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Scientists

## Keetac Tailings Basin – Permit 1965-0351 – Stage 2 Exterior Stability

Keewatin, Minnesota

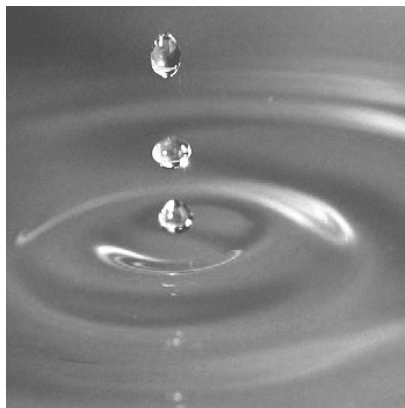
**Submitted to:**

Mr. Jason Boyle, P.E.  
State Dam Safety Engineer  
Minnesota Department of Natural Resources

**Submitted by:**

GEI Consultants, Inc.  
515 NE Second Avenue  
Grand Rapids, Minnesota 55744  
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January 26, 2022  
Project 2100305



James P. Bonner, P.E.  
Senior Engineer

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Senior Vice President



Consulting  
Engineers and  
Scientists

January 26, 2022  
Project 2100305

VIA EMAIL: [jason.boyle@state.mn.us](mailto:jason.boyle@state.mn.us)

Mr. Jason Boyle, P.E.  
State Dam Safety Engineer  
Minnesota Department of Natural Resources

**Re: Keetac Tailings Basin – Stability Analysis Update for Stage 2 Exterior Tailings Basin Permit 1965-0351  
United States Steel Corporation – Keetac  
Keewatin, Minnesota**

Dear Mr. Boyle:

In response to our letter dated December 2, 2021, titled, “Keetac Tailings Basin – Permit 1965-0351 Status”, Minnesota Department of Natural Resources (MDNR) has requested a stability analysis update for the Stage 2 Exterior tailings basin perimeter dam. The purpose of this letter is to provide the requested information.

The intent of the December 2, 2021, letter was to request MDNR Dam Safety confirmation to complete construction of the Stage 2 Exterior Tailings Basin perimeter dike up to the original permitted design elevations. The perimeter dike embankment geometries analyzed for stability in the attached report include the existing perimeter dike embankment with additional vertical expansion up to the original permitted crest elevation. Additional vertical expansion up to the original permitted crest elevation will not require placement of fill materials beyond the upstream or downstream toes of the existing embankment.

We have been pleased to provide our engineering services for this application. If you have any questions, please contact us.

Sincerely,

GEI CONSULTANTS, INC.

A handwritten signature in blue ink, appearing to read "James P. Bonner".

James P. Bonner, P.E.  
Senior Engineer

A handwritten signature in blue ink, appearing to read "Michael J. Wheeler".

Michael J. Wheeler, P.E.  
Senior Vice President

Cc: Chrissy Bartovich, United States Steel Corporation  
Darren Gietzen, United States Steel Corporation  
Lukas Klemke, United States Steel Corporation  
Evan Shefik, PE, United States Steel Corporation

JPB:cah

K:\KEETAC (US Steel)\2100305\_Keetac\_2021 Quarterly Tailings Basin PM\05\_In\_Progress\Reports\Dam Safety Permit Letter\Stability Supplement\R2100305\_Keetac\_Dam Safety Stability\_FINAL.docx

## Proposed Near-Term Phase 1 Solution

A near-term shift to tailings disposal within the Stage 2 Exterior Tailings Basin footprint would allow for hydraulic deposition of tailings for Stage 2 Interior Tailings Basin south dike stability improvement and eliminate or slow additional vertical expansion of the Stage 2 Interior Tailings Basin.

**Figure 1** shows the alignment of the existing Stage 2 Exterior Tailings Basin perimeter dike embankment along with a typical section.

## Summary of Crest Elevations

The current crest elevation of the Stage 2 Exterior dike varies from approximately +1,460 feet along the south portion up to approximately +1,490 feet along the east portion. The Bechtel Incorporated design report, included as **Attachment A**, indicates design crest elevations of +1,470 feet along the south portion and +1,510 along the east portion. A summary of current, designed/permited, and proposed crest elevations along the Stage 2 Exterior dike is provided in the following table.

**Stage 2 Exterior Dike Crest Elevation Summary**

General Area	Approximate Current Crest Elevation	Designed/Permitted Crest Elevation	Proposed Phase 1 Crest Elevation
West	+1,462 feet	+1,470 feet	+1,470 feet
South	+1,462 feet	+1,470 feet	+1,470 feet
East	+1,490 feet	+1,510 feet	+1,500 feet

Phase 1 construction planned for 2022 will be completed under existing Permit 1965-0351, in general accordance with the Bechtel Incorporated design documentation. As indicated in the table above, planned 2022 raising of the perimeter dike will be to interim crest elevations at or below the designed/permited crest elevations.

## Stability Analyses

Consistent with the Bechtel stability analysis, a typical perimeter dike embankment section having the greatest overall height for the permitted crest elevation of +1,470 feet was selected for analysis. The typical section would generally represent the south portion of the Stage 2 Exterior dike. **Attachment A** includes plan and profile drawings showing the location of the typical section along with results of the Bechtel stability analysis. A typical section of the perimeter dike embankment is shown on **Figure 1**.

During 2021 seven (7) borings were advanced through the Stage 2 Exterior Tailings Basin perimeter dam embankment to characterize subsurface materials and collect samples at select depth intervals. Locations of the borings are shown on **Figure 2**.

The 2021 borings were converted to water observation wells upon completion to allow for better measurement of the phreatic surface through the embankment. The 2021 borings confirmed that material types within the dam embankment are consistent with borings completed by Bechtel for the original permit request and material types shown on the original design drawings.

B2021-4EXT was advanced near the location of the typical Stage 2 Exterior Tailings Basin perimeter dike embankment section shown on Figure 1. The boring log from B2021-4EXT is provided in **Attachment B** for reference.

Two-dimensional, force and moment equilibrium embankment slope stability analyses were completed for the Stage 2 Exterior Tailings Basin perimeter dike embankment for existing and Phase 1 embankment geometries. Phase 1 embankment geometry is the permitted design crest elevation consistent with the Bechtel design. The future Phase 1 buildout condition assumes a 10-foot raise using similar clay dike embankment material.

The upstream tailings level for the stability analysis cases was assumed to be 5 feet below the Phase 1 permitted crest elevation. The piezometric line was estimated based on available monitoring data and engineering judgment. Strength parameters for the stability analyses were based on data from the Bechtel study and recent GEI studies.

The slope stability analyses were completed using the computer program SLOPE/W 2019 R2 developed by GEO-SLOPE International, Ltd. This program uses the method of slices to compute the factor of safety against sliding for a layered embankment or slope. The Morgenstern-Price method was used to calculate the factor of safety for all cases analyzed, which is a method that solves for both force and moment equilibrium. Circular slip surfaces were analyzed for all loading cases presented herein. Both effective stress analyses (ESA) and undrained strength analyses (USA) were completed for the existing condition and future Phase 1 perimeter dike crest condition (dike elevation +1,470 feet).

### Material Properties

Material properties utilized for the both the ESA and USA analyses are summarized in the table below:

Material Name	Total Unit Weight (pcf)	Cohesion (psf)	Phi (°)
Buildout Clay dike fill ESA	130	-	31
Buildout Clay dike fill USA	130	1,000	-
Clay dike fill ESA	130	-	31
Clay dike fill USA	130	1,000	-
Drain Material	130	-	36
Layered Fine Tailings and Slimes ESA	130	-	35
Layered Fine Tailings and Slimes USA	130	Tau/Sigma = 0.23, min =400 psf	-
Natural Foundation sand	130	-	31

Material properties of dike embankment materials and natural foundation soils are consistent with Bechtel design parameters included in the documentation for the original permit application request. The Layered Fine Tailings and Slimes material properties were based on previous strength analysis studies performed by GEI. We have conservatively chosen a value of 1,000 psf for the random clay backfill; however, existing field data would likely justify a higher strength.

Only downstream stability was analyzed for this study.

### Stability Analysis Results

Slope stability results are included in **Attachment C**. Critical slip surfaces for each analysis figure are highlighted with a thick white line and the associated minimum factor of safety (FS) value is distinguished with a red dot. Minimum FS values are greater than the required minimum values. Results are summarized in the table below.

Description	Failure Type	Minimum Required Factor of Safety*	ESA Downstream Factor of Safety	USA Downstream Factor of Safety	Bechtel Downstream Factor of Safety
Existing Embankment Geometry	Circular	1.5	1.87	2.04	NA
Interim future conditions (After Phase 1 construction)	Circular	1.5	1.75	1.58	1.5
Interim future conditions, +0.05g seismic	Circular	1.1	1.52	1.37	1.3

\* We have selected a minimum FS criteria of 1.5 for undrained peak strength analysis cases, which is consistent with USACE, USBR, NRCS, FERC, MSHA, TVA and State of Minnesota for long-term steady-state seepage conditions. This is also the current standard of practice for iron ore tailings basins located in the Upper Midwest.

A minimum FS criteria of 1.5 has also been selected for ESA cases. A minimum FS of 1.1 was selected for the pseudo-static cases.

Because of the high shear strength foundation materials, the critical potential failure surfaces tended to be shallow in depth, converging toward a minimum infinite slope factor of safety of 1.5. These shallow sloughing failure surfaces would not affect the overall integrity of the embankment. Therefore, we “forced” the failure surfaces deeper into the slope within the SLOPE/W models, selecting a minimum depth of 15 feet.

The dike materials and foundation materials are not susceptible to liquefaction, and therefore a liquefaction analysis was not completed. The clay like till soils generally have a high plasticity ( $PI > 8$ ) and therefore are not likely susceptible to liquefaction as explained by Idriss and Boulanger (2008)<sup>1</sup> for a fine-grained material that has “clay-like” behavior. Dilative soils with  $N_{1,60} > 15$  or  $qc_1 > 45$  are assumed to not lose strength and generally noncorrected SPT N values for the foundation material and dike embankment material are greater than 15, suggesting these materials are not likely susceptible to liquefaction.

<sup>1</sup> Idriss, I. M. and Boulanger, R. W. (2008) “Soil Liquefaction During Earthquakes,” Earthquake Engineering Research Institute, Oakland, California.

## **Summary**

The proposed 2022 Phase 1 vertical expansion elevations for the Stage 2 Exterior Tailings Basin perimeter dike embankment are at or below the design/permitted Bechtel perimeter dike crest elevations. Stability analysis results for the perimeter dike embankment with the 2022 vertical expansion crest elevation show minimum factors of safety which meet or exceed typical minimum factor of safety criteria for tailings dam perimeter dike embankments.

