DETAILED PROJECT REPORT
WITH ENVIRONMENTAL ASSESSMENT

SECTION 205 FLOOD DAMAGE REDUCTION STUDY

MAD CREEK
MUSCATINE, MUSCATINE COUNTY, IOWA

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1. PURPOSE AND SCOPE

This appendix presents the general geology and specific geotechnical analyses pertinent to the project. Geological information contained in this report has been obtained and condensed from the Iowa Geological Survey reports, bulletins, and circulars. The scope of the study included a review of the *Detailed Project Report for Flood Control at Muscatine*, dated September 9, 1970. The geotechnical information has been determined from soil borings obtained for the Mad Creek Local Flood Control Project during 1948, 1955, 1956, 1968, and 1970; and from additional soil borings obtained at the Mad Creek borrow site, on top of the existing levee at the proposed construction site, and the Hershey Avenue borrow site during December 2000 and January 2001.

The proposed project includes raising the existing levees, 2,300 linear feet, and floodwalls, 1,700 linear feet, adjacent to Mad Creek and the Mississippi River; and vertically extending one existing floodgate at Mulberry Avenue, replacing one existing floodgate at 2nd Street, and installing one new closure structure across the railroad south of Washington Street. The project also requires channel sediment removal underneath and upstream of the 2nd Street Bridge. The project plans and profiles are shown on plates C102 through C105 in Appendix L.

2. LOCATION AND GEOLOGY

The Mad Creek study area is located along the Mississippi River in Muscatine, Iowa. The location of the project is shown on Figure 2 of the main report. The Mad Creek watershed drains approximately 17.3 square miles in the eastern portion of Muscatine and areas north of Muscatine in Muscatine County. The upstream portion of the watershed north of Muscatine is primarily agricultural land, but is rapidly being converted into residential subdivisions and commercial developments. The lower portion of Mad Creek is within the Muscatine city limits, flowing through an area of mixed commercial, industrial, and residential uses near the downtown area before emptying into the Mississippi River. Low-lying areas are subject to flash flooding.

The terrain is a maturely dissected area of Illinoian glacial till, covered with loess on the uplands. Much of the upland is cultivated for crops. The steep valley slopes are usually timbered pasture. Maximum relief is about 230 feet.

3. PHYSIOGRAPHY

The Mad Creek Valley complex is located in the Southern Iowa Drift Plain physiographic province, in an area of Illinoian age (132-300k years BP) glacial till. This till was deposited by an ice sheet entering Iowa from the east and northeast, and in Iowa, extends only along the western edge of the Mississippi Valley from roughly the Quad Cities to Keokuk. The average thickness of this drift is approximately 30 feet. In some areas, this till overlies a more ancient soil complex which may express itself as a weathered, iron rich zone on the flanks of valleys. This area has been relieved of ice for a sufficiently long time that most glacial features have been lost or greatly modified by erosion and deposition. During the most recent glacial event of Wisconsinan age, ending 10,000 years ago, at the same time that the dissected landscape was developing, wind-blown deposits of silt, known as loess, were being deposited over the till. In some locations, the loess mantle is thick enough to provide additional relief and alter slope angles. This leads to topography of steeply rolling hills interspersed with areas of uniformly level upland divides and level alluvial lowlands. Individual hillslopes often display a texture of finely etched rills or drainageways, which give a furrowed appearance to the terrain. The Mad Creek Valley complex is composed of a 3.5-mile upper section, with a steeper gradient; and a lower section of 2.5 miles which begins to flatten out downstream of the juncture of Mad Creek and its western branch below McKee Park. The upper section drops from a divide elevation of roughly 730 feet MSL to approximately 600 feet near the juncture. From here, it flows to the Mississippi, discharging at 540 feet elevation, depending on river stage. In the past, this relatively modest gradient was exploited by railroad companies that aligned their roadbeds along the valleys to gain elevation to the uplands. Several abandoned roadbeds remain throughout the complex.

