2013

Elkhart River and Christiana Creek Dams

Appendix B- Geotechnical

Chicago & Detroit Districts
US Army Corps of Engineers
7/30/2013

ELKHART

PLANNING AND DESIGN ANALYSIS REPORT

GEOTECHNICAL APPENDIX

APPENDIX B

U.S. Army Corps of Engineers, Chicago District
Geotechnical and Survey Section

March 28, 2013

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GEOTECHNICAL APPENDIX
APPENDIX B

INTRODUCTION

General

1. The Army Corps of Engineers is evaluating alternatives to restore the ecology and hydrology of Christiana Creek and the lower section of the Elkhart River in Elkhart, Indiana. The study will be performed under Section 506 Fisheries and Ecosystem Restoration in cooperation with the non-Federal sponsor, the City of Elkhart. The alternatives include the removal of a dam located on the Elkhart River and a second dam located on Christiana Creek. This Geotechnical Appendix presents a summary of the geology and recommendations based on the removal of the dams.

Site Description

2. The project is located in north central Indiana in Elkhart and is part of the St. Joseph River system (Figure B-1). The St. Joseph River extends a total of 210 miles through portions of southern Michigan and northern Indiana. The St. Joseph River flows into Lake Michigan approximately 65 miles downstream from Elkhart.

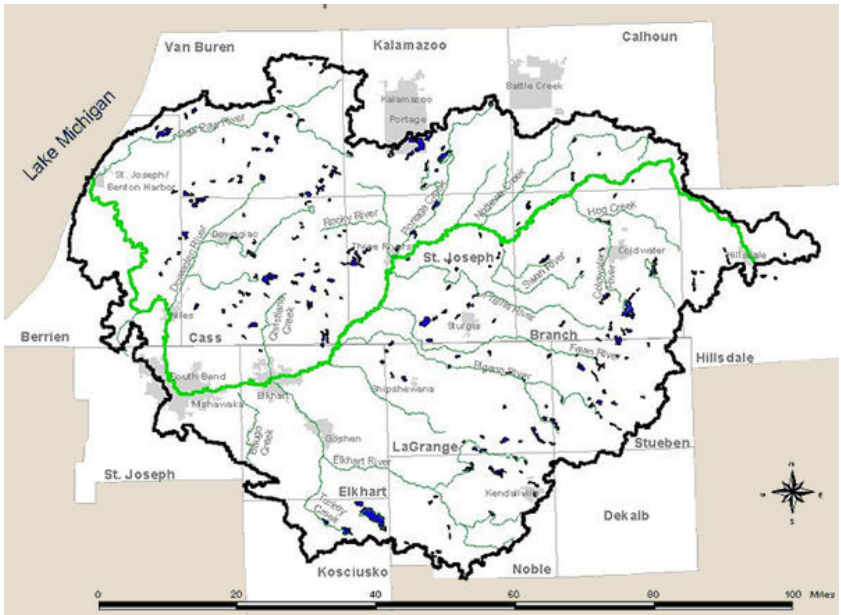

Figure B-1. Site Location Map

3. The proposed restoration for the Elkhart River is located northeast of Elkhart Avenue and Waterfall Drive in the City of Elkhart, Indiana and the proposed restoration for Christiana Creek is located northeast of East Crawford and Cassopolis Street (High Dive Park) in the City of Elkhart, Indiana (Figure B-2**).** The dam located on the Elkhart River and was constructed in 1832 and was permanently rebuilt in 1875. The second dam located on Christiana Creek, is about 60-years old.

Figure B-2. Site Location Map

4. Christiana Creek Dam is about 3-feet high and 50-feet long. This dam is approximately 60-years old. The dam consists of four 3.5 x 3.5 foot concrete piers, one on each bank and two located in-stream. Connecting the piers are three steel lengths, the center piece of which is lower than the outer sections. No sediment sampling has been conducted behind Christiana Creek Dam. However based on site visits, sand and gravel seem to be held back by this dam.

5. Elkhart River Dam is about 10-feet high and 147-feet long. The first dam in this location was constructed in 1832 and it was permanently rebuilt in 1875. The construction materials of Elkhart River Dam are unknown; however they are arranged in a manner so that the water cascades. The river water is turbid and upstream of the dam the river bottom cannot be clearly seen. Upstream of the edge of the dam is approximately 7 feet of concrete just visible below the water surface.