## **Attachments**

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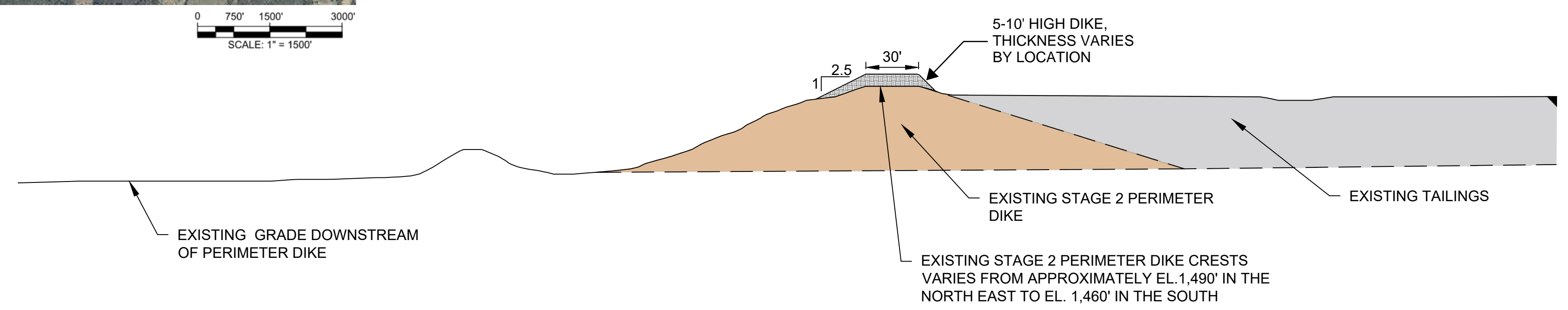
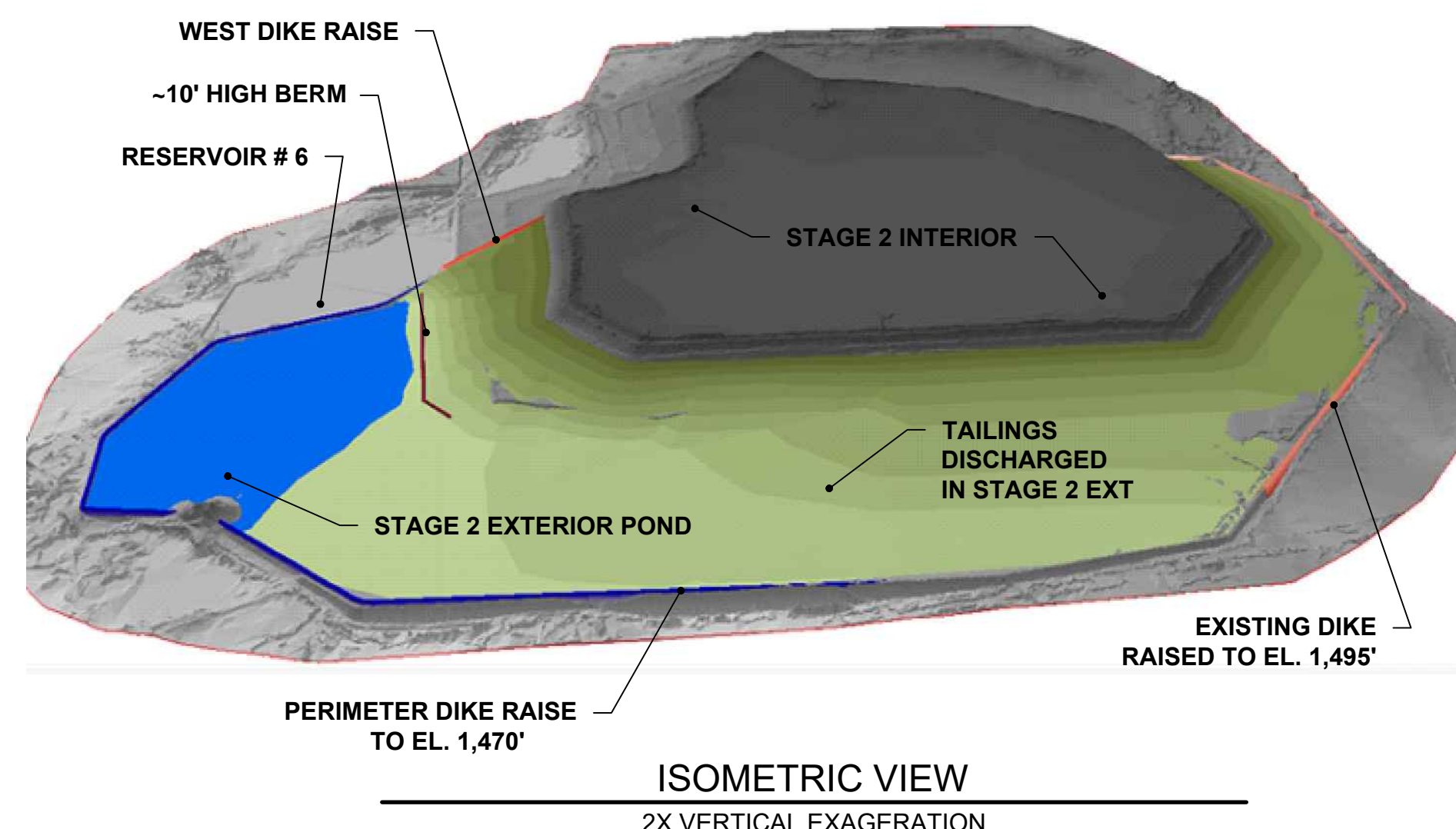
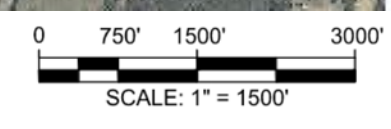
**Figure 1 Dike Typical Sections**

**Figure 2 Stage 2 Exterior Borings and Test Pit Locations**

**Attachment A Bechtel Design Report excluding appendices**

**Attachment B Log of B2021-4EXT**

**Attachment C Stability Analysis Results**



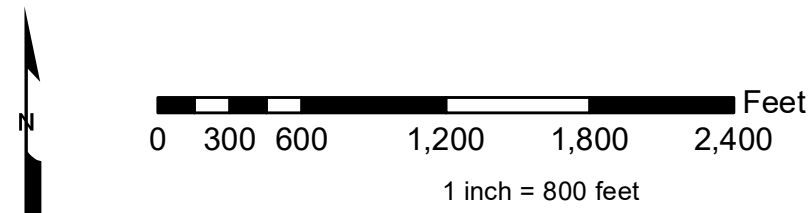
**A** SECTION A  
TYPICAL EXTERIOR DIKE

SCALE: 1" = 50'

Dam Safety Permit Status Keetac Tailings Basin Keewatin, Minnesota		DIKE TYPICAL SECTIONS

**Legend**

- ◆ 2021 STAGE 2 EXT BORINGS
- 2021 STAGE 2 EXT TEST PITS



Coordinate System: NAD 1983 StatePlane Minnesota North FIPS 2201 Feet

NO.	DATE	ISSUE/REVISION	APP



Designed:  
 Checked:  
 Drawn:  
 Approved By:

UNITED STATES STEEL CORP.  
 KEEWATIN TACONITE  
 TAILINGS BASIN  
 KEEWATIN, MINNESOTA

GEI Project 2100867

Keetac Tailings Basin  
 Keewatin, Minnesota

Stage 2 Exterior Borings and Test Pit Locations

FIG. NO.  
**2**

SHEET NO.

National Tailings Basin Stage 2

Design Report

Job 11444-004

December 1977



Rec'd 2/9/78

Design Report

on

West, South, and East Dikes  
Stage 2 Tailing Pond

Prepared by [Signature]

Reviewed by Walter R. Lewis

Approved by Walter R. Lewis

Certification

In accordance with Minnesota Statutes Section 326.12, Subd. 3, I hereby certify that this report was prepared under my direct supervision and that I am a duly Registered Professional Engineer under the Laws of the State of Minnesota.

Walter R. Ferris  
WALTER. R. FERRIS

Date Jan 20, 1978

Registration No. 12201

Design Report  
on  
West, South, and East Dikes  
Stage 2 Tailing Pond

Prepared For  
The Hanna Mining Company  
Hibbing, Minnesota

Prepared by  
Bechtel Incorporated

December 1977

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SECTION 1  
INTRODUCTION

1.1 Scope of Report

The second stage tailings pond for the National Steel Company Plant near Keewatin, Minnesota will be formed by the construction of three dikes on the West, South and East and the previously completed initial basin to the North. The second stage pond is south of the National Steel Company Plant. The dikes, known as the West, South and East Dikes, will be constructed in a single effort conforming to the same general design criteria. It should be noted here that the West Dike referenced to in the general report is the 4400 ft. section comprising the South end of the West Dike. This report presents the design of the starter dikes and discusses the methods of raising the dikes to the ultimate elevations required. The report describes the investigation of the embankment foundations and borrow areas, laboratory testing, foundation conditions, design criteria and engineering analyses. While a spillway will be provided, it is planned that the details of it will be presented in a supplemental report.

1.2 Project Description

The dikes will be homogeneous embankments with internal drainage. The approximate lengths of the three dikes will be about 0.8 miles for the West Dike, 3.5 miles for the South Dike, and 2.8 miles for the East Dike. The ultimate crest height along the three alignments will not exceed 60 feet with an average crest height of considerably less. Construction materials will be obtained from designated borrow areas adjacent to the planned alignments. The starter dikes will be constructed from materials borrowed from both inside and outside the pond; borrow areas for future raising of the dikes will be designated downstream of the dikes to enable their use after tailing have been deposited

erosion control

control  
erosion

in the pond. The general configuration of the Stage 2 Pond is shown on Figure 1.

~~The starter dike will be constructed to about elevation 1440 feet and~~ raised in stages as required. The ultimate section and method of raising are discussed in Section 8. A portion of embankment already constructed as noted on Figure 3 will eventually form the starter embankment of the South Dike. *← constructed in 1975.*

### 1.3 Site Description

The topography in the vicinity of the Stage 2 pond is relatively flat with a few slightly rolling hills. The ground is covered with brush and trees. Natural drainage systems in the area consist of Hay Creek and West Swan River. Hay Creek divides the planned Stage 2 pond into near equal parts and runs southward through it into Swan Lake. West Swan River is to the east of the East Dike, outside the Stage 2 pond, and in the vicinity of the site flows due south. The flow of Hay Creek was interrupted by the construction of the initial National tailing basin. Because of the relatively flat topography, surface drainage is poor and shallow depressions frequently are swampy and contain shallow deposits of muskeg.

SECTION 2  
INVESTIGATIONS

2.1 Previous Investigations

The adjacent tailing pond construction has been investigated in the mid sixties and early seventies and since the soils are geologically similar, the data from those investigations have been used in the current design effort.

Of particular benefit were the data contained in the following two reports:

- ° Report on Reservoir No. 2N Dike for The Hanna Mining Company, September 1972
- ° Design and Construction of South O'Brien Dike, December 1976

Both of the above reports were prepared by Bechtel and were used to provide data pertaining to soil characteristics and parameters. In addition to supplementing the current exploration, the previously obtained data were used in development of preliminary embankment designs.

2.2 Recent Investigation

Test borings were drilled and sampled along the dike alignments by Soil Exploration Company of St. Paul, Minnesota. The boring locations are noted on Figure 1.

Standard penetration tests and split spoon samples were obtained at selected intervals in the borings in accordance with ASTM D1586. This procedure uses 2-inch outside diameter sampler driven by a 140 pound weight falling 30 inches.

The number of blows required to drive the sampler the last 12 of 18 inches is called the standard penetration or "N" value. It is a measure of the relative density of sands and of the consistency of clays.

Relatively undisturbed samples were obtained in thin walled Shelby tubes in accordance with ASTM D1587. These were obtained for testing to determine the engineering properties of the foundation soils.

Samples were visually classified in the field in accordance with ASTM D2488. Logs of the borings were prepared by the drillers and are included in the report submitted by The Soil Exploration Company, Appendix A. *what do they know about dams?*

The Hanna Mining Company located potential borrow areas for dike fill and drain zone material. These areas were then explored by excavating test pits and taking bulk samples for laboratory testing. The test pit locations are noted on Figure 1. The samples were sent to The Hanna Mining Company's laboratory in Cooley for testing and storage. Logs of the test pits are included in Appendix B.

SECTION 3

SUBSURFACE CONDITIONS

3.1 General

Throughout the site area bedrock is overlain by about 100 feet of preconsolidated glacial tills which have locally been eroded and replaced with alluvium from streams throughout the area. As mentioned earlier, depressions on the surface of the till have been filled with shallow marshy deposits of muskeg. The tills are typically clayey near the surface and become sandy or gravelly at depths greater than about 10 feet. Isolated gravels, sandy soils, and silty sandy soils also exist and in some instances extend from the surface to depths greater than 10 feet. *connected w/pond?*  
*are they to be covered w/clayey stuff to protect GW?*

3.2 Foundation

With a few exceptions, which are noted below, the foundation conditions are similar for all three dike alignments. The upper 10 feet, approximately, *check for connections v/s.*  
consists of stiff to hard clayey glacial till over sandy till with lenses of clayey sands, clays, and sands occurring at depths greater than about 20 feet. *check for pockets of liquefiable deposits. Have these things been looked at prior to constructing the completed section of South Dike?*  
The West Dike alignment is one exception where surface or near surface gravelly clays were encountered in test pits W-453, W-455 and W-458. Also along the West Dike alignment, surface silty sands were encountered in test pits W-44 and W-457. *Any seepage D/S of completed section?*  
Near-surface gravelly material was encountered on the South Dike in test pits W-461 and W-462, and on the East Dike near-surface sandy silt was found in test pit W-469. Generally, the near-surface gravelly or sandy deposits were less than 5 feet deep and were underlain with clayey till. One other area which was found to vary was the eastern section of the South Dike *which seemed to have more sandy areas than the remainder of the alignments investigated.* The water table can be within about 5 feet of ground surface,

but based on the data obtained, it varies a great deal depending upon locally perched tables.

For design considerations the materials described above have relatively low permeabilities, except for the sand and gravel lenses, and moderate to high strength under static conditions. The strength under seismic conditions is also moderate to high.

what about silty saturated loose deposits?

### 3.3 Random Material *is this specified?*

Random dike material consists predominantly of clayey till which can be borrowed from either side of the alignments as shown on Figure 1

Since the borrow areas are adjacent to the alignments, the materials described above are essentially the same as those encountered in the designated borrow areas.

### 3.4 Granular Materials

Two possible sources of granular material are designated on Figure 1.

Drain zone materials are available from these areas, either after processing or as excavated. The materials are gravelly sands and typically have suitable characteristics for use in drain zones.

### 3.5 Design Considerations

Generally the clayey and sandy till materials can be grouped as shown on Figure 7. Thus, homogenous dikes have been designed. The drain zone

can be one material that satisfies the filter design criteria discussed in Section 5.

SECTION 4  
LABORATORY TESTING

4.1 General

Laboratory tests were performed on selected disturbed and relatively undisturbed samples to evaluate and determine physical characteristics such as water content, dry density, gradation, Atterberg Limits, specific gravity, compressibility, permeability, maximum dry density, and shear strength. Hanna Mining Company performed gradation analyses on selected bulk samples and the results were used by Bechtel to assign the remainder of the testing program. Soil Exploration Company performed the assigned testing at their laboratory in St. Paul.

The testing performed by Hanna Mining Company is included in Appendix B. The Soil Exploration Company test results were transmitted in reports which are included in Appendix A. The test methods used are described in the report prepared by Soil Exploration Company.

4.2 Engineering Properties and Design Parameters

4.2.1 Foundation Soils

The engineering properties of the foundation soils were evaluated from laboratory test results. The selected design parameters are given in Table 1.