4. SUBSURFACE EXPLORATIONS

Numerous borings were taken for the construction of the Mad Creek Local Flood Control Project during 1948, 1955, and 1956. During 1968 and 1970, additional borings were taken to make improvements to the existing project. To further determine subsurface conditions for this report, the Rock Island District's Geotechnical Branch took four 4-inch-diameter hand augers along the existing levee, sampling every 1 to 2 feet. These are Borings MC-01-1 through MC-01-4 that were taken January 17, 2001. The plans and profiles of the preferred plan are shown on plates C102 through C105 in Appendix L. Boring logs are shown on plate C101 in Appendix L.

Both Mad Creek borrow site and Hershey Avenue borrow site borings were taken by Terracon, Inc., of Cedar Rapids, Iowa. A CME 850 all-terrain rotary drill rig was used. Either a flight auger or a hollow stem auger with SPT tests (split spoon) taken every 2-1/2 feet was used to obtain samples.

Three borings were taken at the Mad Creek borrow site, each between 25 and 30 feet deep. The borings are MCB-00-1, MCB-00-2, and MCB-00-3. Two borings were taken at the Hershey Avenue borrow site, one about 45 feet deep and the other about 20 feet deep. The borings are MCB-00-4 and MCB-00-5, with these boring logs also shown on plate C101 in Appendix L. All borrow site borings were taken December 20, 2000.

Laboratory testing was performed at the Rock Island District Geotechnical Branch soil laboratory. Natural moisture content, percent passing the #200 sieve, and Atterberg (liquid and plastic) limits were taken as needed from the soil samples.

5. BEDROCK

The bedrock of the project area consists of the Pennsylvanian rocks. These Pennsylvanian rocks for the most part consist of cyclic deposits of shale, siltstone, and sandstone with some limestone. Outcrops of Pennsylvanian rocks occur at a few places along Mad Creek. Bedrock was encountered in numerous borings. The depth of the bedrock encountered along the existing project varies approximately from elevation 504 feet MSL to 539 feet MSL.

6. PROPOSED EMBANKMENTS

The Rock Island District built the original Mad Creek Local Flood Control Project in 1961. In 1983, the District extended and upgraded the project, which included a levee and floodwall near the confluence of Geneva Creek with Mad Creek. The levees along the Mississippi River and Mad Creek are composed of semi-compacted impervious sandy lean clay (CL). (See Appendix L for the project plans and profiles.)

Rock Island District Geotechnical Branch personnel inspected the existing levee during May 2001 high-water periods. The entire levee was found to be in satisfactory condition. No evidence of underseepage or through-seepage distress was observed landward or on the side slopes of the entire levee alignment, respectively, during the field inspections. The levee embankments were also noted to be in satisfactory condition with regards to slope stability.

The levee would be raised from 1 to 2 feet above the existing design grade using compacted impervious fill. The compacted impervious fill would be placed on the 1 vertical on 2.5 horizontal landside and riverside slopes of the levee, and slopes would be seeded. The crown of the levee would be a minimum 8 feet wide. (See Appendix L for the plans and profiles and typical cross sections of the levee.) Impervious fill would require moisture and dry density control for the proposed levee to ensure that through-seepage would be eliminated. For moisture control, a range of plus 2 to minus 2 percentage points deviation from the optimum moisture content would be used. For required density, the maximum dry density of 95% would be achieved by controlling the uncompacted lift thickness using standard compaction equipment.

7. FOUNDATIONS FOR EMBANKMENTS

The existing levee landside and riverside slopes levee foundation, and the crown (where the levee will be raised), will be cleared, grubbed, and stripped to remove unsuitable materials. All tap roots, lateral roots, or other projections over 1.5 inches in diameter within the improved levee foundation area will be removed to a depth of 3 feet below natural ground surface. In order to maintain the integrity of the levee, a marginal strip from the slope of the levee would be cleared.

