoundment Drainage Area (square miles)	0.88
Diversion Impoundment Drainage Area (square miles)	0.90
Total Drainage Area (square miles)	1.78
Mean Basin Elevation (feet)	3860
Lag Time for Diversion Impoundment Watershed (hours)	0.32
Curve Number (AMC III)	73
Percent Forest Cover	76

As shown in Table 4.1, the diversion dam reduces the tailings impoundment watershed area by about 50%.

4.4 PROBABLE MAXIMUM PRECIPITATION, SNOWMELT AND NET RUNOFF

The 24-hour general storm PMP with snowmelt was used to compute runoff into the tailings impoundment. Both the 72-hour general storm PMP with snowmelt and the

6-hour local storm PMP were considered for the diversion system. Estimates of snowmelt during the 24-hour and the 72-hour general storm PMP are necessary because of the relatively high mean basin elevation of the area. In addition, based on Hydromet 43, the most critical general storm PMP was determined to occur in June. The spring melt season for this area occurs primarily from spring to early summer. Estimates of snowmelt during the 6-hour local storm PMP were not necessary, since this storm event is associated with summer-autumn thunderstorms.

Precipitation, snowmelt and net runoff for the Little Cherry watershed are summarized in Table 4.2 below. Detailed calculations of net runoff for the storm events are presented in Appendix B.

TABLE 4.2
PRECIPITATION, SNOWMELT AND NET RUNOFF

Precipitation Event	Precipitation (inches)	Precipitation & Snowmelt (inches)	Net Runoff (inches)
6-hour Local Storm PMP	11.7	N/A	8.2
24-hour General Storm PMP	11.9	15.8	9.8
72-hour General Storm PMP	17.0	24.4	10.2

4.5 DESIGN FLOODS

The tailings impoundment was sized to completely contain runoff resulting from the 24-hour general storm PMP plus snowmelt. Since all runoff upstream of the diversion dam will be routed around the tailings impoundment, only the tailings impoundment drainage area (see Table 4.1) was used to estimate the required inflow volume for containment. Depending on pond area, the total inflow volume was estimated to range from about 460 to 540 acre-feet for the starter and final impoundments, respectively (see Appendix B, Figure B-1).

For the diversion dam and channel, the PMF hydrographs for both the 72-hour general storm plus snowmelt and the 6-hour local storm were computed using HEC-1 procedures. Computer printouts of the design flood calculations are presented in

Appendix B. Peak discharges for the 72-hour PMF and the 6-hour PMF are approximately 2510 cfs and 5230 cfs, respectively. Since the larger, more critical peak discharge is produced by the 6-hour PMF, this flood event was used as the design flood for diversion system design.

4.6 DIVERSION FLOOD ROUTING

The 6-hour local storm PMF was routed through the diversion impoundment and channel. Computer printouts of the flood routing calculations, diversion pond area-capacity curves, channel discharge rating curve and hydrographs are presented in Appendix B.

Table 4.3 summarizes the flood routing results for the diversion pond. The diversion pond was assumed to be full (water surface at El. 3680) at the beginning of the storm. Peak discharge for the 6-hour local storm is about 3,460 cfs. The peak design flood flow velocity in the diversion channel was computed to be about 16 feet per second. The 72-hour general storm PMF was also routed through the diversion impoundment for comparison. Results of this routing are also summarized in Table 4.3.

The inflow to the diversion channel from the small catchment adjacent to the channel was ignored for the preliminary design since it is a small area and there is adequate freeboard allowed in the channel design. Final design of the diversion channel will consider this inflow.

TABLE 4.3
LITTLE CHERRY DIVERSION SYSTEM
RESULTS OF FLOOD ROUTING

	6-hr Local PMF [b]	72-hr General PMF
Dam Crest Elevation (feet)	3700	3700
Diversion Channel Crest Elevation (feet)	3680	3680
Diversion Channel Crest Length, L (feet)	20	20
Initial W. S. El. (feet)	3680	3680
Maximum W. S. El. (feet)	3694.6	3689.4
Minimum Freeboard (feet) [a]	5.4	10.6
Peak Inflow (cfs)	5230	2510
Peak Outflow (cfs)	3460	1790

Notes:
a Minimum freeboard equals dam crest elevation minus maximum water surface elevation
b Design flood is the flood resulting from the 6-hour local storm PMP event

CHAPTER 5
STABILITY ANALYSES

5.1 SOIL PARAMETERS

The soil parameters used in the slope stability analysis are summarized in Table 5.1. The unit weights and strength parameters of the cycloned sand tailings and fine pond tailings are based on typical values of similar tailings presented in Vick (1983). For purposes of analyses, the fine tailings were conservatively assumed to have no strength. The blow counts (N-values) from Standard Penetration Tests were used to estimate strength parameters of the foundation soils. Correlations between N-values and friction angles presented in published literature were used to obtain these strength parameters. Published data were used to estimate the strength parameters of rockfill (Leps, 1970). Cohesion values are zero for granular soils. Since adequate undisturbed samples of clayey silty foundation soils could not be obtained for laboratory testing during the drilling program (MKE, Geotechnical Report, January 1989), the cohesion value for these soils was estimated from the results of field penetrometer tests.

TABLE 5.1

SOIL PARAMETERS FOR STABILITY ANALYSES

Soil No.	Description	Wet Unit Weight (pcf)	Saturated Unit Weight (pcf)	Effective Friction Angle (degrees)	Effective Cohesion (psf)
1	Starter Dam Earthfill	124	133	35	0
2	Cycloned Sand	110	123	33	0
3	Toe Dike and Starter Dam Rockfill	140	145	42	0
4	Foundation Layer 1	--	135	35	0
4	Foundation Layer 1	125	--	0*	2000*
5	Foundation Layer 2	--	141	38	0
6	Fine Tailings	--	110	0	0

* Total stress parameters; all other parameters are in terms of effective stresses.

The embankment dam foundation is composed of both granular and silty clayey soils (MKE, Geotechnical Report, 1989). Therefore, as shown in Table 5.1, two sets of parameters were designated for Foundation Layer 1. The first set applies to a granular foundation and the second set applies to a silty clayey foundation.

5.2 CRITERIA AND LOADING CONDITIONS

The maximum sections of the Little Cherry starter dam and final embankment dam were checked for static and seismic stability (see Figure C-1, Appendix C). The design criteria and loading conditions are presented in Table 5.2 for the cases considered in the slope stability analysis. The minimum acceptable factors of safety used in the analyses are as recommended by the Corps of Engineers (1970).

TABLE 5.2
DESIGN CRITERIA AND LOAD CONDITIONS

Case	Load Condition	Embankment Stage	Slope	Maximum Acceptable Factor of Safety
1A,B	End-of-Construction	Starter Dam	Upstream and Downstream	1.3
2A,B	Steady-State Seepage	Starter and Final Dams	Downstream	1.5
3	Design Flood	Final Dam	Downstream	1.4
4A,B	Seismic *	Starter and Final Dams	Downstream	1.0

* Seismic Coefficient = 0.10g

The stability of the starter dam was checked for the end-of-construction condition before tailings are deposited (Cases 1A and 1B). This condition is the most critical static case for the upstream slope since subsequent deposition of fine tailings into the pond will stabilize the slope.

The stability of the downstream slopes of the starter and final embankment dams were analyzed for steady-state seepage and seismic loading (Cases 2A, 2B, 4A and 4B). A conservatively high phreatic surface was also used to check that the stability of the downstream slope would be adequate for the design flood condition, Case 3 (see Chapter 4). A 200-foot wide beach with a 1.0% slope would normally prevent the pond shoreline from reaching the embankment dam.

Seismic stability was evaluated by the "psuedo-static" method. Based on a review of site seismicity, a seismic coefficient of 0.10g was used in the stability analyses (MKE, Geotechnical Report, 1989). In the "pseudo-static" method of stability analysis, the effects of an earthquake on a potential slide mass are represented by an equivalent static horizontal force determined as the product of a seismic coefficient and the weight of the potential slide mass. The use of the maximum ground acceleration (0.22g, see MKE, Geotechnical Report, 1989) as the seismic coefficient would produce an equivalent static horizontal force equal to the maximum transient inertia force developed on the mass during the design earthquake. However, the length of time for which the force acts is an important factor in the development of deformations. Therefore, the use of the maximum transient force as an equivalent static force would be unduly conservative (Seed and Martin, 1966) and the recommended seismic coefficient of 0.10g should be used.

5.3 METHOD AND RESULTS

The computer program STABL (Siegel, 1975) was used to calculate the factors of safety for circular failure surfaces. Hand calculations were performed using the infinite slope method. The results of the stability analyses are presented in Table 5.3 and are compared with the Corps of Engineers (1970) criteria for minimum acceptable factors of safety. The critical failure surfaces for each loading condition are shown on Figures C-2 to C-8, Appendix C.

TABLE 5.3

RESULTS OF STABILITY ANALYSES

Case	Load Condition	Embankment Stage	Slope	Minimum Acceptable Factor of Safety[a]	Calculated Factor of Safety
1A	End-of-Construction	Starter Dam[b]	Upstream	1.3	1.41
1B	End-of-Construction	Starter Dam	Downstream	1.3	1.55 - 2.02
2A	Steady-State-Seepage	Starter Dam	Downstream	1.5	1.62
2B	Steady-State-Seepage	Final Dam[c]	Downstream	1.5	1.97
3	Design Flood[d]	Final Dam	Downstream	1.4	1.65
4A	Seismic[e]	Starter Dam	Downstream	1.0	1.23
4B	Seismic[e]	Final Dam	Downstream	1.0	1.46

Notes:

a. From Corps of Engineers (1970)

b. Crest El. 3500

c. Crest El. 3700

d. 24-hour PMP plus Snowmelt (see Chapter 4)

e. Seismic Coefficient = 0.10g

As shown in Table 5.3, the calculated factors of safety exceed the minimum acceptable values for all cases. The lowest factor of safety was for the end-of-construction condition (Case 1A) for the upstream slope of the starter dam. The upstream slope is therefore critical only after construction of the starter dam.

The results further indicate that the critical failure surfaces for Cases 1, 2 and 4 are shallow and do not intersect the phreatic surface for steady state seepage. However, for Case 3 (flood condition) shown on Figure C-7, Appendix C, a circular failure surface intersects the high phreatic level.

5.4 LIQUEFACTION POTENTIAL

A. Method

Liquefaction potential was evaluated for sandy foundation soils. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking (Seed, 1979). Soil deposits that are particularly susceptible to liquefaction consist of loose, saturated sands.

The design earthquake used for liquefaction analysis was the Maximum Credible Earthquake (MCE) as described in the Geotechnical Report (1989). The MCE is defined as the largest rationally conceivable event that could occur in the tectonic environment in which the project is located (Seed, 1982). The MCE event was determined to be a magnitude 7 event originating on the Bull Hill fault, 20 kilometers to the west of the project site (MKE, Geotechnical Report, January 1989). The peak ground acceleration at the site was estimated to be 0.22g. This acceleration was used to estimate the seismically induced shear stresses.

Seismically induced shear stresses were computed from the following equation (Seed and Idriss, 1982):

$$\frac{Tav}{p_o'} = 0.65 \frac{a_{max}}{g} \frac{p_o}{p_o'} r_d \qquad (1)$$

where: $\frac{Tav}{p_o'}$ = average seismically induced shear stress ratio

a_{max} = maximum ground surface acceleration = 0.22g

g = gravitational acceleration

p_o = total overburden pressure

p_o' = effective overburden pressure

r_d = stress reduction factor (maximum value equals 1.0)

The results of the field exploration indicate that the foundation soils are dense (MKE, Geotechnical Report, January 1989). Therefore, it was conservatively estimated that the soils would respond rigidly to seismic shaking. Therefore, r_d was taken to be 1.0 and equation (1) becomes:

$$\frac{Tav}{p_o'} = 0.143 \frac{p_o}{p_o'} \qquad (2)$$

To evaluate liquefaction potential, the induced shear stresses caused by the MCE acceleration were compared with the stresses required to cause liquefaction. Stresses to cause liquefaction were estimated from normalized Standard Penetration Test (SPT) data (described below) and MCE magnitude.

In this simplified analysis, cyclic stresses causing liquefaction are based on level ground conditions (i.e., they do not consider the embankment slopes). The cyclic strength of soil is influenced by static stresses under which the soil is consolidated. Within the embankment and foundation, under anisotropic stress conditions, cyclic strengths are greater than would occur under level ground conditions (Seed, 1979). Therefore, cyclic strengths used in this analysis are somewhat conservative.

The stress ratio required to cause liquefaction was determined by first normalizing the recorded field SPT data (N) using the relationship shown in Seed and Idriss (1982):

$$N_1 = C_n N \tag{3}$$

where N_1 is the SPT value normalized to an effective overburden pressure of 1 ton per square foot (tsf). The correction factor C_n was obtained from Seed and Idriss (1982) and is greater than 1 for overburden pressures less than 1 tsf and it is less than 1 for greater overburden pressures. Values of N_1 were used to obtain stress ratios to cause liquefaction using procedures in Seed and Idriss (1982) for a magnitude 7.0 earthquake (see Figure C-10, Appendix C). This relationship is applicable to sands with less than 5% fines. For soils with more than 5% fines, the cyclic stress ratios causing liquefaction are greater than those stress ratios for sands with less than 5% fines (Liquefaction of Soils During Earthquakes, 1985).

B. Results

The SPT data show that the foundation soils at the Little Cherry site are dense to very dense. The lowest N_1-value found in silty sandy soils was 42 in Boring USB-1 at a depth of 35 feet (MKE, Geotechnical Report, 1989). This value is much greater than the value that would indicate potentially liquefiable soils (refer to Figure C-10, Appendix C). The results of the evaluation indicate that the foundation soils are sufficiently dense to preclude liquefication.

Proper compaction and drainage will prevent liquefaction of the embankment dam. The cycloned tailings sands in the embankment dam will be compacted by a bulldozer equivalent in weight to a Caterpillar D8. Also, the drainage blanket within the dam (see Chapter 7) will keep the downstream part of the tailings dam from becoming saturated.

CHAPTER 6
IMPOUNDMENT SEEPAGE AND CONTAMINANT TRANSPORT

6.1 GENERAL APPROACH

Seepage from the impoundment was estimated in order to compare its chemistry with groundwater and surface water quality. The analysis was performed as outlined in the following steps:

- Estimate seepage from the impoundment.
- Estimate groundwater flow through the aquifer beneath the impoundment site to evaluate potential dilution of impoundment seepage.
- Perform simplified contaminant transport analyses.
- Compare impoundment seepage with background groundwater quality and surface water quality.

6.2 IMPOUNDMENT SEEPAGE

The permeability of the fine tailings was estimated from correlations with published values (Vick, 1983). Based on the gradation of the projected cyclone overflow, it is expected that the fine tailings would have permeabilities in the range of 1×10^{-6} to 1×10^{-5} cm/sec. The tailings in the bottom of the impoundment will consolidate to a higher density and, therefore, have a lower permeability than the tailings in the upper portion. The impoundment tailings were divided into two layers: the upper 50% was assumed to have a permeability of 1×10^{-5} cm/sec and the lower 50% was assigned a permeability value of 1×10^{-6} cm/sec.

Flow net analyses indicate that the impoundment area adjacent to the tailings dam will contribute seepage into the coarse tailings embankment. This seepage will be conveyed in a blanket drain system to the seepage collection pond downstream of the tailings dam (see Section 7.6). Seepage from the remainder of the impoundment will flow into the aquifer. This seepage component, which affects contaminant transport, is discussed below.

Because the permeabilities of the impoundment soils (see below) are greater than the tailings permeability values, most of the hydraulic head would be lost in the tailings deposit. Seepage through the tailings would therefore be primarily in the vertical direction under a unit hydraulic gradient. Such an analysis provides a conservative estimate of impoundment seepage.

During the 16-year impoundment life, seepage will increase as the impoundment size increases. Based on a one-dimensional seepage analysis for the final impoundment, the maximum seepage (during year 16) was estimated to be about 475 gpm.

6.3 GROUNDWATER FLOW

For groundwater contaminant transport analyses, dilution of the seepage by groundwater flow was estimated. As discussed in the Geotechnical Report (MKE, 1989), the measured permeability of the Little Cherry site soils generally varies from about 1×10^{-5} to 1×10^{-4} cm/sec. The potentiometric surface map (Chen-Northern, 1989) shows that the average gradient of the potentiometric surface is about 0.05. Based on an aquifer cross-sectional area at the damsite of 780,000 square feet, the estimated flow ranges from about 6 to 60 gpm for aquifer permeabilities of 1×10^{-5} and 1×10^{-4} cm/sec, respectively. Even with the higher flow rate of 60 gpm, little dilution is expected of the impoundment seepage (about 475 gpm) by groundwater flow. Dilution will only be significant during the first one or two years of the impoundment life, when seepage rates are less.

6.4 CONTAMINANT TRANSPORT ANALYSES

The term "contaminant transport" as referenced in this report is widely used to describe the movement of an effluent through a groundwater system. Contaminant transport analyses were performed by using the computer program CXPMPM developed by Slotta Engineering Associates of Corvallis, Oregon (1987). The model considers longitudinal dispersion and one-dimensional flow. In these simplified but conservative analyses, potential adsorption and chemical reactions in the aquifer were not considered. Dispersivity values for alluvial aquifers generally range from 20 to 200 meters (Lawrence Livermore Laboratory, 1979). An effective porosity value of 0.21 for the aquifer was used in the analyses (Fetter, 1980).

The results of the contaminant transport analyses are presented in Appendix D. The results of the analyses show that, for a dispersivity value of 20 meters, there would not be significant attenuation of the tailings effluent chemical concentration at the proposed permit boundary at Libby Creek, about 4,000 feet downstream of the impoundment. For a dispersivity of 200 meters, tailings effluent chemical concentrations would decrease to about 60% of their original values in the impoundment. Therefore, between approximately 60% and 100% of the tailings effluent concentrations shown in Table 6.1 are expected to appear at the permit boundary.

6.5 COMPARISON OF IMPOUNDMENT SEEPAGE AND WATER QUALITY

Chemical concentrations of groundwater samples from five wells in the impoundment vicinity are shown in Table 6.1 (Chen-Northern, 1989). The well locations are shown in the Geotechnical Report (MKE, 1989). The table shows that the tailings effluent chemical concentrations generally do not exceed the background groundwater concentrations. Also, as shown in Table 6.1, tailings effluent concentrations are often less than background groundwater concentrations for aluminum, cadmium, iron, manganese and zinc. The detection limits for mercury and silver are not sufficiently low to determine their concentrations relative to background data.

During field reconnaissance work, seeps were observed in both the Little Cherry Creek and Libby Creek channels. Therefore, it is expected that a portion of the effluent will also emerge as seepage in both creek channels. The seepage will mix with the streamflow. The nearest stream measurement station (LB-800) to the confluence of Little Cherry Creek and Libby Creek is on Libby Creek, about 3 miles upstream of the confluence. Minimum dilution will occur during low streamflow. The lowest flow recorded at this station was 7.2 cfs (3,200 gpm) in August 1988 (Chen-Northern, 1989). This flow was recorded during one of the driest summers on record (Chen-Northern, 1989). The maximum impoundment seepage (475 gpm) will be significantly diluted by the flow in Libby Creek, even during low flow.

Most of the chemical concentrations shown in Table 6.1 are the detection limits for the measurement methods used; i.e., actual concentrations are less than the detection

TABLE 6.1

MONTANA PROJECT
WATER CHEMISTRY DATA

WELL:	LCM-011[b]		LCM-010		LCTM-008	PLCM-65N		PLCM-60P		PLCM-60P		LCM-009		LIBBY CREEK[a] (STATION LB-2000)		TAILINGS EFFLUENT[c]	
	GROUNDWATER[a]																
DATE:	8-15-88	10-22-88	8-16-88	11-3-88	8-17-88	8-18-88	10-21-88	8-18-88	10-21-88	8-18-88	10-21-88	8-19-88	10-21-88	10-17-88	11-14-88		
PARAMETER																	PARAMETER
pH - Field	9	8.4	6.9	-	7.1	8.9	8.1	7.1	7.3	7.2	-	7.2	7.1				pH - Field
pH - Lab	9	8.5	7.4	7.6	7.2	8.7	8.1	7.8	7.8	7.8	7.8	7.2	7.2	7.4	7.2	7.6	pH - Lab
SC - Field	240	173	154	-	186	196	161	180	162	170	-	202	184				SC - Field
SC - Lab	244	189	156	154	193	208	198	177	176	179	178	208	196	65	23		SC - Lab
(mg/l):																	(mg/l):
TDS	148	100	108	100	108	145	112	102	101	90	96	112	115	41	22		TDS
TSS														< 1	2		TSS
Hardness	137	77	57	47	95	119	86	92	93	80	93	110	86	26	8		Hardness
Calcium	30	19	16	12	23	31	21	25	24	22	24	29	21	7	3	12	Calcium
Magnesium	15	7	4	4	9	10	8	7	8	6	8	9	8	2	< 1	3	Magnesium
Sodium	48	11	12	10	7	8	5	4	2	2	2	8	7	1	1	13	Sodium
Potassium	3	3	7	5	2	2	1	< 1	1	< 1	< 1	2	2	< 1	1	24	Potassium
Alkalinity, total	203	101	81	78	96	122	106	94	92	97	92	108	94	34	11		Alkalinity, total
Alkalinity, bicarb.	197	123	9	95	117	129	129	115	112	118	112	132	115	41	13		Alkalinity, bicarb.
Alkalinity, carb.	25	0	0	0	0	10	0	0	0	0	0	0	0	0	0		Alkalinity, carb.
Alkalinity, hydrox.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Alkalinity, hydrox.
Chloride	4	2	5	2	< 1	1	< 1	1	1	< 1	< 1	2	2	< 1	< 1		Chloride
Fluoride	0.12	0.12	0.11	0.21	0.09	0.11	0.14	0.09	0.1	0.06	0.1	0.12	0.15	< 0.05	< 0.05		Fluoride
Nitrate & Nitrite	0.38	0.52	0.11	0.32	0.87	0.15	0.57	0.04	0.04	0.03	0.03	0.65	1.38	0.03	0.09		Nitrate & Nitrite
Sulfate	7	11	6	3	3	2	1	1	< 1	1	1	3	2	2	1		Sulfate
Aluminum	< 0.1	< 0.01	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.8	< 0.1	< 0.1	0.1	Aluminum
Arsenic	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	Arsenic
Cadmium	< 0.001	< 0.001	0.001	0.001	0.006	0.002	< 0.002	0.001	< 0.001	0.004	0.002	0.003	0.002	0.0007	0.0005	< 0.001	Cadmium
Chromium	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	Chromium
Copper	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.001	< 0.001	< 0.01	Copper
Iron	< 0.05	< 0.05	< 0.05	0.07	< 0.05	< 0.05	0.14	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.55	< 0.05	0.06	0.05	Iron
Lead	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.001	< 0.001	< 0.01	Lead
Manganese	0.81	0.02	0.33	1.09	0.14	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.76	0.13	< 0.02	< 0.02	0.06	Manganese
Mercury	< 0.0002	< 0.0002	< 0.0002	0.0003	< 0.0002	< 0.0002	0.0003	< 0.0002	0.0002	< 0.0002	0.0002	< 0.0002	0.0002	< 0.0002	< 0.0002	< 0.001	Mercury
Molybdenum	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.01	Molybdenum
Silver	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.0003	< 0.0002	< 0.005	Silver
Zinc	< 0.02	< 0.02	< 0.02	< 0.02	0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.21	< 0.02	< 0.02	< 0.02	< 0.01	Zinc
Ammonia																	Ammonia
Antimony																0.01	Antimony
Cobalt																< 0.01	Cobalt
Beryllium																< 0.005	Beryllium
Barium																< 0.1	Barium
Selenium																< 0.005	Selenium
Phosphorous														0.01	< 0.005		Phosphorous
Nickel																< 0.03	Nickel

NOTES:
a. From Chen-Northern (1989).
b. Wells are located in the vicinity of impoundment site.
c. From Energy Laboratories Inc., Water Analysis, Final Tailings Solution, Cycle 5, 12-20-88.

limits. Therefore, it cannot be determined whether many of the tailings effluent concentrations, after dilution with streamflow, would exceed the background surface water quality in Libby Creek.

The main effluent constituents include lead, mercury, silver and cadmium. The concentrations of lead, mercury and silver, after dilution with streamflow, may or may not exceed background surface water concentrations. However, the background surface water concentrations for cadmium are greater than its detection limits. Therefore, a conservative mass-balance estimate was made of the cadmium concentration after dilution with streamflow. For a conservative approach, the detection limit for cadmium (0.001 mg/l) was assumed to be its concentration. After dilution with streamflow, the concentration of cadmium will be less than 0.0007 mg/l, which was the background concentration recorded in Libby Creek in October 1988.

Nitrate is not shown in the tailings effluent assay (Table 6.1). However, it is expected that nitrate will be present in the tailings effluent. Mine water, which will contain nitrate, will be utilized in the milling process; tailings and mill water slurry will be piped to the impoundment. The nearby Troy Project reported 12 mg/l nitrate in the tailings effluent (Hydrometrics, 1987). This concentration was used for preliminary estimating purposes. After dilution of impoundment seepage water with the Libby Creek streamflow, the nitrate concentration was estimated to be between 1 and 2 mg/l. This estimate conservatively assumes no loss of nitrate in groundwater flow or in seepage areas where nitrate will be utilized by vegetation.

The results of the seepage and contaminant transport analyses are presented for the final impoundment, a condition when seepage would be a maximum. After the impoundment has been filled to capacity, the effluent will be evaporated from the tailings surface. Seepage will therefore decrease with time resulting in a diminished migration of effluent from the impoundment.

CHAPTER 7
TAILINGS IMPOUNDMENT DESIGN AND CONSTRUCTION

7.1 DESIGN CRITERIA

A conceptual design was prepared of the Little Cherry tailings impoundment. The design has not been optimized; the design will be finalized during subsequent design development studies. General preliminary design criteria are presented in the Design Basis Memorandum (DBM), Appendix A.

The operating stages, after completion of the initial stage of the impoundment, will be constructed by the "downstream" method using cycloned tailings sands. A tailings slurry of 30% solids will be conveyed in a pipeline from the mill to the impoundment site. Decant water from the impoundment will be returned to the mill by a pump mounted on a barge.

Based on the results of bench-scale flotation tests, the tailings feed will consist of silt and sand particles with 52% passing the No. 200 sieve (0.074mm). The tailings production rate will be 20,000 dry tons per day and will total about 120,000,000 tons. This tailings production rate and required storage capacity indicate that the impoundment operational life will be about 16 years. Impoundment area-capacity curves, together with expected tailings production rates, were used to determine the tailings pond and dam crest elevations versus time curves.

For conceptual impoundment design, the upstream slope of the tailings retention embankment will be 2(H):1(V) and the downstream slope of the embankment will be 3:1. The embankment crest width will be 30 feet to accommodate vehicular access, cyclones and slurry pipelines.

The required dam crest elevation was based on providing the following:

- Tailings storage
- Storage of tailings effluent for 20 days at 8,000 gpm (about 700 acre-feet)
- Storage of design flood (see Chapter 4)
- Minimum freeboard of 3 feet above the peak flood water surface

Topographical features were utilized to minimize earthfill dam volume requirements and watershed runoff storage. A diversion dam and channel were designed to decrease the tailings impoundment watershed area. Downstream slopes of the starter, diversion and seepage control dams will be constructed of rockfill to protect against erosion and increase stability. The rockfill slope of the starter dam will also act as a drain to lower the phreatic surface within the tailings retention dam.

Riprap lined seepage collection ditches will be constructed along the toe of the downstream slope to carry seepage and runoff to collection ponds downstream. The seepage collection dam was sized to store (1) runoff resulting from the 100-year, 24-hour precipitation or seepage for one week during an assumed pump system breakdown and (2) water from cycloned sand spigotted onto the downstream embankment dam slope.

A blanket drain will be constructed along the base of the embankment dam to control seepage. The blanket drain will be more permeable than the relatively clean cycloned sands that contain approximately 10 percent passing the No. 200 sieve. Based on grain size data, the cycloned sands would be about 100 times more permeable than the fine tailings in the pond.

7.2 SITE PREPARATION

Prior to placement of embankment fill, the foundation will be cleared of vegetation and stripped of subsoil containing organic matter. The subsoil will be stockpiled for later reclamation activities. Any loose or soft materials will be removed from the dam foundation and replaced with compacted fill. Based on the results of the test pit excavations, the depth of stripping is anticipated to be 1 to 2 feet in the impoundment area; however, the actual depth of stripping will be determined during construction.

All debris and tree stumps will be removed from the embankment dam foundations. After stripping, the embankment foundation surfaces will be scarified and compacted. All embankment subgrade areas will have to be kept well drained to prevent ponding during foundation preparation operations.

As indicated in the Geotechnical Report (1989), sand or gravel fluvial outwash deposits were found in the impoundment site. If soils consisting of sandy gravels and cobbles are exposed during impoundment site stripping and borrow excavation operations, these areas will be covered with a 2- to 3-foot thick layer of compacted clayey soil to minimize the infiltration of water from the tailings or from the seepage collection pond (see Section 7.6).

7.3 AVAILABILITY OF CONSTRUCTION MATERIALS

Earthfill materials will be obtained from the diversion channel and seepage pond excavations and from an impoundment borrow area (Figure 4). The diversion channel excavation and seepage collection pond excavation (1,995,000 cubic yards) will provide earthfill materials for constructing the initial impoundment structures. During operations, approximately 1,300,000 cubic yard of soils will be excavated from the impoundment for completion of the required earthfill construction (north and south saddle dams). The borrow area covers approximately 145 acres below the final pond level at El. 3690. The average excavation depth in the borrow area would be about 6 feet after stripping.

Based on an in-place embankment density of 140 pcf, preliminary estimates indicate that approximately 831,000 cubic yards of rockfill will be available at the time of mill start-up. Subsequently, an estimated 74,000 cubic yards of rockfill will be available annually. The total volume of rockfill, drain, filter and riprap required is 2,771,000 cubic yards, which exceeds the estimated 2,000,000 cubic yards of mine waste rock available over the mine life. Therefore, a quarry will be required, or materials will have to be imported.

Rockfill and riprap will be obtained from mine waste or from a quarry. Blanket drain and filter materials will be obtained by crushing, screening and washing mine waste or quarried rock, or the material will be imported from a commercial source.

A large portion of the embankment dam will be constructed of cycloned coarse tailings (underflow). The fine tailings (overflow) will be deposited in the impoundment. Based on a production rate of 20,000 tons per day and on in-place dry densities of 100 pounds per cubic foot (pcf) for coarse tailings and 70 pcf for fine tailings, approximately 1,764,000 cubic yards of coarse tailings and 5,202,000 cubic years of fine tailings will be produced annually.

7.4 EMBANKMENT ZONES

The embankments will be zoned earth- and rockfill structures. A summary of materials, sources, placement and compaction requirements is presented in Table 7.1. The information shown in the table is for preliminary planning and will be confirmed during final design studies. A summary of estimated quantities is shown in Table 7.2. Descriptions of the various embankment zones follow:

- Zone 1: Earthfill materials consisting of clayey silty and silty gravelly soils will be obtained from required excavations and from borrow areas within the impoundment (see Figure 4). The coarser materials will be routed to the exterior slopes for transition with the upstream riprap and downstream rockfill zones. The material will be placed in 8 to 12-inch thick lifts, depending on material gradation, and will be compacted to a dry density equal to at least 95% of the maximum dry density as determined by ASTM D698 (Standard Proctor compaction). The results of the field exploration (MKE, Geotechnical Report, 1989) show that moisture conditioning will be required to bring the soils within plus or minus 2% of the optimum moisture content.

- Zone 2: As described in Section 7.5, the cycloned sand will contain 10% fines and will be obtained from a double-cycloning operation. As the sands are spigotted onto the downstream slope, a bulldozer equivalent in size to a Caterpillar D8 will be used to spread and compact the sands. The approximate lift thickness will be about 8-inches parallel to the downstream slope and the sands will be compacted by 4 passes of the dozer.

- Zone 3: Rockfill will be obtained from mine waste rock. A quarry will be needed as a back-up source in the event there is insufficient mine waste rock. The lift thickness will be adjusted to accommodate the rockfill materials, but it is anticipated that lift thicknesses will be 24 inches. A 10-ton smooth drum

TABLE 7.1

CONSTRUCTION MATERIAL SUMMARY[a]

ZONE	DESCRIPTION	MATERIAL	SOURCE	LIFT THICKNESS (in.)	COMPACTION
1	Earthfill	Clayey silty and silty gravelly soils, coarse particles routed to exterior slopes.	On-site borrow and diversion channel excavation	8 - 12	95% ASTM D698
2	Cycloned Sand	10% finer than 0.074 mm (No. 200 Sieve).	Mill operation	8 (parallel to slope)	4 passes of D8 Dozer[b]
3	Rockfill	24 inches maximum size.	Mine waste or quarry	24	4 passes of 10-ton vibratory roller or D8 Dozer[b]
4	Filter	Well-graded, 1-inch maximum size and not more than 2% finer than 0.074 mm.	Mine waste, quarry or import	9	4 passes of D8 Dozer[b]
5	Blanket Drain	Well-graded, 3 inch maximum size.	Mine waste, quarry or Import	12	4 passes of D8 Dozer[b]
6	Riprap	Well-graded, 30-inch average size.	Mine waste or quarry	36	Dumped

Notes:

a. Subject to confirmation during final design.

b. Or equivalent dozer.

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TABLE 7.2

ESTIMATED IMPOUNDMENT CONSTRUCTION QUANTITIES

	Maximum Embankment Height (ft.)	Embankment Length (ft.)	Zone 1: Earthfill (c.y.)	Zone 2: Coarse Tailings (c.y.)	Zone 3: Rockfill (c.y.)	Zone 4: Filter (c.y.)	Zone 5: Blanket Drain (c.y.)	Zone 6: Riprap (c.y.)	Excavation (c.y.)	Total Embankment Fill (c.y.)
Fill:										
Starter Dam	120	3050	762,000		433,000	30,000				1,225,000
Toe Dike	100	6600			789,000	75,000				864,000
Final Dam	380	3950		27,844,000		463,000	281,000			28,588,000
North Earthfill Saddle Dam	40	1400	111,000							111,000
South Earthfill Saddle Dam	130	3550	1,681,000		465,000	37,000				2,183,000
Total Tailings Retention Dam										32,971,000
Diversion Dam	85	850	173,000		66,000	5,000		8,000		252,000
Seepage Collection Dam	80	500	66,000		42,000	7,000		2,000		117,000
Excavation:										
Diversion Channel								56,000	1,755,000	--
Collection Ditches								12,000	24,000	--
Seepage Collection Pond									240,000	--
TOTALS			2,793,000	27,844,000	1,795,000	617,000	281,000	78,000	2,019,000	33,340,000

Stripping - 1,000,000 c. y.

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vibratory roller will be used to compact the rockfill in the diversion dam, seepage collection dam, starter dam, south saddle dam and initial stages of the toe dike. A D8 dozer or equivalent will be used to compact subsequent stages of the toe dike rockfill. Four passes of either the roller or dozer will be needed for compaction.

- Zone 4: Filter materials will consist of well-graded sand and gravel with a maximum particle size of 1-inch and not more than 2% finer than the No. 200 Sieve. The material could be crushed, screened and washed from mine waste rock or quarried rock. Washing will require that a sediment pond be constructed. Alternatively, the drain material could be imported from commercial sources in Libby. The drain material will be placed in 9-inch thick lifts and compacted by 4 passes of a D8 dozer.

- Zone 5: Well-graded gravel blanket drain will be processed to a maximum particle size of 3 inches from mine waste or quarried rock, or the gravel will be imported. The material will be placed in 12-inch thick lifts and compacted by 4 passes of a D8 dozer.

- Zone 6: Riprap will be obtained from mine waste rock or quarry. The material will be well-graded and will have a 30-inch average (D_{50}) size. The material will be placed by dumping; compaction is not required for riprap.