#### 4.2.2 Dike Materials

The engineering properties of the random borrow materials were evaluated from the soil testing program and are presented in Table 2.

The angle of internal friction for the gravel drain zone was evaluated on a conservative basis from data presented on Table 4.2.1, entitled "Approximate Statistical Relationships between Relative Density and Angle of Internal Friction for Pervious Sands and Gravels" in Earth and Earth Rock Dams by Sherard, Woodward, Gizienski, and Clevenger. The unit weight of the gravel drain was estimated from Figure 16 titled "Maximum Dry Density Versus Gravel Content for Compacted Soils" of the Earth Manual. The permeabilities of the gravel drain were estimated from gradation curves versus coefficient of permeability given in Figure 8-5 of the U.S. Navy Design Manual, DM-7.and test results on selected materials molded to the specified unit weight.

TABLE 1

Properties of Foundation Soils  
*Design Parameters*

<u>Properties</u>	Values Based on Laboratory Test Results	
	<u>Sandy Till</u>	<u>Clayey Till</u>
In-Situ Dry Unit Wt., $\gamma_d$		
In-Situ Moisture Content, $w$	4%	14%
N-Values (Field Blowcounts)		
N, Range		
N, Average		
Percent passing No. 200 Sieve (Ave.)	20%	70%
Permeability	$1 \times 10^{-6}$ cm/sec.	$1 \times 10^{-8}$ cm/sec.
Strength Parameters (Drained)		
Cohesion, $C$		0.3 tsf <i>maybe high</i>
Angle of Internal Friction, $\phi$	38°	37°
Strength Parameters (Undrained)		
Cohesion, $C$	--	0.3 tsf <i>high</i>
Angle of Internal Friction, $\phi$	38°	37°

*What are they?*

*What are they?*

*questionable for -- uniformity.*

*how was this determined? Remolded value?*

TABLE 2

Properties of Dike Materials

<u>Properties</u>	Values Based on Laboratory Test Results	Values Assumed
	<u>Random Till</u>	<u>Drain Material</u>
In-Situ Dry Unit Wt., $\gamma_d$	<i>What's that?</i>	<i>What is it?</i>
In-Situ Moisture Content, w	4 to 14%	
Maximum Unit Wt., $\gamma_d$	110 pcf to 125 pcf	130 pcf
Optimum Moisture Content, w	18 to 10%	
Percent Passing No. 200 Sieve (Ave.)	25%	8%
Permeability	$1 \times 10^{-6}$ cm/sec.	$1 \times 10^{-3}$ cm/sec.
Strength Parameters	<i>this must be remolded value.</i>	
(Drained)		
Cohesion, C	--	--
Angle of Internal Friction, $\phi$	31°	36°
(Undrained)		
Cohesion, C		
Angle of Internal Friction, $\phi$		

## SECTION 5

### Dike Design

#### 5.1 General

The three dikes, the West, South and East, are designed to the crest elevations required by The Hanna Mining Company and to the criteria outlined in the following paragraphs.

#### 5.2 Design Criteria

##### 5.2.1 General Criteria

The dikes are designed to:

- ° Provide ultimate crest elevations required by The Hanna Mining Company as shown on Figures 2, 3, 4, and 5.
- ° Be approximately along the alignments required by The Hanna Mining Company as shown on Figures 2, 3, 4, and 5.
- ° Be raised in stages using downstream construction methods.

##### 5.2.2 Foundation Design Criteria

The foundation treatment is designed to:

- ° Provide adequate strength to safely support the planned dikes. This requirement was further defined as:

- Saturated foundations under static loading conditions must be capable of supporting the dikes under static and earthquake conditions. An earthquake peak ground acceleration of 0.05 g was used in this analysis.

\* Any liquefiable loose deposits or near-surface similar pockets?

- Provide horizontal drain zones within the dikes capable of draining seepage from the underlying natural soil.

### 5.2.3 Dike Design Criteria

Specific dike designs incorporate the following criteria:

- Dike slopes must have a minimum factor of safety of 1.5 for normal operating conditions. For temporary and earthquake conditions the minimum factor of safety is 1.2.
- Drain zone must be sized to safely carry water seeping through the dikes when the water in the pond is at the maximum level. *where are the wells?*
- Drain zone materials must have gradations that will prevent piping of finer material into the drain and they must have adequate permeability. This can be achieved using the following criteria:

$$- \frac{D_{15} \text{ of the drain}}{D_{85} \text{ of dike/foundation}} = 5 \text{ or less}$$

Where  $D_{15}$  represents the diameter of the particles at which 15 percent of the total soil particles are smaller, and  $D_{85}$  represents that at which 85 percent of the total soil particles are smaller.

- The grain size distribution curve of the drain material is reasonably well graded from coarse to fine with no gaps or skips.

- Maximum particle size in the drain zone is three inches to minimize segregation of large stones during construction.

- Drain zone gradation should provide sufficient permeability to minimize seepage forces, using the following criterion:

$$- \frac{D_{15} \text{ of the drain}}{D_{15} \text{ of the dike/foundation}} = 5 \text{ or more}$$

° Crest width of 25 feet.

° Freeboard of 10 feet above maximum water level.

### 5.3 DESIGN

#### 5.3.1 Selection of Alignment and Crest Elevations

The alignment and crest elevations were established by Hanna Mining Company and are shown on Figures 2, 3, 4, and 5.

The land downstream of the dikes is available for expansion of the dikes when raised. Thus, the stated general criteria have been met.

#### 5.3.2 Foundation Strength

The depth of required stripping of loose and soft materials for foundation preparation was determined on the basis of field exploration to be at depths in sands where the blowcounts equalled or exceeded 20 and in clays where the blowcounts equalled or exceeded 8. Provided that this basis is used in the foundation preparation, the foundation will satisfy the required strength criteria.

#### 5.3.3 Dikes

The three dikes have been designed as homogeneous embankments utilizing the soil described in Section 4. Based on the criteria as outlined and the selected design parameters, the dikes have 2.5 horizontal to 1 vertical downstream slopes and 2.5 horizontal to 1 vertical upstream slopes. The method

of analysis and the results are presented in Section 5. The factors of safety obtained satisfy the criteria stated.

The drain zones consist of vertical chimney drains connecting to near horizontal drains that extend to the downstream toes of the dikes. The drain zones have been designed to the stated criteria using a permeability of  $1 \times 10^{-3}$  centimeters per second. The principle purpose of the designed drainage system is to keep seepage from discharging on the downstream slope. Thus the phreatic surface is controlled through the dam and this information was used in making stability analyses.

The required characteristics of the drain zone material are based on the dike materials and the stated criteria. The sources of drain material are shown on Figure 1. The required gradation of the drain zone to satisfy the stated criteria are shown on Figure 6 and are tabulated below: *Filters needed bet'n drain & fill or foundation ?*

<u>Size</u>	<u>Percent Passing</u>
3"	100
#4	60-98
#20	30-80
#50	2-60
#200	0-8

Upstream slope protection will only be required if water is stored against the slope for extended periods of time. Should that be the case, rip rap and rip rap bedding recommendations will be provided

Downstream slope protection will not be required

*\* has S.S. analysis taken into account this situation ?*

because localized erosion caused by rainfall can be detected by routine inspections and corrected by maintenance if necessary. The downstream slopes can be effectively stabilized by grassing if necessary.

approval  
condition.

## SECTION 6

### Analyses

#### 6.1 Stability

Stability analyses were performed for the portion of the dikes having the greatest crest height for the final dike. Both upstream and downstream slopes were analyzed for steady state seepage at maximum pool elevation and also the same condition with an applied seismic force due to 0.05 g acceleration. A pseudo-static procedure was used for the seismic analyses.

*vertical and/or horizontal*

*cyclic effects on sand during earthquakes*

Since the foundation is strong and the dike materials may be treated as cohesionless, the critical potential surfaces of sliding will tend to be shallow. Therefore, the factors of safety may be calculated using infinite slope methods.

Computer analyses were also made using the ICES computer program "LEASE" which verified that the critical circles tend to be very shallow and the factors of safety tend toward the infinite slope values. Representative circles that were analyzed are shown on Figure 8.

The soil strength parameters selected for the analyses are based on test results and are summarized in Table 3.

The following assumptions were considered in the evaluation of stability:

- 1) The grain will control seepage in the downstream shell.
- 2) Seepage forces are neglected in the upstream slope. why?

- 3) A seismic factor of 0.05 g is applied to the total weight of soil and water and the resulting force acts horizontally. Resisting forces are based on effective stresses.
- 4) Rapid drawdown is not considered because the pond will be maintained at a normal operating level. Even during periods of heavy runoff, the pond will only be returned to a normal operating level using a decant tower, thus rapid drawdown is not a consideration.

*what's the effect of shaking on both the loose foundation deposits, and the stacked up tails?*

## 6.2 Drain Zone

A laboratory testing program was conducted to evaluate the coefficient of permeability for compacted soils in the dikes. The specimens were prepared to simulate the design compaction criterion of 95 percent of the maximum dry unit weight as determined by ASTM Test Method D698.

The seepage into the dikes from ponded water upstream is estimated by a simplified approach using Darcy's formula:

$$Q = K \cdot i \cdot A$$

where:

Q = discharge in cubic feet per minute

K = coefficient of permeability of the dike in feet per minute

i = hydraulic gradient, h/l

h = difference in head causing flow to occur, feet

l = length of flow path

A = area through which flow takes place, square feet

The dike is divided into equal layers and the discharge, Q, is computed for each layer. The total seepage into the dike is the sum of the discharge for each layer.

Using the formula and method outlined, a coefficient of permeability of  $1 \times 10^{-6}$  centimeters per second and a 50 foot head on the dike, seepage into a dike of height 60 feet is estimated to be 14 cubic feet per year per foot of dike length.

*does this include Q from seepage foundation? Seems that more Q will be foundational rather than from embankment.*

The drain, as shown in Figure 6, has a thickness of 5 feet in the chimney portion and 5 feet in the horizontal portion. Capacities of the two portions are calculated using the Darcy Formula as described above. Using this formula, the capacity of the chimney drain is 5000 cubic feet per year per foot of dike. The capacity of the horizontal drain is 150 cubic feet per year per foot of dike. These capacities are based on a coefficient of permeability for the drain zone of 1000 feet per year ( $1 \times 10^{-3}$  centimeters per second).

The gradation of the drain zone is based on the stated criteria and the random material in the dikes depicted on Figure 7. The drain zone material should be a clean, durable material and have a gradation within the following limits with no gaps or skips:

<u>Size</u>	<u>Percent Passing</u>
3"	100
#4	60-98
#20	30-80
#50	2-60
#200	0-8

### 6.3 Settlement

Guidelines as presented in Woodward, Sherard, Gizienski, and Clevenger. Earth and Earth Rock Dams, 1967, Page 203, were consulted and resulted in an estimate of settlement within the dike of 9 inches.

TABLE 3

STRENGTH PARAMETERS *for what timeframe?*

Material	Total Unit Weight lbs/ft. <sup>3</sup>	Shear Strength Parameters	
		Cohesion (C) lb/ft <sup>2</sup>	Angle of Internal friction ( $\phi$ ) deg
Dike (Random)	130	0	31
Drain	130*	0	36*
Foundation	130	0	31

*31*  
*can this be right in loose deposits?*

\* Value assumed on basis of given in Section 4.

TABLE 4  
 RESULTS OF STABILITY ANALYSES: *ultimate conditions*

<u>DESCRIPTION</u>	<u>Minimum Factors of Safety</u>		
	<u>Required</u>	<u>Computed</u>	
		<u>Upstream</u> 2.5 to 1	<u>Downstream</u> 2.5 to 1
Maximum Pool-Steady State Seepage	1.5	1.5	1.5
Maximum Pool-Steady State Seepage plus 0.05 g Seismic	1.2	1.2	1.3

SECTION 7  
CONSTRUCTION

7.1 General

The specifications for the construction of the dikes are given on Figures 2, 3, 4, 5, and 6.

The following paragraphs are intended to elaborate on these items.

7.2 Foundation Preparation

All soft and loose material must be removed from within the limits of the dikes down to dense sandy till or sand with standard penetration test blowcounts of 20 or more per foot, or stiff clay with blowcounts of 8 or more per foot. The stripped surface should be free of roots and deleterious material. It should be scarified to a depth of about 6 inches, moisture conditioned, and compacted as specified for the dikes. The dike foundation surfaces should be maintained free of standing water by providing drainage to low areas and pumping from sumps located in the low areas.

*what's that depth?  
how the contractor will be excavating without the benefit of blow count drills present?*

7.3 Materials

7.3.1 General

The materials to be used in the dikes must conform to the gradation requirements of the following paragraphs.

7.3.2 Random Materials

The random materials should consist of silty sand or clayey silty sand with at least 20 percent passing the number 200 sieve.

*insufficient spec!*

### 7.3.3 Drain Zone Materials

The drain zone should consist of sands or sand and gravel with gradations within the limits shown on Figure 6.

### 7.4 Borrow Area

The dike sections should be constructed from clayey and sandy till of the type encountered in the explorations performed by The Hanna Mining Company. The borrow areas and test pit locations are shown on Figures 1, 3, 4, and 5. The typical ranges of gradation are shown on Figure 7.