An extensive subsurface investigation was made to ascertain the levee foundation conditions during 1948, 1955, 1956, 1968, and 1970. Four additional hand auger borings, MC-01-1 through MC01-4, were taken during January 2001 on top of the existing levee to ascertain the existing levee composition. According to borings, which were pertinent to the levee raise study, the foundation material consists of alluvial deposits. Atterberg limits, moisture contents, and shear strength tests indicate no exceptionally weak soils. (See Appendix L for boring logs.) The top stratum varies in thickness from 7 feet to more than 34 feet and consists of normally consolidated impervious and semi-impervious alluvial deposits. A few borings show a top layer of 2 to 6 feet consisting of rubble that is underlain by layers of impervious and semi-impervious alluvial deposits. One exception to this is boring 75 obtained in February 1956. It indicates a rubble thickness of approximately 30 feet underlain by bedrock.

Impervious and semi-impervious alluvial deposits are underlain by pervious alluvial deposits, varying in thickness from 2 to 19 feet deep. Detailed descriptions of the encountered materials are shown on the boring logs on plate C101 in Appendix L. In borings 33, 63, and 45, a 2-foot-thick layer of sand (SP) was found interbedded between impervious and semi-impervious alluvial deposits.

An inspection trench will be not required for increasing the flood protection height since the U.S. Army Corps of Engineers, Rock Island District, originally built the project. Original construction of the system required an inspection trench excavated along the entire length of the project.

8. FOUNDATION FOR OTHER STRUCTURES

Raising of the Existing Retaining Wall. The existing retaining wall is to be raised by a maximum of 2 feet at several locations as indicated by their stationing. Borings at these locations indicate the following foundation soils under the base of the wall:

a. <u>Station 0+10 to Station 8+39</u>. A predominantly lean clay (CL) layer of 0 to 11 feet lays directly below the wall base. Beneath this is a mixture of poorly graded sand (SP) and silty sand (SM) until bedrock is encountered about 30 feet below the wall base.

b. <u>Station 14+87 to Station 15+42</u>. The soil beneath the wall base is a 12-foot layer of predominantly lean clay (CL) with some rubble. Beneath this layer is well-graded sand (SW). Bedrock is encountered about 20 feet below the wall base.

c. <u>Station 17+01 to Station 17+26</u>. An 8-foot layer of lean clay (CL) lies beneath the wall base. Beneath this layer is a silty sand (SM). Bedrock is encountered 20 feet below the wall base.

d. <u>Station 17+55 to Station 20+78</u>. A lean clay (CL) layer 2 to 3 feet thick lies directly beneath the wall base. Predominantly silty sand (SM) underlays the clay. Bedrock is encountered 33 feet below the wall base.

e. <u>Station 28+20 to 30+46</u>. A layer 3 to 8 feet thick of lean clay (CL) lies directly beneath the wall base. A silty sand (SM) underlays the clay. Bedrock is encountered about 28 feet below the wall base.

f. <u>Existing Structure at Mulberry Street (Station 0+25N)</u>. The soil beneath the bottom of the structure is predominantly a silty sand (SM). Bedrock is encountered 25 feet below the bottom of the structure.

g. <u>New Wall and Closure Structure at 2nd Street (Station 15+40 to Station 17+55)</u>. A layer 6 to 12 feet thick of predominantly lean clay (CL) underlays the bottom of the structure and wall. Silty sand (SM) lays beneath the clay. Bedrock is encountered about 17 feet below the wall base.

h. <u>I&M Rail Link Railroad Closure (Station 5+70S)</u>. The borings in the vicinity indicate a layer of lean clay (CL) beneath the bottom of the structure that is about 10 feet thick. Predominantly silty sand (SM) lays beneath this. Bedrock is encountered about 45 feet beneath the bottom of the structure.

9. GROUNDWATER

Water levels were measured during the boring operation. The groundwater levels are noted in the borings shown on boring logs in Appendix K, plate C101. They are noted with a "wt" on each boring.

The water table was found to be consistent throughout the project area (Station 0+00 to Station 36+00), ranging between elevations 539 feet MSL to 543 feet MSL. This put the water table between 3 and 10 feet below the base of the existing levee.

The water tables noted were at one specific point in time. However, groundwater tables tend to fluctuate during different seasons in the year.