SUBSURFACE CONDITIONS

Surficial Geology

6. The Elkhart area experienced three major glaciations: the pre-Illinoisan, Illinoisan, and the Wisconsin. The glaciers deposited various types of sediment. Till is a homogenous, unsorted mixture of particles ranging in size from clay to boulders deposited directly by the ice; Outwash is sediment that is transported and deposited by the direct action of glacial melt water, and consists of sorted and stratified sand and gravel.

7. Outwash deposits extend northwestward and northward into broad lowland that can be subdivided into two parts in the Elkhart area. The northeastern part has an assortment of gravel-filled outwash channels, ground moraines composed of loamy till, and hummocky ridges. The southwestern part is characterized by larger outwash channels that are now valleys of major tributaries of the St. Joseph River, including the Elkhart, Little Elkhart and Pigeon Rivers.

8. The Kankakee Lowland is a broad, flat region that extends from Illinois, across northwestern Indiana, and into southwestern Michigan. The part extending east of South Bend is now occupied by the St. Joseph River. The lowland is a level plain covered by fine-grained Holocene alluvium that is underlain by thick outwash sand and gravel which overlies lake muds. Soils in the St. Joseph basin generally fall within one of three classes: 1) sandy or loamy soils developed on outwash and allumium; 2) silty or clayey soils developed on till; and 3) muck soils developed in depressional wetland areas.

Figure B-3. Indiana Surficial Geology Map (IGS)

9. The thickness of overburden material within the St. Joseph River basin ranges from less than 30 feet to 500 feet in the eastern part of the basin. The thickness in the Elkhart area is about 200 feet.

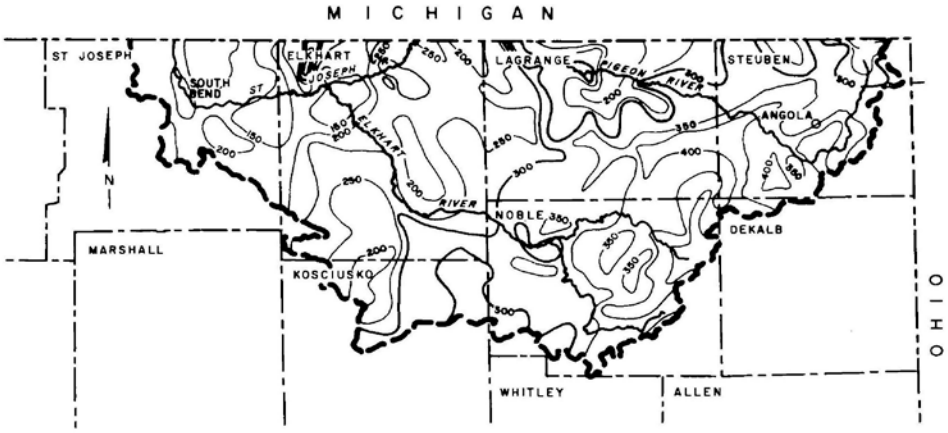

Figure B-4. Thickness of Unconsolidated Materials (IGS)

10. Dominant soils in this area include the excessively drained Psamments and Bristol soils; and the moderately well drained Bronson soils. These are all loamy sandy soils with water tables deeper than 6 ft. The soils of the Elkhart River and Christiana Creek are shown in the figure below (NRCS).