7.5 IMPOUNDMENT CONSTRUCTION

A conceptual design was prepared for the initial and final stages of the Little Cherry tailings impoundment. The vicinity topography and watershed are shown on Figure 3. The plan and typical sections are shown on Figures 4 and 5, respectively.

The Little Cherry impoundment will consist of the following structures:

- Diversion Dam

- Diversion Channel

- Tailings Retention Dam that includes a Starter Dam and Toe Dike
- Two Earthfill Saddle Dams
- Seepage Collection Dam
- Collection Ditches

The conceptual impoundment construction schedule is shown on Figure 6. The schedule shows construction of the initial stage during two 6-month seasons prior to mill start-up and during mill operations for impoundment expansion.

The initial stage of the impoundment work will include construction of the diversion channel and the 85-foot high diversion dam. The channel excavation will total about 1,755,000 cubic yards. The channel excavation could include some rock; the Geotechnical Report shows weathered rock outcrops south of the proposed channel. Material excavated from the channel will be used to construct the diversion dam. As shown on Figure 4, the diversion dam bounds the southwest part of the tailings impoundment. The downstream portion of this dam will be constructed of rockfill obtained from mine and adit waste rock.

After the diversion dam has been completed, the starter dam, seepage collection dam and toe dike will be constructed. The 120-foot high starter dam will be constructed of soils excavated from the diversion channel. The starter dam size was based on providing about 1 year of tailings storage. As proposed for the diversion dam, the downstream portion of the starter dam will be constructed of rockfill to promote drainage. Materials from the remainder of the diversion channel excavation will be used to construct about a third of the south saddle dam earthfill. Approximately 20% of the rockfill toe dike will be constructed prior to mill operations.

Construction scheduling during operations is based on obtaining earthfill borrow materials from the impoundment before they become covered by tailings. The south saddle dam will be completed by the end of the fourth year of operations. Materials for completing this embankment will be obtained from the impoundment borrow area (Figure 4). As mine waste rock becomes available, rockfill will be placed in the toe dike and in the downstream portion of the south saddle dam. The north saddle dam will be constructed of materials excavated from the impoundment during the tenth year of operations. The blanket drain will be placed ahead of the cycloned tailings during mill operation.

The 380-foot high final tailings dam will have a crest length of about 5,950 feet and will be at El. 3700 as shown on Figure 4. The total embankment dam volume is about 32,971,000 cubic yards (see Table 7.2). Approximately 27,844,000 cubic yards of the dam will be constructed of cycloned sand having about 10 percent passing the No. 200 Sieve. A two-stage cycloning process will be required to produce this gradation of sand (see Appendix E). The estimated coarse sand recovery will be about 33% (by weight) of the total tailings feed. A summary of the cyclone operation showing the amount of overflow and underflow and percent fines for each stage is presented in Table 7.3.

TABLE 7.3

SUMMARY OF CYCLONE OPERATION[a]

Cyclone	Feed		Overflow		Underflow	
Stage	TPD[b]	% fines[c]	TPD[b]	% fines[c]	TPD[b]	% fines[c]
First	20,000[d]	52	11,840	73	8,160	21
Second	8,160	21	1,637	68	6,523	10

Notes:

a. See also Appendix E
b. Production in tons per day
c. Material finer than 0.074mm
d. From mill

The underflow (coarse tailings) from the second stage of the cyclone process will be spigotted onto the downstream slope of the dam. The cyclones will be moved along the crest of the dam for uniform distribution of the coarse tailings. A bulldozer will be required full time to grade and compact the face of the dam. The cycloned sand will probably have to be stockpiled during freezing weather conditions. The runoff water from the cyclone process (585 gpm) will flow into the seepage collection pond and the water will be pumped back to the impoundment.

During operation, wind erosion of the embankment dam coarse tailings will be mitigated by sprinkling the face of the dam with pond water. Any erosion rills will be filled with coarse tailings.

The cyclone overflow (fine tailings) will be stored in the impoundment. The final pond will store about 83,610,000 cubic yards of fine tailings and will have an area of about 445 acres. The total storage of both fine and coarse tailings will be 111,454,000 cubic yards, or about 120,000,000 tons. Impoundment area-capacity curves, tailings production curves and impoundment staging curves are shown on Figure 7.

7.6 TAILINGS DAM SEEPAGE CONTROL

To control seepage through the tailings embankment, a blanket drain will be placed on the foundation as the dam is being raised. The drain will consist of processed clean gravel and will be 3 feet thick in the valley bottom and 2 feet thick at higher elevations (see Figure 4). Also, the rockfill zone in the downstream portion of the starter dam will promote drainage within the tailings embankment. To prevent piping of the tailings and foundation soils into the gravel drain, 1.5-foot thick well-graded gravelly sand filter blankets will be located above and below the blanket drain (see Figure 5). The filter will also be placed on the downstream face of the starter dam and on the upstream face of the toe dike to prevent piping of tailings sand into the rockfill zones. Finger drains on the upper part of the abutments (Figure 4) will be constructed of the same gravelly sand used for filter blankets.

Seepage through the dam or storm runoff will be routed via ditches to the seepage collection pond. The water in the pond will be pumped back to the tailings impoundment. Any fines that collect against the upstream face of the toe dike will be removed during operations.

To determine the required blanket drain capacity, seepage through the embankment dam was estimated. During the operational life of the impoundment, seepage will increase as the impoundment size increases. For the final tailings embankment dam configuration, the results of flow net analyses indicate that seepage collected in the blanket drain and conveyed to the collection pond could be about 320 gpm. Preliminary engineering results indicate that the 2- to 3-foot thick blanket drain consisting of clean gravel will be adequate to control this seepage quantity.

7.7 SURFACE WATER CONTROL

The tailings impoundment will be developed by constructing a dam across Little Cherry Creek. The watershed area above the proposed tailings dam is 1.78 square miles. A permanent diversion system consisting of a dam at the upstream end of the impoundment and diversion channel will be required to route the creek around the impoundment and to reduce the watershed area of the tailings impoundment; the diversion channel will lead to a natural stream channel. The diversion system was designed to divert the design flood (Chapter 4) around the south side of the tailings impoundment.

The diversion channel will be 3,400 feet long and will have a bottom width of 20 feet. Side slopes will be 2(H):1(V) and the channel will have a 2.4% gradient. The channel will be protected against erosion by a 3-foot thick layer of riprap. The riprap will be well-graded and the rock will have an average (D_{50}) size of 30 inches. To minimize the potential for erosion of the natural stream channel, rockfill bars will be placed perpendicular to the channel to serve for flow energy dissipation. Locations of the bars will be determined by observing performance of the channel during the 16-year operational period.

To minimize runoff into the tailings impoundment during operation, temporary diversion ditches will be excavated around the tailings impoundment. As the impoundment fills, new ditches will be excavated further uphill.

CHAPTER 8

STABILITY MONITORING AND CONTINGENCY PLANS

8.1 STABILITY MONITORING PLAN

A. General

A program will be established to monitor the performance of the impoundment facilities. The program includes periodic visual inspections, reviews by engineers experienced in tailings dam design and construction, and measuring embankment seepage and foundation piezometric pressures.

B. Instrumentation

To monitor the development of pore water pressures in the foundation beneath the dam during operation and for several years after closure of the impoundment, pneumatic piezometers will be installed in at least three transverse sections of the dam. The leads from these piezometers will be extended to read-out terminals at the downstream toe of the dam. To measure foundation pore pressures downstream of the dam, standpipe piezometers will be installed.

The piezometric pressures will be measured quarterly. Piezometric pressures will be evaluated annually by a tailings dam engineer to confirm that the dam is performing as planned and to make recommendations for remedial actions if foundation pressures are higher than anticipated. The piezometric data will be used to determine the necessity for installing pressure relief wells to reduce high foundation pore pressures.

A V-notch weir will be located at the downstream toe of the dam to monitor seepage rates. The flow from the cycloned sand will also pass through the weir. Since this flow rate in known, it will be subtracted from the total flow to determine the seepage rate.

C. Inspections

Weekly visual inspections will be made to observe and document the conditions of the embankment dams, diversion channels and abutments. A checklist will be prepared as a guide for systematically inspecting the site facilities. The checklist will include the following:

- o Freeboard Adequacy
- o Tailings Beach Width
- o Embankment Dams and Abutments:
  - Cracking, sloughing, depressions and erosion
  - Changing trends in seepage quantities, turbid seepage (piping) and wet spots on abutments and on downstream faces of embankments
  - Conditions of piezometer terminals and standpipe piezometers
- o Diversion Channel:
  - Cracking, sliding and erosion
  - Condition of riprap
  - Debris and vegetation in channel

The checklist will be completed by designated operations personnel trained in the inspection and maintenance of tailings dams. The inspectors will report their findings to management. The visual inspection records will also be reviewed annually by tailings dam engineers. After impoundment closure, the frequency of inspections will be gradually decreased.

8.2 CONTINGENCY PLAN

With the construction of any type of impoundment structure, there is always the possibility, however remote, of partial or total failure. Therefore, a contingency plan is required to (1) identify the type of incident, (2) formulate the required remedial action and (3) to identify the authorities to be contacted.

Actual remedial actions would be determined from the specific conditions of the failure incident. The plant manager or his designate will be contacted in the event that any unusual condition is observed. The plant manager will notify the tailings dam engineer. If, after consultation with the engineer, the condition is considered to be sufficiently serious, the plant manager will notify the U.S. Forest Service in Libby and the Department of State Lands in Helena.

After initial remedial actions have been identified and implemented, an engineering analysis will be conducted to determine the cause of the problem and procedures for long-term stabilization.

CHAPTER 9
CONCEPTUAL RECLAMATION PLAN

9.1 TAILINGS IMPOUNDMENT RECLAMATION PLAN

The tailings impoundment reclamation concept is based on Montana regulations that require the land to be returned to a comparable utility that existed prior to impoundment construction (Administrative Rules of Montana, 1980). The conceptual reclamation plan and section for the Little Cherry impoundment are shown on Figures 8 and 9, respectively.

The intent of the reclamation scheme described in this section is to minimize potential long-term erosion and maximize stability of the tailings embankment dam. Grading the impoundment surface, replacing soil that had been stripped during construction operations and seeding will decrease erosion potential. Draining the water from the tailings impoundment will increase stability of the dam. Final reclamation planning will be done prior to impoundment closure.

The basic plan for reclamation consists of the following operations:

- o Stripping soils containing organic matter during periods of impoundment construction
- o Depositing cycloned sands into the impoundment during the final year of operation
- o Drying the pond surface by promoting natural desiccation and evaporation
- o Grading the pond surface
- o Replacing soil stripped from the site during construction
- o Seeding the reclaimed pond surface.

After final tailings deposition has been completed, the reclamation operations will be performed concurrently over a span of a few years.

During periods of embankment dam construction and impoundment enlargements, soils containing organic materials will be stripped and stockpiled around the impoundment. Based on the results of test pit excavations, it is expected that the depth of stripping will average about 1-foot. The actual stripping depths will be determined during construction.

The three stockpile sites shown on Figure 8 will store about one million cubic yards of soil. The stockpiles will have 3(H):1(V) slopes and the stockpiles will be seeded to minimize erosion. Ditches will be constructed to divert runoff around the stockpiles.

During mill operations, cyclone overflow will be deposited in the pond primarily from the east and south sides of the impoundment. This position of deposition will cause the tailings to slope gradually away from the dam crest. Tailings effluent will flow away from the south and east sides of the impoundment. During the last year of operations, when the tailings dam crest has been completed to its ultimate operating level, the remaining portion of the cycloned coarse tailings (about 370,000 cubic yards) will be deposited into the impoundment along the east and south sides of the impoundment forming a berm.

After the impoundment has been filled to capacity, surface water will be evaporated. Spraying the effluent would increase the evaporation rate. The phreatic level within the tailings will be lowered so construction equipment could work on the surface. Dewatering the top few feet of tailings will be accomplished by promoting natural drying and evaporation.

The coarse tailings berm formed along the south and east sides will be graded downward toward the northwest at a slope of 0.5% to 1%, along the natural slope of the tailings surface. Grading of the fine tailings will be required to shape the pond surface as shown on Figure 8. The small north saddle embankment will be removed so that runoff can drain from the impoundment surface to the Bear Creek drainage.

It is anticipated that a depression will form in the center of the pond due to consolidation settlement of the tailings. During grading activities, this depression will be filled with coarse tailings and mine waste rock. Potential settlement of the pond surface will be estimated during final reclamation studies.

Because the fine pond tailings will contain a significant amount (68 to 73%) of silty fines, some difficulty in dewatering the tailings in the low portion of the impoundment surface is anticipated. In this area, dewatering could be enhanced by excavating trenches that lead to a collection area in a low point on the pond surface. The collected seepage water would be spray evaporated. The tailings in this area will have a low bearing capacity. In order to work on the surface, subgrade reinforcement, such as a geotextile, may be needed.

The final tailings pond surface and downstream face of the embankment dam will be covered with a 1-foot thick layer of the stockpiled subsoil. Approximately one million cubic yards of soil will be replaced during reclamation. The soil will be placed from the high side of the impoundment toward the low area and will be spread by bulldozers.

The soil layer will be vegetated with grass by using conventional seeding methods or by hydro-mulching. The grass will minimize erosion due to wind and surface runoff. To minimize potential gully formation at the tailings dam crest, riprap will be placed on the dam crest and uppermost part of the 3:1 slope (see Figure 9). Filter fabric beneath the riprap layer will prevent piping of the tailings into the riprap.

Because seepage will continue after tailings pond closure, but at reduced rates, the seepage collection pond will remain in place. Seepage collected in the pond will be pumped to the tailings pond surface where it will be spray evaporated and used for irrigating grass.

9.2 DIVERSION CHANNEL RECLAMATION

The diversion channel on the south side of the impoundment will be a permanent channel. Adequate erosion protection measures and slope stability of the channel are required for acceptable long-term performance.

As described in Section 7.7, a 3-foot thick layer of riprap will be provided to prevent erosion of the channel. Also, to minimize erosion of the natural stream channel downstream of the diversion channel, rockfill bars will be constructed to dissipate flow energy.

The 2(H):1(V) slopes of the diversion channel will be benched to control surface water runoff. During construction of the initial impoundment stage, the slopes will be covered with 1-foot of subsoil (that had been previously stripped) and seeded with grass to minimize erosion.

During the 16-year operational life, the channel will be regularly inspected. The performance during this period will be an indicator of long-term performance after pond-closure. Any signs of slope instability will be rectified by flattening slopes, constructing additional benches, providing drainage or by using other suitable methods.

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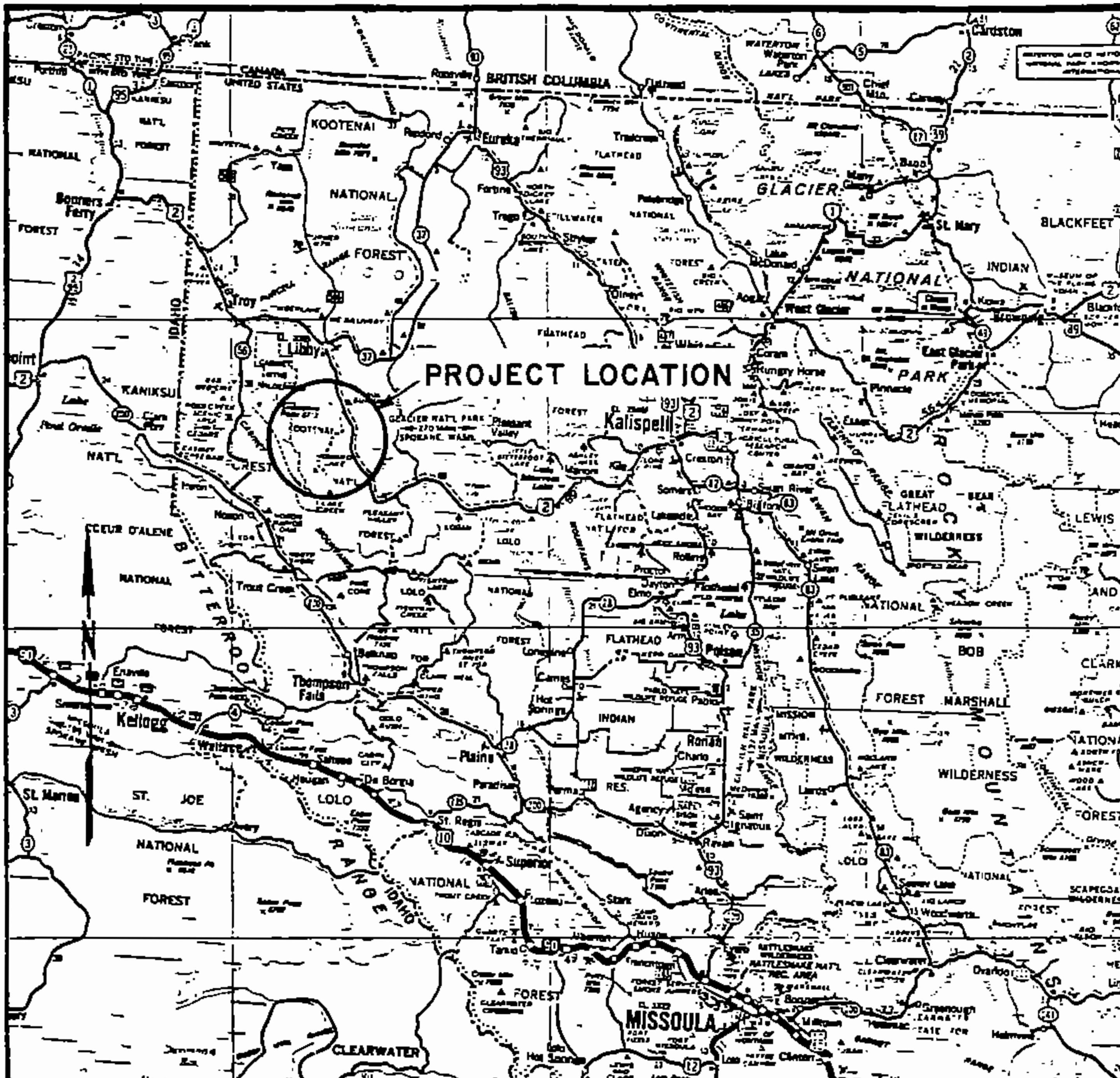
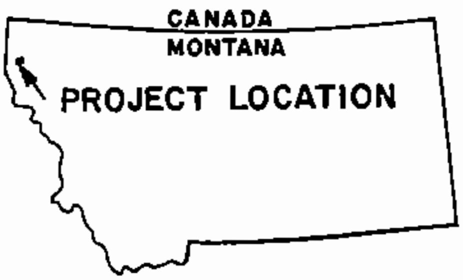
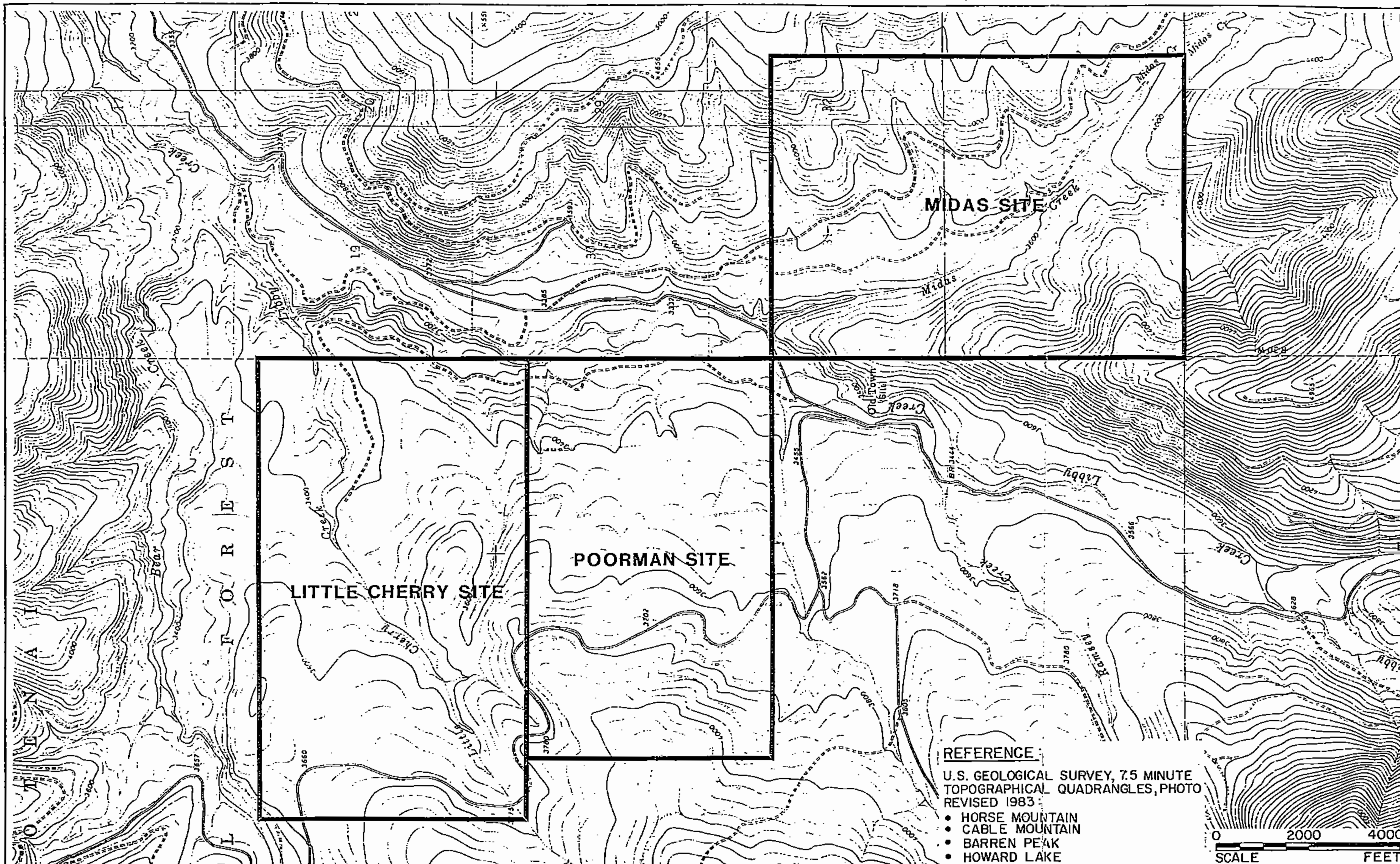




KEY PLAN

25 0 25 50
SCALE MILES

MORRISON-KNUDSEN ENGINEERS, INC. 180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105	MONTANA PROJECT
DESIGNED RB / DRAWN RB / CHECKED MPF / RECOMMENDED	PROJECT LOCATION MAP
DATE OCTOBER 1988 / APPROVED	FIGURE 1



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DATE JANUARY 1989 | APPROVED

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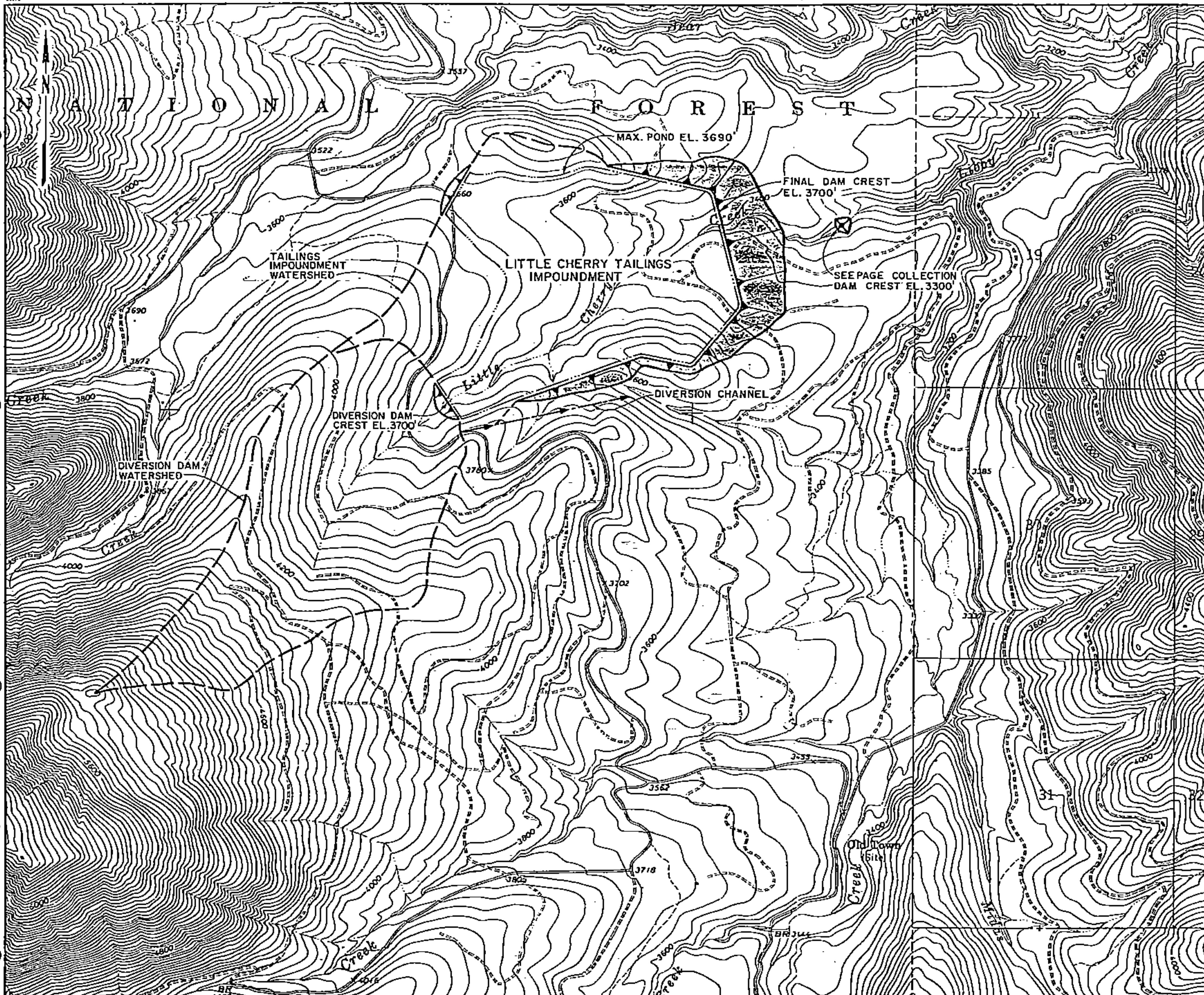
MONTANA PROJECT

ALTERNATIVE TAILINGS IMPOUNDMENT SITES

SHEET OF | REV

FIGURE 2



REFERENCE:

U.S. GEOLOGICAL SURVEY, 7.5 MINUTE CABLE MOUNTAIN TOPOGRAPHICAL QUADRANGLE

CONCEPTUAL-NOT FOR CONSTRUCTION

SCALE 1000 0 1000 2000 FEET

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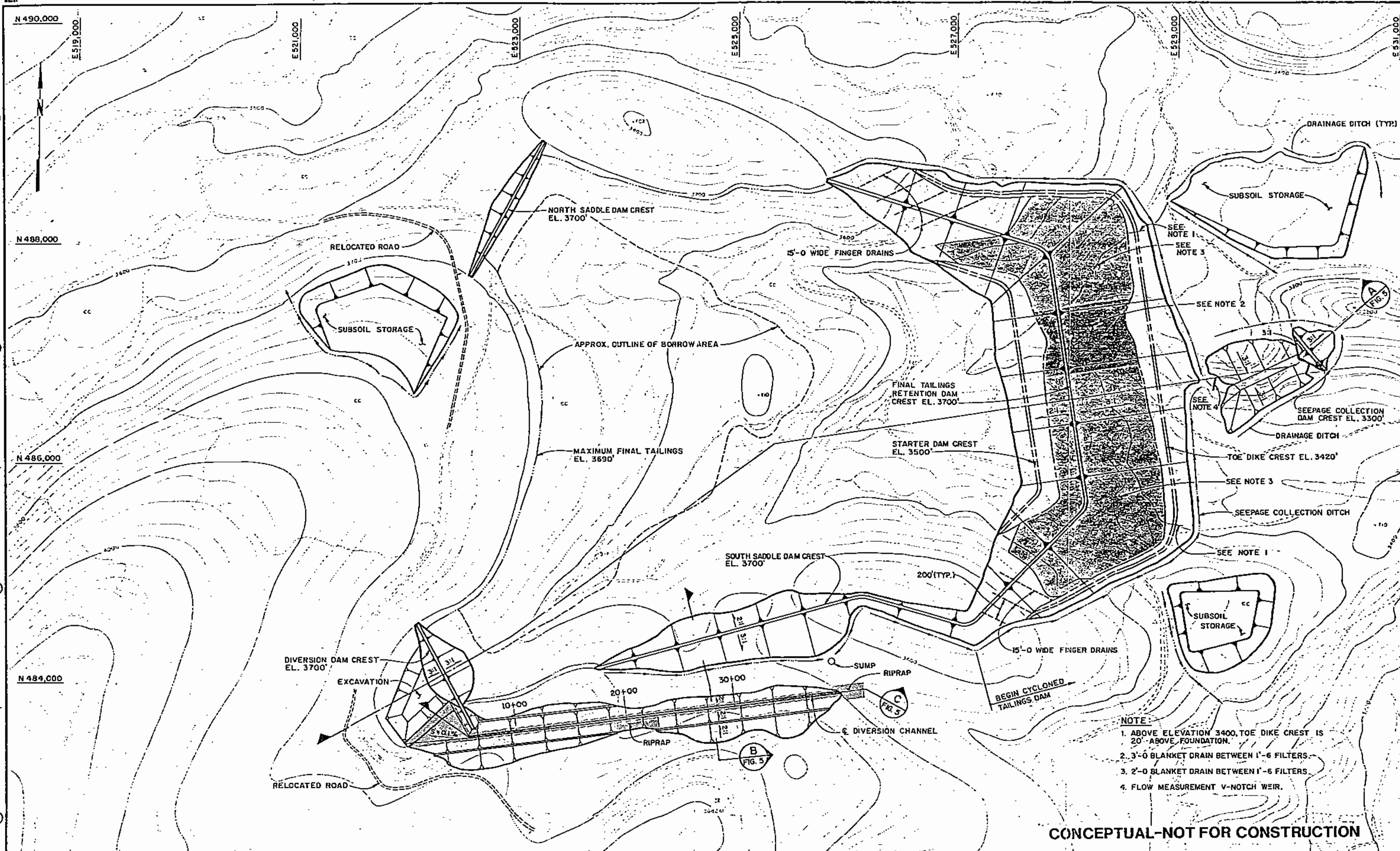
IMPOUNDMENT WATERSHED AREAS

FIGURE 3



400 0 400 800
SCALE FEET

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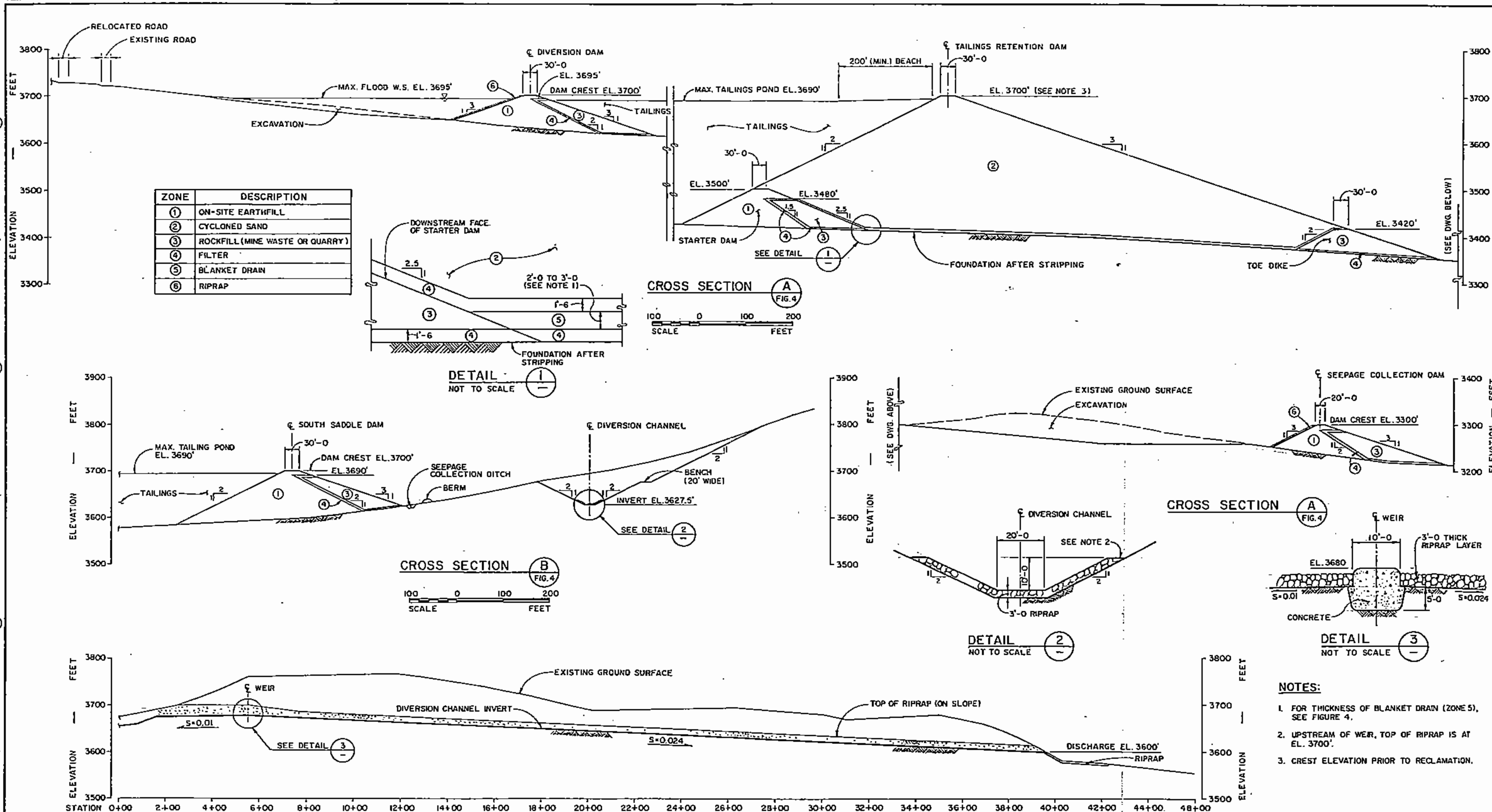
MONTANA PROJECT
LITTLE CHERRY IMPOUNDMENT
SITE PLAN

FIGURE 4



DIVERSION CHANNEL PROFILE

CROSS SECTION C (FIG. 4)

VERTICAL SCALE 100 0 100 200 FEET — HORIZONTAL SCALE 200 0 200 400 FEET

NOTES:

1. FOR THICKNESS OF BLANKET DRAIN (ZONE 5), SEE FIGURE 4.
2. UPSTREAM OF WEIR, TOP OF RIPRAP IS AT EL. 3700'.
3. CREST ELEVATION PRIOR TO RECLAMATION.