*What's the difference bet'n 7.4 & 7.3.2 ?*

Drain Zone material can be obtained from the borrow areas delineated for that purpose on Figure 1. The gradation requirements for the drain zone material are shown on Figure 6.

### 7.5 Fill Placement

The materials used in the dike fills should be free of roots and other debris and should not include boulders larger than 12 inches in diameter. Boulders larger than 12 inches in diameter should be either removed or raked to the upstream faces of the dikes. No frozen material should be placed in the dikes nor should any dike material be placed on frozen ground.

After placement of loose material on the dikes, the moisture content should be adjusted as necessary to be within two percent of the optimum moisture

content. Material placed on the dikes too wet for compaction should be left to drain or be aerated and dried by discing and harrowing until the moisture content of the entire layer is uniform and within two percent of the optimum moisture content. Material placed on the dikes too dry for proper compaction should be moistened by sprinkling with water. The layer should then be disced, harrowed, or otherwise mixed until within the limits stated above.

After moisture conditioning, the dike material should be compacted in lifts as described in the Table 5.

TABLE 5  
METHODS OF COMPACTION

<u>Zone</u>	<u>Type of Compactor</u>	<u>Loose Lift Thickness (in.)</u>	<u>Number of Passes</u>
Random	60 ton roller <i>gross wgt</i> rubber-tire	12	4
Drain	60 ton roller	12	4
Drain	10 ton Vibratory	12	4

*Static wgt* → (points to 10 ton Vibratory)  
*drum* → (points to 10 ton Vibratory)

A pass is one complete coverage of the area with the wheels of the roller.

## SECTION 8

### RAISING

#### 8.1 General

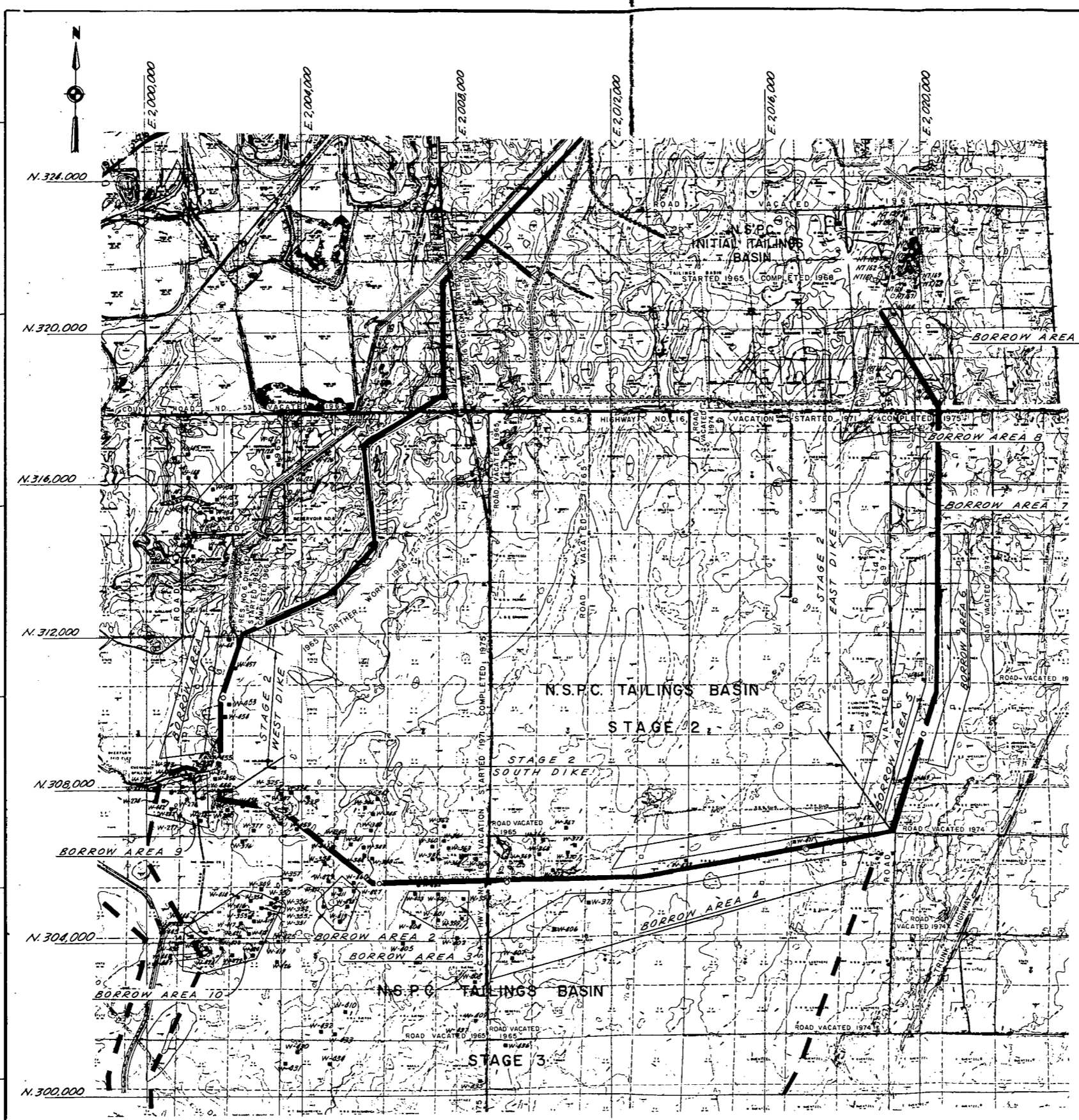
The downstream method of raising will be used to raise the starter dikes as required. The planned ultimate heights of the dikes at their centerlines are shown on the profiles on Figures 2, 3, 4, and 5. The typical ultimate dike section is shown on Figure 6.

Tailings may be stacked higher than the crest of the dikes provided that they do not intersect an imaginary line sloping from the downstream toe of the dike upstream on a gradient of 6 horizontal to 1 vertical.

#### 8.2 Method of Raising

The foundation for a raise should be prepared as discussed in Section 7, and the previously constructed horizontal drain should be excavated to expose a clean drain zone. The vertical drain should be excavated prior to any crest raise to expose uncontaminated material meeting the specification. The raises should be constructed in accordance with the specifications used for the starter dikes.

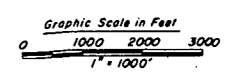
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**GENERAL PLAN**  
Scale: 1" = 1000'

- NOTES:**
- All coordinates and grid lines refer to the Minnesota Coordinate System.
  - Borrow Areas 1 thru 8 are sources for random materials (Sandy and Clayey Till).
  - Borrow Areas 9 thru 11 are sources for drain materials (Gravelly Sand).

- LEGEND:**
- Completed Drill Holes
  - Completed Test Pits
  - Proposed Drill Holes
  - Proposed Test Pits

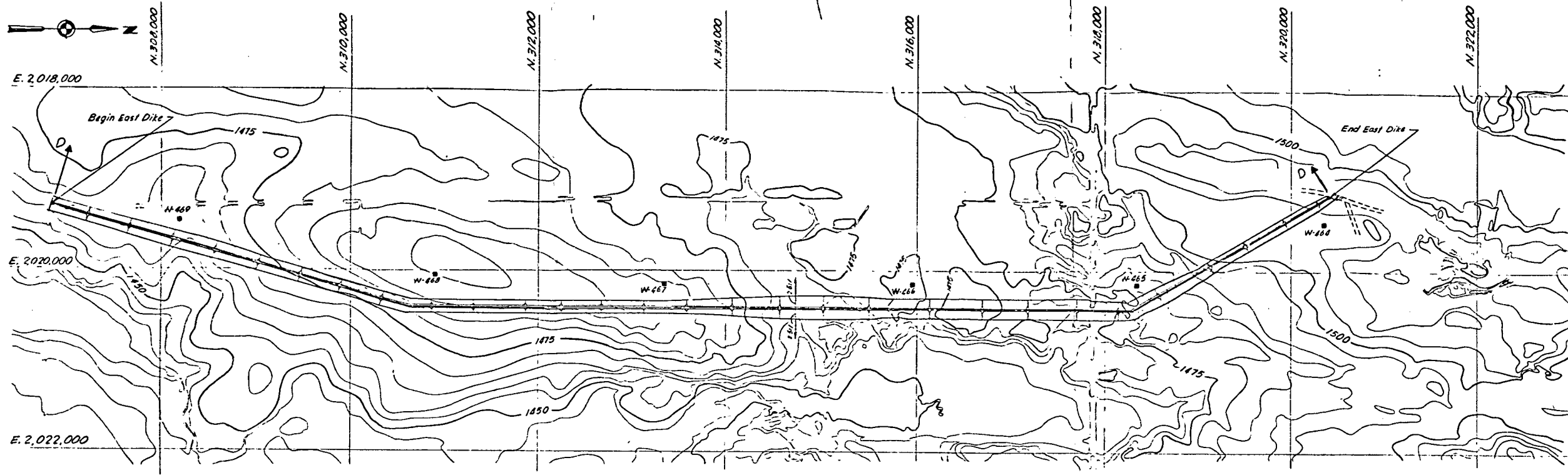


DATE		REVISION		BY		CHKD		APPD	
11/15/77		M.S.		Y.N.					
<b>BECHTEL</b> SAN FRANCISCO									
THE HANNA MINING CO. NATIONAL STEEL PELLET PLANT 2nd STAGE TAILING POND									
<b>GENERAL PLAN</b>									
JOB No.		DRAWING No.		REV.					
11444		Fig. 1		0					

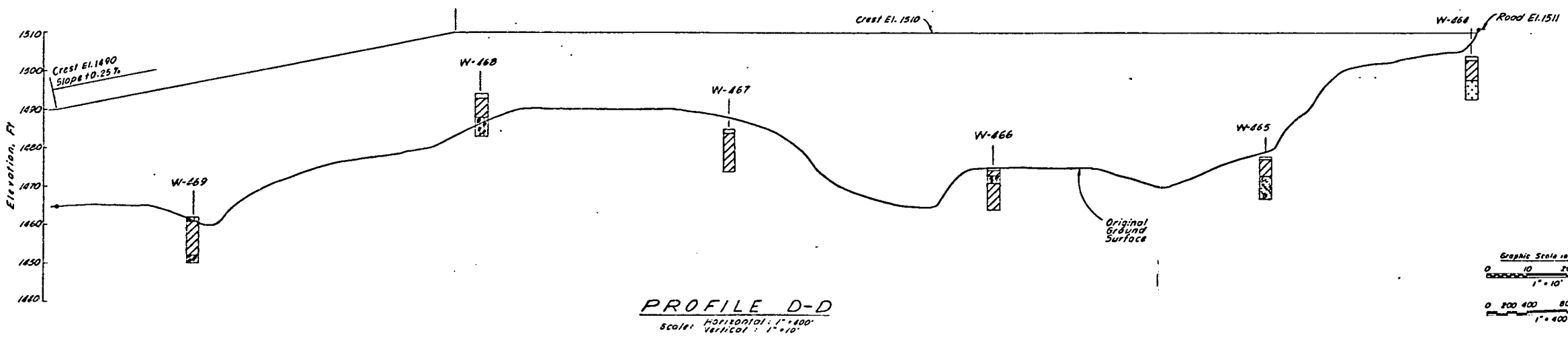




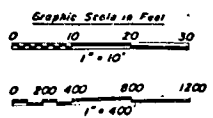




**PLAN**  
Scale: 1" = 400'



**PROFILE D-D**  
Scale: Horizontal: 1" = 400'  
Vertical: 1" = 10'



**NOTES:**

1. All coordinates and grid lines refer to the Minnesota Coordinate System.
2. For general plan of area, see Fig. 1.
3. For Typical Dike Section, see Fig. 6.
4. Drill Holes and Test Pits, shown on the profile, are projected perpendicular to the center line of the Dike.