10. SLOPE STABILITY

A detailed study of all existing embankment and channel improvement sections and soil profiles along the embankment alignment indicated that the existing embankment near Stations 12+00 and 21+50 and channel improvement at the existing parking lot are the most critical with respect to slope stability. The sections were determined to be in those reaches where the existing levee will be raised and the existing channel is needed to be improved. The selected critical sections were analyzed to check the integrity of the existing levee, with UTEXAS4 software program, Spencer methods, in accordance with EM 110-2-1902, *Engineering Design Stability of Earth and Rockfill Dams*, dated 1 April 1970.

The maximum height of the embankment at these selected sections is approximately 16 feet. The typical cross sections are shown on plate C106 in Appendix L. The maximum height of the channel at the selected section is 23 feet, and is shown on plate C106.

To estimate the stability of the embankment, a range of conservative undrained shear strengths (Q) was assumed for the most severe configuration of compacted embankment and foundation. The Undrained shear strength of the compacted impervious embankment is estimated to be at least 800 psf with no friction angle; this estimate is based on test results of similar soils from construction of similar projects. The embankment in these reaches was constructed and will be raised with compacted sandy lean clay (till). The foundation along these reaches consists generally of sandy lean clay (CL), clayey silt (ML-CL), and silty sand (SM). Shear strength estimates for sandy lean clay (CL) and clayey silt (ML-CL) vary from 450 psf to 600 psf. For silty sand (SM), shear strength is estimated to be 200 psf and a friction angle of 20 degrees based on several soils properties, undisturbed soil samples test results of similar soils, and engineering judgment. The selected shear strength values are shown on plates C-1, C-2, and C-3. It should also be noted that the project has not experienced any slope stability problems since the construction of the project during 1961 and after upgrading the project during 1983.

Successive trials of various sliding surfaces were analyzed, and determination of the critical failure arc having the lowest safety factor was made. The summary of the slope stability analyses for critical sections and the solutions of the most critical arcs appear on plates C-1, C-2, and C-3. The computed minimum safety factors were found to be 1.83 at Station 12+00, 1.92 at Station 21+50, and 1.63 for the channel improvement. These exceed the 1.3 that is required by EM 1110-2-1913, *Design and Construction of Levees*, dated March 31, 1978. Therefore, no slope stability problems are expected. A sudden draw down loading and seepage conditions were not evaluated since high water levels will be of such short duration that saturation of compacted embankment cannot occur.

11. UNDERSEEPAGE AND BERM ANALYSES

The underseepage and berm analyses for the Mad Creek Flood Damage Reduction project are based on a study of thickness and permeability, and characteristics of the impervious stratum and pervious substratum, in addition to the extent of the riverward and landward top strata. Based on geotechnical investigations, which were performed during 1948, 1955, and 1956, and additional borings which were taken during 1968 and 1970 to upgrade the existing project during 1983, the top stratum varies in thickness from 7 feet to more than 34 feet and consists of normally consolidated impervious and semi-impervious alluvial deposits. The *Detailed Project Report for Flood Control at Muscatine*, dated September 9, 1970, was also reviewed. It was determined that underseepage is not considered to be a problem since the foundation materials are impervious or semi-impervious and the duration of flooding is very short. It should also be noted that the project has not experienced any underseepage problems since the construction of the project during 1961 and after upgrading the project during 1983.

12. THROUGH-SEEPAGE ANALYSIS

The Mad Creek Flood Damage Reduction project will not be subjected to high water loading for a long enough time to cause through-seepage in its impervious compacted materials. Therefore, seepage is not expected through the levee.

13. SETTLEMENT

The relatively small amount of additional material (1 to 2 feet) to improve the levee will not add an appreciable load to the foundation. Due to the existing load that has been imposed for some 40 years on the foundation, no significant amounts of settlement are anticipated for the improved levee. Therefore, an overbuild will not be required.