CONCEPTUAL-NOT FOR CONSTRUCTION

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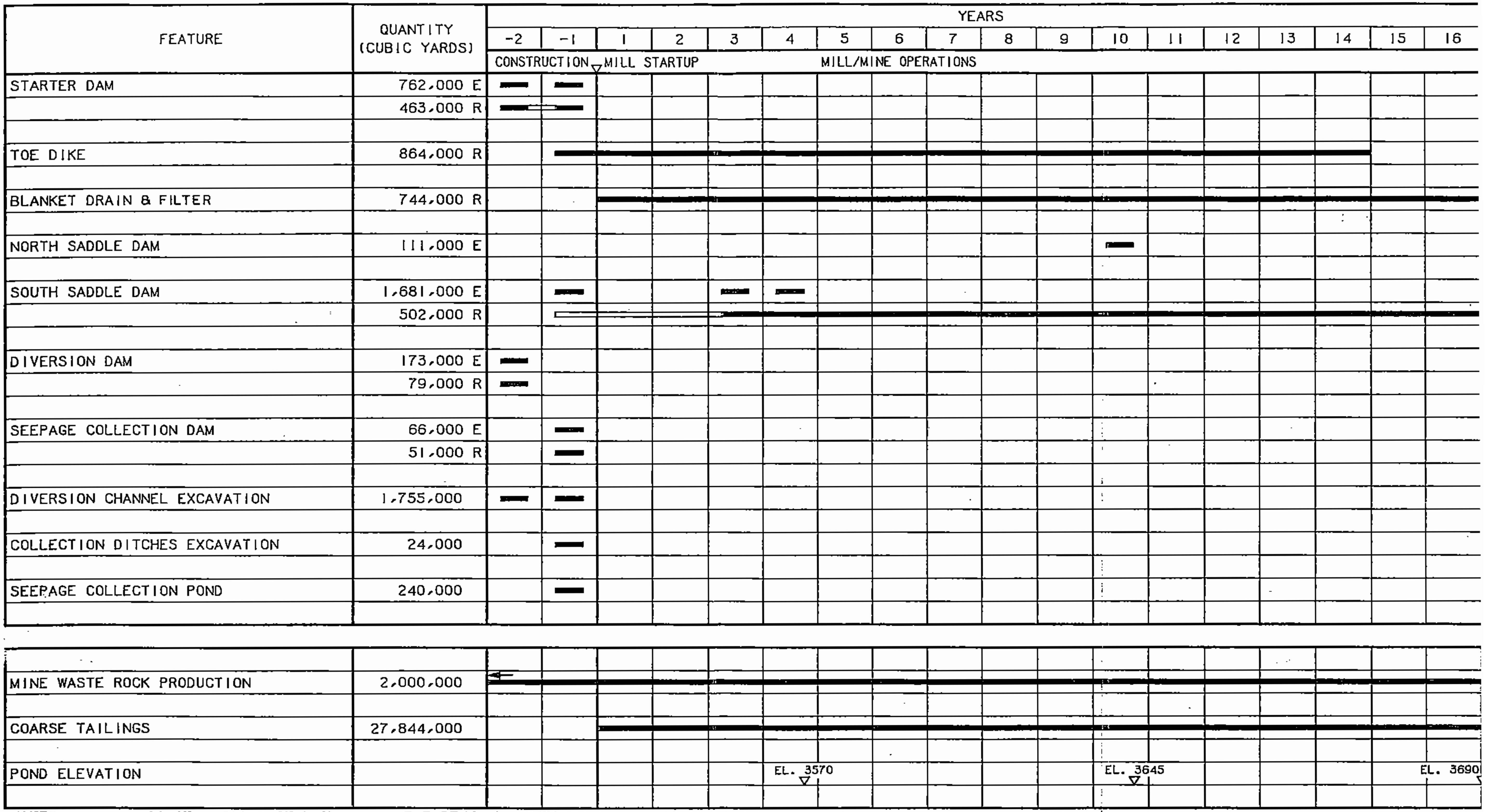
LITTLE CHERRY IMPOUNDMENT
SECTIONS

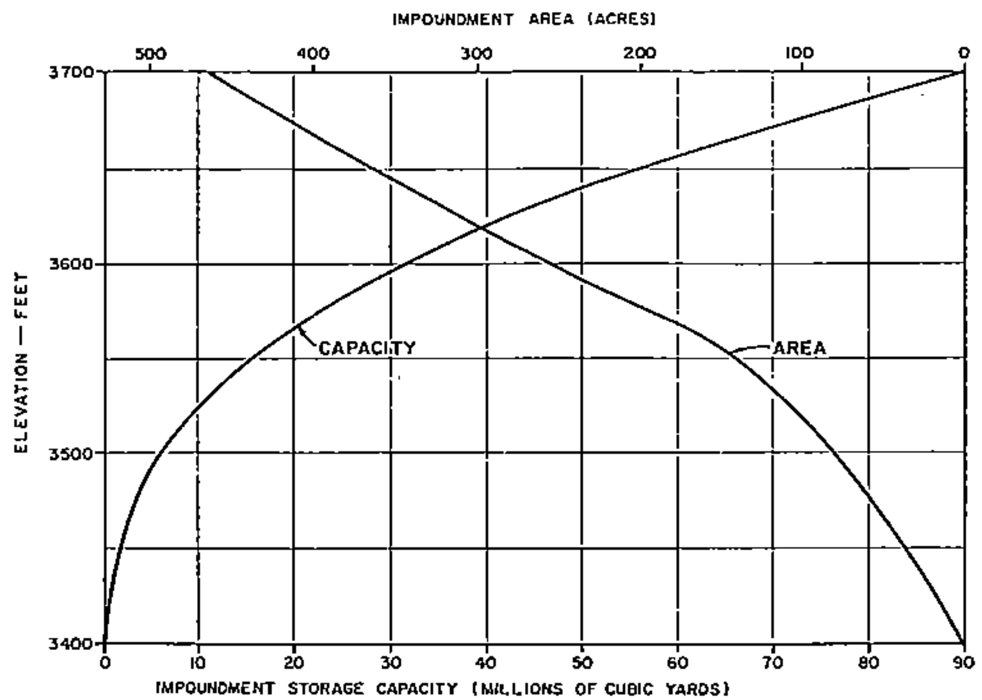
MKE NO.
SHEET OF REV.
FIGURE 5



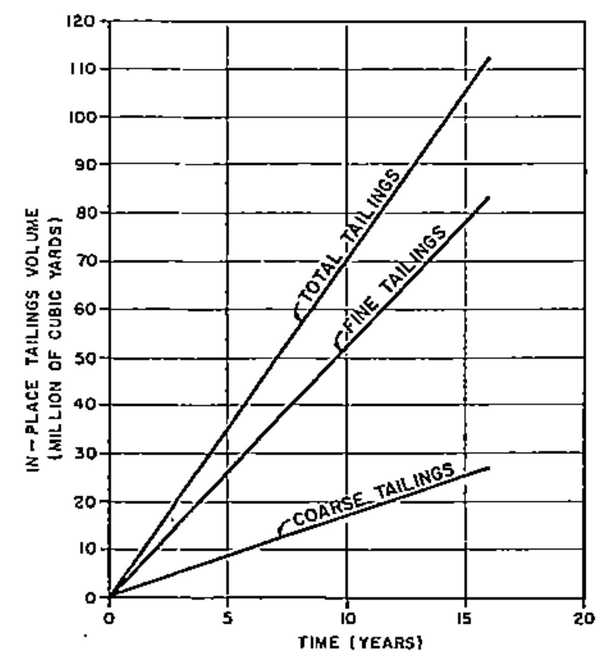
NOTES: ▬ CONSTRUCTION ACTIVITY — E-EARTHFILL MATERIALS (ZONE 1)
▭ FLOAT — R-ROCKFILL MATERIALS (ZONES 3 TO 6)

MONTANA PROJECT
CONCEPTUAL IMPOUNDMENT CONSTRUCTION SCHEDULE
FIGURE 6

B802901GB000900



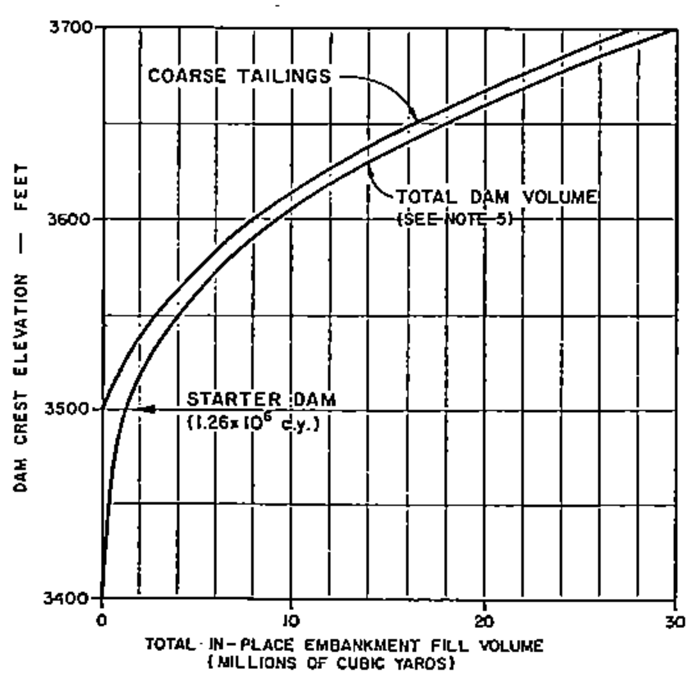
(A) IMPOUNDMENT AREA – CAPACITY CURVES
(SEE NOTE 1)



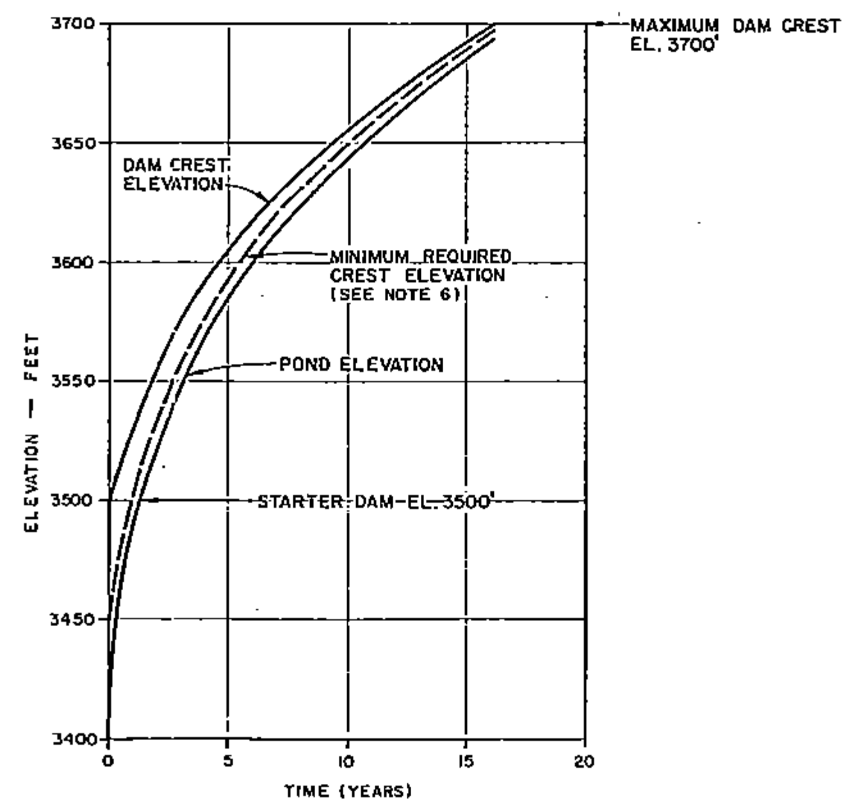
(C) IN-PLACE TAILINGS VOLUME VS. TIME
(SEE NOTES 2,3,& 4)

NOTES:

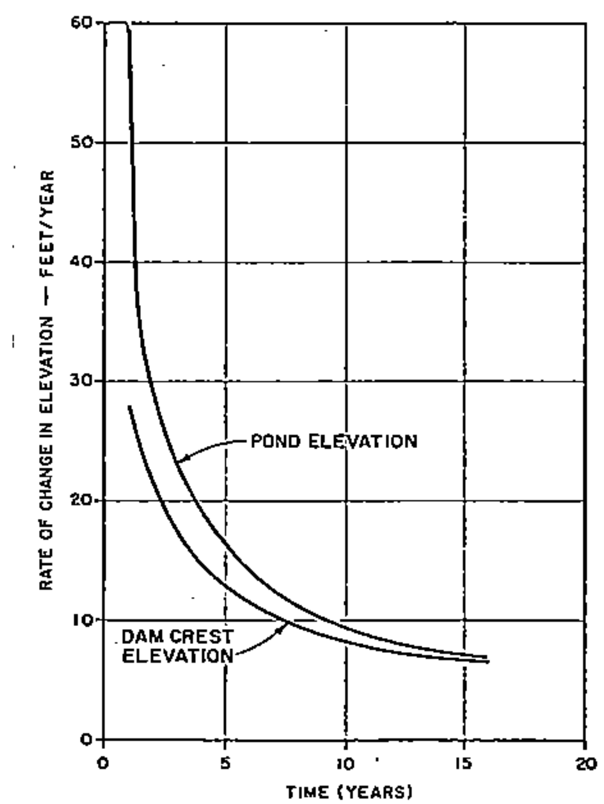
1. AREA-CAPACITY CURVES DO NOT INCLUDE ADDITIONAL STORAGE RESULTING FROM IMPOUNDMENT EXCAVATION.
2. IN-PLACE TAILINGS VOLUME BASED ON 100 POUNDS PER CUBIC FOOT (PCF) FOR COARSE TAILINGS AND 70 PCF FOR FINE TAILINGS.
3. IN-PLACE TAILINGS VS. TIME BASED ON A PRODUCTION RATE OF 20,000 ± DRY TONS OF TAILINGS PER DAY.
4. TWO STAGE CYCLONE PROCESS REQUIRED TO PRODUCE FINE AND COARSE TAILINGS.
5. TOTAL DAM VOLUME INCLUDES APPROXIMATELY 1,225,000 CUBIC YARDS (CY) FOR STARTER DAM, 27,844,000 CY FOR COARSE TAILINGS AND 864,000 CY FOR TOE DIKE.
6. MINIMUM REQUIRED CREST ELEVATION BASED ON 3-FOOT FREEBOARD, STORAGE OF TAILINGS EFFLUENT FOR 20 DAYS AT 8000 GPM (700 AC-FT), AND STORAGE OF DESIGN FLOOD.



(B) DAM CREST ELEVATION VS. FILL VOLUME



(D) IMPOUNDMENT SURFACE ELEVATION AND MINIMUM REQUIRED CREST ELEVATION VS. TIME



(E) RATE OF CHANGE OF POND AND DAM CREST ELEVATION

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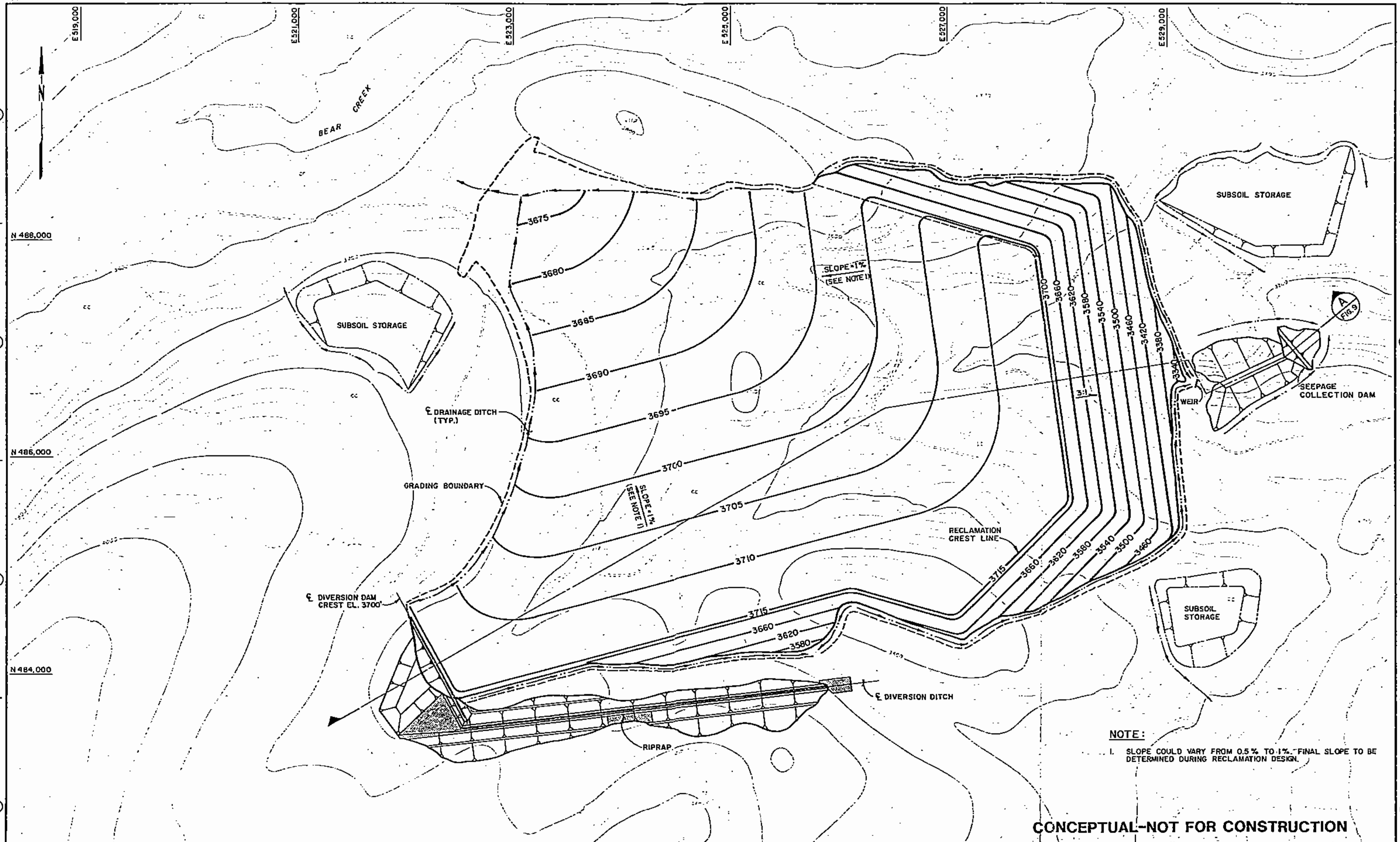
MONTANA PROJECT
LITTLE CHERRY IMPOUNDMENT
AREA-CAPACITY & STAGING CURVES

MKE NO.
SHEET OF REV.
FIGURE 7



NOTE:

1. SLOPE COULD VARY FROM 0.5% TO 1%. FINAL SLOPE TO BE DETERMINED DURING RECLAMATION DESIGN.

CONCEPTUAL-NOT FOR CONSTRUCTION

400 0 400 800
SCALE FEET

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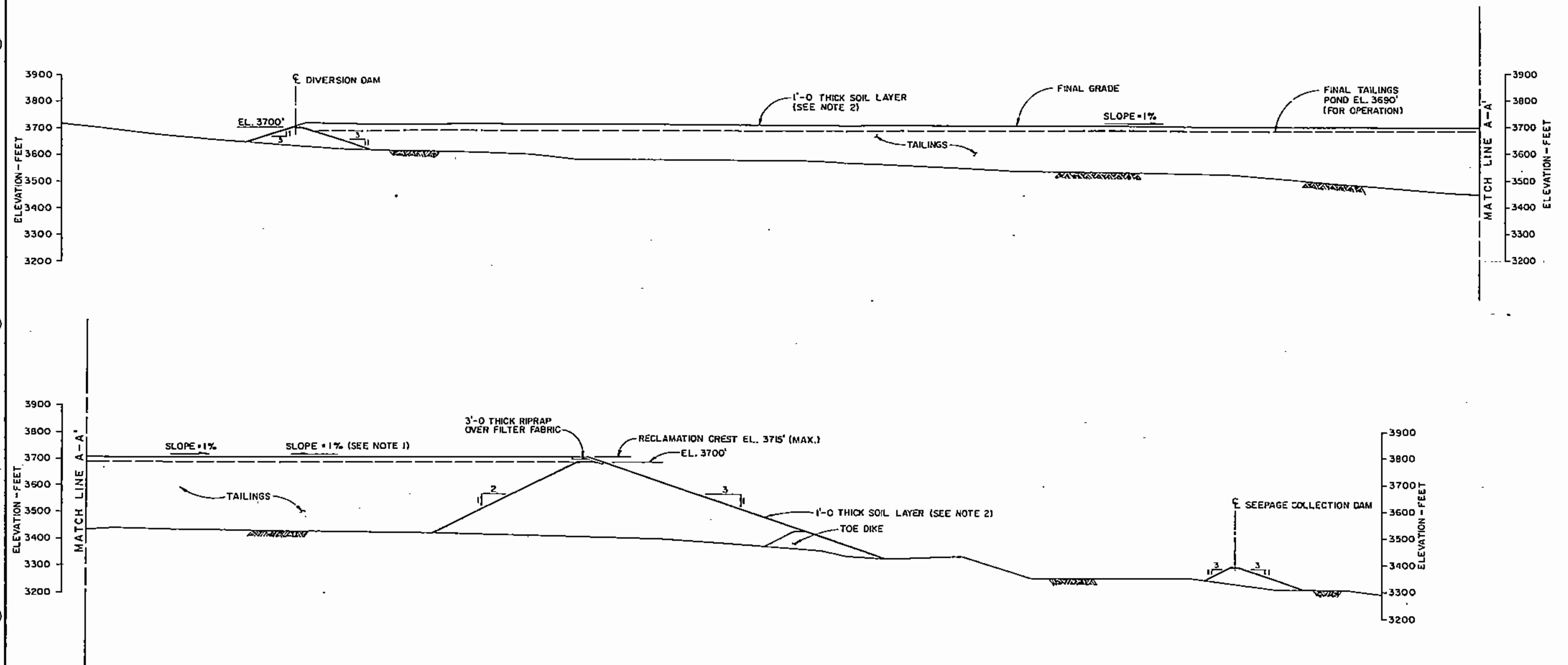
LITTLE CHERRY IMPOUNDMENT RECLAMATION PLAN

FILE NO. | SHEET OF | REV.

FIGURE 8



CROSS-SECTION A FIG. 8

NOTES:

1. SLOPE COULD VARY FROM 0.5% TO 1%. FINAL SLOPE TO BE DETERMINED DURING RECLAMATION DESIGN.
2. SURFACE TO BE SEEDED WITH GRASS.

CONCEPTUAL-NOT FOR CONSTRUCTION

200 0 200 400
SCALE FEET

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MONTANA PROJECT
LITTLE CHERRY IMPOUNDMENT
RECLAMATION SECTION

FIGURE 9

APPENDIX A

DESIGN BASIS MEMORANDUM

Noranda Minerals Corporation
Montana Project
Design Basis Memorandum No. 8029-101-R2
General Preliminary Design Criteria

CONTENTS

Revision Number	Reviewed			Submitted Proj. Mgr.	Approved Ch. Eng.	Issue Date
2	V. Pareveci 1-19-89	[signature] 1-19-89	[signature]	M. Forrest	E.S. Smith	1/18/89

Approved by Noranda Minerals Corporation (Name/Date) [signature] 2/7/89

1.0 INTRODUCTION

On 6 September 1988, U. S. Borax & Chemical Corporation transferred its interest in the Montana Project to Noranda Minerals Corporation. Revision No. 2 of the Design Basis Memorandum follows the completion of the field investigation work.

Noranda Minerals Corporation is currently planning the further development of the Montana Project located between Libby and Noxon in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. The project area is located in the Kootenai and Kaniksu National Forests. As part of this project, geotechnical investigations are required to select the preferred sites for plant facilities, mine portal, tailings impoundment and evaluation adit portal. The following sites will be studied:

- Plant Sites and Mine Portals (Howard Lake Quadrangle):
  - Ramsey Creek
  - Libby Creek

- Tailings Impoundment Sites (Cable Mountain Quadrangle):
  - Little Cherry
  - Poorman
  - Midas

- Evaluation Adit (Elephant Peak Quadrangle):
  - South End Rock Lake
  - Heidelberg Tunnel
  - Upper Heidelberg Road

This Design Basis Memorandum describes preliminary design criteria, procedures and approach for site selection and preliminary design evaluation. Other considerations in the selection of surface facility sites, such as the proximity to the mineral deposit and environmental factors, are not part of this Design Basis Memorandum.

2.0 PROJECT GOAL

The goal of the engineering work and geotechnical investigation outlined in this Design Basis Memorandum is to select the preferred sites, from an engineering standpoint, for plant facilities, mine portal, tailings impoundment and evaluation adit. To accomplish this goal, the scope of work described in Section 3.0 has been developed to define geotechnical conditions at the sites. In addition, preliminary engineering evaluations will be conducted to define basic design of the selected tailings impoundment.

3.0 SCOPE OF WORK

The scope of work for site selection and preliminary design consists of the following tasks:

- Conduct a field investigation that includes the following activities:

  - Data review
  - Reconnaissance
  - Geologic mapping
  - Seismicity evaluation
  - Seismic refraction survey
  - Test pit excavations
  - Exploratory drilling
  - Laboratory testing

- Perform site evaluations that include the following:

  - Tailings impoundments (including seepage, hydrology and stability of the selected impoundment)
  - Plant sites and mine portals
  - Evaluation adits

- Prepare the following technical reports:
  - Geotechnical Report
  - Geotechnical Site Evaluation Report
  - Tailings Impoundment Preliminary Engineering Report

- Attend meetings with Noranda Minerals Corporation and regulatory agencies.

The scope of work is sufficient for (1) site selection, (2) preliminary design, and (3) an application for Plan of Operations for mine development with the U.S. Forest Service and Montana Department of State Lands. Additional evaluations will be needed for final design consisting of the following tasks:

- Further drilling and test pit excavations at the selected plant and impoundment sites
- Additional laboratory testing, including triaxial compression tests, to determine strength parameters of foundation and embankment materials
- Final stability analyses of the tailings dam
- Optimization of tailings impoundment design.

4.0 DESIGN CRITERIA

4.1 Design Flood Criteria

A. Tailings Impoundments - The designation of the tailings impoundment design flood is based on size and hazard potential classifications. The tailings retention dam will be raised incrementally to increase impoundment storage capacity. Size classification is determined by either impoundment storage or dam stage height, whichever gives the larger size category. For this project, dam stage heights control size classification.

The distances, in river miles, to the nearest dwelling and U.S. Highway 2 from the three alternative impoundment sites are shown below:

Site	Nearest Dwelling	U.S. Highway 2
Little Cherry	5.4	5.7
Poorman	6.0	6.3
Midas	6.9	7.2

The U.S. Forest Service and Department of State Lands consider the impoundment sites to have moderate to high hazard potentials (Attachment 1).

Based on dam stage size and hazard potential classifications, the agencies designated the following design flood criteria (Attachment 1) :

- o For containment: 24-hour general storm Probable Maximum Precipitation (PMP)
- o For diversion: 72-hour general storm Probable Maximum Flood (PMF)

Because thunderstorm events should also be considered for small watersheds, the local storm PMF (resulting from the 6-hour PMP) will also be considered for diversion. The more critical of the two diversion floods will be used for diversion system design.

For interim stages less than 100 feet high that would be present for short term (less than 5 years), the containment flood will be calculated from the 24-hour general storm 1/2 PMP.

The minimum embankment dam freeboard (above the peak flood water surface) will be 3 feet.

B. Plant Sites and Portals - Plant sites, mine portals and evaluation adit portals will be located above the 100-year flood level. The 100-year flood peak discharges will be determined by another consultant by using methods based on regression analyses as described in Ref. 1. The flood stage calculations will be based on available topographic maps.

4.2 Tailings Production and Tailings Effluent

A tailings slurry of 30% solids will be conveyed in a pipeline from the mill to the impoundment site. Based on the results of bench-scale flotation tests, the tailings feed will consist of silt and sand particles with 52% finer than the No. 200 sieve (0.074mm). The anticipated tailings gradation from the flotation tests follows:

Tyler Sieve No.	Particle Size (Microns)	Cumulative % Passing
65	208	99.5
100	147	90.2
150	104	69.4
200	74	52.1
270	52	35.9
400	37	25.0

For tailings impoundment sizing, the tailings production rate is 20,000 tons per day, totaling 120,000,000 tons. The dry unit weight of tailings deposited in the impoundment will be based on published correlations with the anticipated tailings gradation.

Storage will also be required for tailings effluent for 20 days at 8,000 gpm (about 700 acre-feet).

4.3 Stability

The maximum sections of the starter and final embankment dam stages will be checked for static and seismic conditions. The tailings in the impoundment will be conservatively assumed to behave as a dense fluid and therefore will be assigned zero shear strength. In addition, the stability of the starter dam will be checked for the end-of-construction condition before tailings are deposited. This condition will be the most critical static case for the upstream slope since subsequent deposition of tailings into the pond will stabilize the slope.

The following minimum acceptable factors of safety will be used in design. The criteria for long-term, end-of-construction and seismic conditions are as recommended by the Corps of Engineers (Ref. 2).

Load Condition	Embankment Stage	Slope	Minimum Acceptable Factor of Safety
End-of-Construction (before tailings deposition)	Starter Dam	Upstream and Downstream	1.3
Long-term (full tailings pond)	Starter and Final Dams	Downstream	1.5
Flood Condition	Final Dam	Downstream	1.4
Seismic	Starter and Final Dams	Downstream	1.0

The project site is located close to the boundaries of Seismic Zones 1, 2 and 3 (see Figure 1). The results of a seismicity evaluation (Subsection 5.2.D) indicated that the seismic coefficient for use in the seismic stability computations using the "pseudo-static" method should be 0.10g as recommended by the Corps of Engineers for Seismic Zone 3 (Ref. 2).

In the "pseudo-static" method of stability analysis, the effects of an earthquake on a potential slide mass are represented by an equivalent static horizontal force determined as the product of a seismic coefficient and the weight of the potential slide mass. The use of the maximum ground acceleration (0.22g, see Subsection 5.2.D) as the seismic coefficient would produce an equivalent static horizontal force equal to the maximum transient inertia force developed on the mass during the design earthquake. However, the length of time for which the force acts is an important factor in the development of deformations. Therefore, the use of the maximum transient force as an equivalent static force would be unduly conservative (Ref. 3) and the recommended seismic coefficient of 0.10g should be used.

The material properties for use in the preliminary stability analyses will be based on the results of the field and laboratory testing programs. Foundation strengths will be obtained from correlations with Standard Penetration Test (SPT) data. Where field or laboratory test results are unavailable, appropriate properties will be selected based on a review of published data on similar materials and on correlations with index properties.

5.0 APPROACH

5.1 General

This section presents the approach for site selection and preliminary engineering. The section is divided into the following tasks as outlined in Section 3.0:

- Field Investigation
- Site Evaluation and Preliminary Design
- Technical Reports
- Meetings

5.2 Field Investigation

A. General

For purposes of preliminary site appraisal, it is appropriate to limit the scope of the field investigations to the work necessary to make a reasonably accurate determination of depths to a suitable foundation and to assess the potential hazards such as rock-slides, avalanches, flooding and unfavorable groundwater conditions.

B. Data Review

Available data including previous reports, maps and aerial photographs were reviewed prior to the initial field reconnaissance. Available U.S. Forest Service soils maps were reviewed (Ref. 4). Potential geotechnical problems at each site were identified as much as possible from the information available, and a checklist of items to be investigated during the field reconnaissance were prepared.

C. Reconnaissance and Geologic Mapping

A helicopter and ground reconnaissance was performed for planning of exploration activities and overall evaluation of the geotechnical factors that can be expected to have a significant influence on site suitability.

Geologic mapping was performed during the course of the field investigations. Geologic data by others were also confirmed during this task. The geological maps show bedrock outcrops, rockslide areas, snowslide areas and springs, faulting, landslides or other evidence of surface instability. To determine the potential for rockslides into portal cuts, the orientation of rock discontinuities were noted. In addition, a geologic map was prepared of the existing Heidelberg Tunnel. Geologic data and locations of seismic lines, drill holes and test pits are shown on the exploration plans.

D. Seismicity Evaluation

A seismicity evaluation was performed to establish suitable seismic criteria for preliminary design of the tailings impoundments. The study utilized historical seismicity data available from National Oceanic and Atmospheric Administration (NOAA), reports on potentially active faulting in the region, and previous studies for other projects in the site area.

A Maximum Credible Earthquake (MCE) for use in tailings dam engineering was determined based on magnitudes of historical earthquakes and correlations between magnitude and length of active faults (potential activity during Pleistocene or Holocene). The MCE is defined as the largest rationally conceivable event that could occur in the tectonic environment in which the project is located (Ref. 5). Appropriate attenuation formulas were used to calculate a range of maximum ground accelerations at the site. The design earthquake was determined to be a magnitude 7 event originating on the Bull Lake fault, 20 kilometers to the west of the project site. The peak ground acceleration was estimated to be 0.22g.

The project site is located close to Seismic Zone 2 for which a seismic coefficient of 0.05g is recommended (Ref. 2). However, this coefficient is incompatible with a nearby magnitude 7 MCE. Since the boundaries of Seismic Zones 1, 2 and 3 are relatively close together in this region, it is appropriate to apply the coefficient for Seismic Zone 3, which is 0.10g.

E. Seismic Refraction Survey

The subsurface investigation began with a seismic refraction survey of each site. The results of this work provided an indication of subsurface conditions, rippability and bedrock depth. The results of the seismic refraction survey, together with reconnaissance observations and aerial photographic interpretation, were used to select drill hole and test pit locations and to estimate required drill footage per site.

F. Test Pits

Test pits were used in conjunction with drill holes to obtain representative samples and to enable observation of conditions to be expected in excavations. The depths of the pits ranged from 3.5 to 16 feet. Test pits were backfilled and covered with topsoil. All sites will be restored as required by the U.S. Forest Service.

G. Drilling

Drilling was limited at this stage to the amount necessary for determining depth to bedrock, and to provide an understanding of bedrock characteristics, the nature of the overburden and the location of groundwater. The results of drilling performed by the consultant for groundwater investigations were also used. Perforated PVC pipes (1-inch diameter) were installed in selected drill holes at each site for groundwater level measurements. All drill sites will be restored as required by the U.S. Forest Service.

Drive samples were taken by using 2-inch O.D. Standard Penetration Test (SPT) samplers (ASTM D1586) and 2.5-inch O.D. samplers. Undisturbed samples of fine grained soils were obtained by using Shelby tube samplers (ASTM D1587).

Field tests were performed to determine permeability coefficients of foundation materials for seepage analyses. Permeability test methods conformed to procedures in the U.S. Bureau of Reclamation's "Earth Manual," Method E-18 (Ref. 6). Open-end casing constant head tests were performed at selected locations in soils. In bedrock, water pressure tests were performed by using single pneumatic packers.

H. Summary of Subsurface Investigations

A summary of the subsurface investigations is given in Table 5-1.

TABLE 5-1

SUMMARY OF SUBSURFACE INVESTIGATIONS

Site	Seismic Lines (Number/Feet)	Drill Holes (Number/Feet)	Test Pits
Plant Sites and Portals			
Ramsey Creek	6/1950	3/145	5
Libby Creek	6/1950	3/134	5
Tailings Disposal			
Little Cherry	7/4525	5/307	10
Poorman	15/7300	5/334	10
Midas (2 dam axes)	15/4485	8/482	12
Eval. Adit/Decline			
South End Rock Lake	1/300		
Heidelberg Tunnel			
Upper Heidelberg Road			
TOTALS	50/20,510	24/1402	42

I. Laboratory Testing

A limited laboratory testing program was performed to obtain preliminary engineering parameters of the soils at the plant and tailings impoundment sites. The tests followed American Society for Testing and Materials (ASTM) procedures and included the following:

- o Grain size analyses - ASTM D422
- o Natural moisture contents - ASTM D2216
- o Plasticity indices - ASTM D4318
- o Dry density
- o Moisture - density relationships - ASTM D698
- o Unconfined compression - ASTM D2166

The results of these tests were used to characterize foundation soils and potential borrow materials. Triaxial compression tests will be performed during a subsequent design development phase to establish strength parameters.

5.3 Site Evaluation and Preliminary Design

A. Site Ranking System

A tabular ranking system will be used to assist the geotechnical evaluation of the various sites for the plant, tailings impoundment and evaluation adit. The following will be included in site evaluations:

- o Topographical conditions
- o Potential for slides and avalanches
- o Flooding potential at portal and plant sites
- o Flood magnitude at the tailings impoundment sites
- o Diversion requirements
- o Foundation conditions for dams and heavy plant machinery, and depth to bedrock
- o Seepage potential at the impoundment sites
- o Availability of embankment dam construction materials and, in particular, the availability of clayey soils
- o Volume of required impoundment construction materials
- o Economic considerations
- o Impoundment capacity
- o Seismicity
- o Site access
- o Vegetative cover

The results of the studies will be used to recommend the preferred sites (from an engineering standpoint) for the mine portal, plant, tailings impoundment and evaluation adit.