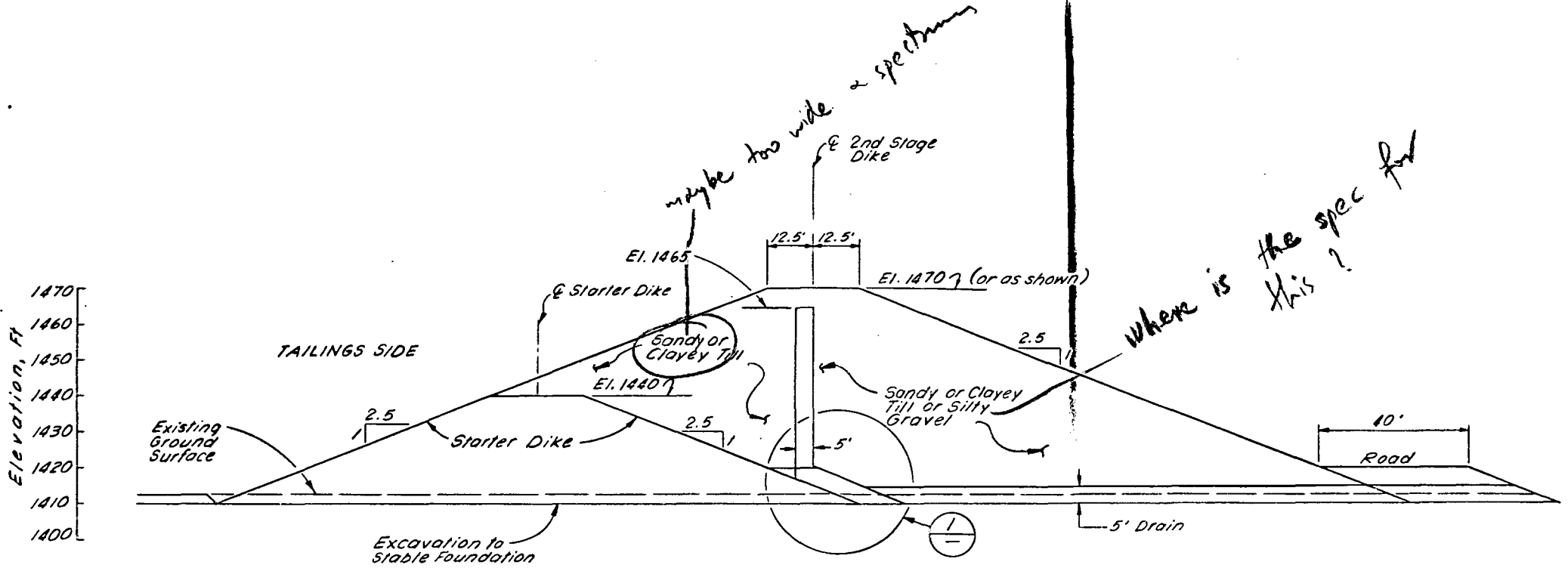
**LEGEND**

- W-467 Test Pit
- [Hatched Box] Well Graded Gravel
- [Dotted Box] Silty Gravel
- [Horizontal Lines Box] Well Graded Sand
- [Vertical Lines Box] Silty Sand
- [Diagonal Lines Box] Silt
- [Cross-hatched Box] Clay

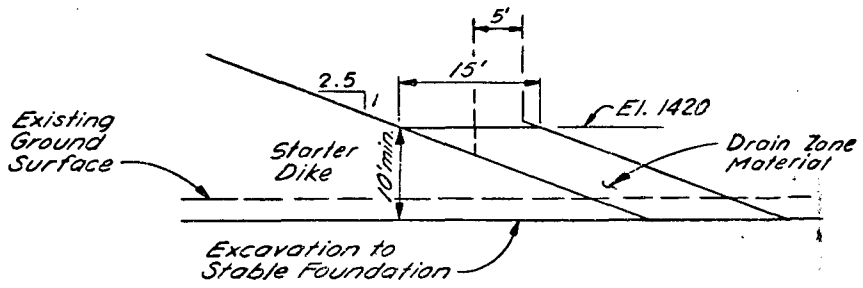
DATE	BY	CHECKED	DATE
<b>BECHTEL</b> SAN FRANCISCO			
THE HANNA MINING CO. NATIONAL STEEL PELLET PLANT 2ND STAGE TAILING POND			
<b>EAST DIKE PLAN &amp; PROFILE</b>			
JOB NO.	DRAWING NO.	SHEET	
11444	Fig. 5	0	

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SECTION E  
Scale: 1" = 20' Fig. 3



DETAIL 1  
Scale: 1" = 10'

NOTES:

1. Foundation Preparation
  - a. All soft silt, clay, and topsoil shall be removed from the foundation to sand or silt/clay free of roots or other deleterious material.
2. Dike Fill
  - a. Dike fill material - the main dike fill shall consist of silt or sandy clay fill from designated borrow areas.
  - b. Drain zone material - the drain zone material shall consist of sand and gravel from designated borrow areas that is clean, durable, and conforming to the following gradation limits with no skips or gaps:
 

U.S. Standard Series Sieve Size	% passing
# 3"	100
# 4	60-98
# 20	30-80
# 50	2-60
# 200	0-8
3. Placement and Compaction
  - a. No ice, snow, or frozen earth shall be placed in the dikes and no fill shall be placed upon a frozen surface.
  - b. The prepared foundation surface shall be maintained free of water. All fill slopes shall be sloped to drain.
  - c. Fill shall be spread in horizontal layers with an uncompacted thickness of not more than 12 inches. All boulders exceeding 12 inches shall be pushed to the upstream edge of the dike and all roots or other debris shall be removed from the fill.
  - d. Fill material shall be moisture conditioned to within plus or minus 2% of the optimum moisture content as determined by ASTM test method D 698. The fill shall be disked as necessary to ensure uniform moisture distribution within the lift.
  - e. Each lift shall be compacted to at least 95% of the maximum dry unit weight determined in accordance with ASTM test method D 698. This may be achieved with four passes of a 60-ton rubber tired roller after the material is placed and moisture conditioned as specified.
  - f. Before any material is placed on fill already compacted, all soft surface material shall be removed to the depth at which the compaction requirements of note 3e have been satisfied.
4. Foundation
  - a. Where the prepared foundation is at or above elevation 1460 feet, a drainage zone is not required in the final dike construction.
5. Starter Dike
  - a. Drainage in the starter dike shall consist of drain material placed as shown in Detail 1, Fig. 6.
  - b. Prior to constructing the second stage of the dike, the starter drain material shall be excavated to expose clean, uncontaminated drain material.
6. Road (Term)
  - a. Should be constructed to dike specifications.
  - b. Along portions of the south dike and east dike an operational road will not be required.

Does this extend all along the dam?

Graphic Scale in Feet

0 10 20 30  
1" = 10'

0 10 20 40 60  
1" = 20'


NO.	DATE	REVISIONS	BY	CHECK	DESIGN	SCALE	PROJ. LEADER	APPV.
SCALE SHOWN	DESIGNED M. S.	DRAWN Y. N.	CHECK	SCALE				
<b>BECHTEL</b> SAN FRANCISCO								
THE HANNA MINING CO. NATIONAL STEEL PELLET PLANT 2nd STAGE TAILING POND								
2nd STAGE DIKE TYPICAL SECTION								
JOB No.			DRAWING No.			REV.		
11444			Fig. 6			0		

DRAIN ZONE CRITERIA:

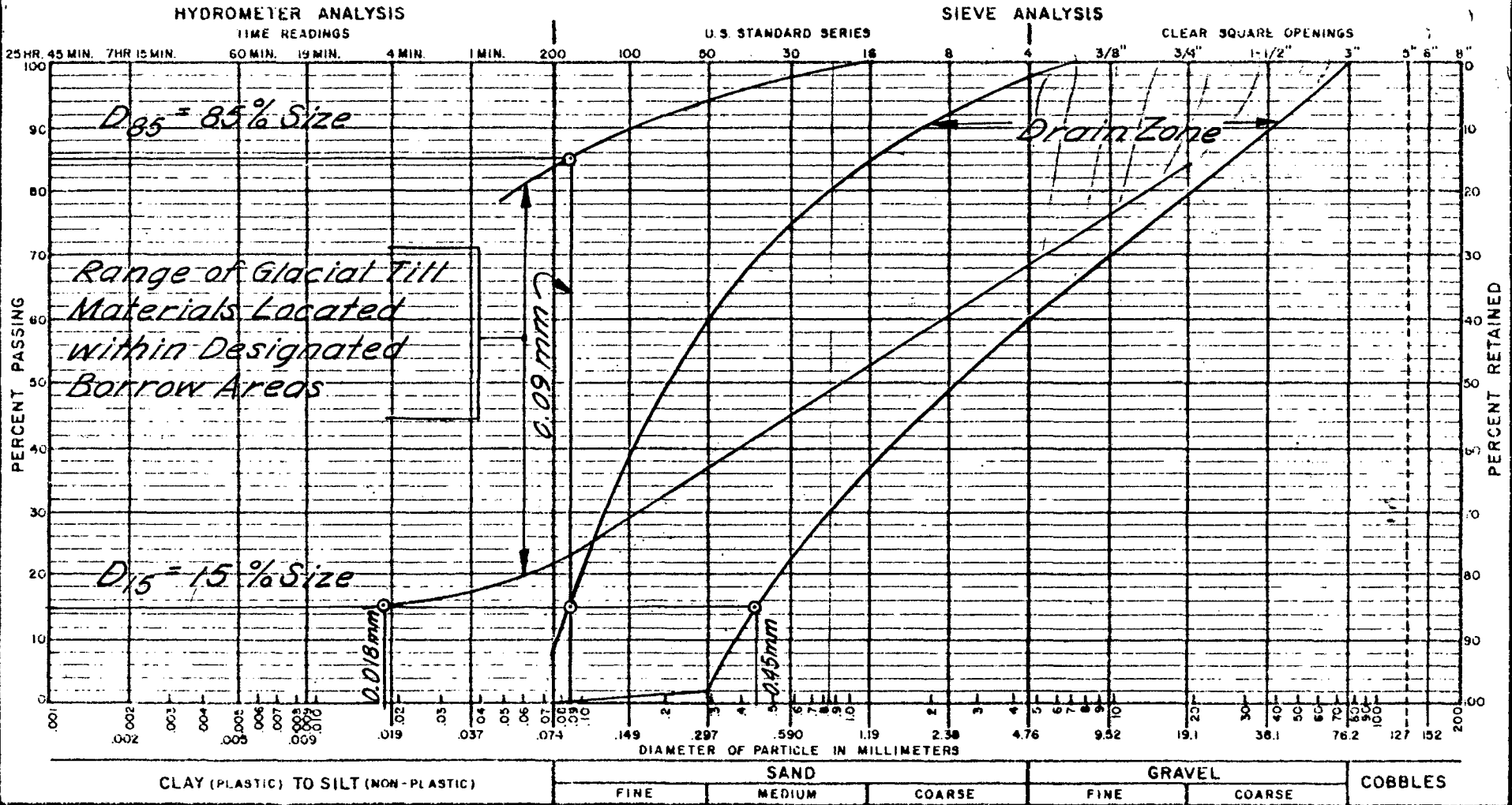
$\frac{D_{15} \text{ Drain}}{D_{85} \text{ Emb.}} < 5$

$\frac{D_{15} \text{ Drain}}{D_{15} \text{ Emb.}} > 5$

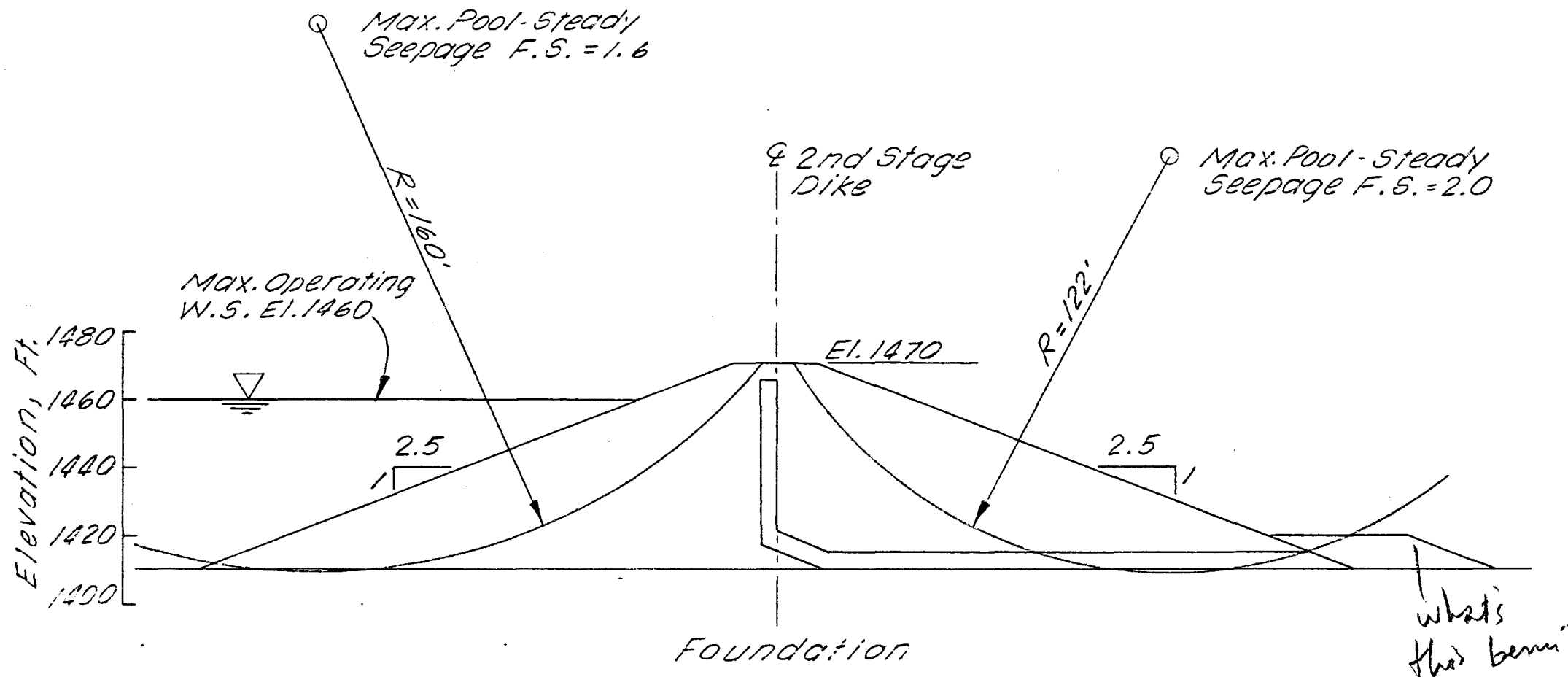
$D_{15} \text{ Drain} < (5) (0.09) < 0.45 \text{ mm}$

$D_{15} \text{ Drain} > (5) (0.018) > 0.09 \text{ mm}$

Tested By \_\_\_\_\_  
 Hole No. \_\_\_\_\_  
 Azon. By \_\_\_\_\_  
 Area \_\_\_\_\_  
 Date \_\_\_\_\_  
 Job No. 11444  
 File No. \_\_\_\_\_  
 Gradation Test Results  
 Fig. No. 7

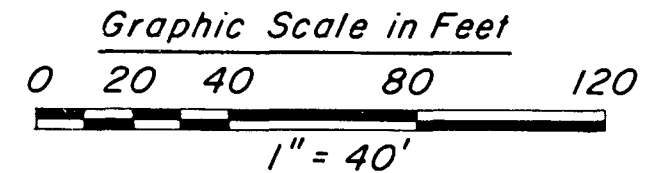


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NOTES:

1. The minimum factors of safety were computed by the infinite slope method.
2. Factors of safety for the deep arcs were computed using the ICES computer program "LEASE".