14. MATERIAL AT PROPOSED BORROW SITES

Two borrow sites were investigated. Mad Creek borrow site was investigated as a possible source of fill for the once proposed Mad Creek and Geneva Creek detention reservoirs (non-selected alternative). No borings were taken at the proposed detention reservoir locations.

Hershey borrow site was investigated as a source of fill for the proposed raising of the existing levees along Station 0+00 to Station 36+00. Both borrow sites were investigated on December 20, 2000. The drilling of the borings was performed by Terracon, Inc., of Cedar Rapids, Iowa, using a CME 850 all-terrain rotary drill rig. Three borings were taken at the Mad Creek borrow site (MCB-00-1, MCB-00-2, MCB-00-3) and two borings were taken at the Hershey borrow site (MCB-00-4, MCB-00-5). The boring logs are shown on plate C101 in Appendix L.

a. Mad Creek Borrow Site. This site is about 45 acres in size and is located at the crest of a shallowly sloping hill in the middle of a horse ranch pasture off 180th Street just north of Muscatine, Iowa. It is about 0.5 mile from the once proposed Mad Creek detention reservoir and about 4.5 miles from the proposed Geneva Creek detention pond.

All three borings taken were about 27 feet deep. The top 14 feet is predominantly a clayey sand (SC) with moisture contents ranging from 8% to 17%, averaging about 10%. Percent of fine materials (silts or clays) in the sand ranged from 8% to 33%.

The sand layer is underlain by a predominantly lean clay (CL) with moisture contents of 16% to 22%, averaging about 17%. Percent of fine materials was between 65% and 90% in the lean clay.

The overall soil in the area can generally be considered a glacial till. The groundwater table was only encountered at boring MCB-00-1. It was encountered at elevation 658 feet NGVD, about 25 feet below the top of the boring.

b. <u>Hershey Borrow Site</u>. This site is about 8.5 acres in size and is located just off Hershey Street near downtown Muscatine. It is a working borrow site in that it has been used in the recent past. Access to the site is at the base of a partially excavated embankment with slopes of about 1H:2.5V. The top of the embankment is about 50 feet. The site is about 2-1/4 miles from the proposed construction site at Mad Creek.