B. Tailings Impoundments

(1) Hydrologic Studies - The development of the tailings impoundment design flood criteria is described in Subsection 4.1.A. The Corps of Engineers Hydrologic Engineering Center's HEC-1 Flood Hydrograph Package will be used for the impoundment design flood studies.

"Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States" (Hydromet 43) developed by NOAA (Ref. 7) will be used as the basis for estimating the local storm and general storm Probable Maximum Precipitation (PMP).

The general storm PMF plus snowmelt and the local storm PMF will be considered. The following precipitation events will be used to derive these design floods:

Purpose	Tailings Dam Stage Height	Design Flood	Precipitation Event
Containment	≥100 feet	General Storm PMF	24-hour PMP plus snowmelt as described below
Containment	<100 feet	General Storm 1/2 PMF	24-hour 1/2 PMP plus snowmelt as described below
Diversion	All Stages	Local Storm PMF	6-hour PMP
Diversion	All Stages	General Storm PMF	72-hour PMP plus snowmelt as described below

Unit hydrographs will be developed following the Soil Conservation Service (SCS) method, as described in the "Design of Small Dams" (Ref. 8). Infiltration and retention losses also will be estimated following SCS curve number (CN) procedures. These estimates will be based on soil conditions and vegetal cover as determined from field observations and from a review of available reports and aerial photographs. The antecedent-moisture conditions (AMC) for the PMF estimates will be AMC III (i.e., soil is nearly saturated).

Snowmelt will be assumed to occur during both the 24-hour and 72-hour PMP's. The snowmelt potential during the PMP will be assumed to be unrestricted by snowpack depth. Snowmelt calculations will be based on the Corps of Engineers' "Runoff from Snowmelt" (Ref. 9). Depending upon forest cover, the appropriate snowmelt equation will be used. Dew point temperature and wind speed information during the PMP will be computed by using procedures described in Hydromet 43 (Ref. 7).

Required heights of diversion dams and sizes of diversion channels will be based on the results of routing the local storm PMF and the 72-hour general storm PMF. Routing will be performed by using HEC-1 procedures.

(2) Embankment Design and Impoundment Capacity - The topographical conditions and the results of the field investigation will be used to locate the tailings dam. The dam will be located so that flood waters on adjacent stream channels will not encroach on the embankment.

The ultimate impoundment will be sized to store 120 million tons of tailings. The starter impoundment will be sized to store at least 7 million tons (1 year of production). For capacity calculations, the tailings density will be based on experience with similar tailings materials. Impoundment area and capacity curves will be prepared. These curves, together with expected tailings production rates, will be used to determine the tailings level and dam crest elevation versus time.

The required impoundment storage for the design flood will be determined from the results of studies described in Subsection 5.3.B.(1). Embankment slopes will be determined from the results of stability analyses described in Subsection 5.3.B.(3).

The embankment dam stages will be constructed of (1) materials excavated from the impoundment, (2) evaluation adit and mine waste rock and (3) tailings sands. Based on an in-place rockfill density of 140 pcf, preliminary estimates indicate that approximately 831,000 cubic yards of rockfill will be available at the time of mill start-up. Subsequently, an estimated 74,000 cubic yards of rockfill will be available annually.

The operating stages after the initial stage of the impoundment will be constructed by the downstream method by using cycloned tailings sands. A seepage control dam downstream of the tailings dam will be required. An embankment drain system will be designed to control seepage and prevent piping.

Plans and typical sections of the initial and final tailings impoundment at the selected site will be prepared. Construction quantities will also be estimated.

(3) Stability Analyses - Preliminary stability analyses will be performed for the initial and final dam stages by using the Modified Bishop and infinite slope methods of analysis. The computer program STABL (Ref. 10) or other program will be used to determine the factor of safety for circular sliding surfaces. Hand calculations will be performed using the infinite slope method. The minimum factor of safety calculated for each loading condition will be compared to the minimum acceptable values given in Section 4.3. Stability will be evaluated for a wide range of phreatic surface conditions. Final stability analyses will be performed during a subsequent design development phase.

Liquefaction potential of sandy foundation soils due to the MCE event (see Subsection 5.2.D) will be evaluated by methods outlined in Refs. 11 and 12. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking (Ref. 13). Soil deposits that are particularly susceptible to liquefaction consist of loose, saturated sands.

In the proposed approach to evaluate liquefaction potential, the induced shear stresses caused by the MCE acceleration will be compared to the stresses required to cause liquefaction. Stresses to cause liquefaction will be estimated from SPT data (see Subsection 5.2.G) and MCE magnitude.

(4) Seepage and Contaminant Transport - For control of seepage from the impoundments, the Montana regulations for non-degradation of water quality will be followed (Ref. 14). Seepage potential from the impoundment site will be evaluated

from the results of the field exploration and laboratory testing of foundation and embankment construction materials. Permeabilities of the foundation materials will be obtained from the results of field tests, including pump tests. The permeability of the fine tailings will be estimated from correlations with grain size data. For preliminary studies, simplified calculations will be performed to estimate seepage rates from the tailings impoundment for varying pond elevations.

The potential migration of tailings effluent from the selected impoundment will be evaluated. Seepage and contaminant transport analyses will be performed by using simplified analytical methods. The computed concentration of chemical constituents at a predetermined point of compliance will be compared with background chemistry data and State maximum contaminant levels. The chemical assay of the effluent for the Montana Project is shown in Attachment 2.

(5) Reclamation - A conceptual impoundment reclamation scheme will be presented. Montana regulations require that the land be returned to comparable utility that existed prior to impoundment construction (Ref. 15). The reclamation plan will basically consist of (1) subsoil stripping and stockpiling at the beginning of each impoundment construction stage, (2) capping the final tailings surface with soil, including the stockpiled subsoil, and (3) seeding the cap. Provisions to minimize erosion and promote surface drainage will also be included in the reclamation scheme.

C. Plant Sites, Mine Portals and Evaluation Adits

Evaluation studies for plant sites, mine portals and evaluation adits will concentrate on rating relative suitability of (1) access, (2) slope stability, (3) exposure to rockslides and avalanches, (4) depth to suitable rock for establishing portals, (5) potential for developing adequate working area, and (6) availability of suitable waste rock disposal areas. For plant sites, foundations will be evaluated for suitability for machine foundations. Mine portal sites will be located at least 300 feet from the wilderness boundary and plant crushers will be located at least 1,000 feet from the boundary.

5.4 Technical Reports

The following reports will be prepared:

- o Geotechnical Report
- o Geotechnical Site Evaluation Report
- o Tailings Impoundment Preliminary Engineering Report

The Geotechnical Report will contain the following:

- o Site exploration plans, showing geologic data and locations of drill holes, test pits and seismic refraction lines
- o Geologic sections
- o Seismicity evaluation
- o Results of seismic refraction surveys
- o Drill hole and test pit logs
- o Laboratory test results

The report will be organized on an individual site basis.

The Geotechnical Site Evaluation Report will present recommendations for selection of the (1) plant site, (2) mine portal location, (3) tailings impoundment site and (4) evaluation adit site. Each site will be evaluated in a separate section of the report. Also, recommendations will be included for further investigation of the recommended sites.

The Tailings Impoundment Preliminary Engineering Report will present the results of the preliminary design studies for the selected tailings impoundment. The report will include results of seepage, hydrology, stability and reclamation studies. Plans and sections of the conceptual design will be presented.

The technical reports will be organized in formats agreed upon with Noranda Minerals Corporation. Each report will begin with a summary section that gives a complete overview of the work completed and results. All support information and data will be contained in readily referenced appendices.

5.5 Meetings

As the work progresses, periodic meetings will be held with Noranda Minerals Corporation, the Montana Department of State Lands and the U.S. Forest Service. The meetings will be used to discuss results of investigations and any critical project decisions.

6.0 REFERENCES

1. Omang, R. J., Parrett, C. and Hull, J. A., "Methods for Estimating Magnitude and Frequency of Floods in Montana, Based on Data Through 1983," U. S. Geological Survey, Water Resources Investigative Report 86-4027, Helena, Montana, 1986.

2. U.S. Corps of Engineers, "Engineering and Design, Stability of Earth and Rock-fill Dams, "EM 1110-2-1902, April 1970, and Change 1, 17 February 1982.

3. Seed, H.B. and Martin, G.R., "The Seismic Coefficient in Earth Dam Design," Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, Vol. 92, SM3.

4. U.S. Department of Agriculture, U.S. Forest Service, Kootenai National Forest, Libby, MT, Kootenai National Forest Area, Land System Inventory, 1984.

5. Seed, H.B., "The Selection of Design Earthquakes for Critical Structures," Bulletin of the Seismological Society of America, Vol. 72, No. 6, December 1982.

6. U.S. Department of the Interior, Bureau of Reclamation, "Earth Manual," Second Ed., 1974.

7. U.S. Department of Commerce, Weather Bureau, "Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States," 1966.

8. U.S. Department of the Interior, Bureau of Reclamation, "Design of Small Dams," 1977.

9. U.S. Corps of Engineers, Manual EM-1110-2-1406, "Runoff from Snowmelt," 1960.

10. Siegel, R.A., "STABL User Manual," Joint Highway Research Project, Report JHRP-75-9, June 1988.

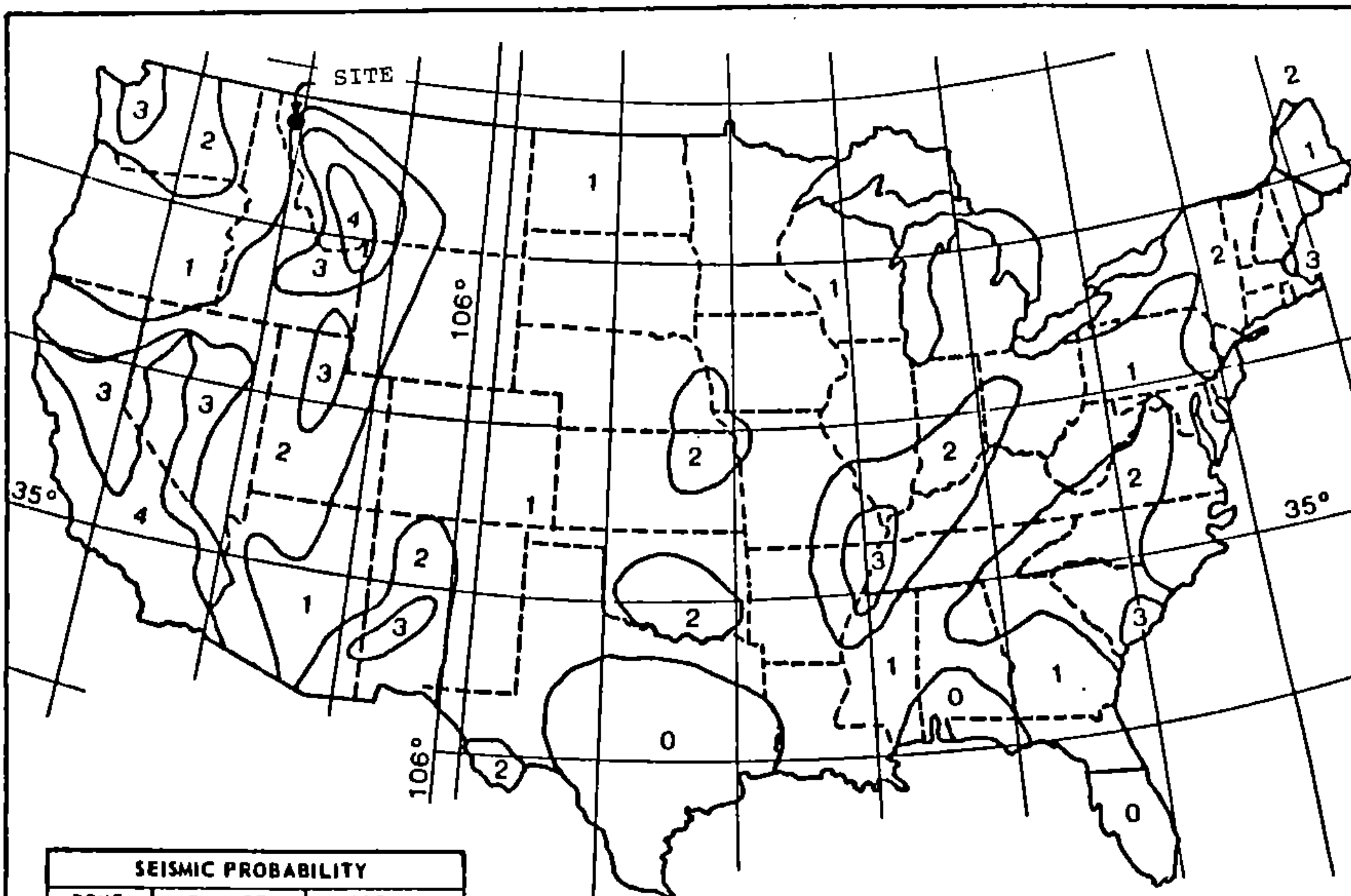
11. Seed, H.B., and Idriss, I.M., "Ground Motions and Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, 1982.

12. "Liquefaction of Soils During Earthquakes," Committee on Earthquake Engineering, National Academy of Sciences, 1985.

13. Seed, H.B., "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, ASCE, Vol. 105, GT2, February 1979.

14. Administrative Rules of Montana, Department of Health and Environmental Sciences, Water Quality, Sub-Chapter 7, Non-degradation of Water Quality, 31 December 1984 and Sub-Chapter 10, Montana Groundwater Pollution Control System, 31 December 1982.

15. Administrative Rules of Montana, Chapter 4, Reclamation, Part 3 - Metal Mine Reclamation and Sub-Chapter 1, Rules and Regulations Governing the Montana Metal Mine Reclamation Act, 1 July 1980.



SEISMIC PROBABILITY		
ZONE	DAMAGE	COEFF.
0	NONE	0
1	MINOR	0.025
2	MODERATE	0.05
3	MAJOR	0.10
4	GREAT	0.15

SEISMIC ZONE MAP OF THE CONTIGUOUS STATES

U.S. Corps of Engineers. "Engineering and Design, Stability of Earth and Rock-Fill Dams", EM 1110-2-1902,

April 1970, and Change 1, 17 February 1982.

FIGURE 1

ATTACHMENT 1

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

HEADQUARTERS OFFICE
180 HOWARD STREET
SAN FRANCISCO, CALIFORNIA U.S.A. 94105
TELEX (WUI) 677058, (ITT) 470040, (RCA) 278362, (WUO) 34376
PHONE (415) 442-7300

8029-810

19 October 1988

U. S. Forest Service
Kootenai National Forest
506 U.S. Highway 2 West
Libby, MT 59923

Attention: Mr. Ron Erickson
FS Project Coordinator

Subject: Montana Silver Venture Project
Response to Comments on Design Basis Memorandum

Gentlemen:

In the attached 15 September 1988 letter, the Forest Service and Department of State Lands submitted their comments on the Design Basis Memorandum (Revision 0) for the Montana Silver Venture project. Morrison-Knudsen Engineers' (MKE) response to those comments follows.

Comment 1: Impoundment design flood criteria. We understand that the agencies consider the site to have moderate to high hazard potential. Based on the ultimate large size of the tailings impoundment and on this hazard potential rating, the agencies have designated the following design flood criteria:

- o For Containment: 24-hour general storm Probable Maximum Precipitation (PMP)
- o For Diversion: 72-hour general storm Probable Maximum Flood (PMF)

We will use these criteria for tailings impoundment design. In addition, because thunderstorm events should also be considered for small watersheds, the local storm PMF (resulting from the 6-hour PMP) will also be computed for diversion. The more critical of the two diversion floods will be used for diversion system design.

As discussed with the Forest Service regional office in Missoula, for short-term (about 5 years) interim stages less than 100 feet high, the containment flood will be calculated from the 24-hour general storm 1/2 PMP.

Comment 2: Comparison of design floods with measured flows. The agencies have asked that the results of our studies be compared with analyses based on measured flows. The PMF is such a large and infrequent event that it cannot be compared with historical streamflow data. The return period of a PMF may be on the order of tens of thousands of years for which comparison with extrapolations of streamflow data would not be meaningful.

Computations of PMP magnitudes were based on procedures described in Hydrometeorological Report No. 43. Unit hydrographs were developed following methods developed by the Soil Conservation Service (SCS). Infiltration and retention losses were estimated following SCS curve number procedures for forested areas. Snowmelt during both the 24 and 72-hour general storm PMP's were computed. Flood hydrographs are currently being developed by using the Corps of Engineers HEC-1 procedures.

Comment 3: Method of calculation of the 100-year flood peak discharge. In the plant sites, the 100-year flood was determined by using equations derived from regression analysis of watershed characteristics as reported in R. J. Omang et al., "Methods for Estimating Magnitudes and Frequency of Floods in Montana," U. S. Geological Survey, 1986.

Comment 4: Fracture and joint data. We have measured joint attitudes and spacing on the west side of the Cabinet Mountains, where good exposures of meta-sedimentary rocks occur. These data will be used in the evaluation of adit portal stability. Rock exposures in the east side sites are much less prevalent and joint data were not measured. However, joint data are noted on the drill logs where rock coring was done. We will also obtain joint data available from Noranda's baseline work.

Comment 5: Phreatic conditions in dam stability analyses. MKE will examine stability of the dam for a range of phreatic surface conditions during preliminary design studies.

Comment 6: Monitor well drilling and completion. We acknowledge that new rules are proposed by the Department of Natural Resources and Conservation for monitor well drilling and completion. We would appreciate information on how we can obtain the rules.

Based in part on the 15 September letter, MKE is preparing Revision No. 1 of the Design Basis Memorandum (DBM). The revised DBM will be resubmitted to the agencies for their review.

If there are any further questions, please call me at (415) 442-7593.

Sincerely,

M. P. Forrest

M. P. Forrest
Project Manager

Attachment: U. S. Forest Service letter, 15 September 1988

cc: K. Walther, Department of State Lands
R. White, Regional Office, U.S. Forest Service
J. Scheuering, Noranda
B. Bailey, Noranda
G. Fletcher

7415G

United States Department of Agriculture
Forest Service
Kootenai NF
506 US Highway 2 West
Libby, MT 59923

Reply to: 2810

Date: 9/15/88

Ken Reim
U.S. Borax
3075 Wilshire Blvd.
Los Angeles, CA 90010

Dear Ken,

On July 5, 1988, Borax submitted a Design Basis Memorandum prepared by Morrison-Knudsen Engineers, for the preliminary geotechnical investigation work for the Montana Silver Venture. The following are comments on the design memo from both the Forest Service and Department of State Lands.

1. Based on the attached criteria (FSM 7511.1-.2, Amendment 12, and FSM 7531.2, Amendment 10), the agencies consider the impoundment to be a Class A structure (the highest rating) of moderate to high hazard potential. Consequently, it is recommended that the acceptable criteria for flood hydrology design of the tailings area are:

   a. 24 hour, general storm, PMP for containment
   b. 72 hour, general storm, PMP for diversion

2. In section 5.3 B (1), Hydrologic Studies, three methods of calculating the design flood and precipitation events are documented. The agencies would like these results compared with analyses based on measured flows. It is recommended that MKE share their numbers and procedures early in the design process with the agencies so that all parties are in agreement on the actual design event figures.

3. On page 5, Section 4.1 B, it states that another consultant will determine peak discharges. What method(s) will the consultant use?

4. The geologic mapping and field investigation, described on page 7 does not include a fracture/joint density study. However, the geologic baseline data Borax is collecting should include fracture and joint data. This information should be shared with MKE.

5. An analysis of the embankment stability to a variety of phreatic conditions should be included at some point in the study. This may not be necessary at the preliminary design phase, but will definitely be needed for final design.

6. For your awareness, the State Department of Natural Resources and Conservation is proposing new rules and accreditation procedures for monitoring well drilling and completion.

At Borax's request the agencies can meet to clarify the above concerns. If you have questions, please contact either Kit Walther @ 444-2074 or me @ 293-3171.

Sincerely,

Ron Erickson

Ron Erickson
ES Project Coordinator

Encl.

cc: Kit Walther, DSL
Mike Forrest, MKE

TITLE 7500 - WATER STORAGE AND TRANSMISSION

CHAPTER 7510 - ADMINISTRATION

7511 - PROJECT CLASSIFICATION. The potential effect of a water-control structure on the safety and economy of downstream areas varies with the size of the structure and probable consequences of its failure. The required scope of investigations, precision of design, quality and capacity of components, and subsequent cost vary with the acceptable degree of design risk.

Minimum acceptable criteria for design, operation, maintenance, and monitoring should be based on the size and hazard classifications established for the structure in order to keep requirements in line with structure importance.

In designing or reviewing the design of a project, the individual responsible shall investigate and evaluate all factors that may influence the potential hazard classification of the dam. The hazard rating must be consistent with the degree of downstream development that reasonably can be expected during the life of the dam. See FSH 7509.11 for details on hazard potential assessment.

7511.1 - Administrative Classification. For administrative purposes, projects are classified as follows:

1. Class A Projects

a. Dams that are 100 feet or more high or impound 50,000 acre-feet or more of water.

b. Channels, flumes, and tunnels that have a design capacity of 1,000 cubic feet or more per second (cfs).

2. Class B Projects

a. Dams that are 40 feet or more, but less than 100 feet high or impound 1,000 or more, but less than 50,000, acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 100 cfs or more, but less than 1,000 cfs.

TITLE 7500 - WATER STORAGE AND TRANSMISSION

3. Class C Projects

a. Dams that are 25 feet or more, but less than 40 feet high or impound 50 or more, but less than 1,000 acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 10 cfs or more, but less than 100 cfs.

4. Class D Projects

a. Dams that are less than 25 feet high and impound less than 50 acre-feet of water.

b. Channels, flumes and pipes that have a design capacity less than 10 cfs.

7511.2 - Hazard-Potential Classification. Dams are also classified according to hazard potential based on the loss of life or property damage that could occur if the structure failed.

1. Low Hazard. Dams built in undeveloped areas where failure would result in minor economic loss, damage would be limited to undeveloped or agricultural lands, and improvements are not planned in the foreseeable future. Loss of life would be unlikely.

2. Moderate Hazard. Dams built in areas where failure would result in serious environmental damage or appreciable economic loss with damage to improvements, such as commercial and industrial structures, public utilities and transportation systems. No urban development and no more than a small number of habitable structures are involved. Loss of life would be unlikely.

3. High Hazard. Dams built in areas where failure would likely result in loss of life or excessive economic loss. Generally this would involve urban or community development with more than a small number of habitable structures.

Where a spillway design flood range is given, select the magnitude commensurate with the involved risk.

It is recognized that failure of some dams with a relatively small reservoir capacity may have little influence on the potential damage anticipated during the spillway design flood event.

Exceptions to the recommended spillway design flood magnitude may be permissible for some structures. Requests for an exception must include sufficient documentation to demonstrate that economic loss and/or the potential for loss of life resulting from dam failure during occurence of the proposed spillway design flood would be essentially the same as would occur without a dam failure. The Regional Director of Engineering must approve exceptions to the recommended spillway design flood. When documentation is not available to support an exception, use the recommended spillway design flood criteria shown in table 1.

Table 1

RECOMMENDED SPILLWAY DESIGN FLOOD

Hazard potential	Size class	Spillway design flood
High	A	PMF
	B	PMF
	C	1/2 PMF to PMF
	D	100 yr. to 1/2 PMF
Moderate	A	PMF
	B	1/2 PMF to PMF
	C	100 yr. to 1/2 PMF
Low	A	1/2 PMF to PMF
	B	100 yr. to 1/2 PMF
	C	50 yr. to 100 yr.

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.

P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
800-873-5227

ATTACHMENT 2

LABORATORY REPORT

TO: Noranda, Inc.
ADDRESS: P.O. Box 15636
Denver, Colorado 80215
Attn: Brent Bailey

LAB NO.: 88-18886
DATE: 01/05/89 pjf

RECEIVED JAN 10 1989

WATER ANALYSIS

Final Tailings Solution
Cycle 5
Submitted 12/20/88

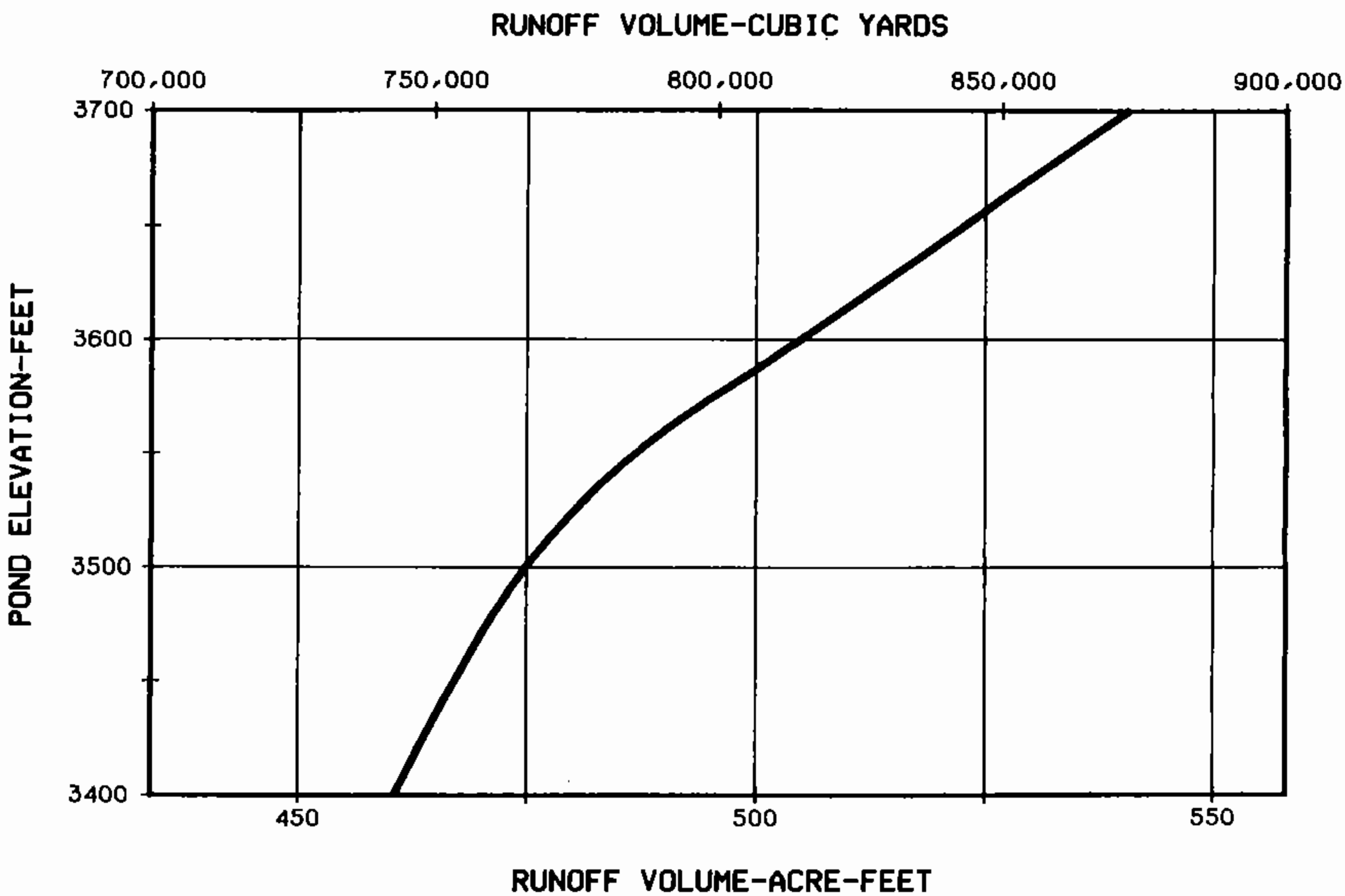
CONSTITUENT	mg/l
Potassium	24
Sodium	13
Calcium	12
Magnesium	3

Dissolved Metals:	DISSOLVED (mg/l)	TOTAL (mg/l)
Arsenic	<0.005	<0.005
Aluminum	0.1	0.1
Barium	<0.1	<0.1
Beryllium	<0.005	<0.005
Cadmium	<0.001	<0.001
Chromium	<0.02	<0.02
Copper	<0.01	0.02
Cobalt	<0.01	<0.01
Iron	0.05	0.08
Lead	<0.01	<0.01
Manganese	0.06	0.09
Mercury	<0.001	<0.001
Molybdenum	0.010	0.010
Nickel	<0.03	<0.03
Selenium	<0.005	<0.005
Silver	<0.005	<0.005
Antimony	0.01	0.01
Zinc	<0.01	0.05