DESIGN PARAMETERS			
Material	Total Unit Weight pcf	Shear Strength Parameters	
		Cohesion (C) psf	Angle of Internal Friction (φ) deg
Dike (Random)	130	0	31
Drain	130	0	36
Foundation	130	0	31

RESULT OF STABILITY ANALYSES			
Description	Minimum Factors of Safety		
	Required	Computed	
		Upstream	Downstream
Max. Pool, Steady Seepage	1.5	1.5	1.5
Max. Pool, Steady Seepage + 0.05g Seismic	1.2	1.2	1.3

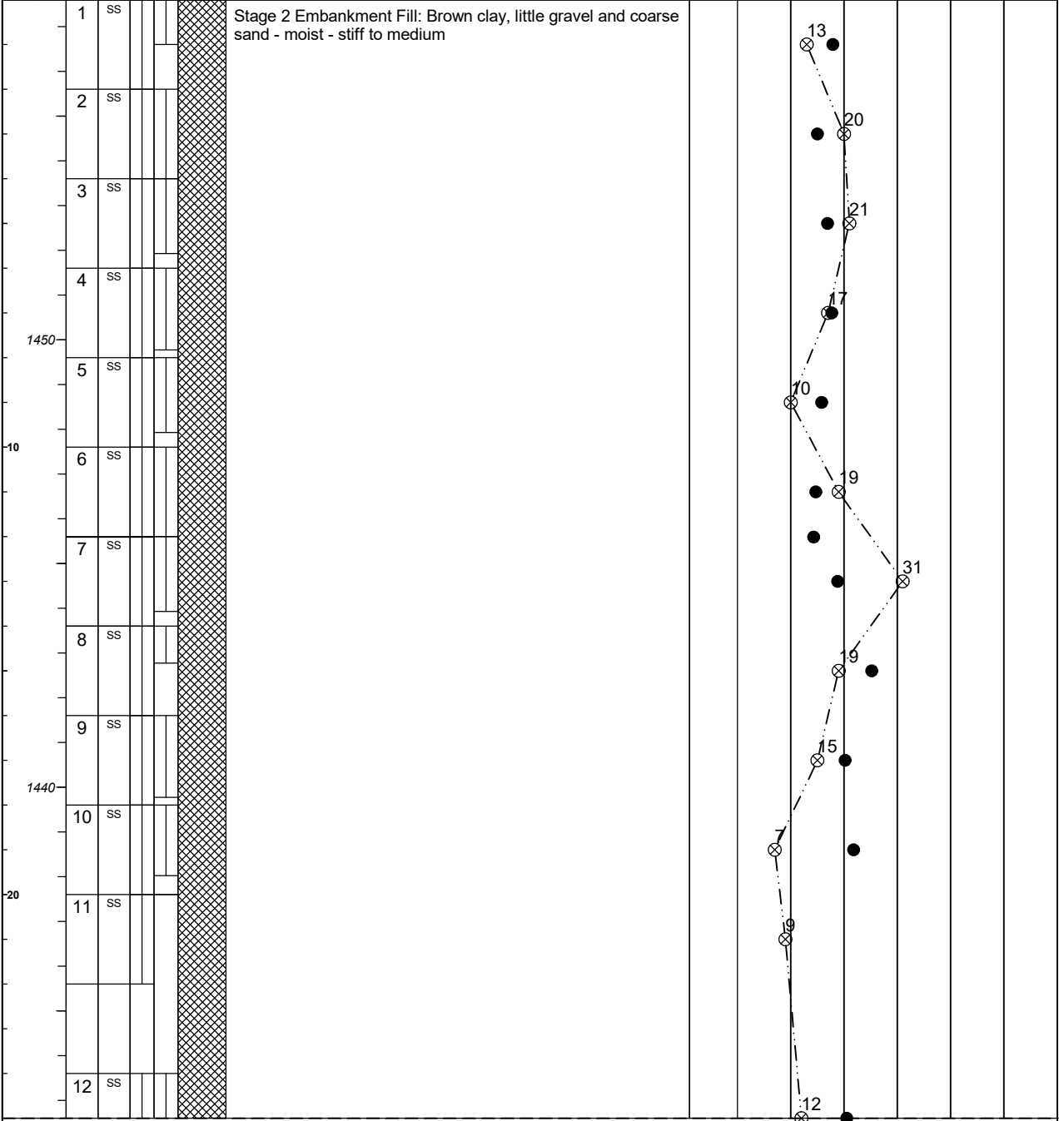
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No.	DATE	REVISIONS	BY	CH'K	DES. SUPV.	ENGR	PROJ. ENGR	APPR	
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<b>BECHTEL</b> SAN FRANCISCO									
THE HANNA MINING CO. NATIONAL STEEL PELLET PLANT 2nd STAGE TAILING POND									
2nd STAGE DIKE STABILITY ANALYSES									
		JOB No.	DRAWING No.		REV.				
		11444	Fig. 8		0				



CLIENT:  
**United States Steel Corporation**  
 PROJECT NAME:  
**Keetac Stage 2 Exterior Exploration**

LOG OF BORING NUMBER **B2021-4EXT**  
 ARCHITECT-ENGINEER  
**GEI Consultants, Inc.**

DEPTH (FT) ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	LOCATION:	UNCONFINED COMPRESSIVE STRENGTH TONS/FT <sup>2</sup>
					DESCRIPTION OF MATERIAL	
					SURFACE ELEVATION (ft.) 1,457.6	UNIT DRY WT. LBS/FT <sup>3</sup>
						STANDARD PENETRATION BLOWS/FT



The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

WATER LEVEL: 1,417.0 (05/13/21)	BORING STARTED <b>5/4/2021</b>	GEI OFFICE <b>Green Bay, WI</b>	
	BORING COMPLETED <b>5/5/2021</b>	ENTERED BY <b>CAH</b>	APPROVED BY <b>JPB</b>
NORTHING	EASTING	GEI PROJECT NO. <b>2101163</b>	PAGE NO. 1 OF 4
	RIG/FOREMAN <b>3230DT / LD</b>		

MIDWEST BORING LOG 2101163\_KEETAC\_STAGE 2 EXTERIOR EXPLORATION\_JPB.GPJ GEI DATA TEMPLATE.GDT 6/15/21



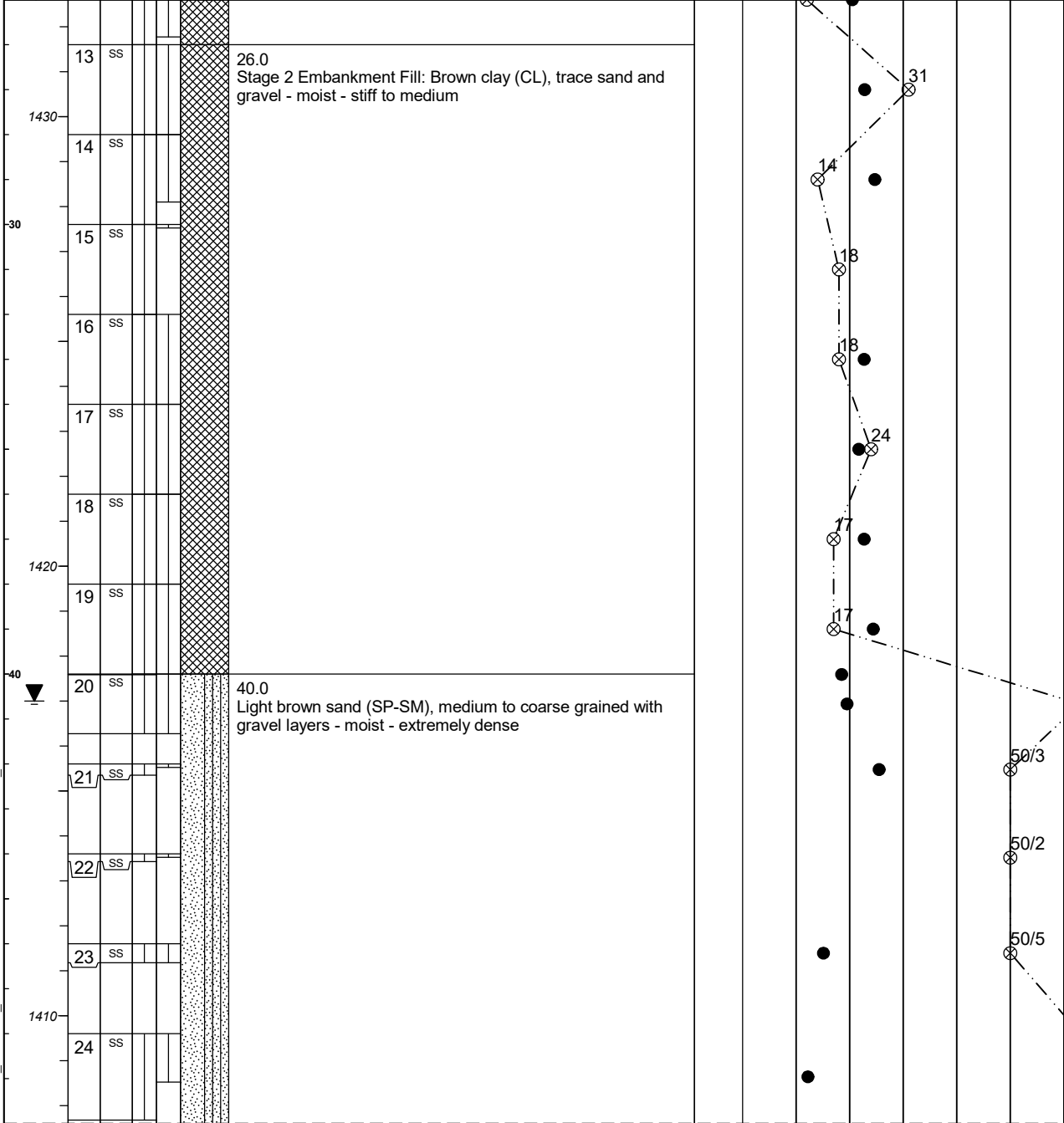
CLIENT:  
**United States Steel Corporation**

PROJECT NAME:  
**Keetac Stage 2 Exterior Exploration**

LOG OF BORING NUMBER **B2021-4EXT**

ARCHITECT-ENGINEER  
**GEI Consultants, Inc.**

DEPTH (FT) ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	LOCATION:	UNCONFINED COMPRESSIVE STRENGTH TONS/FT <sup>2</sup>	
					DESCRIPTION OF MATERIAL		1 2 3 4 5
							PLASTIC LIMIT (%) WATER CONTENT (%) LIQUID LIMIT (%)
10 20 30 40 50	UNIT DRY WT. LBS/FT <sup>3</sup>	10 12 20 30 40 50 60					



The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

WATER LEVEL: 1,417.0 (05/13/21)		BORING STARTED <b>5/4/2021</b>		GEI OFFICE <b>Green Bay, WI</b>	
		BORING COMPLETED <b>5/5/2021</b>		ENTERED BY <b>CAH</b>	
				APPROVED BY <b>JPB</b>	
NORTHING	EASTING	RIG/FOREMAN <b>3230DT / LD</b>	GEI PROJECT NO. <b>2101163</b>		PAGE NO. 2 OF 4