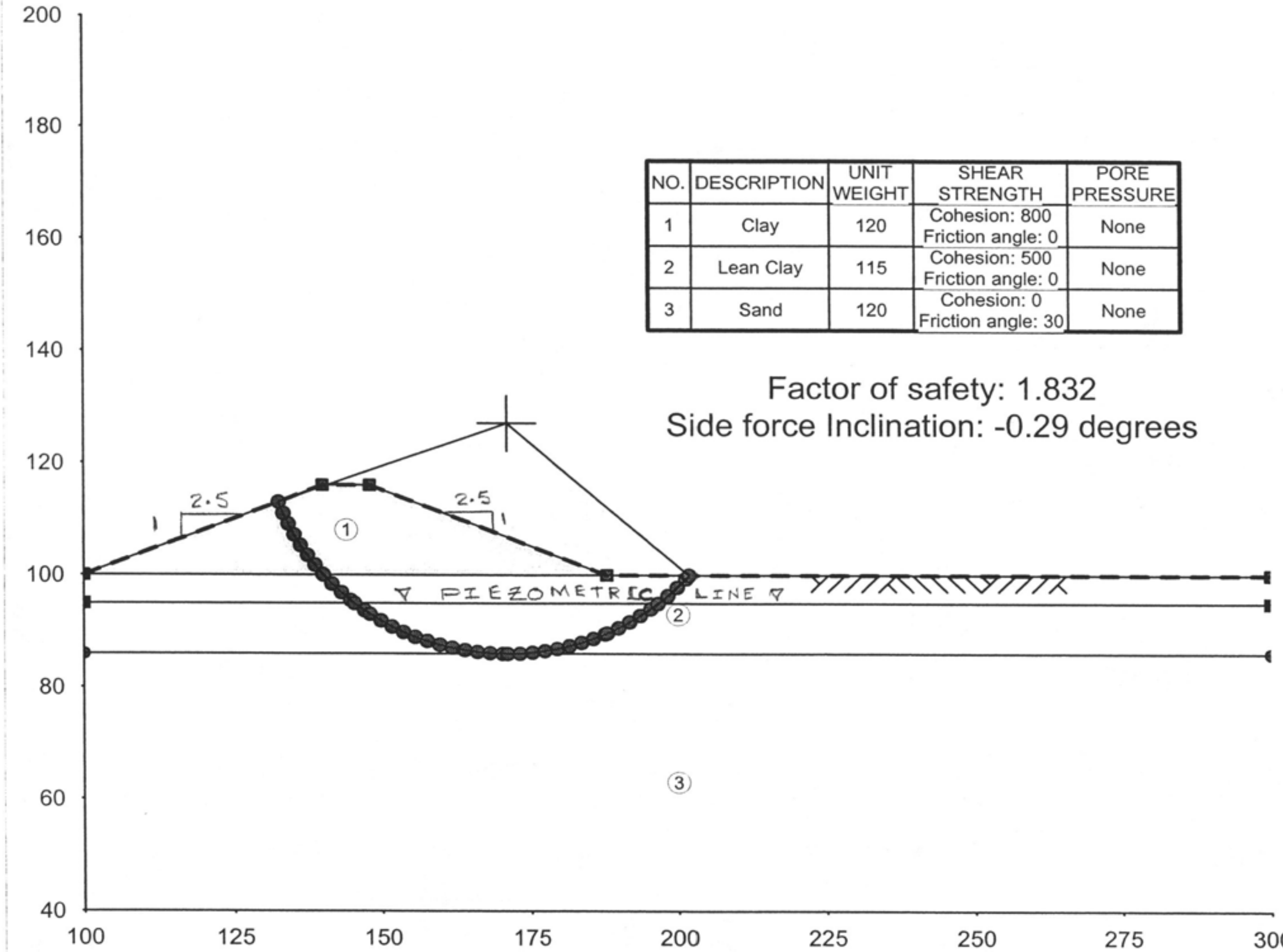
Boring MCB-00-4 was taken near the top of the embankment and is 46 feet deep. Boring MCB-00-5 was taken at a bench about a third of the way up the embankment and is 17 feet deep. No groundwater table was encountered.

The soil encountered was predominantly a sandy lean clay (CL) with lenses of clayey sand (SC), essentially a glacial till. The sandy lean clay has moisture contents between 14% and 24%. Its fine soil percentage is between 52% and 83%.

The clayey sand encountered has moisture contents between 5% and 14%. Its fine soil percentage is between 15% and 48%.

Mixing the soil would create a very acceptable lean clay (CL) that could be used for the proposed raising of the existing levees at Mad Creek.