APPENDIX B

HYDROLOGIC STUDIES

7633G



MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

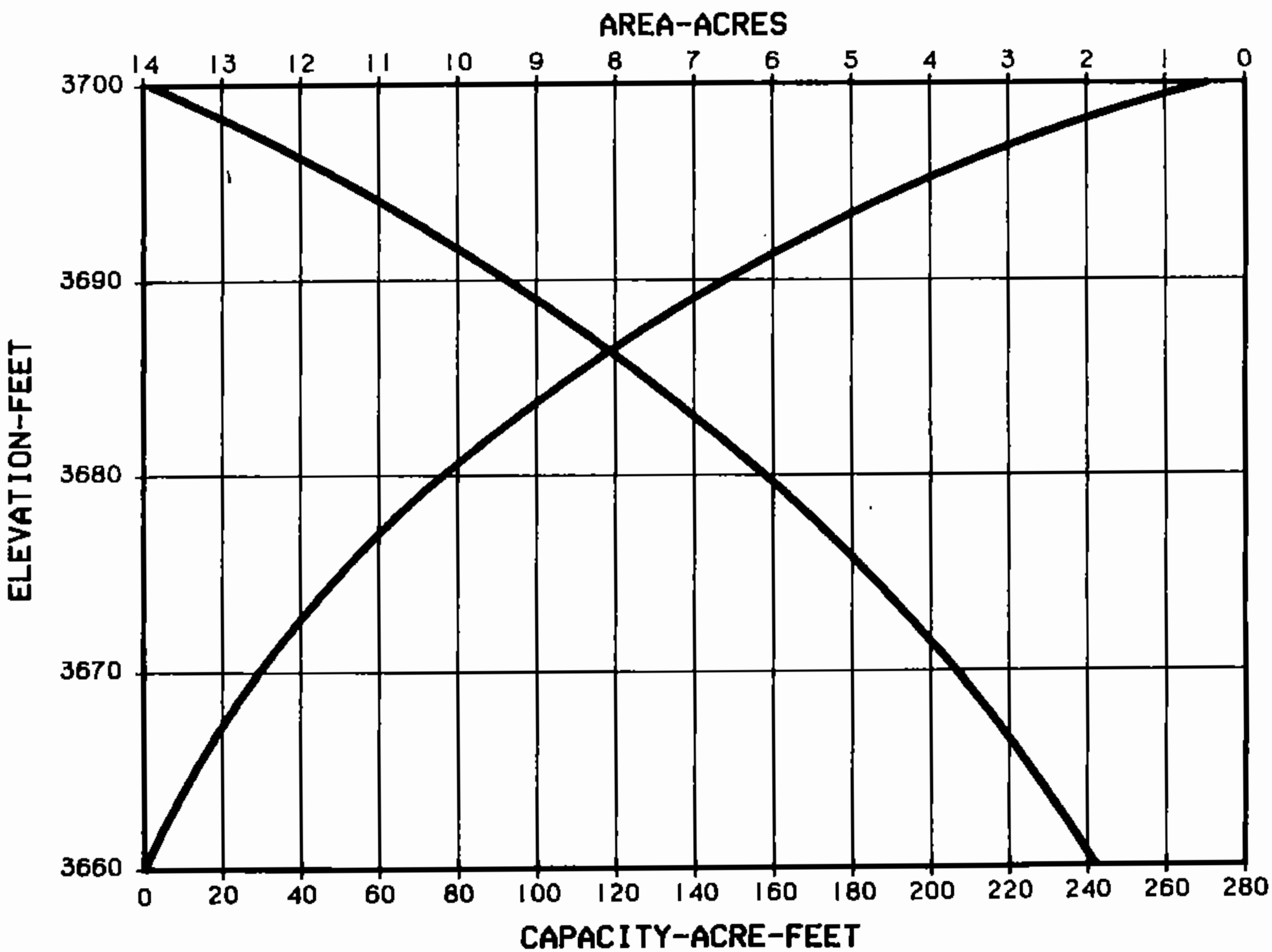
DESIGNED MAN	DRAWN CADS	CHECKED MPF	RECOMMENDED
DATE	DECEMBER 1988		APPROVED

MONTANA SILVER VENTURE

LITTLE CHERRY TAILINGS IMPOUNDMENT

RUNOFF VOLUME

FIGURE B-1



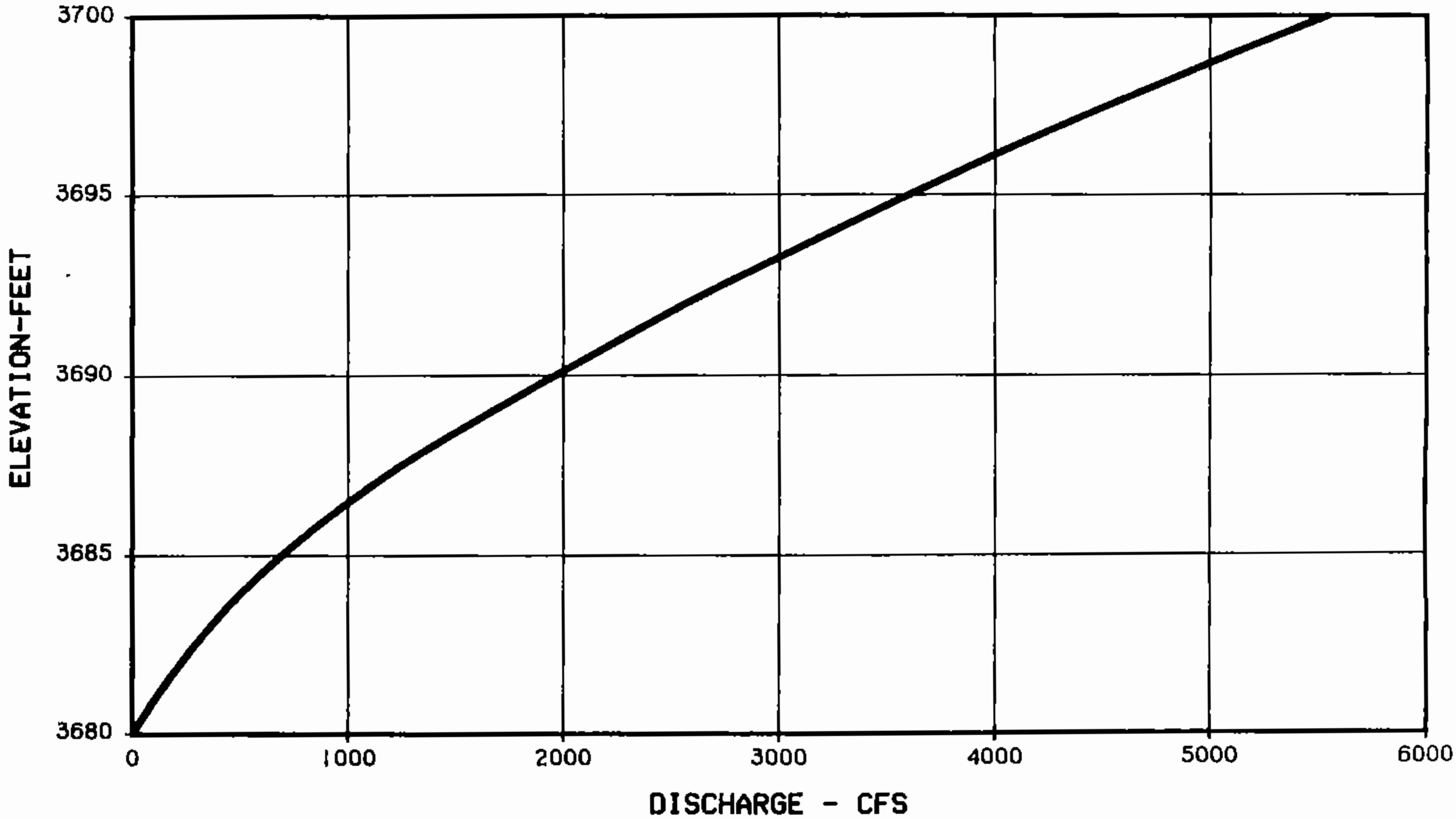
MONTANA SILVER VENTURE

DIVERSION IMPOUNDMENT
AREA-CAPACITY CURVES

FIGURE B-2

MORRISON-KNUDSEN ENGINEERS, INC.
STREET, SAN FRANCISCO, CALIFORNIA 94105

MAN	CADS	MPF	
DECEMBER 1988			

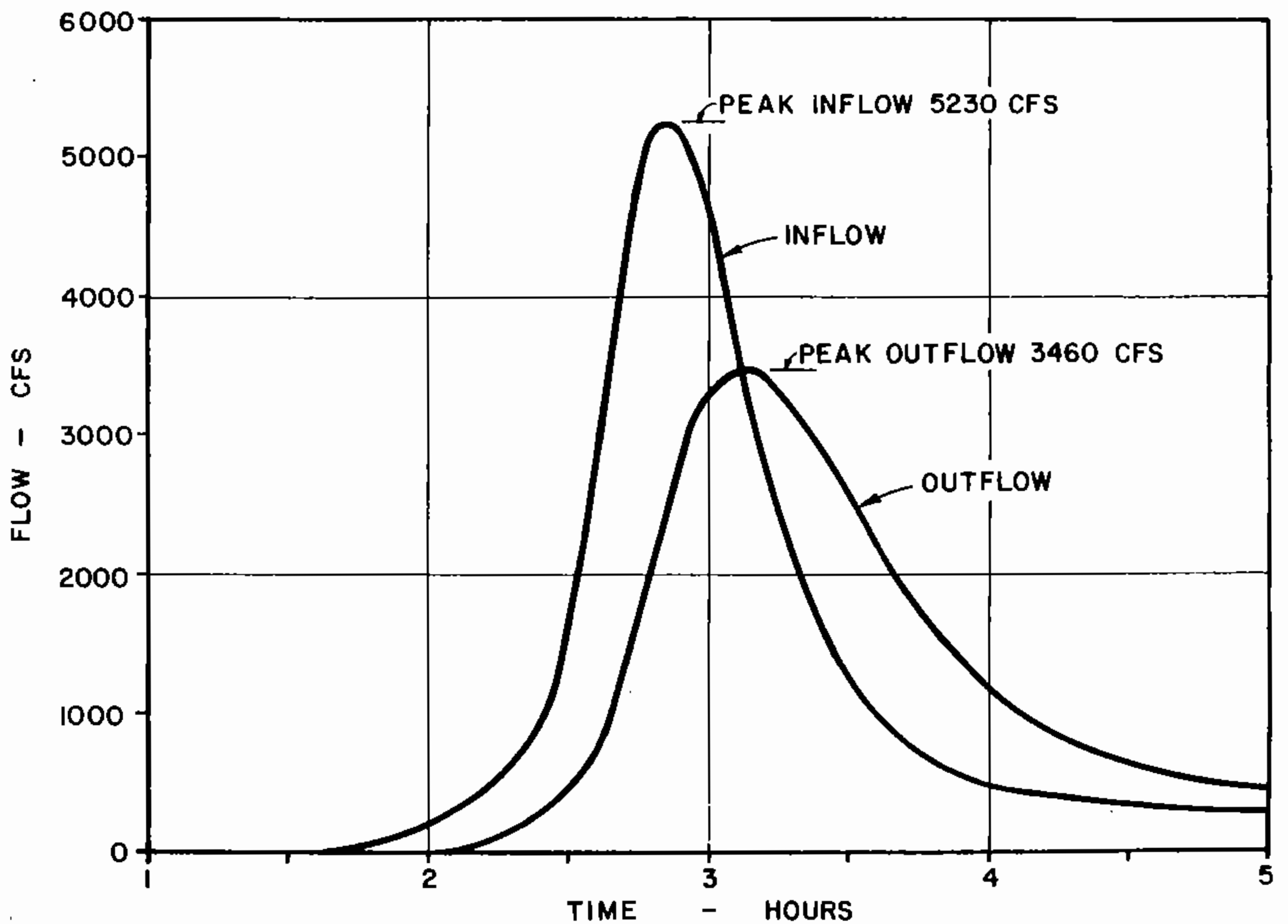


MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

MAN		CADS		MPF		
DECEMBER 1988						

MONTANA SILVER VENTURE
DIVERSION CHANNEL
DISCHARGE RATING CURVE
FIGURE B-3

B802901GA000800

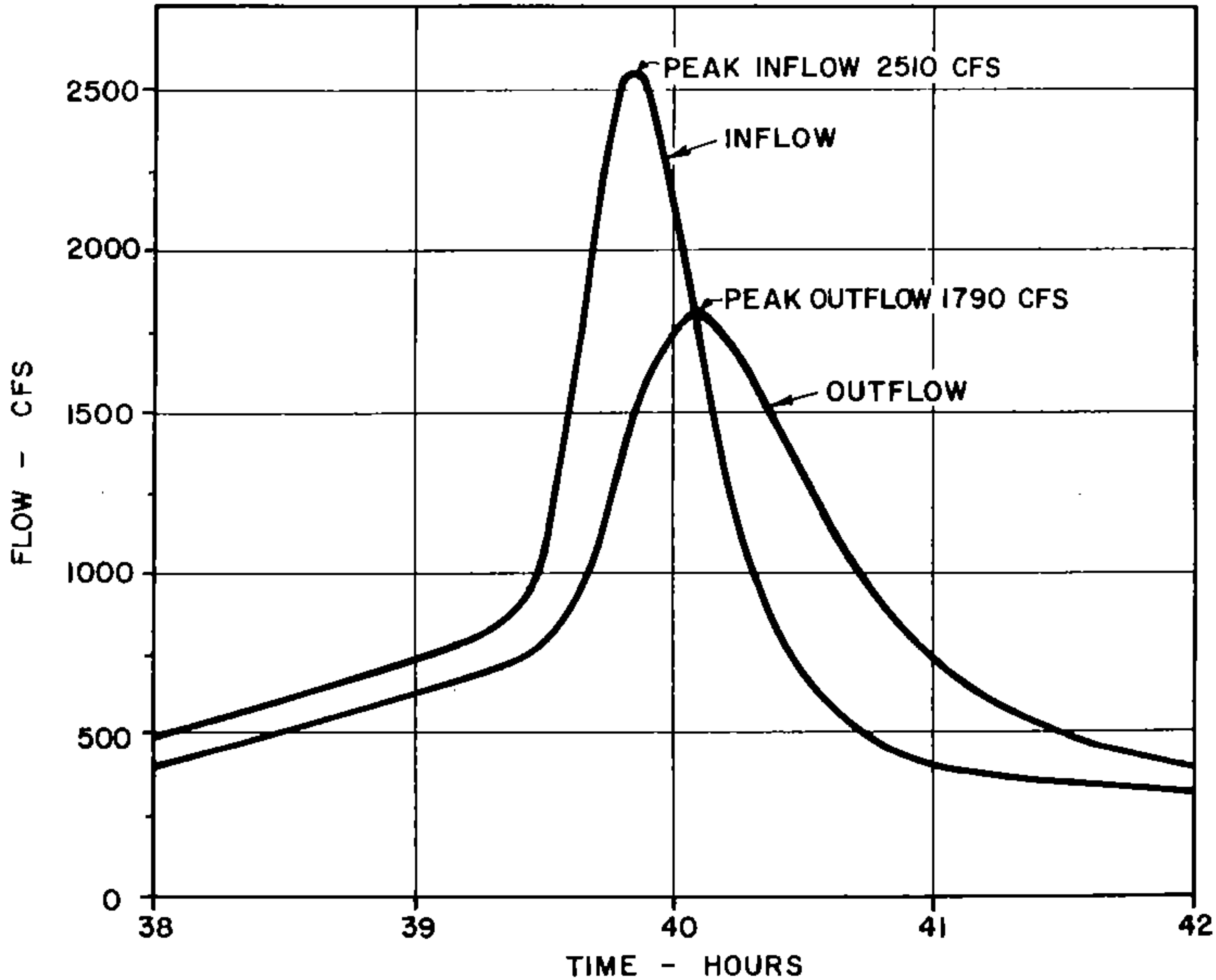


MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

DESIGNED DMB	DRAWN RB	CHECKED MPF	RECOMMENDED

MONTANA SILVER VENTURE

LITTLE CHERRY CREEK DIVERSION
6-HOUR LOCAL STORM PMF



MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

DESIGNED DMB	DRAWN R B	CHECKED MPF	RECOMMENDED

MONTANA SILVER VENTURE

LITTLE CHERRY CREEK DIVERSION
72-HOUR GENERAL STORM PMF

6-HOUR LOCAL STORM PMF

(HEC-1 Output)

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                                   ****
               FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
   U.S. ARMY CORPS OF ENGINEERS. THE HYDROLOGIC ENGINEERING CENTER. 609 SECOND STREET, DAVIS, CA. 95616
                                   ****


  THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS. AND THE NUMBER OF PLANS ARE REDUCED TO 3


                                 HEC-1 INPUT                                                     PAGE

LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   MSV LITTLE CHERRY CREEK DIVERSION DAM
  2           ID   THUNDERSTORM PMF
  3           IT       5                      72
  4           IO       2       2       0

  5           KK   POND INFLOW
  6           BA     0.9
  7           PB       0
  8           PI     .02     .02     .02     .02     .03     .03     .03     .03     .05     .05
  9           PI     .05     .05     .08     .08     .10     .10     .12     .12     .14     .14
 10           PI     .15     .15     .16     .16     .24     .32     .40     .48     .72    1.36
 11           PI    2.00     .88     .64     .40     .32     .24     .10     .10     .10     .07
 12           PI     .07     .07     .07     .07     .07     .06     .06     .06     .05     .05
 13           PI     .05     .05     .05     .05     .05     .05     .05     .05     .05     .05
 14           PI     .04     .04     .04     .04     .04     .04     .02     .02     .02     .02
 15           PI     .02     .02
 16           LS       0      73       0
 17           UD     .32

 18           KK   ROUTING THRU POND
 19           RS       1    ELEV    3680
 20           SA     1.9     6.1    13.9
 21           SE    3660    3680    3700
 22           SS    3680      20     3.1     1.5
```

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                              ****
          FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                              ****


              MSV LITTLE CHERRY CREEK DIVERSION DAM
              THUNDERSTORM PMF

4 IO       OUTPUT CONTROL VARIABLES
                IPRNT          2  PRINT CONTROL
                IPLOT          2  PLOT CONTROL
                QSCAL          0. HYDROGRAPH PLOT SCALE

  IT       HYDROGRAPH TIME DATA
                 NMIN          5  MINUTES IN COMPUTATION INTERVAL
                IDATE     1    0  STARTING DATE
                ITIME       0000  STARTING TIME
                   NQ         72  NUMBER OF HYDROGRAPH ORDINATES
               NDDATE     1    0  ENDING DATE
               NDTIME       0555  ENDING TIME

            COMPUTATION INTERVAL     .08 HOURS
                 TOTAL TIME BASE    5.92 HOURS

     ENGLISH UNITS
```

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** **

              **************
              *            *
  5 KK        *    POND    *     INFLOW
              *            *
              **************

                 SUBBASIN RUNOFF DATA

  6 BA             SUBBASIN CHARACTERISTICS
                         TAREA          .90  SUBBASIN AREA

                   PRECIPITATION DATA

  7 PB                   STORM        11.74  BASIN TOTAL PRECIPITATION

  8 PI               INCREMENTAL PRECIPITATION PATTERN
                          .02        .02        .02        .02        .03        .03        .03        .03        .05
                          .05        .05        .08        .08        .10        .10        .12        .12        .14
                          .15        .15        .16        .16        .24        .32        .40        .48        .72
                         2.00        .88        .64        .40        .32        .24        .10        .10        .10
                          .07        .07        .07        .07        .07        .06        .06        .06        .05
                          .05        .05        .05        .05        .05        .05        .05        .05        .05
                          .04        .04        .04        .04        .04        .04        .02        .02        .02
                          .02

 16 LS             SCS LOSS RATE
                         STRTL          .74  INITIAL ABSTRACTION
                        CRVNBR        73.00  CURVE NUMBER
                         RTIMP          .00  PERCENT IMPERVIOUS AREA

 17 UD             SCS DIMENSIONLESS UNITGRAPH
                          TLAG          .32  LAG

                                                      ***

                                                UNIT HYDROGRAPH
                                            21 END-OF-PERIOD ORDINATES
                153.       489.       968.      1192.      1152.       954.       657.       437.       304.       211.
                144.        99.        67.        46.        32.        22.        15.        11.         8.         5.
                  2.
```

HYDROGRAPH AT STATION POND

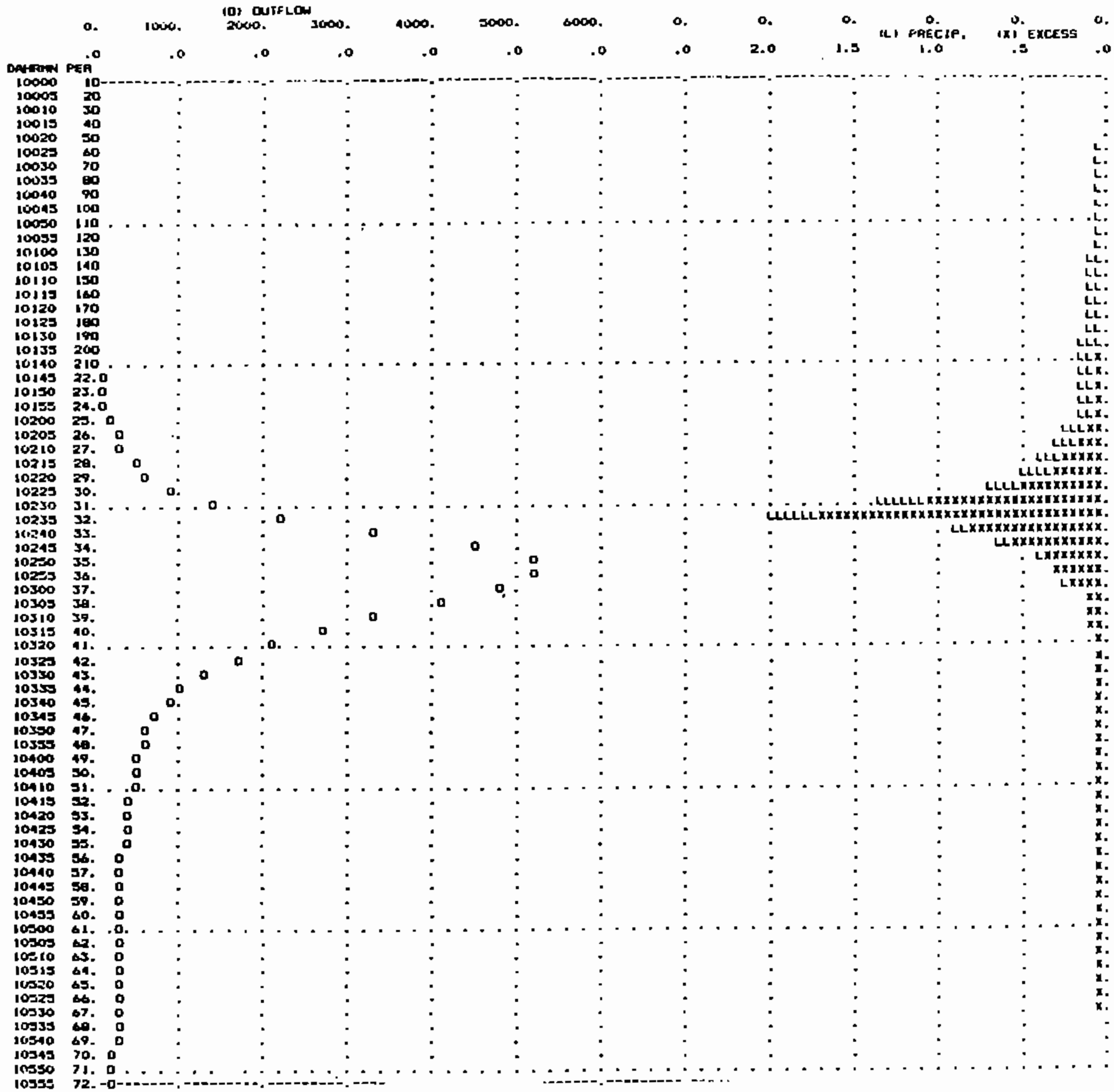
DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1		0000	1	.00	.00	.00	0.	1		0300	37	.24	.02	.22	4802.
1		0005	2	.02	.02	.00	0.	1		0305	38	.10	.01	.09	4081.
1		0010	3	.02	.02	.00	0.	1		0310	39	.10	.01	.09	3342.
1		0015	4	.02	.02	.00	0.	1		0315	40	.10	.01	.09	2673.
1		0020	5	.02	.02	.00	0.	1		0320	41	.07	.01	.06	2107.
1		0025	6	.03	.03	.00	0.	1		0325	42	.07	.01	.06	1652.
1		0030	7	.03	.03	.00	0.	1		0330	43	.07	.01	.06	1301.
1		0035	8	.03	.03	.00	0.	1		0335	44	.07	.01	.06	1046.
1		0040	9	.03	.03	.00	0.	1		0340	45	.07	.01	.06	865.
1		0045	10	.05	.05	.00	0.	1		0345	46	.07	.01	.06	735.
1		0050	11	.05	.05	.00	0.	1		0350	47	.06	.00	.06	645.
1		0055	12	.05	.05	.00	0.	1		0355	48	.06	.00	.06	580.
1		0100	13	.05	.05	.00	0.	1		0400	49	.06	.00	.06	529.
1		0105	14	.08	.08	.00	0.	1		0405	50	.05	.00	.05	487.
1		0110	15	.08	.08	.00	0.	1		0410	51	.05	.00	.05	450.
1		0115	16	.10	.10	.00	0.	1		0415	52	.05	.00	.05	416.
1		0120	17	.10	.10	.00	0.	1		0420	53	.05	.00	.05	388.
1		0125	18	.12	.11	.01	1.	1		0425	54	.05	.00	.05	368.
1		0130	19	.12	.11	.01	4.	1		0430	55	.05	.00	.05	353.
1		0135	20	.14	.12	.02	14.	1		0435	56	.05	.00	.05	343.
1		0140	21	.14	.11	.03	33.	1		0440	57	.05	.00	.05	337.
1		0145	22	.15	.11	.04	62.	1		0445	58	.05	.00	.05	332.
1		0150	23	.15	.10	.05	100.	1		0450	59	.05	.00	.05	330.
1		0155	24	.16	.10	.06	146.	1		0455	60	.05	.00	.05	328.
1		0200	25	.16	.10	.06	196.	1		0500	61	.05	.00	.05	327.
1		0205	26	.24	.13	.11	255.	1		0505	62	.04	.00	.04	325.
1		0210	27	.32	.16	.16	334.	1		0510	63	.04	.00	.04	320.
1		0215	28	.40	.17	.23	454.	1		0515	64	.04	.00	.04	311.
1		0220	29	.48	.18	.30	634.	1		0520	65	.04	.00	.04	299.
1		0225	30	.72	.22	.50	902.	1		0525	66	.04	.00	.04	289.
1		0230	31	1.36	.32	1.04	1350.	1		0530	67	.04	.00	.04	280.
1		0235	32	2.00	.31	1.69	2161.	1		0535	68	.02	.00	.02	271.
1		0240	33	.88	.10	.78	3309.	1		0540	69	.02	.00	.02	258.
1		0245	34	.64	.07	.57	4488.	1		0545	70	.02	.00	.02	237.
1		0250	35	.40	.04	.36	5165.	1		0550	71	.02	.00	.02	212.
1		0255	36	.32	.03	.29	5233.	1		0555	72	.02	.00	.02	190.

TOTAL RAINFALL = 11.74, TOTAL LOSS = 3.51, TOTAL EXCESS = 8.23

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	5.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 5233.	2.92		797.	797.	797.	797.
		(INCHES)	8.114	8.114	8.114	8.114
		(AC-FT)	389.	389.	389.	389.

CUMULATIVE AREA = .90 SQ MI

STATION POND



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*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

               **************
               *            *
 18 KK         *    ROUTI   *     NG THRU POND
               *            *
               **************

                  HYDROGRAPH ROUTING DATA

 19 RS               STORAGE ROUTING
                          NSTPS            1  NUMBER OF SUBREACHES
                           ITYP         ELEV  TYPE OF INITIAL CONDITION
                         RSVRIC      3680.00  INITIAL CONDITION
                              X          .00  WORKING R AND D COEFFICIENT

 20 SA                       AREA         1.9        6.1       13.9

 21 SE               ELEVATION      3660.00    3680.00    3700.00

 22 SS               SPILLWAY
                           CREL      3680.00  SPILLWAY CREST ELEVATION
                          SPWID        20.00  SPILLWAY WIDTH
                           COQW         3.10  WEIR COEFFICIENT
                           EXPW         1.50  EXPONENT OF HEAD

                                                            ***

                                              COMPUTED STORAGE-ELEVATION DATA

            STORAGE         .00      76.03     270.75
          ELEVATION     3660.00    3680.00    3700.00

                                              COMPUTED OUTFLOW-ELEVATION DATA

            OUTFLOW         .00        .00        .95       7.60      25.68      60.85     118.86     205.38     326.14     486.86
          ELEVATION     3660.00    3680.00    3680.06    3680.25    3680.56    3680.99    3681.54    3682.22    3683.02    3683.95

            OUTFLOW      693.18     950.87    1265.63    1643.10    2089.06    2609.21    3209.18    3894.75    4671.64    5545.45
          ELEVATION     3685.00    3686.17    3687.47    3688.89    3690.43    3692.10    3693.89    3695.80    3697.84    3700.00

                                          COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

            STORAGE         .00      76.03      76.41      77.54      79.47      82.21      85.82      90.37      95.94     102.64
            OUTFLOW         .00        .00        .95       7.60      25.68      60.85     118.86     205.38     326.14     486.86
          ELEVATION     3660.00    3680.00    3680.06    3680.25    3680.56    3680.99    3681.54    3682.22    3683.02    3683.95

            STORAGE      110.58     119.92     130.81     143.46     158.08     174.92     194.27     216.44     241.80     270.75
            OUTFLOW      693.18     950.87    1265.63    1643.10    2089.06    2609.21    3209.18    3894.75    4671.64    5545.45
          ELEVATION     3685.00    3686.17    3687.47    3688.89    3690.43    3692.10    3693.89    3695.80    3697.84    3700.00

*******************************************************************************************************************************
```

HYDROGRAPH AT STATION ROUTI

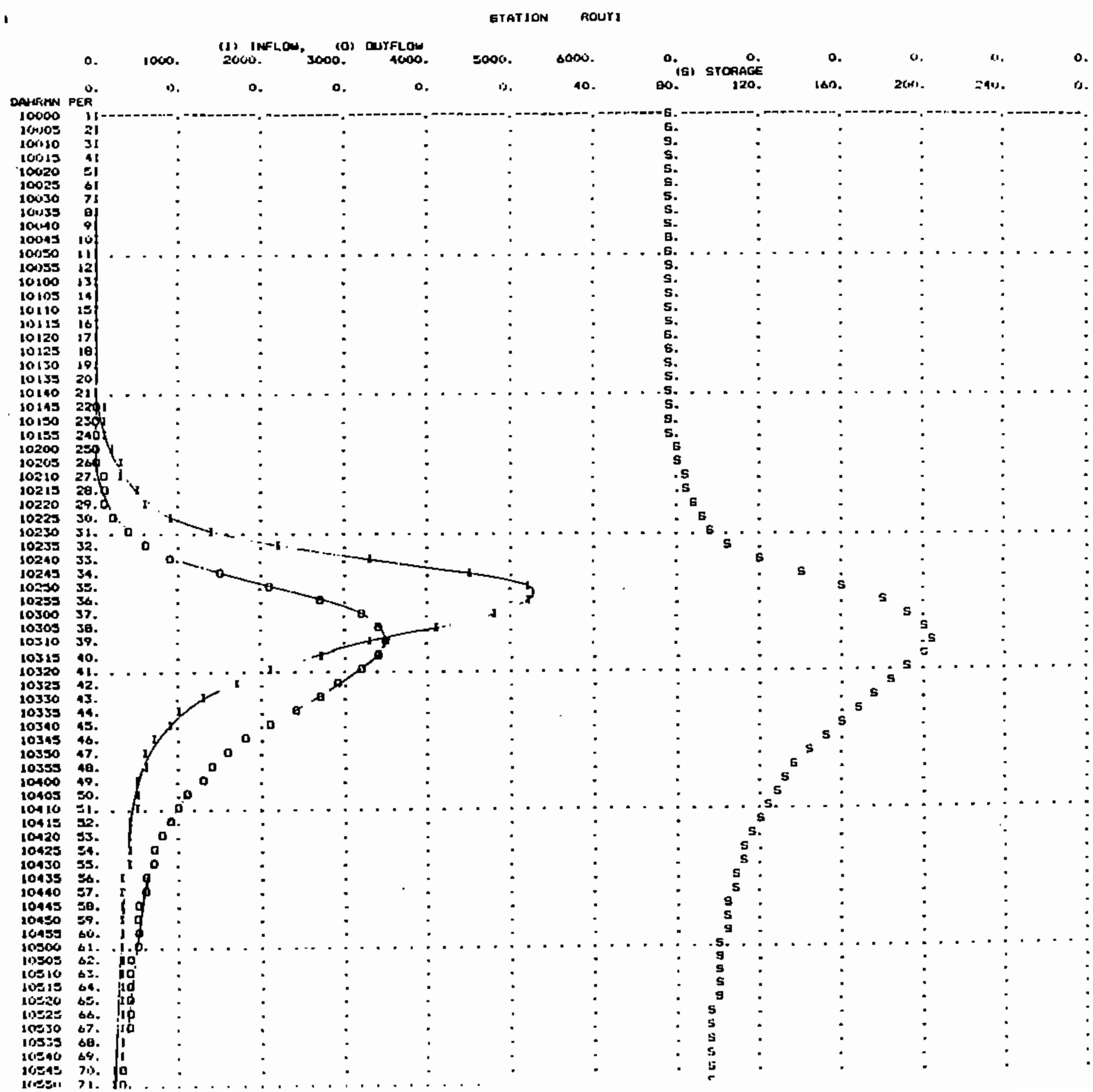
DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	0.	76.0	3680.0	1		0200	25	21.	79.0	3680.5	1		0400	49	1275.	131.1	3687.5
1		0005	2	0.	76.0	3680.0	1		0205	26	37.	80.3	3680.7	1		0405	50	1136.	126.3	3686.9
1		0010	3	0.	76.0	3680.0	1		0210	27	59.	82.0	3681.0	1		0410	51	1015.	122.1	3686.4
1		0015	4	0.	76.0	3680.0	1		0215	28	93.	84.2	3681.3	1		0415	52	911.	118.5	3686.0
1		0020	5	0.	76.0	3680.0	1		0220	29	144.	87.2	3681.7	1		0420	53	823.	115.3	3685.6
1		0025	6	0.	76.0	3680.0	1		0225	30	223.	91.2	3682.3	1		0425	54	746.	112.5	3685.2
1		0030	7	0.	76.0	3680.0	1		0230	31	351.	97.0	3683.2	1		0430	55	680.	110.1	3684.9
1		0035	8	0.	76.0	3680.0	1		0235	32	571.	105.9	3684.4	1		0435	56	625.	108.0	3684.7
1		0040	9	0.	76.0	3680.0	1		0240	33	940.	119.5	3686.1	1		0440	57	578.	106.2	3684.4
1		0045	10	0.	76.0	3680.0	1		0245	34	1481.	138.0	3688.3	1		0445	58	538.	104.6	3684.2
1		0050	11	0.	76.0	3680.0	1		0250	35	2114.	158.9	3690.5	1		0450	59	504.	103.3	3684.0
1		0055	12	0.	76.0	3680.0	1		0255	36	2707.	178.1	3692.4	1		0455	60	476.	102.2	3683.9
1		0100	13	0.	76.0	3680.0	1		0300	37	3153.	192.5	3693.7	1		0500	61	454.	101.2	3683.8
1		0105	14	0.	76.0	3680.0	1		0305	38	3401.	200.5	3694.4	1		0505	62	434.	100.4	3683.6
1		0110	15	0.	76.0	3680.0	1		0310	39	3461.	202.4	3694.6	1		0510	63	417.	99.7	3683.5
1		0115	16	0.	76.0	3680.0	1		0315	40	3374.	199.6	3694.3	1		0515	64	402.	99.1	3683.5
1		0120	17	0.	76.0	3680.0	1		0320	41	3184.	193.5	3693.8	1		0520	65	387.	98.5	3683.4
1		0125	18	0.	76.0	3680.0	1		0325	42	2933.	185.3	3693.1	1		0525	66	373.	97.9	3683.3
1		0130	19	0.	76.1	3680.0	1		0330	43	2652.	176.3	3692.2	1		0530	67	359.	97.3	3683.2
1		0135	20	0.	76.1	3680.0	1		0335	44	2367.	167.1	3691.3	1		0535	68	346.	96.8	3683.1
1		0140	21	1.	76.3	3680.0	1		0340	45	2096.	158.3	3690.5	1		0540	69	334.	96.3	3683.1
1		0145	22	2.	76.6	3680.1	1		0345	46	1849.	150.2	3689.6	1		0545	70	321.	95.7	3683.0
1		0150	23	5.	77.1	3680.2	1		0350	47	1629.	143.0	3688.8	1		0550	71	308.	95.1	3682.9
1		0155	24	11.	77.9	3680.3	1		0355	48	1440.	136.6	3688.1	1		0555	72	293.	94.4	3682.8

```
  PEAK FLOW      TIME                         MAXIMUM AVERAGE FLOW
                                      6-HR        24-HR        72-HR       5.92-HR
+   (CFS)        (HR)
                             (CFS)
+    3461.       3.17                  759.         759.         759.         759.
                          (INCHES)    7.732        7.732        7.732        7.732
                           (AC-FT)     371.         371.         371.         371.

 PEAK STORAGE    TIME                       MAXIMUM AVERAGE STORAGE
                                      6-HR        24-HR        72-HR       5.92-HR
+  (AC-FT)       (HR)
     202.        3.17                  108.         108.         108.         108.

  PEAK STAGE     TIME                        MAXIMUM AVERAGE STAGE
                                      6-HR        24-HR        72-HR       5.92-HR
+   (FEET)       (HR)
   3694.59       3.17               3684.21      3684.21      3684.21      3684.21

                          CUMULATIVE AREA =     .90 SQ MI
```


STATION ROUT1
(I) INFLOW, (O) OUTFLOW
0. 1000. 2000. 3000. 4000. 5000. 6000.
(S) STORAGE
80. 120. 160. 200. 240.
DAHRMN PER

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
				6-HOUR	24-HOUR	72-HOUR			
HYDROGRAPH AT	POND	5233.	2.92	797.	797.	797.	.90		
ROUTED TO	ROUTI	3461.	3.17	759.	759.	759.	.90	3694.59	3.17

72-HOUR GENERAL STORM PMF

(HEC-1 Output)

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                                   ****
            FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                   ****


THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3


                                   HEC-1 INPUT                                        PAGE  1

LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1        ID   MSV LITTLE CHERRY CREEK DIVERSION DAM
  2        ID    72-HR GENERAL PMF
  3        IT       5                       300
  4        IO       2       2       0

  5        KK    POND INFLOW
  6        BA     0.9
  7        PB       0
  8        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
  9        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 10        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 11        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 12        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 13        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 14        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 15        PI    .005    .005    .016    .016    .016    .016    .016    .016    .016    .016
 16        PI    .016    .016    .016    .016    .016    .016    .016    .016    .016    .016
 17        PI    .016    .016    .016    .016    .016    .016    .026    .026    .026    .026
 18        PI    .026    .026    .026    .026    .026    .026    .026    .026    .026    .026
 19        PI    .026    .026    .026    .026    .026    .026    .026    .026    .026    .026
 20        PI    .036    .036    .036    .036    .036    .036    .036    .036    .036    .036
 21        PI    .036    .036    .036    .036    .036    .036    .036    .036    .036    .036
 22        PI    .036    .036    .036    .036    .042    .042    .042    .042    .047    .047
 23        PI    .047    .047    .052    .052    .052    .052    .057    .057    .057    .057
 24        PI    .066    .066    .066    .066    .075    .075    .075    .075    .100    .100
 25        PI    .100    .100    .105    .105    .105    .105    .110    .110    .110    .110
 26        PI    .112    .121    .151    .180    .272    .513    .755    .332    .242    .151
 27        PI    .121    .070    .062    .062    .062    .062    .056    .056    .056    .056
 28        PI    .050    .050    .050    .050    .048    .048    .048    .048    .047    .047
 29        PI    .047    .047    .046    .046    .046    .046    .015    .015    .015    .015
 30        PI    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
 31        PI    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
 32        PI    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
 33        PI    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
 34        PI    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
 35        PI    .015    .015    .015    .015    .015    .015    .006    .006    .006    .006
 36        PI    .006    .006    .006    .006    .006    .006    .006    .006    .005    .005
 37        PI    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
 38        LS       0     100       0
 39        UD    0.32

 40        KK    ROUTING THRU POND
 41        RS       1    ELEV    3680
 42        SA     1.9     6.1    13.9
 43        SE    3660    3680    3700
 44        SS    3680      20     3.1     1.5
 45        ZZ
```

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                    FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                        ****

            MGV LITTLE CHERRY CREEK DIVERSION DAM
             72-HR GENERAL PMF

IO       OUTPUT CONTROL VARIABLES
               IPRNT           2  PRINT CONTROL
               IPLOT           2  PLOT CONTROL
               QSCAL          0.  HYDROGRAPH PLOT SCALE

IT       HYDROGRAPH TIME DATA
                NMIN           5  MINUTES IN COMPUTATION INTERVAL
               IDATE      1    0  STARTING DATE
               ITIME        0000  STARTING TIME
                  NQ         300  NUMBER OF HYDROGRAPH ORDINATES
              NDDATE      2    0  ENDING DATE
              NDTIME        0055  ENDING TIME

          COMPUTATION INTERVAL     .08 HOURS
               TOTAL TIME BASE   24.92 HOURS

     ENGLISH UNITS
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              **************
              *            *
5 KK          *    POND    *     INFLOW
              *            *
              **************
```

SUBBASIN RUNOFF DATA

6 BA SUBBASIN CHARACTERISTICS
TAREA .90 SUBBASIN AREA

PRECIPITATION DATA

7 PB STORM 10.13 BASIN TOTAL PRECIPITATION

8 PI INCREMENTAL PRECIPITATION PATTERN

.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.01	.01	.01	.01	.01	.01	.01
.01	.01	.01	.01	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.01	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.03	.03	.03	.03
.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
.04	.04	.04	.04	.04	.04	.04	.04	.05	.05
.05	.05	.05	.05	.05	.05	.06	.06	.06	.06
.07	.07	.07	.07	.08	.08	.08	.08	.10	.10
.10	.10	.10	.11	.11	.11	.11	.11	.11	.11
.11	.12	.15	.18	.27	.51	.76	.33	.24	.15
.12	.07	.06	.06	.06	.06	.06	.06	.06	.06
.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
.05	.05	.05	.05	.05	.05	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
.01	.01	.01	.01	.01	.01	.01	.01	.01	

38 LS SCS LOSS RATE
STRTL .00 INITIAL ABSTRACTION
CRVNBR 100.00 CURVE NUMBER
RTIMP .00 PERCENT IMPERVIOUS AREA

39 UD SCS DIMENSIONLESS UNITGRAPH
TLAG .32 LAG

***

UNIT HYDROGRAPH
21 END-OF-PERIOD ORDINATES

153.	489.	968.	1192.	1152.	954.	657.	437.	304.	211.
144.	99.	67.	46.	32.	22.	15.	11.	8.	5.