MIDWEST BORING LOG 2101163\_KEETAC\_STAGE 2 EXTERIOR EXPLORATION\_JPB.GPJ GEI DATA TEMPLATE.GDT 6/15/21



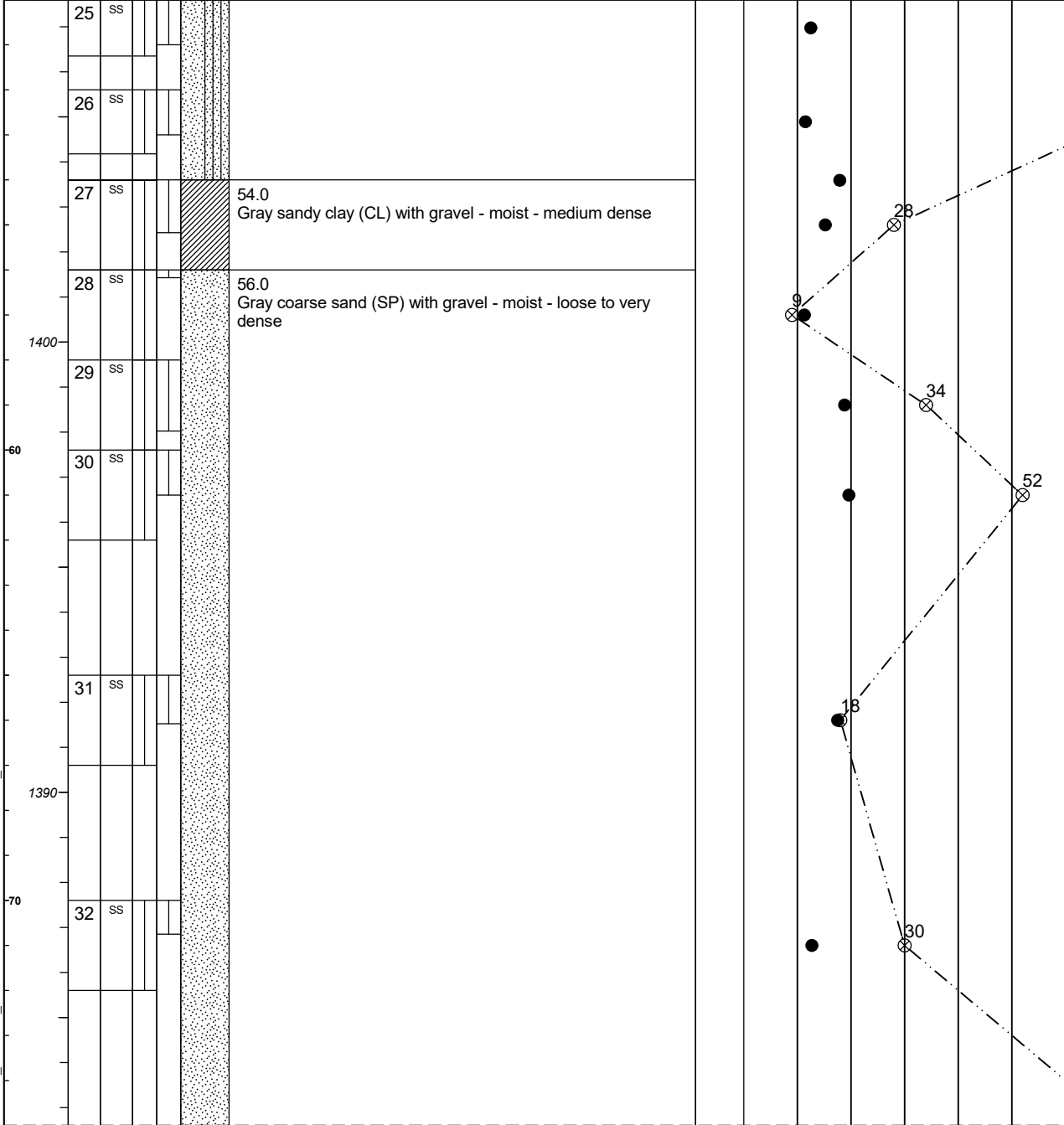
CLIENT:  
**United States Steel Corporation**

PROJECT NAME:  
**Keetac Stage 2 Exterior Exploration**

LOG OF BORING NUMBER **B2021-4EXT**

ARCHITECT-ENGINEER  
**GEI Consultants, Inc.**

DEPTH (FT) ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	LOCATION:	UNCONFINED COMPRESSIVE STRENGTH TONS/FT <sup>2</sup>
					DESCRIPTION OF MATERIAL	
					SURFACE ELEVATION (ft.) 1,457.6	PLASTIC LIMIT (%) WATER CONTENT (%) LIQUID LIMIT (%)
						10 X 20 30 40 50
						⊗ STANDARD PENETRATION BLOWS/FT
						10 20 30 40 50 60



The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

WATER LEVEL: 1,417.0 (05/13/21)	BORING STARTED 5/4/2021	GEI OFFICE <b>Green Bay, WI</b>	
	BORING COMPLETED 5/5/2021	ENTERED BY <b>CAH</b>	APPROVED BY <b>JPB</b>
NORTHING	EASTING	GEI PROJECT NO. <b>2101163</b>	PAGE NO. 3 OF 4

MIDWEST BORING LOG 2101163\_KEETAC\_STAGE 2 EXTERIOR EXPLORATION\_JPB.GPJ GEI DATA TEMPLATE.GDT 6/15/21



CLIENT:  
**United States Steel Corporation**

PROJECT NAME:  
**Keetac Stage 2 Exterior Exploration**

LOG OF BORING NUMBER **B2021-4EXT**

ARCHITECT-ENGINEER  
**GEI Consultants, Inc.**

DEPTH (FT) ELEVATION (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	LOCATION:	UNCONFINED COMPRESSIVE STRENGTH TONS/FT <sup>2</sup>	1	2	3	4	5
					DESCRIPTION OF MATERIAL		PLASTIC LIMIT (%)	WATER CONTENT (%)		LIQUID LIMIT (%)	
							10	20	30	40	50
SURFACE ELEVATION (ft.) 1,457.6						UNIT DRY WT. LBS/FT <sup>3</sup>	⊗ STANDARD PENETRATION BLOWS/FT				

1380	33	SS			77.0 End of Boring at 77.0 feet (Practical Refusal) Boring advanced to 10.0 feet with hollow-stem auger Boring advanced from 10.0 to 77.0 feet with rock bit and drilling fluid Boring flushed with water and converted to observation well upon completion 10.0 foot screen (0.010) 35/45 Red Flint Sand to 5.0 feet 5.0 feet surface seal (chips)						
1370											
1360											

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

WATER LEVEL: 1,417.0 (05/13/21)		BORING STARTED <b>5/4/2021</b>	GEI OFFICE <b>Green Bay, WI</b>	
		BORING COMPLETED <b>5/5/2021</b>	ENTERED BY <b>CAH</b>	APPROVED BY <b>JPB</b>
NORTHING	EASTING	RIG/FOREMAN <b>3230DT / LD</b>	GEI PROJECT NO. <b>2101163</b>	PAGE NO. 4 OF 4

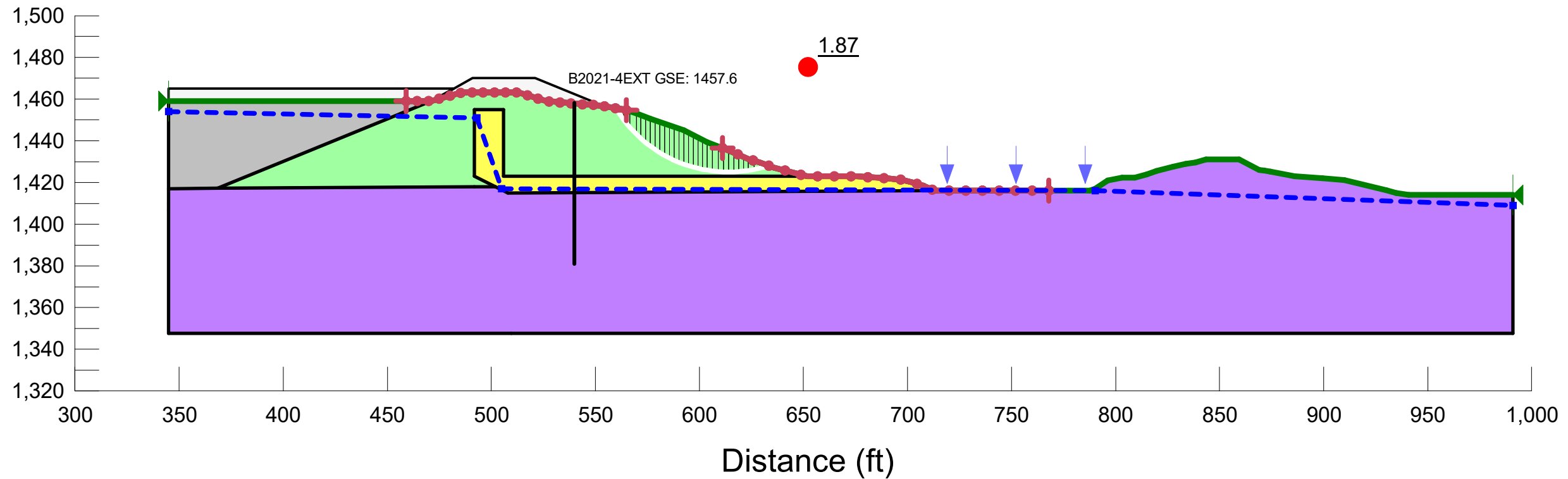
MIDWEST BORING LOG 2101163\_KEETAC\_STAGE 2 EXTERIOR EXPLORATION\_JPB.GPJ\_GEI DATA TEMPLATE.GDT\_6/15/21

1  
83


United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT

File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: ESA Existing Conditions\_4EXT (circular 1)

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
Green	Clay dike fill ESA	Mohr-Coulomb	130	0	31	0	1
Yellow	Drain Material	Mohr-Coulomb	130	0	36	0	1
Grey	Layered Fine Tailings and Slimes ESA	Mohr-Coulomb	130	0	35	0	1
Purple	Natural Foundation sand	Mohr-Coulomb	130	0	31	0	1



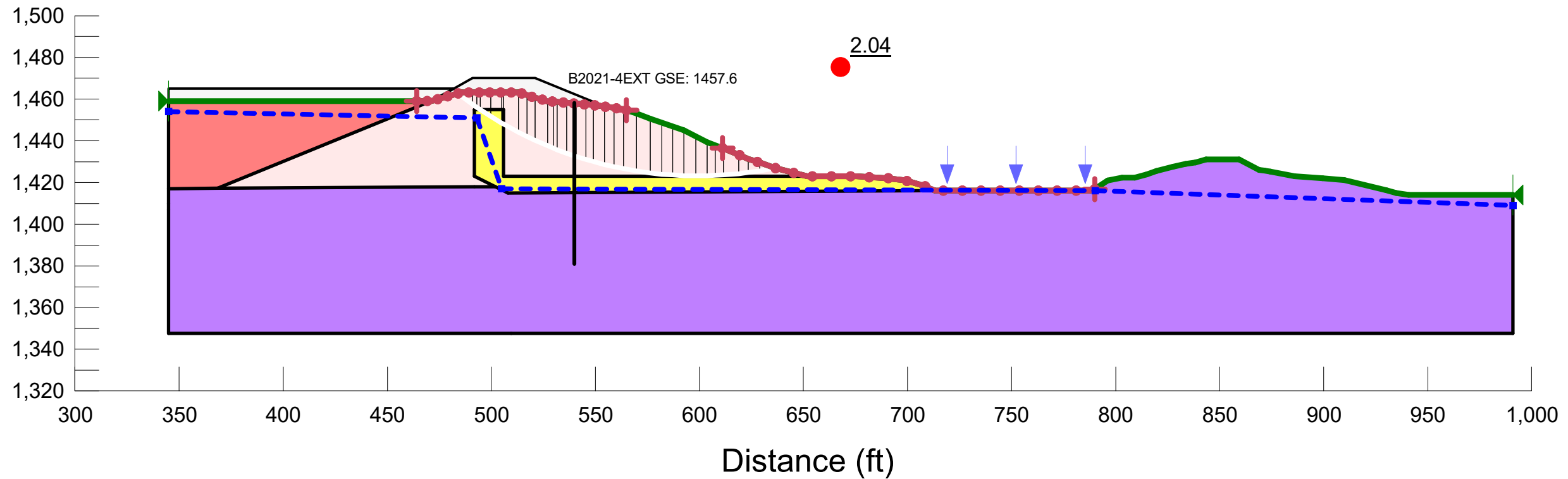
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 01/10/2022

Stage 2 Exterior Dam Raise Keetac Tailings Basin Keewatin, Minnesota	 <b>GEI</b> Consultants	ESA Existing Conditions	
United States Steel Corporation - Keetac Keewatin, Minnesota		Project 2100305	January 2022

United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT

File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: USA Existing Conditions\_4EXT (circular 1)

Color	Name	Model	Unit Weight (pcf)	Minimum Strength (psf)	Tau/Sigma Ratio	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
Light Pink	Clay dike fill USA	Mohr-Coulomb	130			1,000	0	0	1
Yellow	Drain Material	Mohr-Coulomb	130			0	36	0	1
Red	Layered Fine Tailings and Slimes USA	SHANSEP	130	400	0.23				1
Purple	Natural Foundation sand	Mohr-Coulomb	130			0	31	0	1