Mad Creek LFP - Section 205 - Stewart



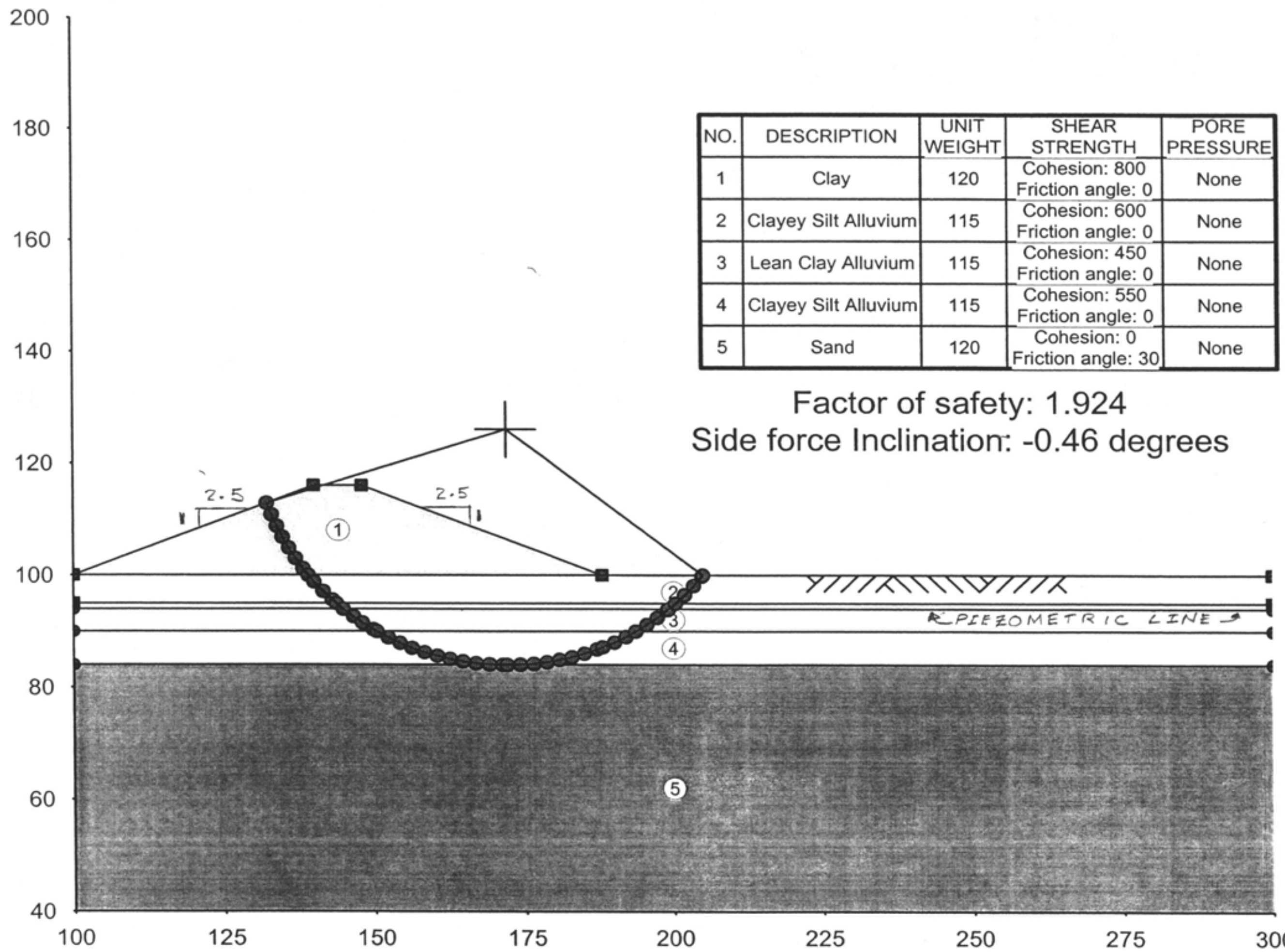
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Clay	120	Cohesion: 800 Friction angle: 0	None
2	Lean Clay	115	Cohesion: 500 Friction angle: 0	None
3	Sand	120	Cohesion: 0 Friction angle: 30	None

Factor of safety: 1.832
Side force Inclination: -0.29 degrees

Date: Wed Aug 08 2001 Filename: C:\WINUT4\MadCreek.UT4 Time: 06:25:11

PLATE C-1

Mad Creek LFP - Section 205 - Stewart



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Clay	120	Cohesion: 800 Friction angle: 0	None
2	Clayey Silt Alluvium	115	Cohesion: 600 Friction angle: 0	None
3	Lean Clay Alluvium	115	Cohesion: 450 Friction angle: 0	None
4	Clayey Silt Alluvium	115	Cohesion: 550 Friction angle: 0	None
5	Sand	120	Cohesion: 0 Friction angle: 30	None

Factor of safety: 1.924
Side force Inclination: -0.46 degrees

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PLATE C-2

Mad Creek LFP - Section 205 - Stewart

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Clayey Silt	120	Cohesion: 600 Friction angle: 0	None
2	Lean Clay	115	Cohesion: 550 Friction angle: 0	None
3	Silty Sand	120	Cohesion: 200 Friction angle: 20	None
4	Bedrock	160	Cohesion: 0 Friction angle: 45	None