****

HYDROGRAPH AT STATION POND

****

DA	MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	1	1230	151	.05	.00	.05	284.
1	0005	2	.00	.00	.00	1.	*	1	1235	152	.05	.00	.05	292.
1	0010	3	.00	.00	.00	3.	*	1	1240	153	.05	.00	.05	301.
1	0015	4	.00	.00	.00	8.	*	1	1245	154	.05	.00	.05	309.
1	0020	5	.00	.00	.00	14.	*	1	1250	155	.05	.00	.05	318.
1	0025	6	.00	.00	.00	20.	*	1	1255	156	.05	.00	.05	327.
1	0030	7	.00	.00	.00	25.	*	1	1300	157	.05	.00	.05	336.
1	0035	8	.00	.00	.00	28.	*	1	1305	158	.06	.00	.06	344.
1	0040	9	.00	.00	.00	30.	*	1	1310	159	.06	.00	.06	353.
1	0045	10	.00	.00	.00	32.	*	1	1315	160	.06	.00	.06	362.
1	0050	11	.00	.00	.00	33.	*	1	1320	161	.06	.00	.06	370.
1	0055	12	.00	.00	.00	33.	*	1	1325	162	.07	.00	.07	379.
1	0100	13	.00	.00	.00	34.	*	1	1330	163	.07	.00	.07	390.
1	0105	14	.00	.00	.00	34.	*	1	1335	164	.07	.00	.07	403.
1	0110	15	.01	.00	.01	34.	*	1	1340	165	.07	.00	.07	416.
1	0115	16	.01	.00	.01	35.	*	1	1345	166	.08	.00	.08	430.
1	0120	17	.01	.00	.01	35.	*	1	1350	167	.08	.00	.08	444.
1	0125	18	.01	.00	.01	35.	*	1	1355	168	.08	.00	.08	460.
1	0130	19	.01	.00	.01	35.	*	1	1400	169	.08	.00	.08	475.
1	0135	20	.01	.00	.01	35.	*	1	1405	170	.10	.00	.10	493.
1	0140	21	.01	.00	.01	35.	*	1	1410	171	.10	.00	.10	516.
1	0145	22	.01	.00	.01	35.	*	1	1415	172	.10	.00	.10	547.
1	0150	23	.01	.00	.01	35.	*	1	1420	173	.10	.00	.10	582.
1	0155	24	.01	.00	.01	35.	*	1	1425	174	.10	.00	.10	615.
1	0200	25	.01	.00	.01	35.	*	1	1430	175	.11	.00	.11	644.
1	0205	26	.00	.00	.00	35.	*	1	1435	176	.11	.00	.11	667.
1	0210	27	.00	.00	.00	35.	*	1	1440	177	.11	.00	.11	685.
1	0215	28	.00	.00	.00	35.	*	1	1445	178	.11	.00	.11	699.
1	0220	29	.00	.00	.00	35.	*	1	1450	179	.11	.00	.11	712.
1	0225	30	.00	.00	.00	35.	*	1	1455	180	.11	.00	.11	725.
1	0230	31	.00	.00	.00	35.	*	1	1500	181	.11	.00	.11	735.
1	0235	32	.00	.00	.00	35.	*	1	1505	182	.11	.00	.11	745.
1	0240	33	.00	.00	.00	35.	*	1	1510	183	.12	.00	.12	754.
1	0245	34	.00	.00	.00	35.	*	1	1515	184	.15	.00	.15	770.
1	0250	35	.00	.00	.00	35.	*	1	1520	185	.18	.00	.18	804.
1	0255	36	.00	.00	.00	35.	*	1	1525	186	.27	.00	.27	876.
1	0300	37	.00	.00	.00	35.	*	1	1530	187	.51	.00	.51	1036.
1	0305	38	.00	.00	.00	35.	*	1	1535	188	.76	.00	.76	1360.
1	0310	39	.00	.00	.00	35.	*	1	1540	189	.33	.00	.33	1826.
1	0315	40	.00	.00	.00	35.	*	1	1545	190	.24	.00	.24	2285.
1	0320	41	.00	.00	.00	35.	*	1	1550	191	.15	.00	.15	2507.
1	0325	42	.00	.00	.00	35.	*	1	1555	192	.12	.00	.12	2460.
1	0330	43	.00	.00	.00	35.	*	1	1600	193	.07	.00	.07	2201.
1	0335	44	.00	.00	.00	35.	*	1	1605	194	.06	.00	.06	1834.
1	0340	45	.00	.00	.00	35.	*	1	1610	195	.06	.00	.06	1483.
1	0345	46	.00	.00	.00	35.	*	1	1615	196	.06	.00	.06	1192.
1	0350	47	.00	.00	.00	35.	*	1	1620	197	.06	.00	.06	944.

1	0355	48	.00	.00	.00	35.	*	1	1625	198	.06	.00	.06	798.
1	0400	49	.00	.00	.00	35.	*	1	1630	199	.06	.00	.06	680.
1	0405	50	.00	.00	.00	35.	*	1	1635	200	.06	.00	.06	595.
1	0410	51	.00	.00	.00	35.	*	1	1640	201	.06	.00	.06	534.
1	0415	52	.01	.00	.01	35.	*	1	1645	202	.05	.00	.05	489.
1	0420	53	.00	.00	.00	35.	*	1	1650	203	.05	.00	.05	455.
1	0425	54	.00	.00	.00	35.	*	1	1655	204	.05	.00	.05	428.
1	0430	55	.00	.00	.00	35.	*	1	1700	205	.05	.00	.05	406.
1	0435	56	.00	.00	.00	35.	*	1	1705	206	.05	.00	.05	388.
1	0440	57	.00	.00	.00	35.	*	1	1710	207	.05	.00	.05	373.
1	0445	58	.00	.00	.00	35.	*	1	1715	208	.05	.00	.05	362.
1	0450	59	.00	.00	.00	35.	*	1	1720	209	.05	.00	.05	353.
1	0455	60	.00	.00	.00	35.	*	1	1725	210	.05	.00	.05	347.
1	0500	61	.00	.00	.00	35.	*	1	1730	211	.05	.00	.05	342.
1	0505	62	.00	.00	.00	35.	*	1	1735	212	.05	.00	.05	338.
1	0510	63	.00	.00	.00	35.	*	1	1740	213	.05	.00	.05	335.
1	0515	64	.00	.00	.00	35.	*	1	1745	214	.05	.00	.05	333.
1	0520	65	.00	.00	.00	35.	*	1	1750	215	.05	.00	.05	331.
1	0525	66	.00	.00	.00	35.	*	1	1755	216	.05	.00	.05	328.
1	0530	67	.00	.00	.00	35.	*	1	1800	217	.05	.00	.05	326.
1	0535	68	.00	.00	.00	35.	*	1	1805	218	.02	.00	.02	320.
1	0540	69	.00	.00	.00	35.	*	1	1810	219	.02	.00	.02	303.
1	0545	70	.00	.00	.00	35.	*	1	1815	220	.02	.00	.02	273.
1	0550	71	.00	.00	.00	35.	*	1	1820	221	.02	.00	.02	235.
1	0555	72	.00	.00	.00	35.	*	1	1825	222	.02	.00	.02	199.
1	0600	73	.00	.00	.00	35.	*	1	1830	223	.02	.00	.02	169.
1	0605	74	.02	.00	.02	37.	*	1	1835	224	.02	.00	.02	148.
1	0610	75	.02	.00	.02	42.	*	1	1840	225	.02	.00	.02	135.
1	0615	76	.02	.00	.02	53.	*	1	1845	226	.02	.00	.02	125.
1	0620	77	.02	.00	.02	66.	*	1	1850	227	.02	.00	.02	119.
1	0625	78	.02	.00	.02	78.	*	1	1855	228	.02	.00	.02	114.
1	0630	79	.02	.00	.02	89.	*	1	1900	229	.02	.00	.02	111.
1	0635	80	.02	.00	.02	96.	*	1	1905	230	.02	.00	.02	109.
1	0640	81	.02	.00	.02	101.	*	1	1910	231	.02	.00	.02	108.
1	0645	82	.02	.00	.02	104.	*	1	1915	232	.02	.00	.02	107.
1	0650	83	.02	.00	.02	107.	*	1	1920	233	.02	.00	.02	106.
1	0655	84	.02	.00	.02	108.	*	1	1925	234	.02	.00	.02	105.
1	0700	85	.02	.00	.02	109.	*	1	1930	235	.02	.00	.02	105.
1	0705	86	.02	.00	.02	110.	*	1	1935	236	.02	.00	.02	105.
1	0710	87	.02	.00	.02	110.	*	1	1940	237	.02	.00	.02	105.
1	0715	88	.02	.00	.02	111.	*	1	1945	238	.02	.00	.02	105.
1	0720	89	.02	.00	.02	111.	*	1	1950	239	.02	.00	.02	105.
1	0725	90	.02	.00	.02	111.	*	1	1955	240	.02	.00	.02	105.
1	0730	91	.02	.00	.02	111.	*	1	2000	241	.02	.00	.02	105.
1	0735	92	.02	.00	.02	111.	*	1	2005	242	.02	.00	.02	105.
1	0740	93	.02	.00	.02	111.	*	1	2010	243	.02	.00	.02	105.
1	0745	94	.02	.00	.02	112.	*	1	2015	244	.02	.00	.02	105.
1	0750	95	.02	.00	.02	112.	*	1	2020	245	.02	.00	.02	105.
1	0755	96	.02	.00	.02	112.	*	1	2025	246	.02	.00	.02	105.
1	0800	97	.02	.00	.02	112.	*	1	2030	247	.02	.00	.02	105.
1	0805	98	.03	.00	.03	113.	*	1	2035	248	.02	.00	.02	105.
1	0810	99	.03	.00	.03	118.	*	1	2040	249	.02	.00	.02	105.
1	0815	100	.03	.00	.03	128.	*	1	2045	250	.02	.00	.02	105.
1	0820	101	.03	.00	.03	140.	*	1	2050	251	.02	.00	.02	105.
1	0825	102	.03	.00	.03	151.	*	1	2055	252	.02	.00	.02	105.
1	0830	103	.03	.00	.03	161.	*	1	2100	253	.02	.00	.02	105.
1	0835	104	.03	.00	.03	167.	*	1	2105	254	.02	.00	.02	105.

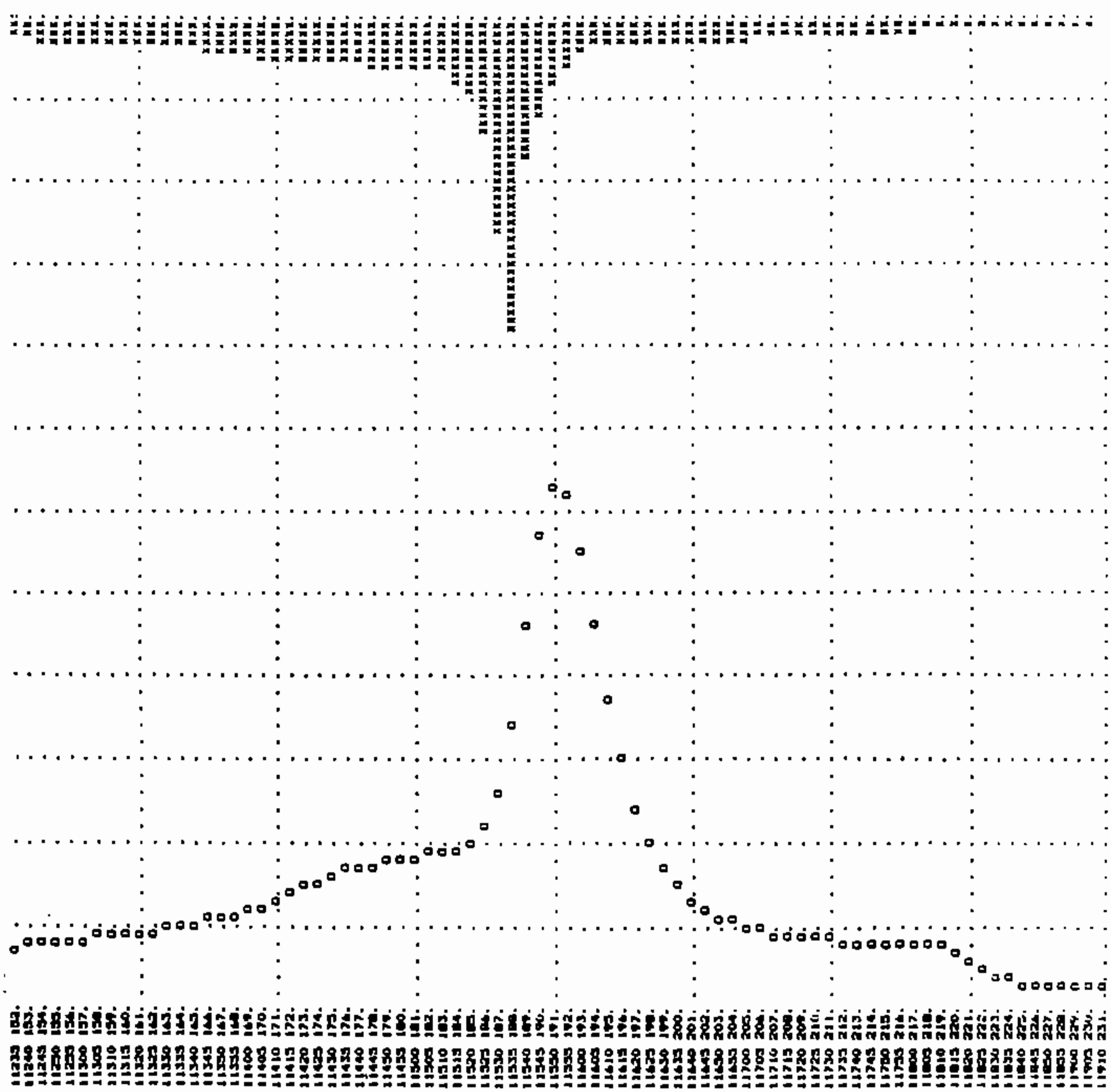
1	0840	105	.03	.00	.03	172.	*	1	2110	255	.02	.00	.02	10[illegible].
1	0845	106	.03	.00	.03	175.	*	1	2115	256	.02	.00	.02	105.
1	0850	107	.03	.00	.03	177.	*	1	2120	257	.02	.00	.02	105.
1	0855	108	.03	.00	.03	178.	*	1	2125	258	.02	.00	.02	105.
1	0900	109	.03	.00	.03	179.	*	1	2130	259	.02	.00	.02	105.
1	0905	110	.03	.00	.03	180.	*	1	2135	260	.02	.00	.02	105.
1	0910	111	.03	.00	.03	180.	*	1	2140	261	.02	.00	.02	105.
1	0915	112	.03	.00	.03	181.	*	1	2145	262	.02	.00	.02	105.
1	0920	113	.03	.00	.03	181.	*	1	2150	263	.02	.00	.02	105.
1	0925	114	.03	.00	.03	181.	*	1	2155	264	.02	.00	.02	105.
1	0930	115	.03	.00	.03	181.	*	1	2200	265	.02	.00	.02	105.
1	0935	116	.03	.00	.03	181.	*	1	2205	266	.02	.00	.02	105.
1	0940	117	.03	.00	.03	181.	*	1	2210	267	.02	.00	.02	105.
1	0945	118	.03	.00	.03	181.	*	1	2215	268	.02	.00	.02	105.
1	0950	119	.03	.00	.03	181.	*	1	2220	269	.02	.00	.02	105.
1	0955	120	.03	.00	.03	181.	*	1	2225	270	.02	.00	.02	105.
1	1000	121	.03	.00	.03	181.	*	1	2230	271	.02	.00	.02	105.
1	1005	122	.04	.00	.04	183.	*	1	2235	272	.02	.00	.02	105.
1	1010	123	.04	.00	.04	188.	*	1	2240	273	.02	.00	.02	105.
1	1015	124	.04	.00	.04	197.	*	1	2245	274	.02	.00	.02	105.
1	1020	125	.04	.00	.04	209.	*	1	2250	275	.02	.00	.02	105.
1	1025	126	.04	.00	.04	221.	*	1	2255	276	.02	.00	.02	105.
1	1030	127	.04	.00	.04	230.	*	1	2300	277	.02	.00	.02	105.
1	1035	128	.04	.00	.04	237.	*	1	2305	278	.01	.00	.01	103.
1	1040	129	.04	.00	.04	241.	*	1	2310	279	.01	.00	.01	99.
1	1045	130	.04	.00	.04	244.	*	1	2315	280	.01	.00	.01	90.
1	1050	131	.04	.00	.04	246.	*	1	2320	281	.01	.00	.01	79.
1	1055	132	.04	.00	.04	248.	*	1	2325	282	.01	.00	.01	69.
1	1100	133	.04	.00	.04	249.	*	1	2330	283	.01	.00	.01	60.
1	1105	134	.04	.00	.04	249.	*	1	2335	284	.01	.00	.01	54.
1	1110	135	.04	.00	.04	250.	*	1	2340	285	.01	.00	.01	51.
1	1115	136	.04	.00	.04	250.	*	1	2345	286	.01	.00	.01	48.
1	1120	137	.04	.00	.04	250.	*	1	2350	287	.01	.00	.01	46.
1	1125	138	.04	.00	.04	251.	*	1	2355	288	.01	.00	.01	45.
1	1130	139	.04	.00	.04	251.	*	2	0000	289	.01	.00	.01	44.
1	1135	140	.04	.00	.04	251.	*	2	0005	290	.01	.00	.01	43.
1	1140	141	.04	.00	.04	251.	*	2	0010	291	.01	.00	.01	42.
1	1145	142	.04	.00	.04	251.	*	2	0015	292	.01	.00	.01	41.
1	1150	143	.04	.00	.04	251.	*	2	0020	293	.01	.00	.01	39.
1	1155	144	.04	.00	.04	251.	*	2	0025	294	.01	.00	.01	38.
1	1200	145	.04	.00	.04	251.	*	2	0030	295	.01	.00	.01	37.
1	1205	146	.04	.00	.04	252.	*	2	0035	296	.01	.00	.01	36.
1	1210	147	.04	.00	.04	255.	*	2	0040	297	.01	.00	.01	36.
1	1215	148	.04	.00	.04	261.	*	2	0045	298	.01	.00	.01	36.
1	1220	149	.04	.00	.04	268.	*	2	0050	299	.01	.00	.01	35.
1	1225	150	.05	.00	.05	275.	*	2	0055	300	.01	.00	.01	35.

****

TOTAL RAINFALL = 10.13, TOTAL LOSS = .00, TOTAL EXCESS = 10.13

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	24.92-HR
(CFS)	(HR)					
		(CFS)				
2507.	15.83		662.	244.	236.	236.
		(INCHES)	6.842	10.075	10.105	10.105
		(AC-FT)	328.	484.	485.	485.

CUMULATIVE AREA = .90 SQ MI



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              **************
              *            *
40 KK         *    ROUT    *     ING THRU POND
              *            *
              **************

                HYDROGRAPH ROUTING DATA

41 RS             STORAGE ROUTING
                       NSTPS            1  NUMBER OF SUBREACHES
                        ITYP         ELEV  TYPE OF INITIAL CONDITION
                      RSVRIC      3680.00  INITIAL CONDITION
                           X          .00  WORKING R AND D COEFFICIENT

42 SA                   AREA          1.9        6.1       13.9

43 SE             ELEVATION     3660.00    3680.00    3700.00

44 SS             SPILLWAY
                        CREL      3680.00  SPILLWAY CREST ELEVATION
                       SPWID        20.00  SPILLWAY WIDTH
                        COQW         3.10  WEIR COEFFICIENT
                        EXPW         1.50  EXPONENT OF HEAD

                                                   ***
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COMPUTED STORAGE-ELEVATION DATA

STORAGE	.00	76.03	270.75
ELEVATION	3660.00	3680.00	3700.00

COMPUTED OUTFLOW-ELEVATION DATA

OUTFLOW	.00	.00	.95	7.60	25.68	60.85	118.86	205.38	326.14	486.86
ELEVATION	3660.00	3680.00	3680.06	3680.25	3680.56	3680.99	3681.54	3682.22	3683.02	3683.95
OUTFLOW	693.18	950.87	1265.63	1643.10	2089.06	2609.21	3209.18	3894.75	4671.64	5545.45
ELEVATION	3685.00	3686.17	3687.47	3688.89	3690.43	3692.10	3693.89	3695.80	3697.84	3700.00

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

STORAGE	.00	76.03	76.41	77.54	79.47	82.21	85.82	90.37	95.94	102.64
OUTFLOW	.00	.00	.95	7.60	25.68	60.85	118.86	205.38	326.14	486.86
ELEVATION	3660.00	3680.00	3680.06	3680.25	3680.56	3680.99	3681.54	3682.22	3683.02	3683.95
STORAGE	110.58	119.92	130.81	143.46	158.08	174.92	194.27	216.44	241.80	270.75
OUTFLOW	693.18	950.87	1265.63	1643.10	2089.06	2609.21	3209.18	3894.75	4671.64	5545.45
ELEVATION	3685.00	3686.17	3687.47	3688.89	3690.43	3692.10	3693.89	3695.80	3697.84	3700.00

HYDROGRAPH AT STATION ROUT

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	0.	76.0	3680.0
1		0005	2	0.	76.0	3680.0
1		0010	3	0.	76.0	3680.0
1		0015	4	0.	76.1	3680.0
1		0020	5	0.	76.2	3680.0
1		0025	6	1.	76.3	3680.0
1		0030	7	1.	76.4	3680.1
1		0035	8	2.	76.6	3680.1
1		0040	9	3.	76.8	3680.1
1		0045	10	4.	77.0	3680.2
1		0050	11	5.	77.1	3680.2
1		0055	12	6.	77.3	3680.2
1		0100	13	7.	77.5	3680.2
1		0105	14	9.	77.7	3680.3
1		0110	15	11.	77.9	3680.3
1		0115	16	12.	78.0	3680.3
1		0120	17	13.	78.2	3680.3
1		0125	18	15.	78.3	3680.4
1		0130	19	16.	78.4	3680.4
1		0135	20	17.	78.6	3680.4
1		0140	21	18.	78.7	3680.4
1		0145	22	19.	78.8	3680.4
1		0150	23	20.	78.9	3680.5
1		0155	24	21.	79.0	3680.5
1		0200	25	22.	79.1	3680.5
1		0205	26	23.	79.2	3680.5
1		0210	27	24.	79.3	3680.5
1		0215	28	24.	79.3	3680.5
1		0220	29	25.	79.4	3680.5
1		0225	30	26.	79.5	3680.6
1		0230	31	26.	79.5	3680.6
1		0235	32	27.	79.6	3680.6
1		0240	33	28.	79.6	3680.6
1		0245	34	28.	79.7	3680.6
1		0250	35	29.	79.7	3680.6
1		0255	36	29.	79.8	3680.6
1		0300	37	30.	79.8	3680.6
1		0305	38	30.	79.8	3680.6
1		0310	39	31.	79.9	3680.6
1		0315	40	31.	79.9	3680.6
1		0320	41	31.	79.9	3680.6
1		0325	42	32.	79.9	3680.6
1		0330	43	32.	80.0	3680.6
1		0335	44	32.	80.0	3680.6
1		0340	45	32.	80.0	3680.6
1		0345	46	33.	80.0	3680.6
1		0350	47	33.	80.0	3680.6

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0820	101	108.	85.2	3681.4
1		0825	102	112.	85.4	3681.5
1		0830	103	117.	85.7	3681.5
1		0835	104	122.	86.0	3681.6
1		0840	105	128.	86.3	3681.6
1		0845	106	133.	86.6	3681.7
1		0850	107	139.	86.9	3681.7
1		0855	108	143.	87.1	3681.7
1		0900	109	148.	87.3	3681.8
1		0905	110	152.	87.5	3681.8
1		0910	111	155.	87.7	3681.8
1		0915	112	158.	87.9	3681.9
1		0920	113	161.	88.0	3681.9
1		0925	114	163.	88.2	3681.9
1		0930	115	166.	88.3	3681.9
1		0935	116	168.	88.4	3681.9
1		0940	117	169.	88.5	3681.9
1		0945	118	171.	88.5	3681.9
1		0950	119	172.	88.6	3682.0
1		0955	120	173.	88.7	3682.0
1		1000	121	174.	88.7	3682.0
1		1005	122	175.	88.8	3682.0
1		1010	123	176.	88.8	3682.0
1		1015	124	178.	88.9	3682.0
1		1020	125	181.	89.1	3682.0
1		1025	126	186.	89.3	3682.1
1		1030	127	190.	89.6	3682.1
1		1035	128	196.	89.9	3682.1
1		1040	129	201.	90.1	3682.2
1		1045	130	206.	90.4	3682.2
1		1050	131	212.	90.7	3682.3
1		1055	132	217.	90.9	3682.3
1		1100	133	221.	91.1	3682.3
1		1105	134	225.	91.3	3682.4
1		1110	135	228.	91.4	3682.4
1		1115	136	231.	91.6	3682.4
1		1120	137	234.	91.7	3682.4
1		1125	138	236.	91.8	3682.4
1		1130	139	238.	91.9	3682.4
1		1135	140	240.	92.0	3682.5
1		1140	141	242.	92.0	3682.5
1		1145	142	243.	92.1	3682.5
1		1150	143	244.	92.1	3682.5
1		1155	144	245.	92.2	3682.5
1		1200	145	246.	92.2	3682.5
1		1205	146	247.	92.3	3682.5
1		1210	147	247.	92.3	3682.5

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		1640	201	1075.	124.2	3686.7
1		1645	202	973.	120.7	3686.3
1		1650	203	885.	117.5	3685.9
1		1655	204	808.	114.7	3685.5
1		1700	205	740.	112.3	3685.2
1		1705	206	681.	110.1	3684.9
1		1710	207	632.	108.2	3684.7
1		1715	208	588.	106.5	3684.5
1		1720	209	550.	105.1	3684.3
1		1725	210	517.	103.8	3684.1
1		1730	211	489.	102.7	3684.0
1		1735	212	466.	101.8	3683.8
1		1740	213	446.	100.9	3683.7
1		1745	214	429.	100.2	3683.6
1		1750	215	414.	99.6	3683.5
1		1755	216	401.	99.1	3683.5
1		1800	217	390.	98.6	3683.4
1		1805	218	380.	98.2	3683.3
1		1810	219	369.	97.7	3683.3
1		1815	220	357.	97.2	3683.2
1		1820	221	341.	96.6	3683.1
1		1825	222	323.	95.8	3683.0
1		1830	223	303.	94.9	3682.9
1		1835	224	283.	94.0	3682.7
1		1840	225	264.	93.1	3682.6
1		1845	226	245.	92.2	3682.5
1		1850	227	228.	91.4	3682.4
1		1855	228	212.	90.7	3682.3
1		1900	229	199.	90.0	3682.2
1		1905	230	188.	89.5	3682.1
1		1910	231	179.	89.0	3682.0
1		1915	232	170.	88.5	3681.9
1		1920	233	162.	88.1	3681.9
1		1925	234	155.	87.7	3681.8
1		1930	235	149.	87.4	3681.8
1		1935	236	143.	87.1	3681.7
1		1940	237	139.	86.9	3681.7
1		1945	238	134.	86.6	3681.7
1		1950	239	131.	86.4	3681.6
1		1955	240	128.	86.3	3681.6
1		2000	241	125.	86.1	3681.6
1		2005	242	122.	86.0	3681.6
1		2010	243	120.	85.9	3681.6
1		2015	244	118.	85.8	3681.5
1		2020	245	117.	85.7	3681.5
1		2025	246	116.	85.6	3681.5
1		2030	247	114.	85.5	3681.5

1	0355	48	33.	80.0	3680.6	*	1	1215	148	249.	92.4	3682.5	*	1	2035	248	113.	85.5	3681.5
1	0400	49	33.	80.0	3680.6	*	1	1220	149	251.	92.5	3682.5	*	1	2040	249	112.	85.4	3681.5
1	0405	50	33.	80.1	3680.6	*	1	1225	150	254.	92.6	3682.5	*	1	2045	250	112.	85.4	3681.5
1	0410	51	33.	80.1	3680.7	*	1	1230	151	257.	92.8	3682.6	*	1	2050	251	111.	85.3	3681.5
1	0415	52	34.	80.1	3680.7	*	1	1235	152	262.	93.0	3682.6	*	1	2055	252	110.	85.3	3681.5
1	0420	53	34.	80.1	3680.7	*	1	1240	153	267.	93.2	3682.6	*	1	2100	253	110.	85.2	3681.5
1	0425	54	34.	80.1	3680.7	*	1	1245	154	272.	93.4	3682.7	*	1	2105	254	109.	85.2	3681.4
1	0430	55	34.	80.1	3680.7	*	1	1250	155	278.	93.7	3682.7	*	1	2110	255	109.	85.2	3681.4
1	0435	56	34.	80.1	3680.7	*	1	1255	156	284.	94.0	3682.7	*	1	2115	256	108.	85.2	3681.4
1	0440	57	34.	80.1	3680.7	*	1	1300	157	290.	94.3	3682.8	*	1	2120	257	108.	85.1	3681.4
1	0445	58	34.	80.1	3680.7	*	1	1305	158	297.	94.6	3682.8	*	1	2125	258	107.	85.1	3681.4
1	0450	59	34.	80.1	3680.7	*	1	1310	159	304.	94.9	3682.9	*	1	2130	259	107.	85.1	3681.4
1	0455	60	34.	80.1	3680.7	*	1	1315	160	312.	95.3	3682.9	*	1	2135	260	107.	85.1	3681.4
1	0500	61	34.	80.1	3680.7	*	1	1320	161	319.	95.6	3683.0	*	1	2140	261	107.	85.1	3681.4
1	0505	62	34.	80.1	3680.7	*	1	1325	162	327.	96.0	3683.0	*	1	2145	262	106.	85.0	3681.4
1	0510	63	34.	80.1	3680.7	*	1	1330	163	336.	96.3	3683.1	*	1	2150	263	106.	85.0	3681.4
1	0515	64	34.	80.1	3680.7	*	1	1335	164	345.	96.7	3683.1	*	1	2155	264	106.	85.0	3681.4
1	0520	65	34.	80.1	3680.7	*	1	1340	165	355.	97.1	3683.2	*	1	2200	265	106.	85.0	3681.4
1	0525	66	34.	80.2	3680.7	*	1	1345	166	365.	97.6	3683.3	*	1	2205	266	106.	85.0	3681.4
1	0530	67	34.	80.2	3680.7	*	1	1350	167	376.	98.0	3683.3	*	1	2210	267	106.	85.0	3681.4
1	0535	68	35.	80.2	3680.7	*	1	1355	168	388.	98.5	3683.4	*	1	2215	268	106.	85.0	3681.4
1	0540	69	35.	80.2	3680.7	*	1	1400	169	400.	99.0	3683.5	*	1	2220	269	105.	85.0	3681.4
1	0545	70	35.	80.2	3680.7	*	1	1405	170	413.	99.6	3683.5	*	1	2225	270	105.	85.0	3681.4
1	0550	71	35.	80.2	3680.7	*	1	1410	171	427.	100.1	3683.6	*	1	2230	271	105.	85.0	3681.4
1	0555	72	35.	80.2	3680.7	*	1	1415	172	443.	100.8	3683.7	*	1	2235	272	105.	85.0	3681.4
1	0600	73	35.	80.2	3680.7	*	1	1420	173	461.	101.6	3683.8	*	1	2240	273	105.	85.0	3681.4
1	0605	74	35.	80.2	3680.7	*	1	1425	174	482.	102.4	3683.9	*	1	2245	274	105.	85.0	3681.4
1	0610	75	35.	80.2	3680.7	*	1	1430	175	506.	103.4	3684.0	*	1	2250	275	105.	85.0	3681.4
1	0615	76	36.	80.3	3680.7	*	1	1435	176	531.	104.3	3684.2	*	1	2255	276	105.	85.0	3681.4
1	0620	77	38.	80.4	3680.7	*	1	1440	177	554.	105.2	3684.3	*	1	2300	277	105.	84.9	3681.4
1	0625	78	41.	80.7	3680.7	*	1	1445	178	577.	106.1	3684.4	*	1	2305	278	105.	84.9	3681.4
1	0630	79	45.	80.9	3680.8	*	1	1450	179	598.	106.9	3684.5	*	1	2310	279	104.	84.9	3681.4
1	0635	80	49.	81.3	3680.8	*	1	1455	180	618.	107.7	3684.6	*	1	2315	280	103.	84.9	3681.4
1	0640	81	53.	81.6	3680.9	*	1	1500	181	636.	108.4	3684.7	*	1	2320	281	101.	84.7	3681.4
1	0645	82	57.	81.9	3680.9	*	1	1505	182	653.	109.0	3684.8	*	1	2325	282	99.	84.6	3681.3
1	0650	83	61.	82.2	3681.0	*	1	1510	183	669.	109.7	3684.9	*	1	2330	283	95.	84.3	3681.3
1	0655	84	66.	82.5	3681.0	*	1	1515	184	684.	110.2	3685.0	*	1	2335	284	91.	84.1	3681.3
1	0700	85	71.	82.8	3681.1	*	1	1520	185	702.	110.9	3685.0	*	1	2340	285	87.	83.8	3681.2
1	0705	86	75.	83.1	3681.1	*	1	1525	186	726.	111.8	3685.1	*	1	2345	286	83.	83.6	3681.2
1	0710	87	78.	83.3	3681.2	*	1	1530	187	766.	113.2	3685.3	*	1	2350	287	79.	83.4	3681.2
1	0715	88	82.	83.5	3681.2	*	1	1535	188	841.	115.9	3685.7	*	1	2355	288	76.	83.1	3681.1
1	0720	89	85.	83.7	3681.2	*	1	1540	189	972.	120.7	3686.3	*	2	0000	289	72.	82.9	3681.1
1	0725	90	88.	83.9	3681.2	*	1	1545	190	1168.	127.4	3687.1	*	2	0005	290	69.	82.7	3681.1
1	0730	91	90.	84.0	3681.3	*	1	1550	191	1394.	135.1	3688.0	*	2	0010	291	67.	82.6	3681.0
1	0735	92	92.	84.2	3681.3	*	1	1555	192	1597.	141.9	3688.7	*	2	0015	292	64.	82.4	3681.0
1	0740	93	94.	84.3	3681.3	*	1	1600	193	1736.	146.5	3689.2	*	2	0020	293	61.	82.2	3681.0
1	0745	94	96.	84.4	3681.3	*	1	1605	194	1789.	148.3	3689.4	*	2	0025	294	59.	82.1	3681.0
1	0750	95	98.	84.5	3681.3	*	1	1610	195	1765.	147.4	3689.3	*	2	0030	295	58.	81.9	3680.9
1	0755	96	99.	84.6	3681.4	*	1	1615	196	1683.	144.8	3689.0	*	2	0035	296	56.	81.8	3680.9
1	0800	97	100.	84.7	3681.4	*	1	1620	197	1570.	141.0	3688.6	*	2	0040	297	54.	81.7	3680.9
1	0805	98	102.	84.7	3681.4	*	1	1625	198	1442.	136.7	3688.1	*	2	0045	298	53.	81.6	3680.9
1	0810	99	103.	84.8	3681.4	*	1	1630	199	1311.	132.3	3687.6	*	2	0050	299	51.	81.4	3680.9
1	0815	100	105.	85.0	3681.4	*	1	1635	200	1188.	128.1	3687.1	*	2	0055	300	50.	81.3	3680.9

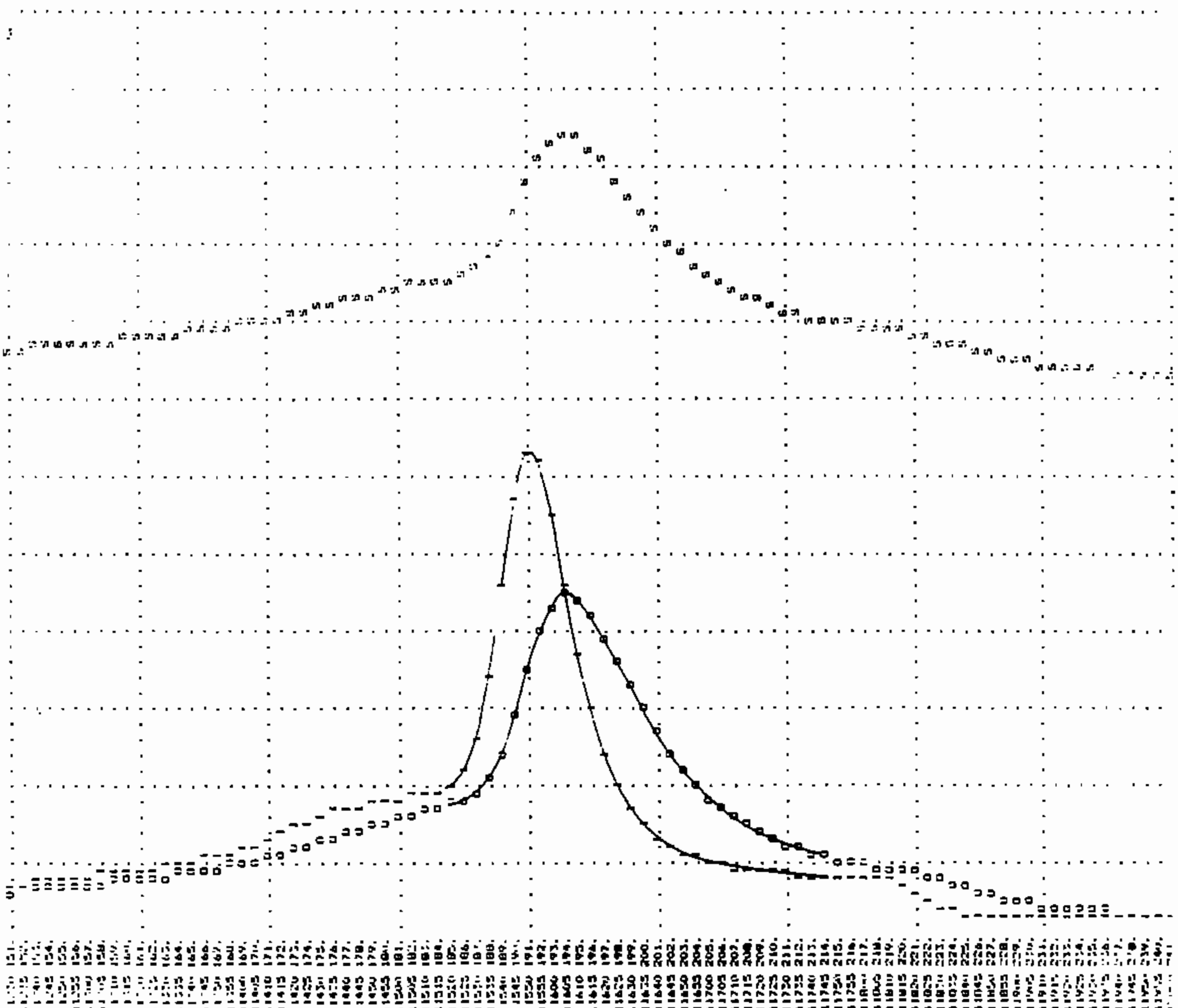
****

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	24.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 1789.	16.08		656.	242.	233.	233.
		(INCHES)	6.781	9.992	9.995	9.995
		(AC-FT)	325.	480.	480.	480.