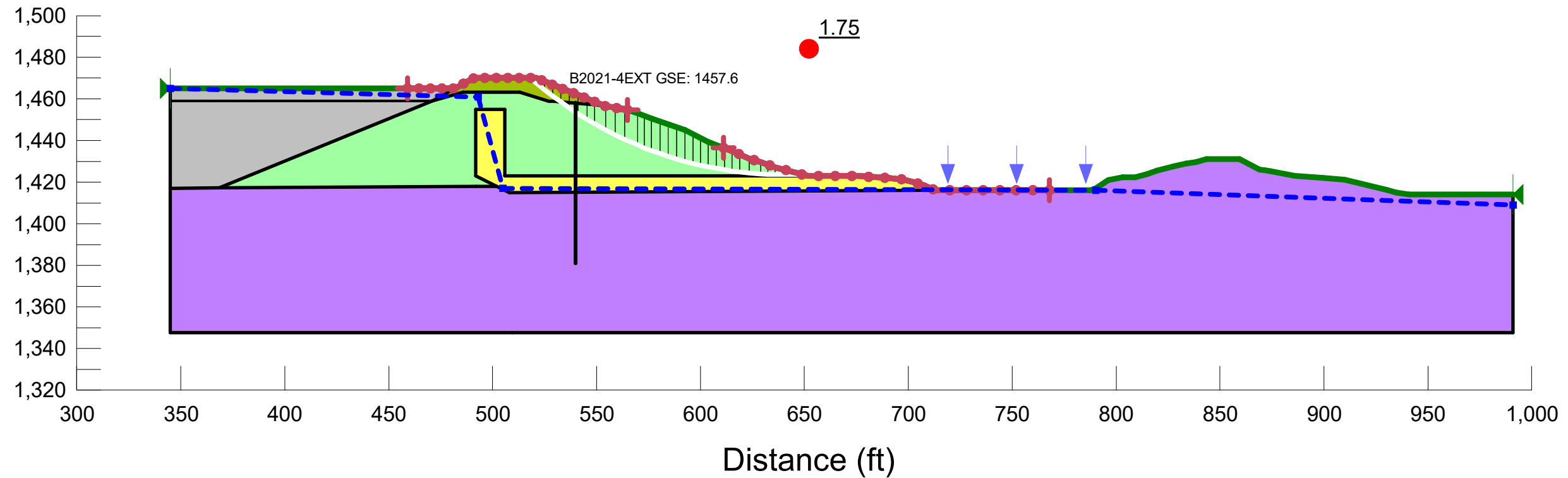


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United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT

File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: ESA Interim Future Conditions\_4EXT (circular 1)

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
Green	Buildout Clay dike fill ESA	Mohr-Coulomb	130	0	31	0	1
Light Green	Clay dike fill ESA	Mohr-Coulomb	130	0	31	0	1
Yellow	Drain Material	Mohr-Coulomb	130	0	36	0	1
Grey	Layered Fine Tailings and Slimes ESA	Mohr-Coulomb	130	0	35	0	1
Purple	Natural Foundation sand	Mohr-Coulomb	130	0	31	0	1



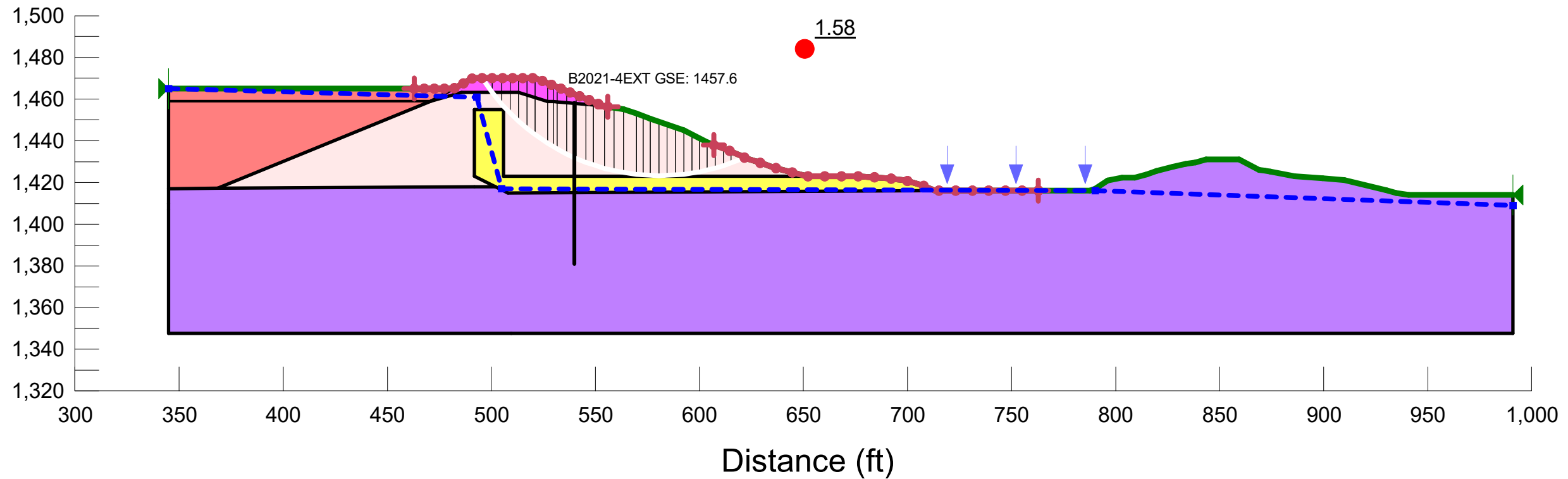
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 Last Edited By: Fritsch, Casey  
 01/10/2022

Stage 2 Exterior Dam Raise Keetac Tailings Basin Keewatin, Minnesota	 <b>GEI</b> Consultants	ESA Interim Future Conditions
United States Steel Corporation - Keetac Keewatin, Minnesota		Project 2100305 January 2022


United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT

File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: USA Interim Future Conditions\_4EXT (circular 1)

Color	Name	Model	Unit Weight (pcf)	Minimum Strength (psf)	Tau/Sigma Ratio	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
█	Buildout Clay dike fill USA	Mohr-Coulomb	130			1,000	0	0	1
█	Clay dike fill USA	Mohr-Coulomb	130			1,000	0	0	1
█	Drain Material	Mohr-Coulomb	130			0	36	0	1
█	Layered Fine Tailings and Slimes USA	SHANSEP	130	400	0.23				1
█	Natural Foundation sand	Mohr-Coulomb	130			0	31	0	1



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 Last Edited By: Fritsch, Casey  
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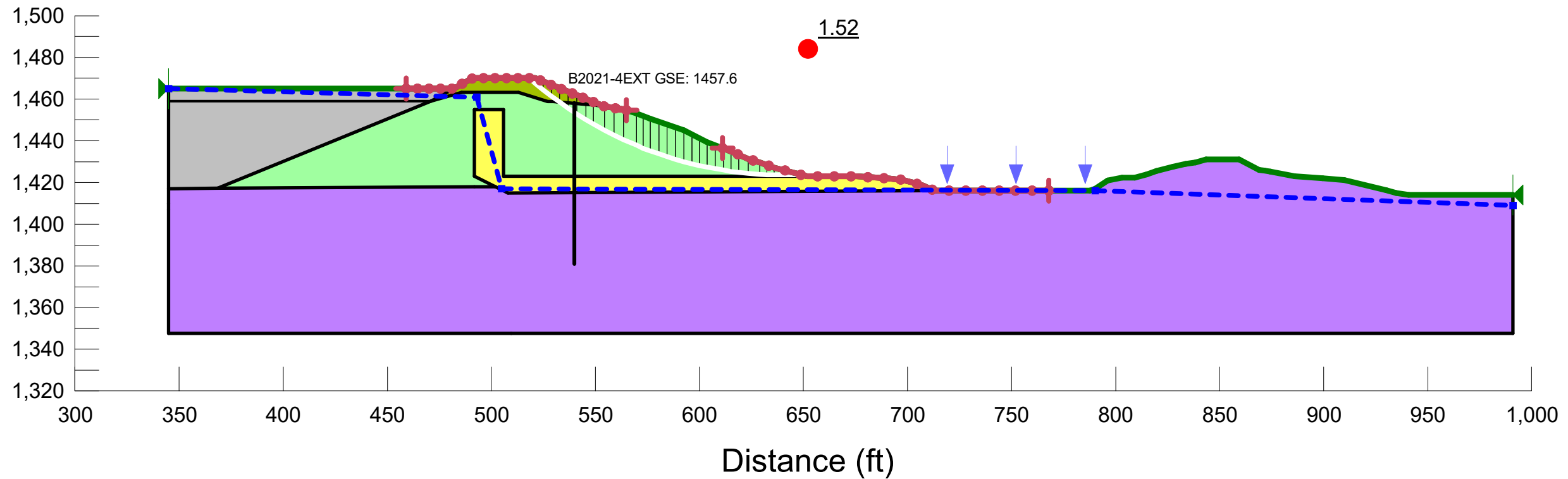
Stage 2 Exterior Dam Raise Keetac Tailings Basin Keewatin, Minnesota		USA Interim Future Conditions
United States Steel Corporation - Keetac Keewatin, Minnesota	Project 2100305	January 2022 <span style="float: right;">Fig. 4</span>

United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT


File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: ESA Interim Future Conditions\_4EXT (circular 1) +0.05g seismic

Horz Seismic Coef.: 0.05

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
Green	Buildout Clay dike fill ESA	Mohr-Coulomb	130	0	31	0	1
Light Green	Clay dike fill ESA	Mohr-Coulomb	130	0	31	0	1
Yellow	Drain Material	Mohr-Coulomb	130	0	36	0	1
Grey	Layered Fine Tailings and Slimes ESA	Mohr-Coulomb	130	0	35	0	1
Purple	Natural Foundation sand	Mohr-Coulomb	130	0	31	0	1



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 Last Edited By: Fritsch, Casey  
 01/10/2022

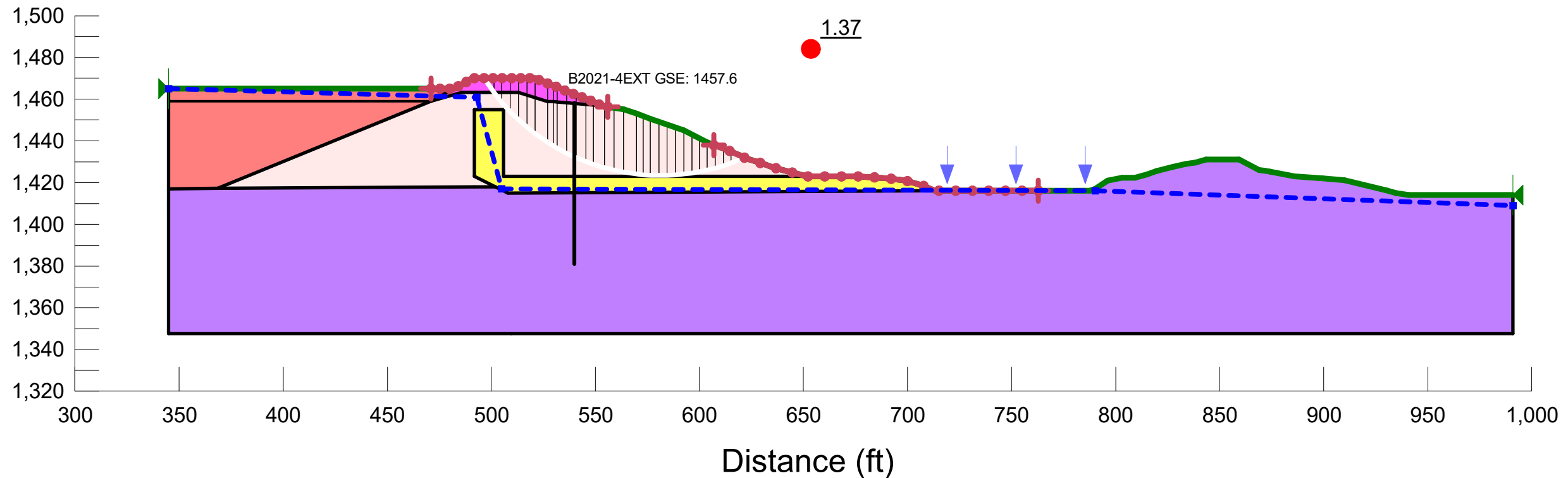
Stage 2 Exterior Dam Raise Keetac Tailings Basin Keewatin, Minnesota	 <b>GEI</b> Consultants	ESA Interim Future Conditions + 0.05g seismic
United States Steel Corporation - Keetac Keewatin, Minnesota		Project 2100305

United States Steel Corporation  
 Keetac Tailings Basin  
 Stage 2 Exterior  
 B2021-4EXT

File Name: Stage 2 Exterior B21-4EXT.gsz  
 Method: Morgenstern-Price  
 Name: USA Interim Future Conditions\_4EXT (circular 1) +0.05g seismic

Horz Seismic Coef.: 0.05

Color	Name	Model	Unit Weight (pcf)	Minimum Strength (psf)	Tau/Sigma Ratio	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
Light Blue	Buildout Clay dike fill USA	Mohr-Coulomb	130			1,000	0	0	1
Light Green	Clay dike fill USA	Mohr-Coulomb	130			1,000	0	0	1
Light Yellow	Drain Material	Mohr-Coulomb	130			0	36	0	1
Light Red	Layered Fine Tailings and Slimes USA	SHANSEP	130	400	0.23				1
Light Purple	Natural Foundation sand	Mohr-Coulomb	130			0	31	0	1



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 Last Edited By: Fritsch, Casey  
 01/10/2022

Stage 2 Exterior Dam Raise  
 Keetac Tailings Basin  
 Keewatin, Minnesota  
 United States Steel Corporation - Keetac  
 Keewatin, Minnesota

USA Interim Future  
 Conditions + 0.05g  
 seismic

Project 2100305 January 2022

Fig. 6