Factor of safety: 1.629
Side force Inclination: -2.93 degrees

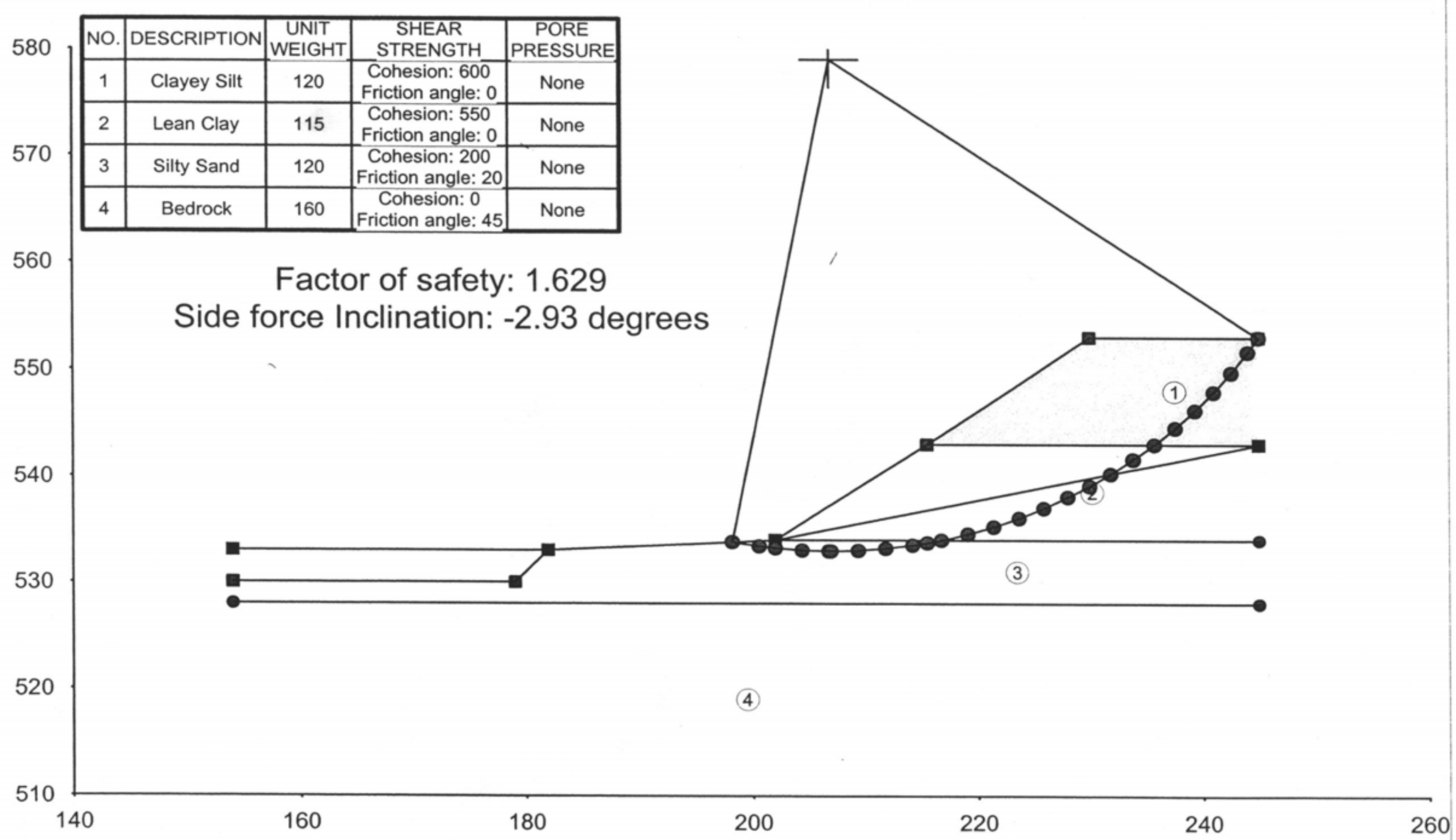

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PLATE C-3