PEAK STORAGE	TIME	MAXIMUM AVERAGE STORAGE			
		6-HR	24-HR	72-HR	24.92-HR
+ (AC-FT)	(HR)				
148.	16.08	108.	90.	90.	90.

PEAK STAGE	TIME	MAXIMUM AVERAGE STAGE			
		6-HR	24-HR	72-HR	24.92-HR
+ (FEET)	(HR)				
3689.40	16.08	3684.64	3682.15	3682.08	3682.08

CUMULATIVE AREA = .90 SQ MI



RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGI
				6-HOUR	24-HOUR	72-HOUR			
HYDROGRAPH AT	POND	2507.	15.83	662.	244.	236.	.90		
ROUTED TO	ROUT	1789.	16.08	656.	242.	233.	.90	3689.40	16.08

APPENDIX C

STABILITY ANALYSES

SOIL NO.	DESCRIPTION	MOIST UNIT WEIGHT (pcf)	SATURATED UNIT WEIGHT (pcf)	EFFECTIVE FRICTION ANGLE (degrees)	EFFECTIVE COHESION (psf)
1	EARTHFILL STARTER DAM	124	133	35	0
2	CYCLONED SAND	110	123	33	0
3	ROCKFILL TOE DIKE	140	145	42	0
4	FOUNDATION LAYER 1 (SAND)	-	135	35	0
	FOUNDATION LAYER 1 (CLAY)	125	-	0	2000
5	FOUNDATION LAYER 2	-	141	38	0
6	FINE TAILINGS	-	110	0	0

NOTES:

1. SEE FIGURE 4, SECTION A FOR LOCATION OF CROSS-SECTION USED IN ANALYSIS.
2. TOE DIKE WAS NOT CONSIDERED IN STABILITY ANALYSES.

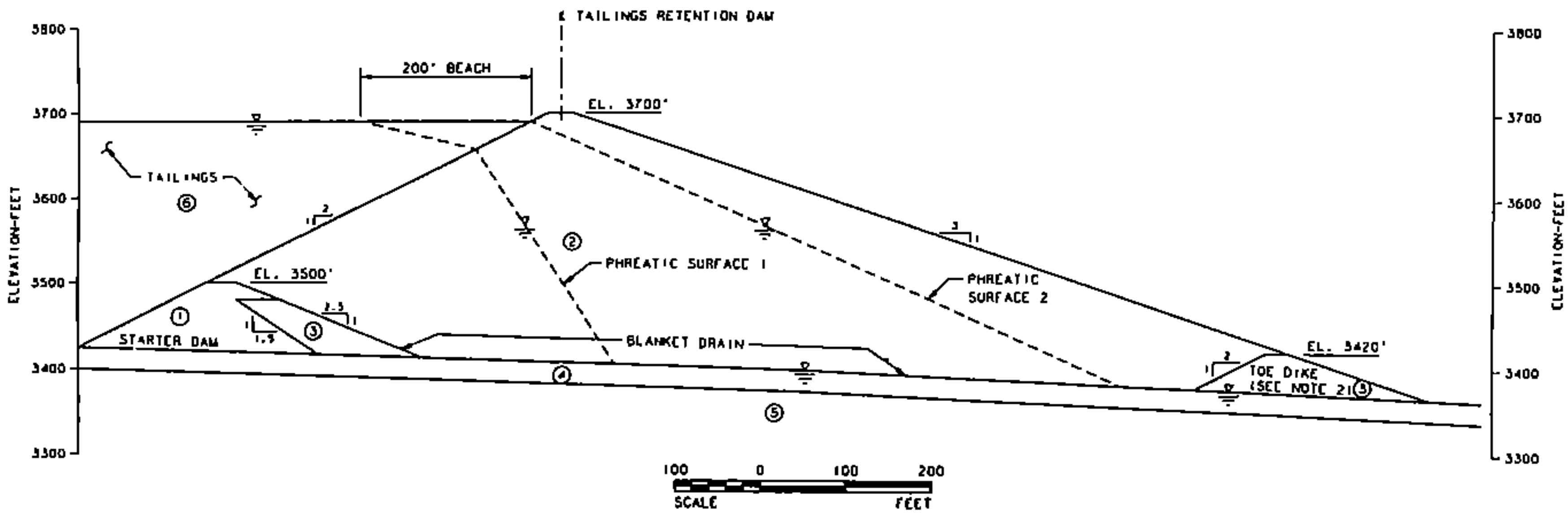


FIGURE C-1
CROSS-SECTION FOR ANALYSIS

8602901G8000800/SECT

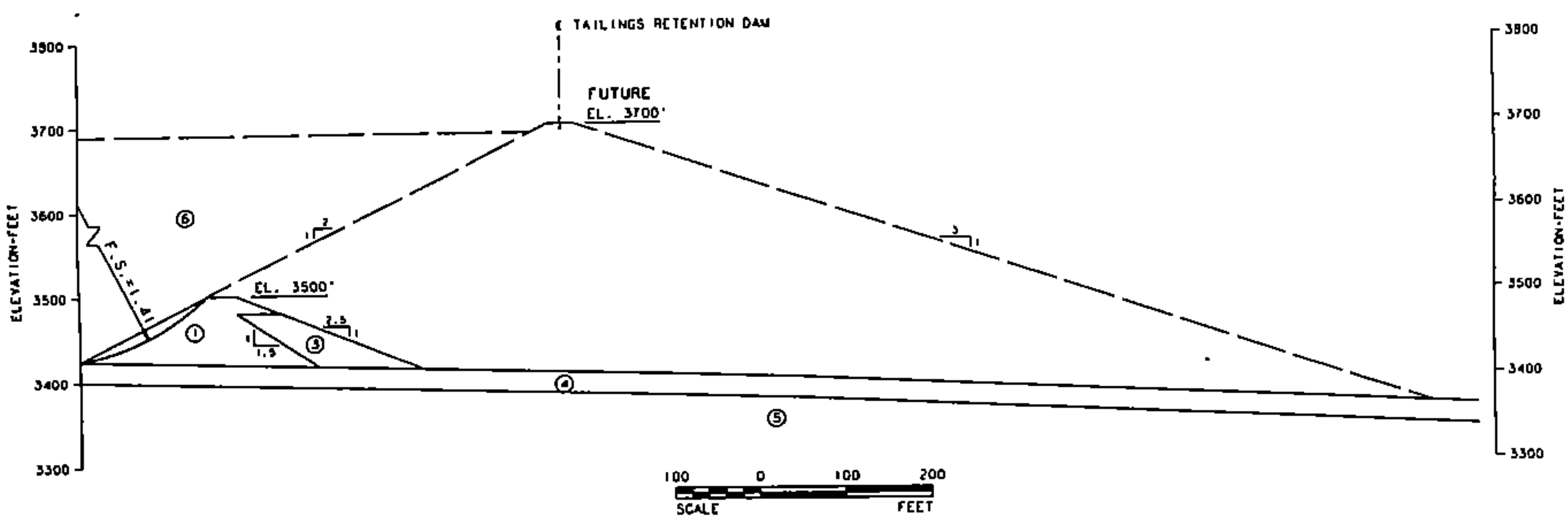


FIGURE C-2
CASE IA
STARTER DAM-UPSTREAM SLOPE
END OF CONSTRUCTION

980280168000800/CASE IA

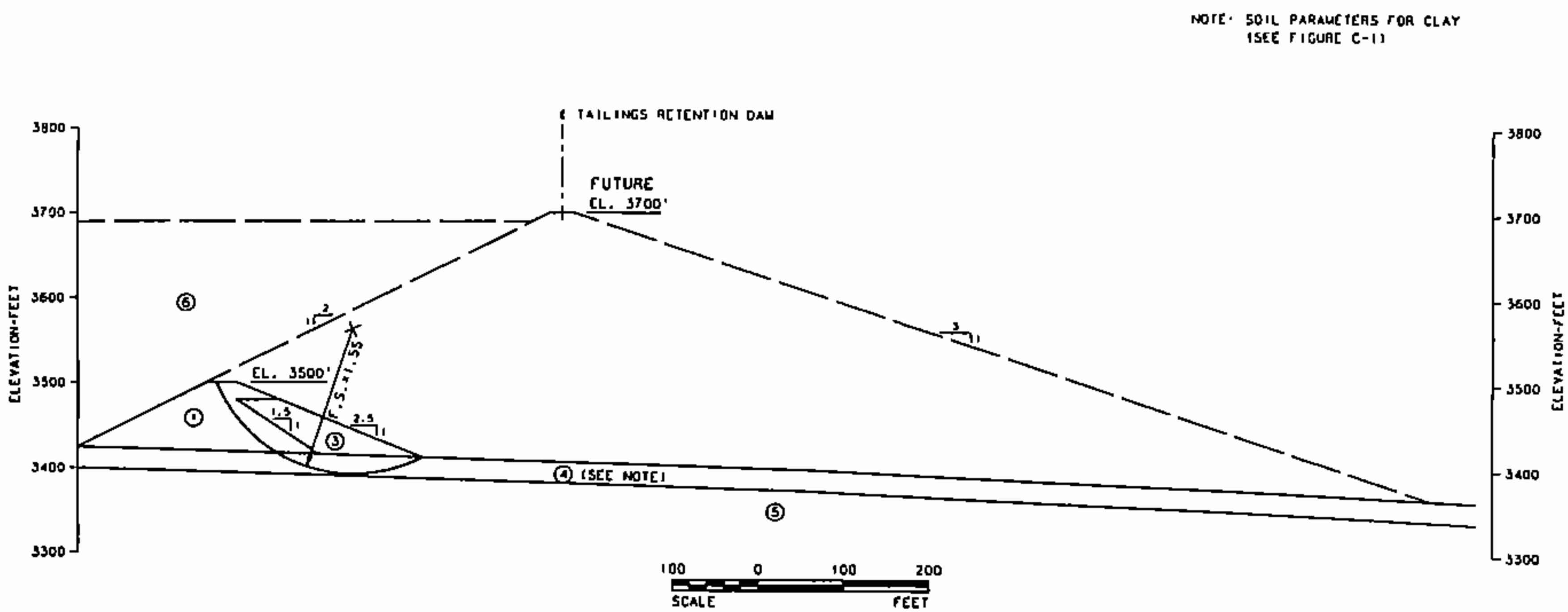


FIGURE C-3
CASE 1B
STARTER DAM-DOWNSTREAM SLOPE
END OF CONSTRUCTION

5802931G8000600/CASE1B

NOTE: SOIL PARAMETERS FOR SAND (SEE FIGURE C-11)

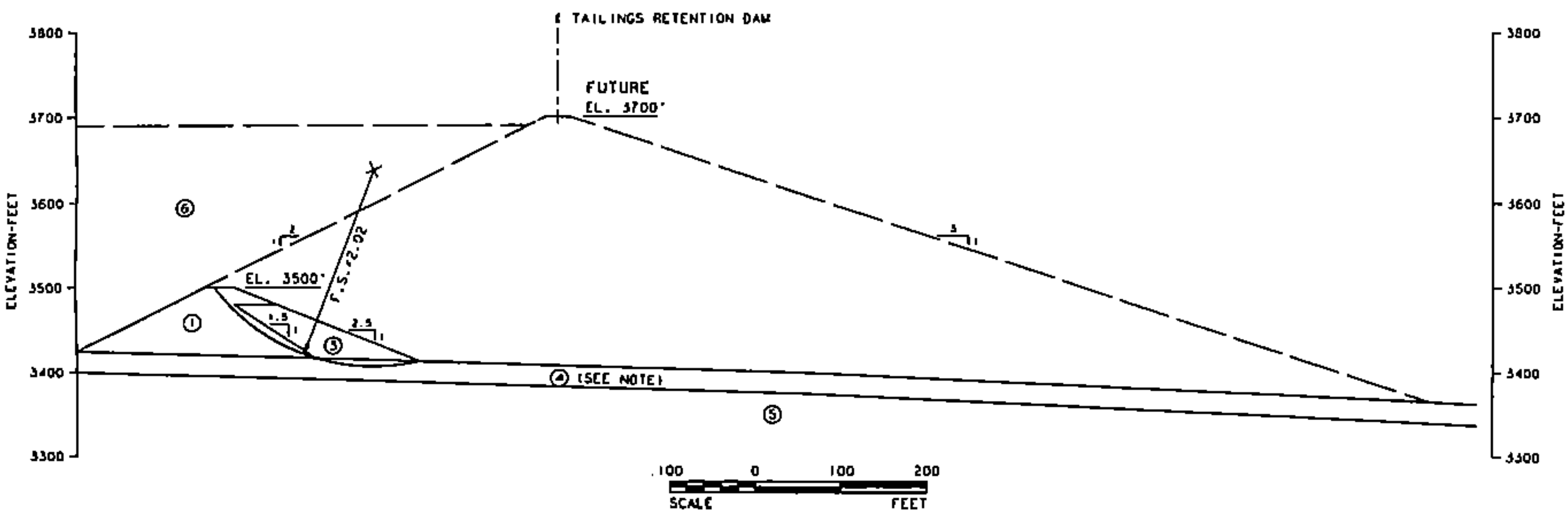


FIGURE C-4
CASE IB
STARTER DAM-DOWNSTREAM SLOPE
END OF CONSTRUCTION

330290/G8000800/CASE1B2

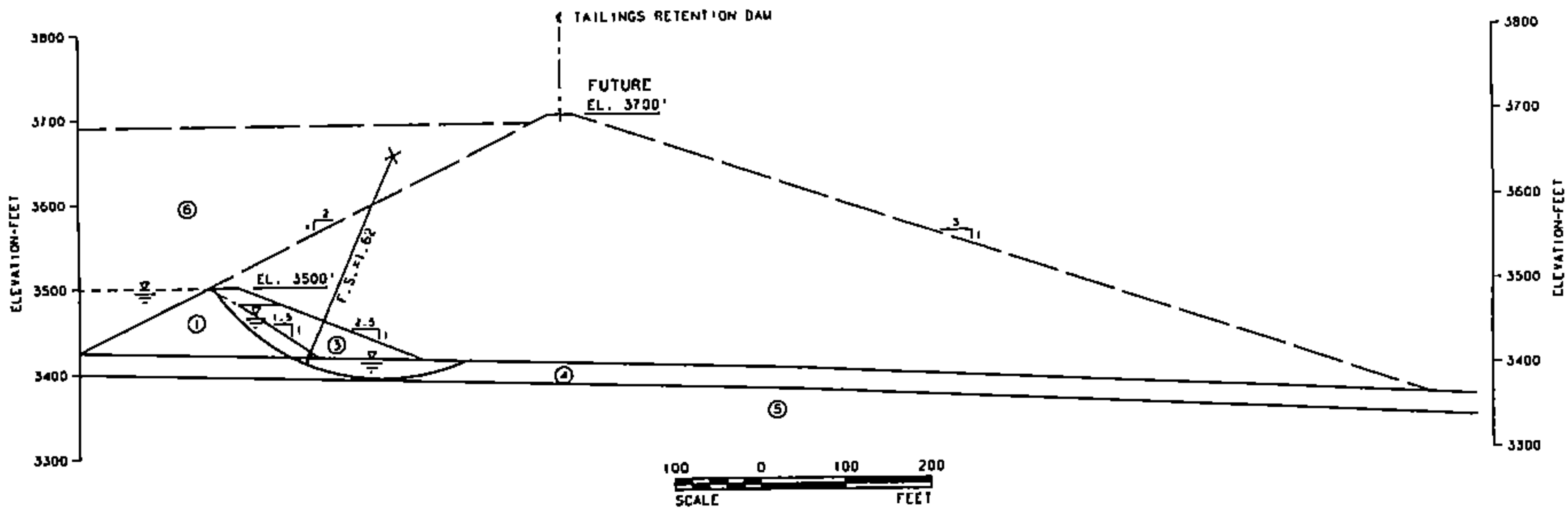


FIGURE C-5
CASE 2A
STARTER DAM-DOWNSTREAM SLOPE
STEADY STATE SEEPAGE

9802901G8000800/CASE2A

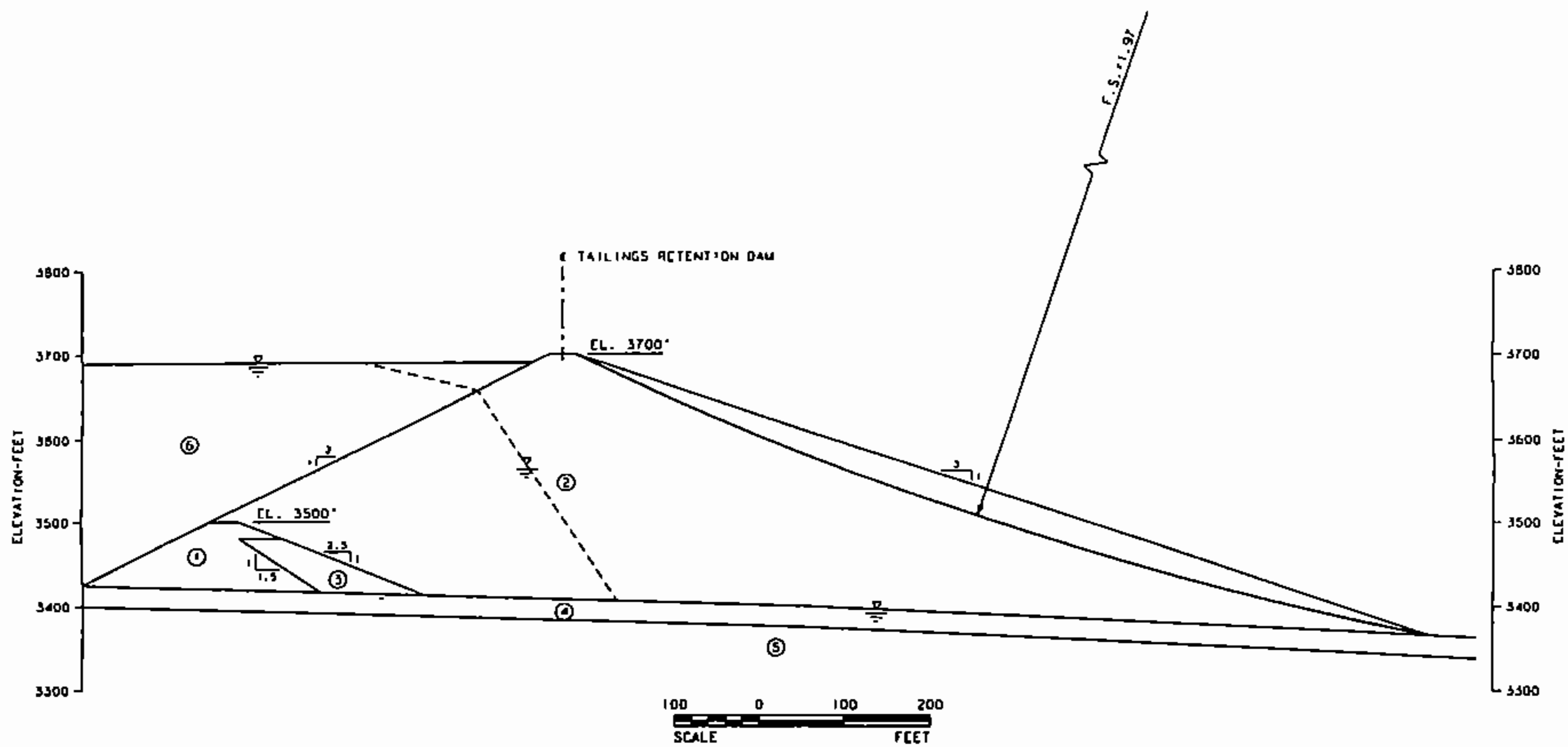


FIGURE C-6
CASE 2B
FINAL DAM-DOWNSTREAM SLOPE
STEADY STATE SEEPAGE

980790IC6000800/CASE2B

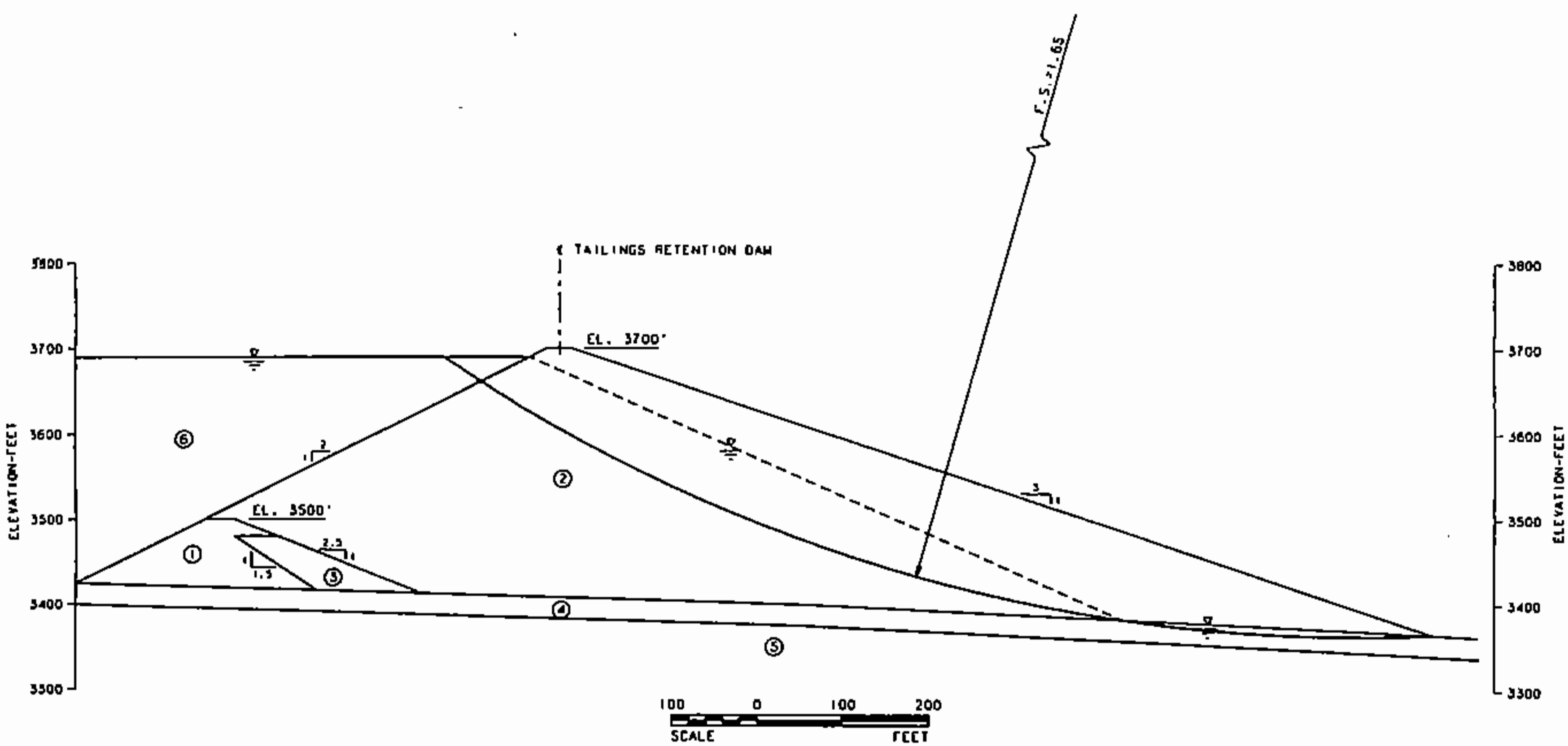


FIGURE C-7
CASE 3
FINAL DAM-DOWNSTREAM SLOPE
DESIGN FLOOD CONDITION

5802031G0000500/CASE3

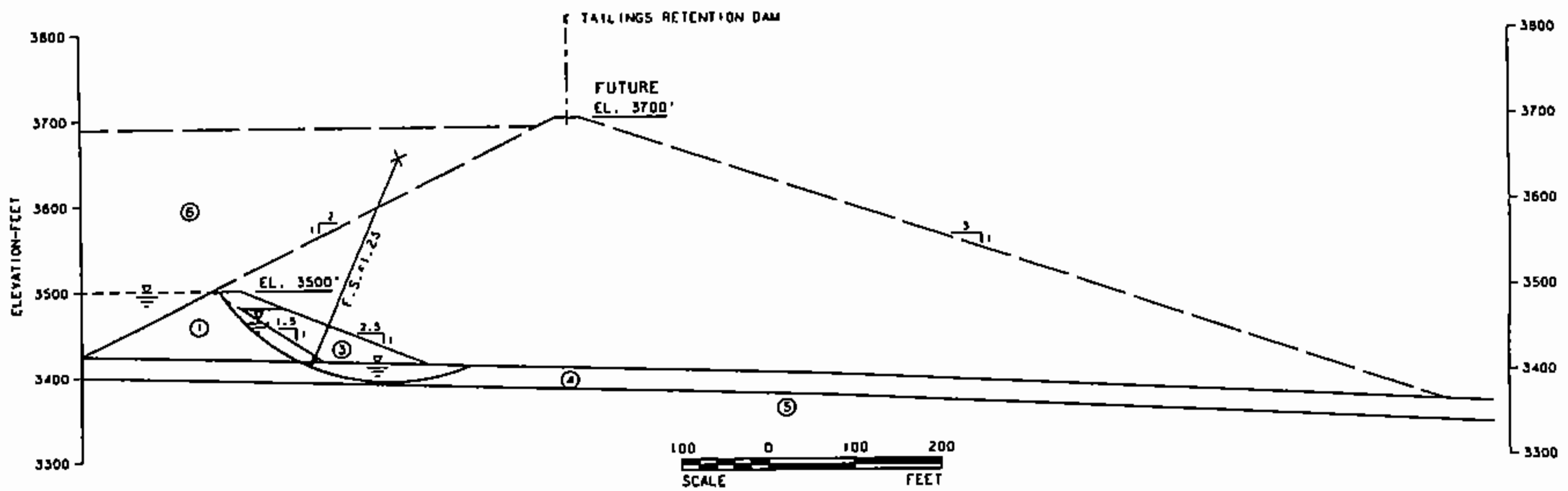


FIGURE C-8

CASE 4A
STARTER DAM-DOWNSTREAM SLOPE
SEISMIC LOADING (K=0.10)

9802901C8000800/CASE 4A

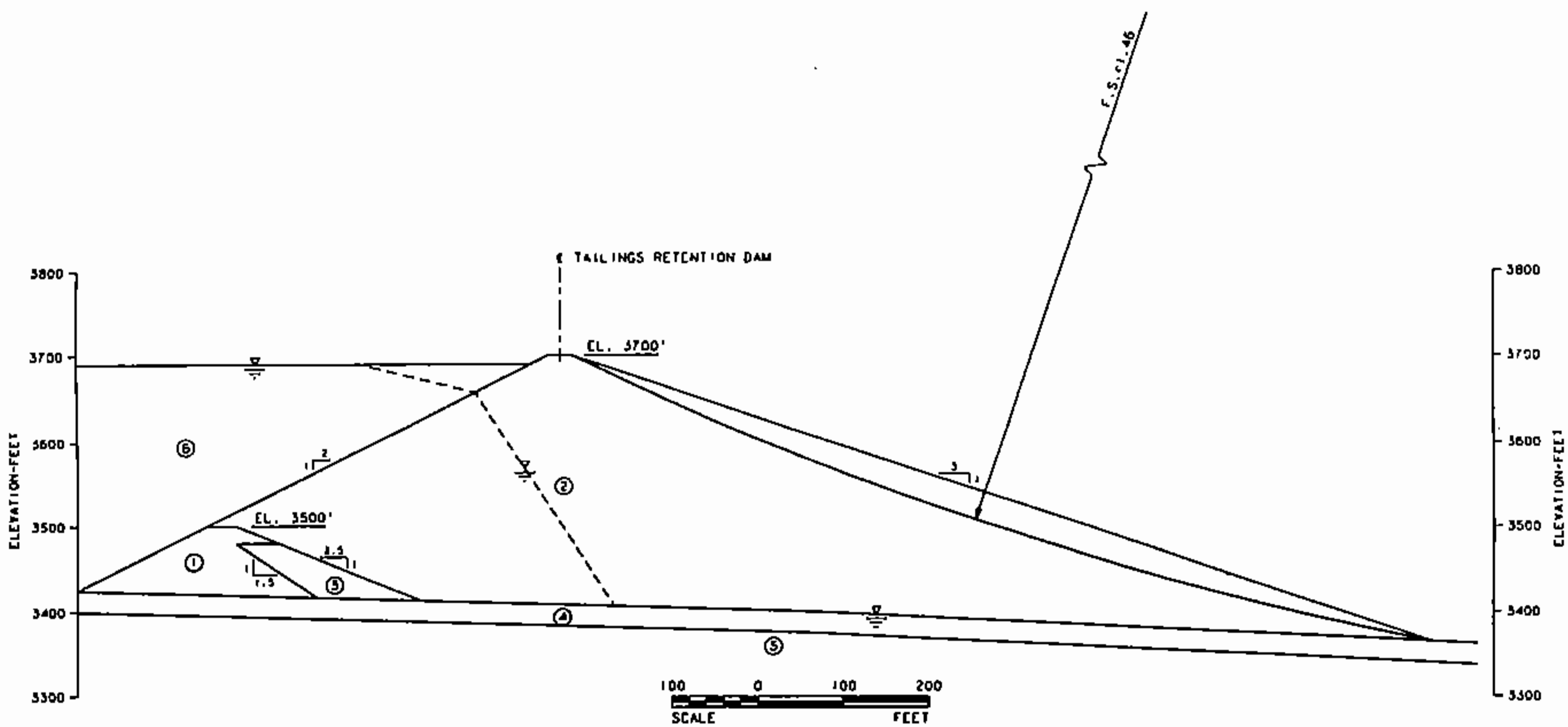
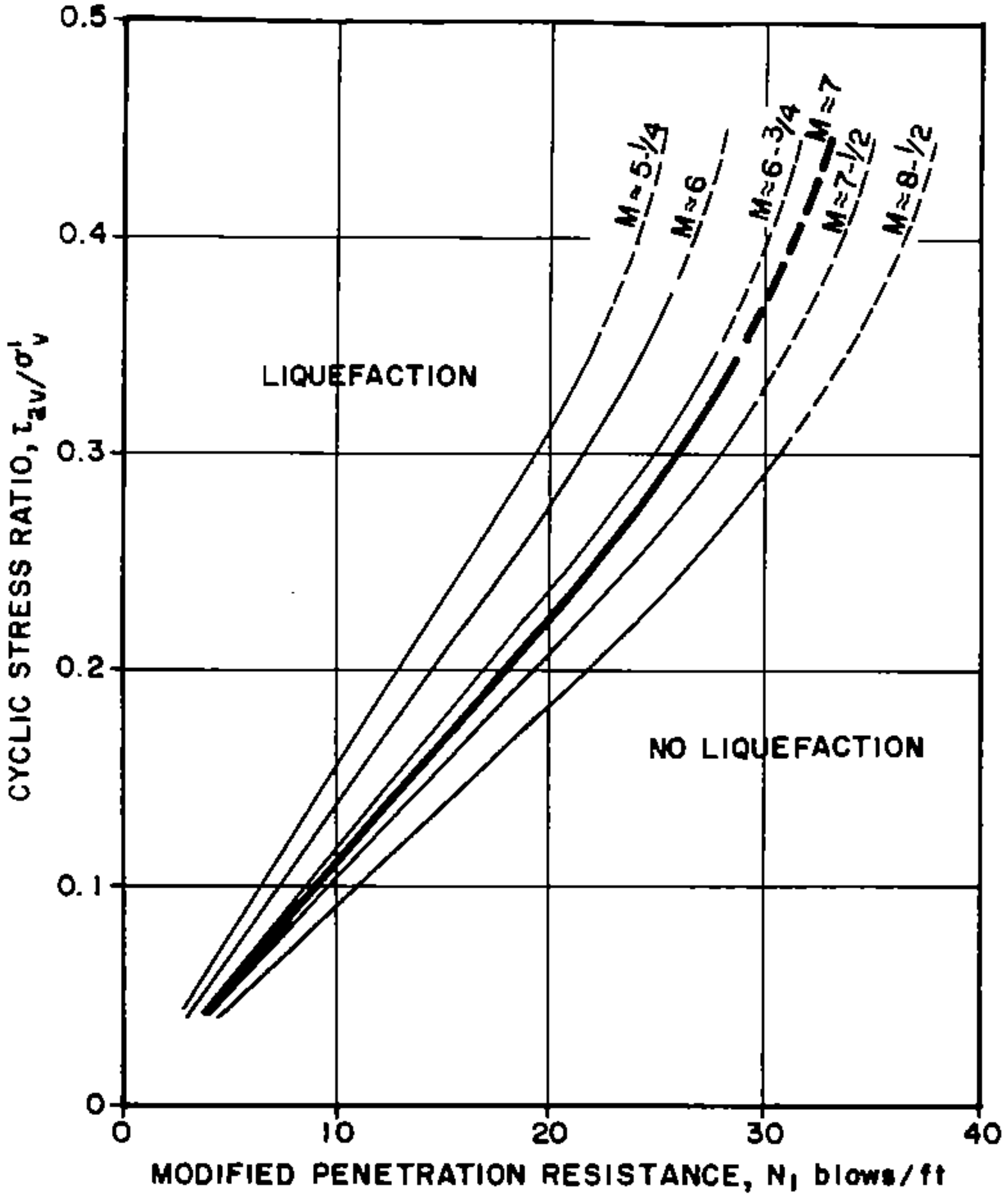


FIGURE C-9
CASE 4B
FINAL DAM-DOWNSTREAM SLOPE
SEISMIC LOADING (K=0.10)

980290168000800/CASC4B



REF: FROM SEED, H.B. AND IDRISS, I.M. "GROUND MOTIONS AND SOIL LIQUEFACTION DURING EARTHQUAKES," EARTHQUAKE ENGINEERING RESEARCH INSTITUTE, 1982.

FIGURE C-10

EVALUATION OF LIQUEFACTION POTENTIAL FOR SANDS
(PERCENT FINES ≤ 5%)

APPENDIX D

RESULTS OF SEEPAGE & CONTAMINANT TRANSPORT ANALYSES

APPENDIX D

RESULTS OF SEEPAGE & CONTAMINANT TRANSPORT ANALYSES

The computer code CXPMPM (Slotta Engineering Associates, Corvallis, Orgeon, 1987) is a convection-dispersion one dimensional model of the spatial transport and fate of a previously distributed contaminant, introduced into a water-saturated porous medium. The concentration of the contaminant within the aquifer is computed as a function of one dimensional space and time.

For the Little Cherry site, the following input parameters were used in the computer analysis:

- o Dispersivity = 20 meters and 200 meters

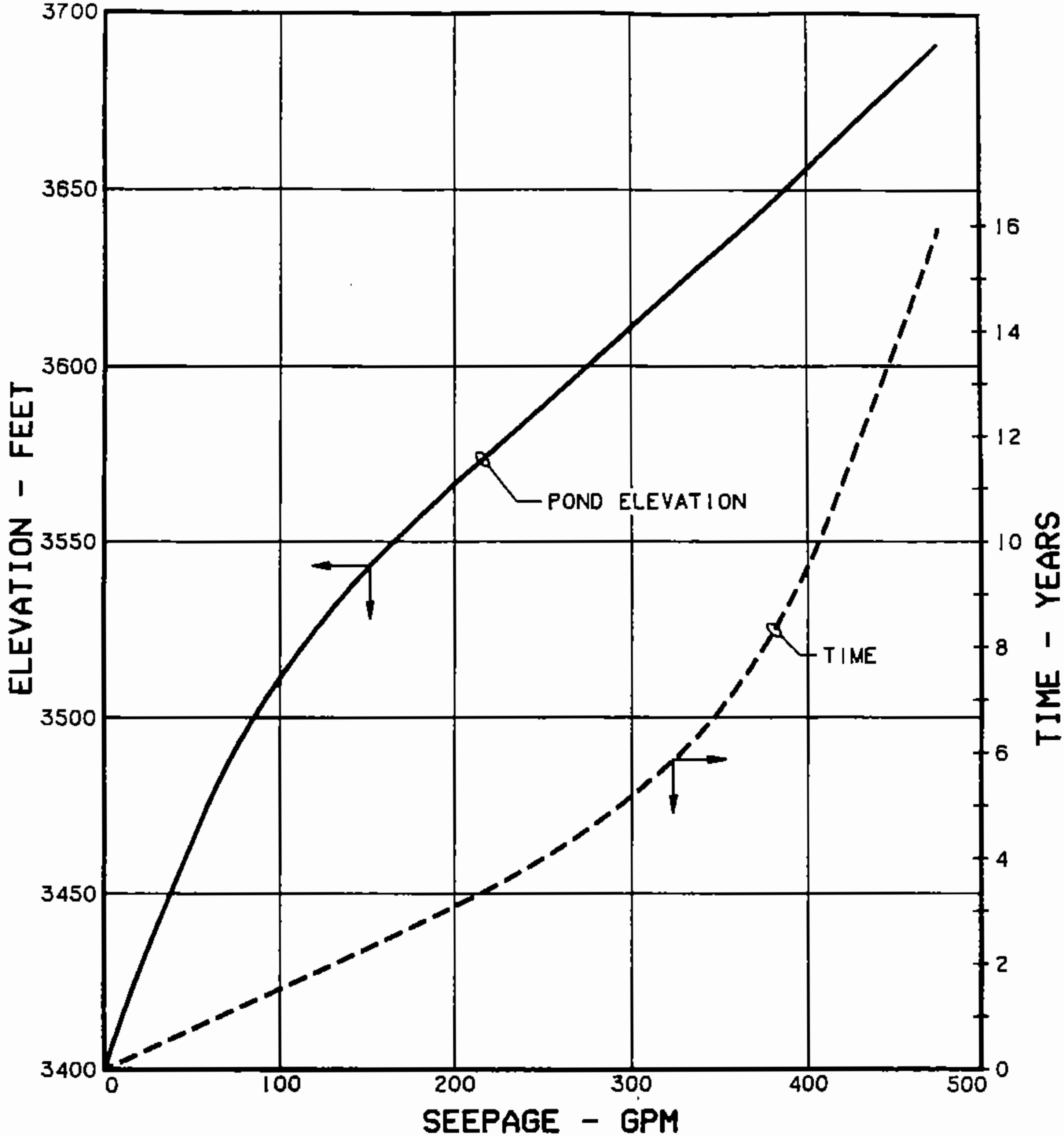
- o Effective porosity = 0.21

- o Groundwater velocity: (meters/day)
  - (k aquifer = 10^{-4} cm/sec): 0.191
  - (k aquifer = 10^{-5} cm/sec): 0.172

- o Impoundment life = 16 years

- o No adsorption or chemical reactions

Time intervals of 5, 10, 15 and 30 years were analyzed. The initial concentration was modeled as a step function with a constant normalized value of 1 between 0 and 16 years.



MONTANA PROJECT
ESTIMATED SEEPAGE FROM IMPOUNDMENT
FIGURE D-1

B802901GA001000-S2

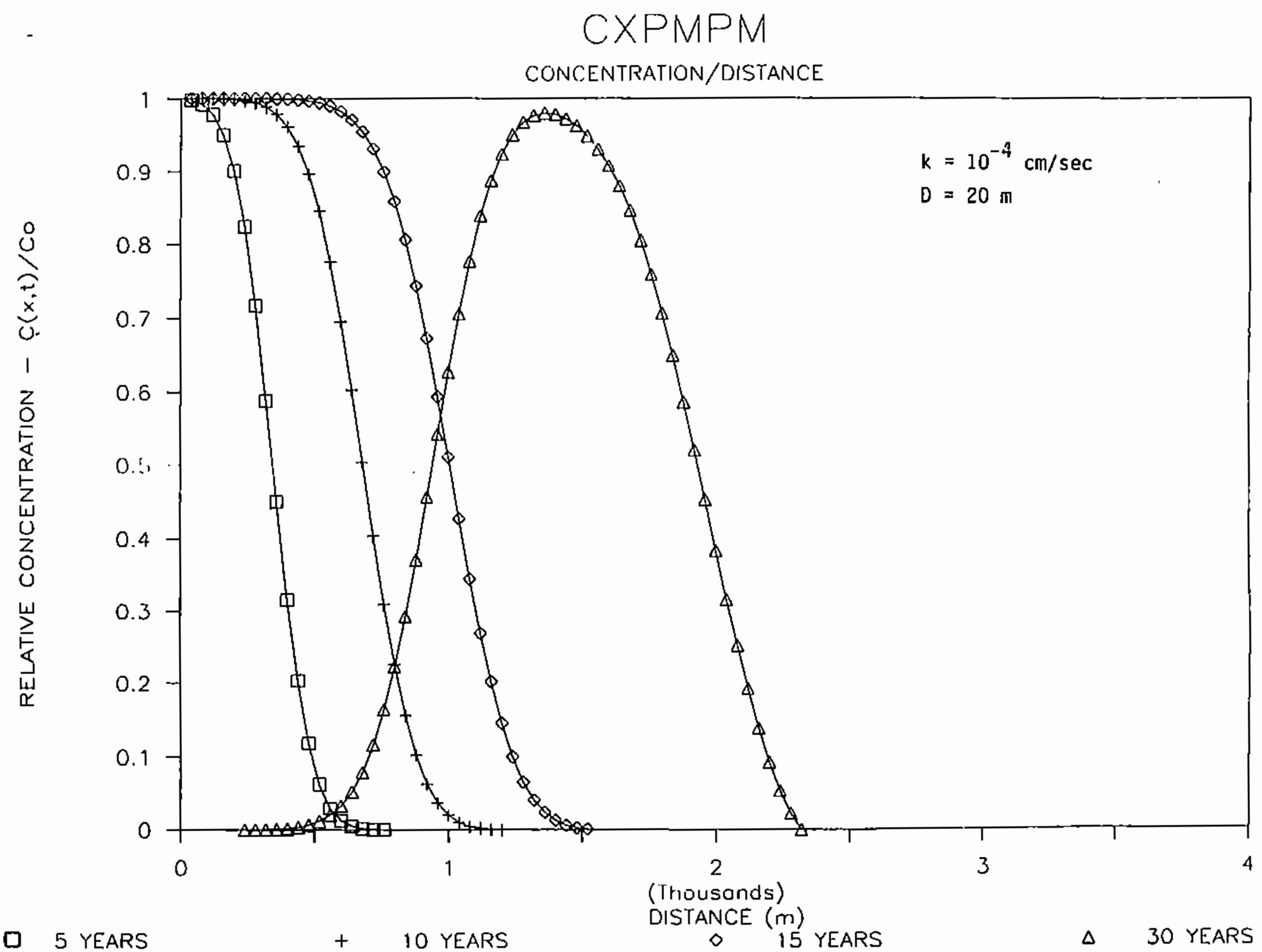

CXPMPM
CONCENTRATION/DISTANCE
k = 10^-4 cm/sec
D = 20 m
RELATIVE CONCENTRATION – C(x,t)/Co
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
(Thousands)
DISTANCE (m)
5 YEARS
10 YEARS
15 YEARS
30 YEARS

FIGURE D-2

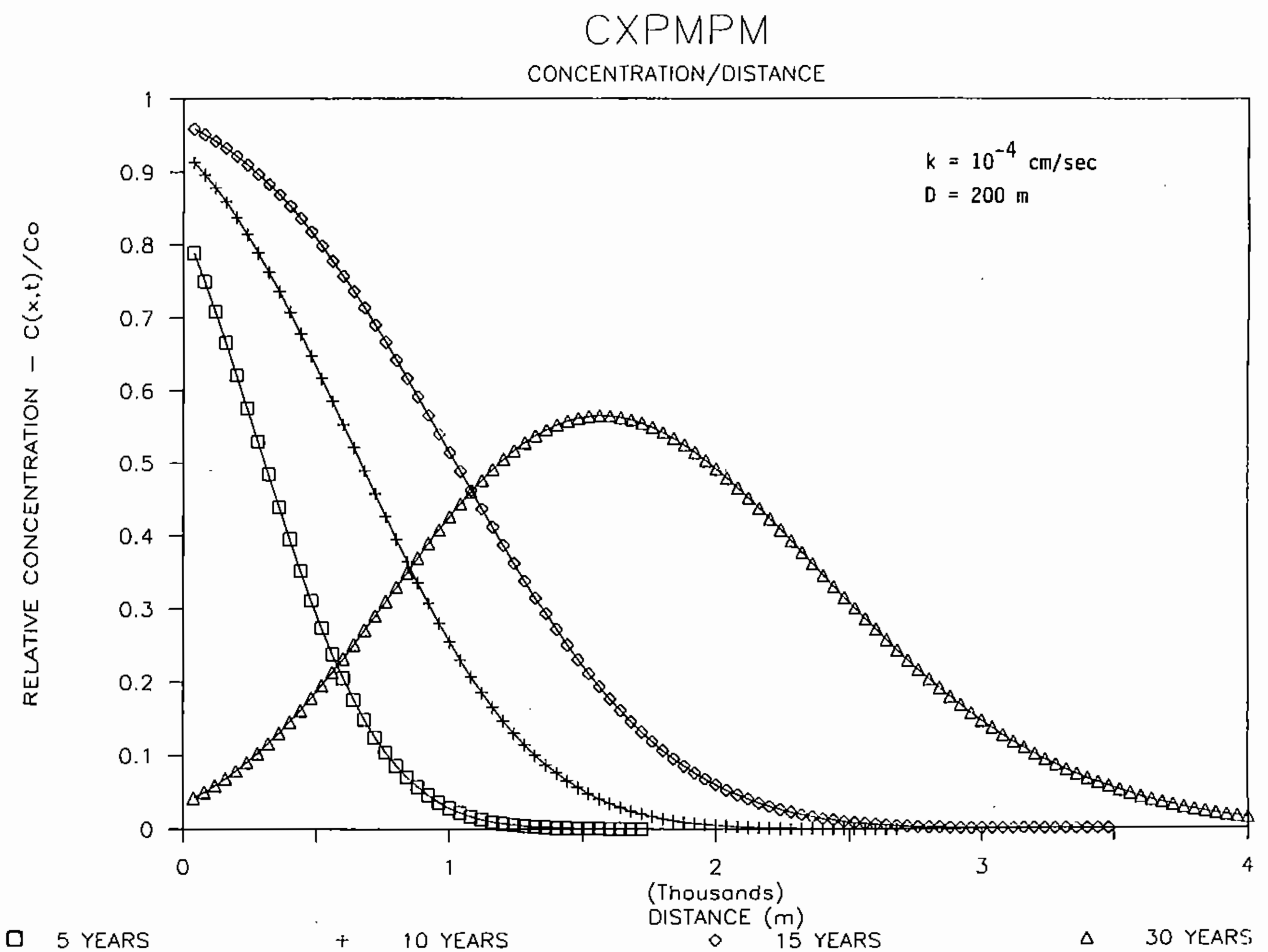

CXPMPM
CONCENTRATION/DISTANCE
k = 10^-4 cm/sec
D = 200 m
RELATIVE CONCENTRATION — C(x,t)/Co
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
(Thousands)
DISTANCE (m)
□ 5 YEARS
+ 10 YEARS
◇ 15 YEARS
△ 30 YEARS

FIGURE D-3

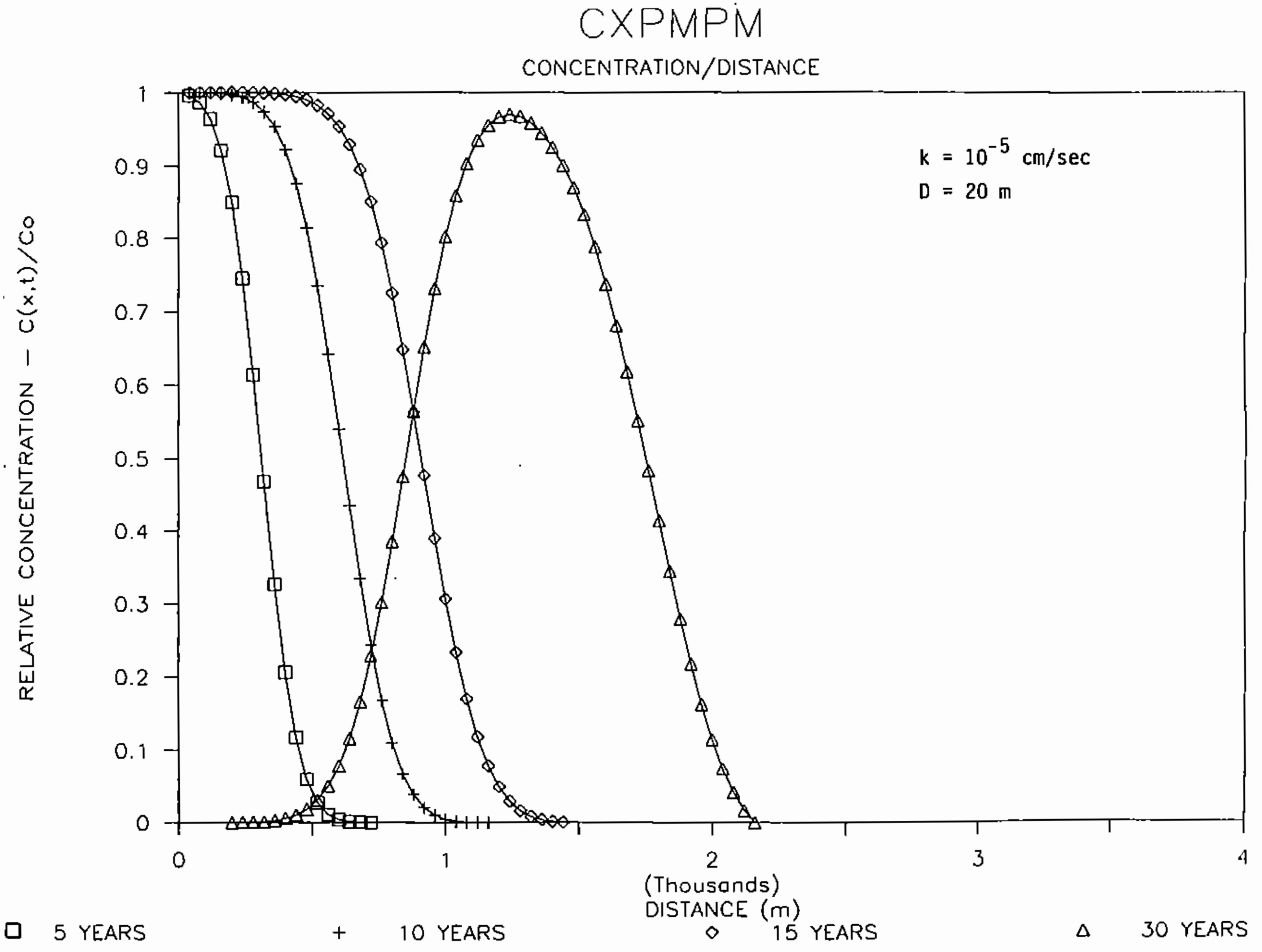

CXPMPM
CONCENTRATION/DISTANCE
k = 10-5 cm/sec
D = 20 m
RELATIVE CONCENTRATION — C(x,t)/Co
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
(Thousands)
DISTANCE (m)
5 YEARS
10 YEARS
15 YEARS
30 YEARS

FIGURE D-4

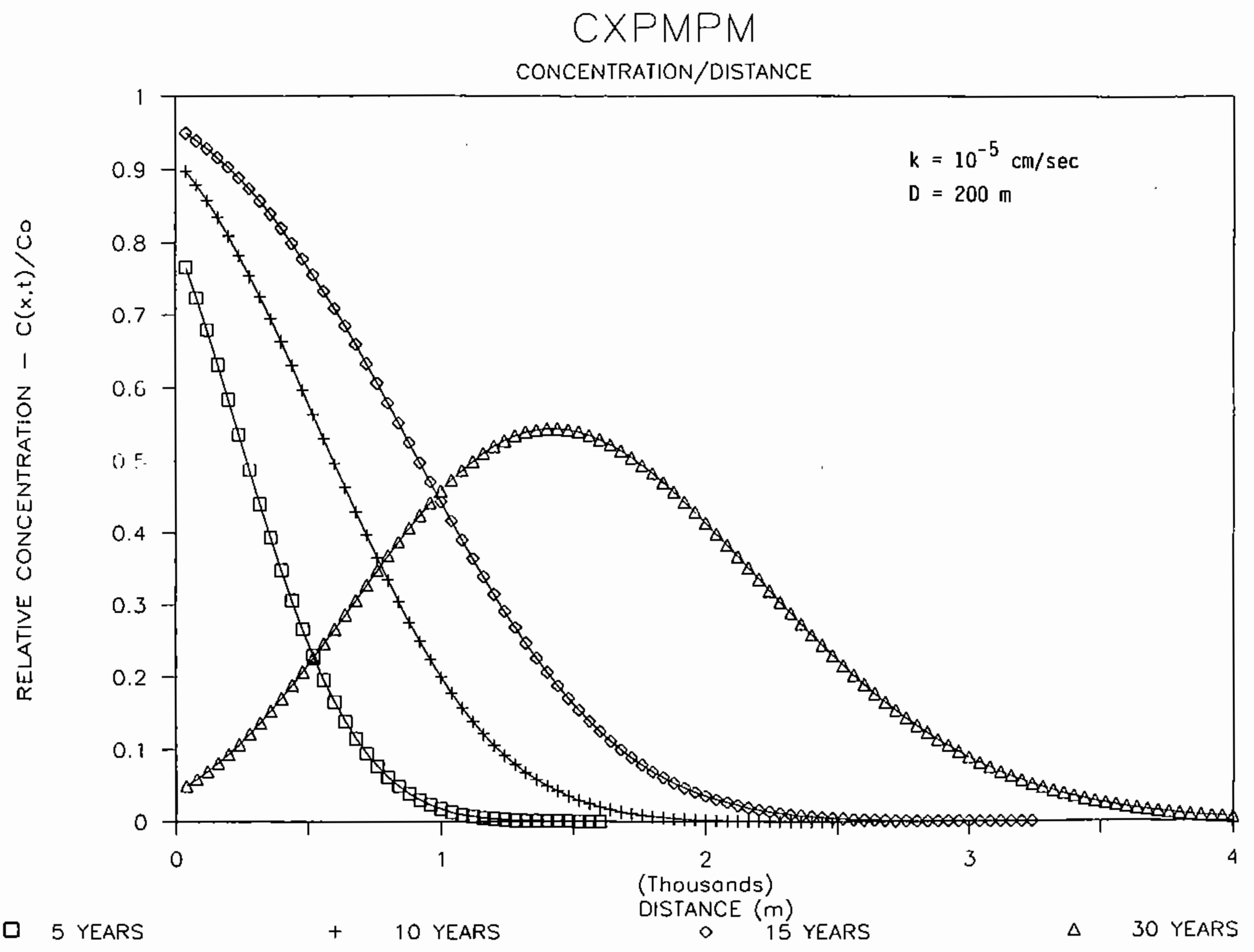

CXPMPM
CONCENTRATION/DISTANCE
k = 10^-5 cm/sec
D = 200 m
RELATIVE CONCENTRATION — C(x,t)/Co
(Thousands)
DISTANCE (m)
5 YEARS
10 YEARS
15 YEARS
30 YEARS

FIGURE D-5

APPENDIX E
CYCLONED TAILINGS ANALYSIS

7633G

KREBS
ENGINEERS 1205 CHRYSLER DRIVE MENLO PARK CALIFORNIA

January 10, 1989

M. K. Engineers, Inc.
180 Howard St.
San Francisco, California 94105

Attention Mr. Mike Forrest

Reference: Krebs Cyclones.

Dear Mr. Forrest:

Attached is a copy of our fax dated December 20, 1988 and the cyclone problem analysis sheets that you requested.

If there is any thing else that you need or if we can be of any further assistance please don't hesitate to contact us.

Sincerely yours,

KREBS ENGINEERS

H. Michael Trew

H. Michael Trew

HMT/mt
cc: ACP
Rick Howie

KREBS ENGINEERS
1205 CHRYSLER DRIVE • MENLO PARK, CA 94025-9928 • TEL (415) 325-0751
TELEX: WUI 348403 or RCA 278769 • FAX: (415) 326-7048

SHEET 1
DATE 12-20-88
BY HMT

Krebs Cyclone Problem Analysis

CLIENT: MORRISON-KNUDSON ENGINEERS INC.

PROBLEM: RECOVER +200 MESH SAND TO THE CYCLONE UNDERFLOW.
FIRST STAGE RECOVERY.

NUMBER, MODEL KREBS CYCLONES: 6 OPERATING KREBS MODEL D26B CYCLONES.

ORIFICES: Inlet 45.0 SQ.IN. Vortex Finder 10.0 IN. Apex ______ Δp 10 PSI

SPECIFIC GRAVITY: Solids 2.64 Liquid 1.00 Temp. ______ pH ______

	FEED	OVERFLOW	UNDERFLOW
TPH SOLIDS	833.0	493.0	340.0
TPH LIQUID	1943.7	1760.6	183.1
TPH PULP	2776.7	2253.6	523.1
% SOLIDS WT	30.00	21.88	65.00
SP. GR. PULP	1.23	1.16	1.68
% SOLIDS VOL	14.0	9.6	41.3
U.S. GPM PULP	9025.5	7779.5	1246.0

OPEN CIRCUIT ______ OR CLOSED CIRCUIT ______ AT ______ % CIRCULATING LOAD

	FEED			OVERFLOW			UNDERFLOW				
MESH	CUM.	IND.	TPH	CUM.	IND.	TPH	CUM.	IND.	TPH	REC.	
65	0.5	0.5	4.2	0.0	0.0	0.0	1.2	1.2	4.2	100.0	
100	9.8	9.3	77.5	0.7	0.7	3.3	23.0	21.8	74.2	95.8	
150	30.6	20.8	173.3	9.9	9.2	45.6	60.6	37.6	127.7	73.7	
200	47.9	17.3	144.1	26.6	16.7	82.4	78.7	18.1	61.7	42.8	
270	64.1	16.2	134.9	47.2	20.6	101.4	88.6	9.9	33.6	24.9	
400	75.0	10.9	90.8	62.4	15.2	74.9	93.3	4.7	15.9	17.5	
-400	100.0	25.0	208.3	100.0	37.6	185.4	100.0	6.7	22.8	11.0	
TOTAL		100.0	833.0		100.0	493.0		100.0	340.0		

KREBS ENGINEERS
1205 CHRYSLER DRIVE • MENLO PARK, CA 94025-9928 • TEL (415) 325-0751
TELEX: WUI 348403 or RCA 278789 • FAX: (415) 326-7048

SHEET 2
DATE 12-20-88
BY HMT

Krebs Cyclone Problem Analysis

CLIENT: MORRISON-KNUDSON ENGINEERS INC.

PROBLEM: RECOVER +200 MESH SAND TO THE CYCLONE UNDERFLOW.
SECOND STAGE RECOVERY.

NUMBER, MODEL KREBS CYCLONES: 8 OPERATING KREBS MODEL D15B CYCLONES.

ORIFICES: Inlet 11.0 SQ.IN. Vortex Finder 6.0 IN. Apex ______ Δp 8 PSI

SPECIFIC GRAVITY: Solids 2.64 Liquid 1.00 Temp. ______ pH ______

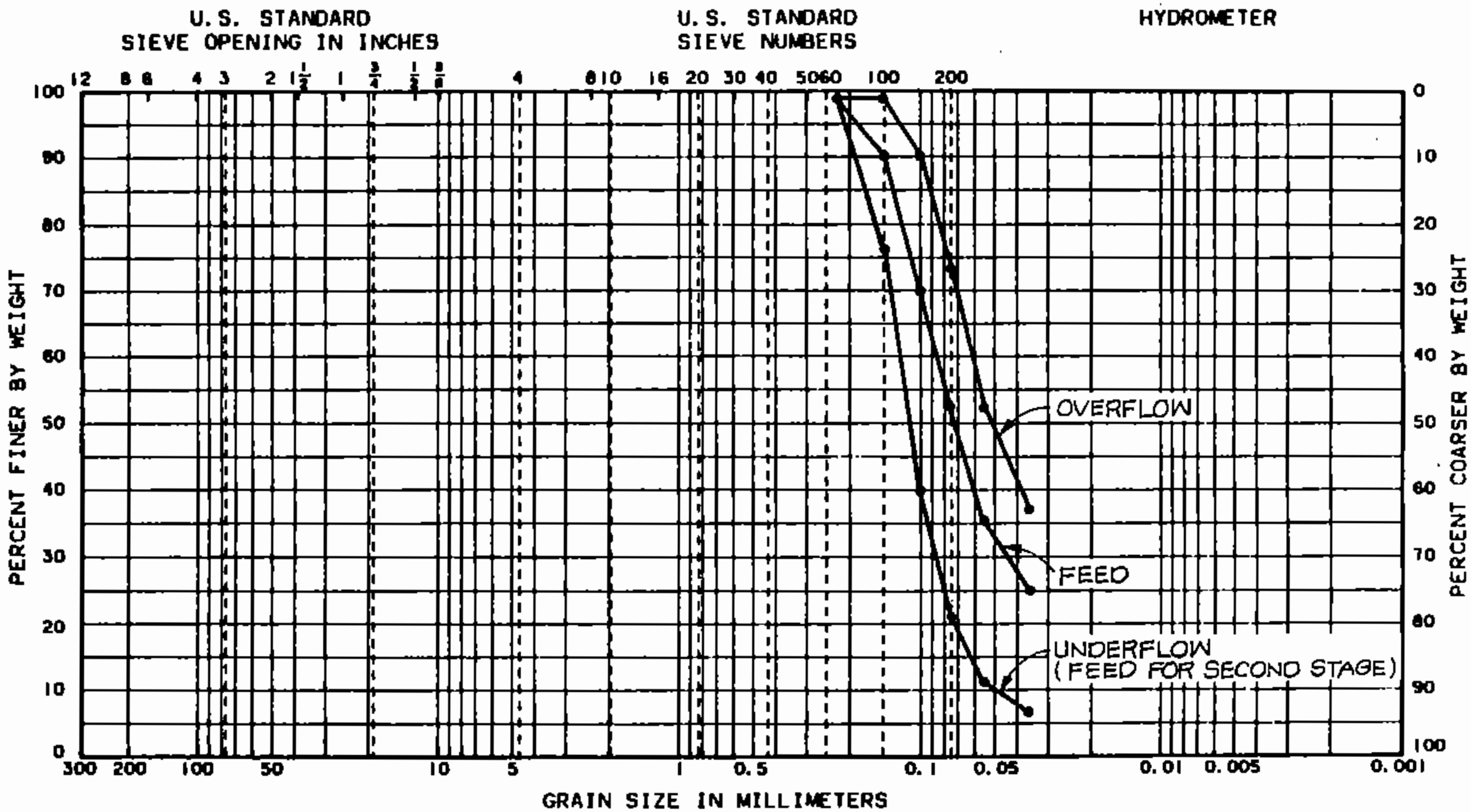
	FEED	OVERFLOW	UNDERFLOW
TPH SOLIDS	340.0	68.2	271.8
TPH LIQUID	793.3	647.0	146.3
TPH PULP	1133.3	715.2	418.1
% SOLIDS WT	30.00	9.54	65.00
SP. GR. PULP	1.23	1.06	1.68
% SOLIDS VOL	14.0	3.8	41.3
U.S. GPM PULP	3683.9	2688.0	995.9

OPEN CIRCUIT ______ OR CLOSED CIRCUIT ______ AT ______ % CIRCULATING LOAD

	FEED			OVERFLOW			UNDERFLOW				
MESH	CUM.	IND.	TPH	CUM.	IND.	TPH	CUM.	IND.	TPH	REC.	
65	1.2	1.2	4.1	0.0	0.0	0.0	1.5	1.5	4.1	100.0	
100	23.0	21.8	74.1	0.3	0.3	0.2	28.7	27.2	73.9	99.7	
150	60.6	37.6	127.8	9.4	9.1	6.2	73.5	44.8	121.7	95.2	
200	78.7	18.1	61.5	32.0	22.6	15.5	90.4	17.0	46.1	74.9	
270	88.6	9.9	33.7	57.8	25.8	17.6	96.3	5.9	16.1	47.8	
400	93.3	4.7	16.0	73.5	15.7	10.7	98.3	1.9	5.3	32.9	
-400	100.0	6.7	22.8	100.0	26.5	18.1	100.0	1.7	4.7	20.6	
TOTAL		100.0	340.0		100.0	68.2		100.0	271.8		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY

GRAIN SIZE ANALYSIS



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT MONTANA PROJECT

JOB NO. 8029-01

AREA FIRST STAGE

TWO STAGE TAILINGS RECOVERY

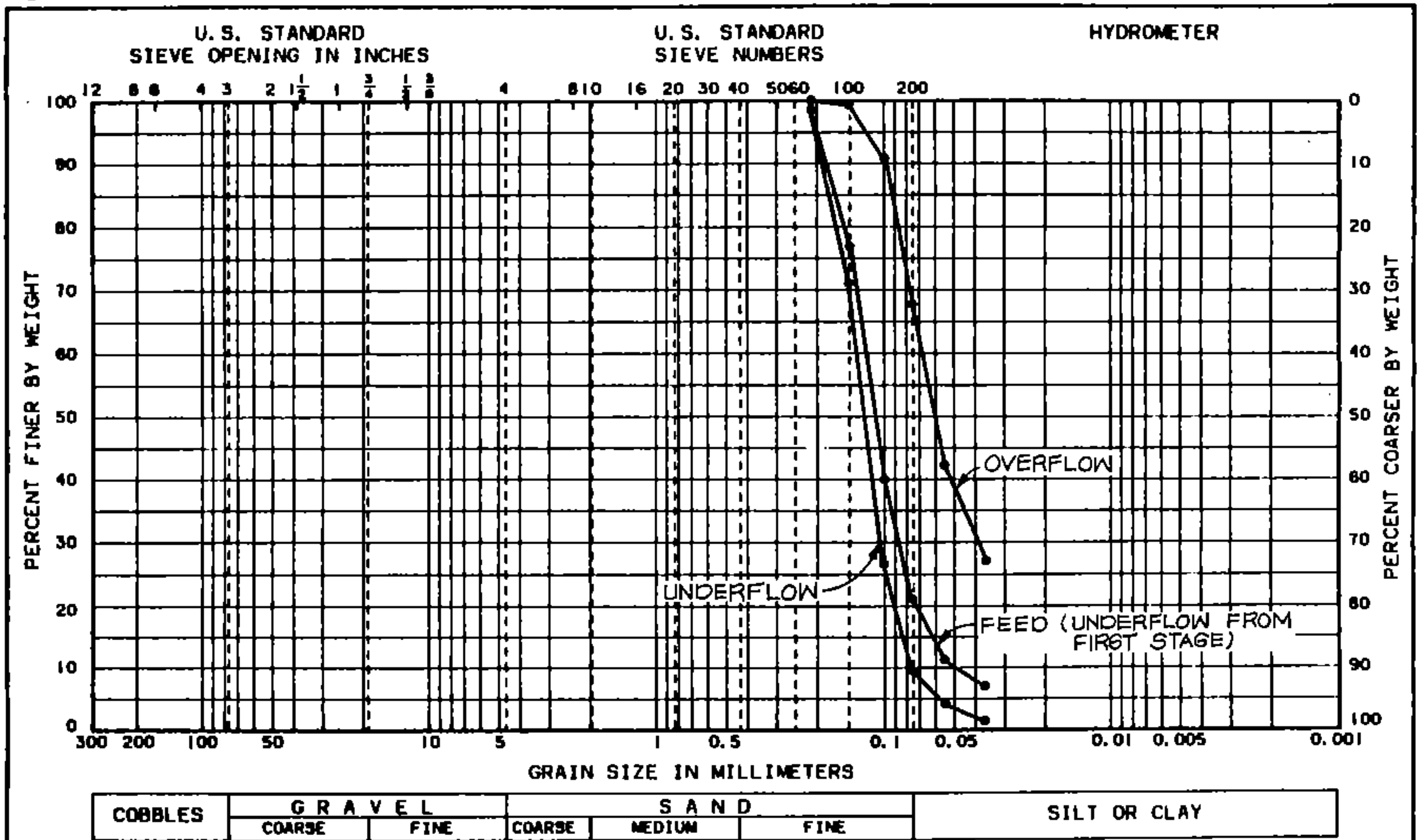
DATE DEC. 1988

FIGURE E-1

CAB110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY

GRAIN SIZE ANALYSIS



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT	MONTANA PROJECT
JOB NO.	8029-01
AREA	SECOND STAGE
TWO STAGE TAILINGS RECOVERY	
DATE DEC. 1988	FIGURE E-2

CAB110