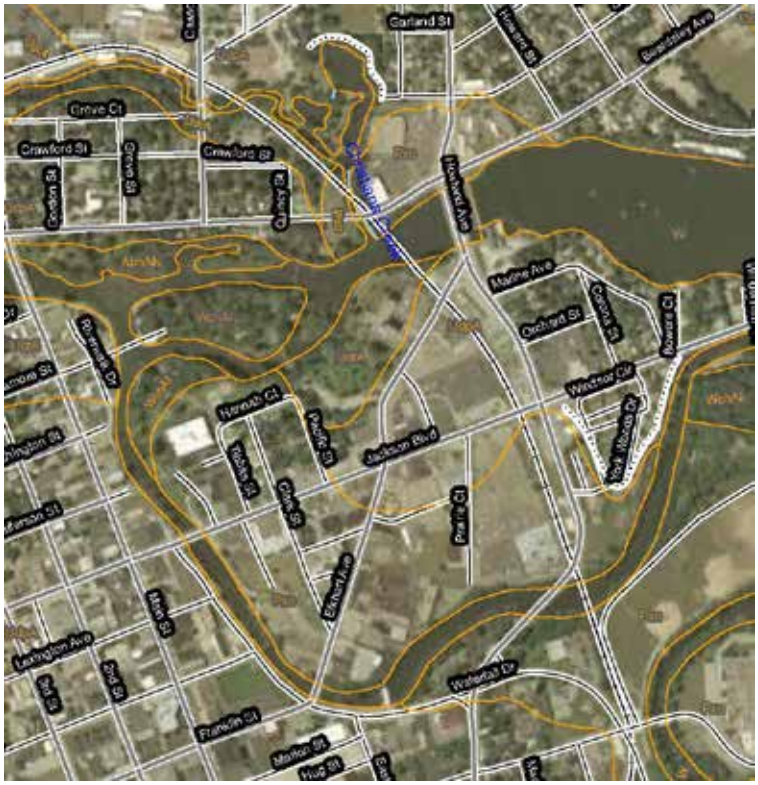

Figure B-5. Soil Map (NRCS)

Bedrock Geology

11. The principal bedrock formations in the Elkhart River and Christiana Creek watersheds are associated mainly with rocks of Silurian to middle Mississippian age, and consist primarily of layered Paleozoic limestone, dolomite, sandstone, siltstone and shale. The bedrock underlying the St. Joseph River basin consists mainly of layered Paleozoic

limestone, dolomite, sandstone, siltstone and shale. Beneath these rocks are Precambrian igneous basement rocks composed mainly of granite, basalt and arkose.

12. The sedimentary rock sequence ranging between the uppermost and lowermost units, the Coldwater Shale and the Mt. Simon Sandstone spans Mississippian through Cambrian time, from about 360 million to more than 600 million years ago. Three major Shale units can be found within the St. Joseph River basin. The main branch of the Elkhart River lies above the alternating beds of black and gray-green of the Ellsworth Shale unit. The slightly silty, gray to greenish-gray Coldwater Shale lies in the northeast and the brownish-black, noncalcareous Antrim Shale lies to the south.

13. The bedrock is deformed regionally to form the Kankakee and Cincinnati Arches. The sedimentary formations dip about 30 feet per mile to the northeast into the major structural feature called the Michigan Basin along the northern side. The rocks at the bedrock surface become progressively younger toward the northeast.

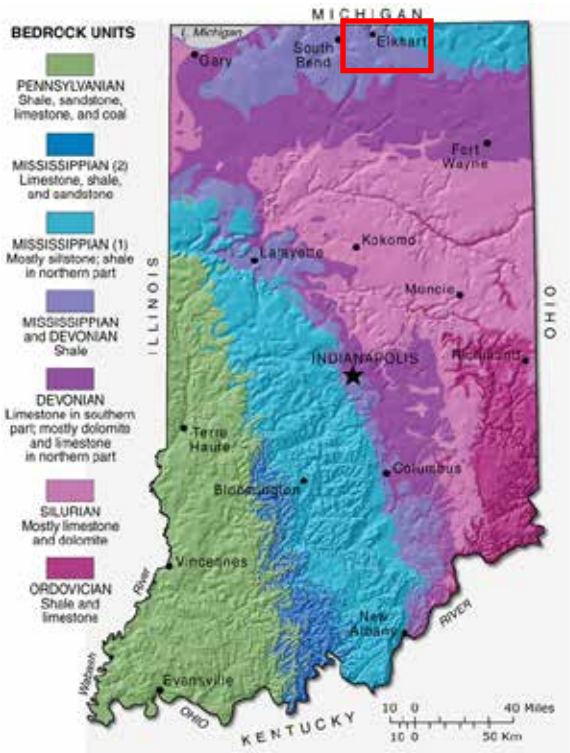

Figure B-6. Indiana Bedrock Geology Map (IGS)

Investigations

<u>TesTech (2011)</u>

14. A concrete coring and testing investigation was performed by TesTech in 2011 on Elkhart Dam. The investigation included three cores to be drilled to a depth of 10 ft from the top of the dam in order to determine the thickness and strength of the existing concrete cap and the fill material below the cap. The Contractor encountered refusal at 1.75 ft to 5 ft below the existing surface of the dam. The thickness of the cap varied between 3 inches to 1 ft. The core holes were tremie backfilled with 4500 psi grout and some loss of grout was noted due to voids.

Figure B-7. TesTech Core Locations

15. TesTech encountered large cobbles and boulders during the coring which may have been part of the original dam fill. Clay soils were observed in the smaller holes used to install the safety cables. It was undetermined whether these were part of the dam or sediment that may have washed into the voids. See the figure below. Sand was observed all around the dam but none was observed in the cores.

Figure B-8. Concrete core from C-3

<u>FutureNet Group, Inc (2011)</u>

16. A total of twenty one (21) sediment samples were collected from Elkhart River and Christiana Creek by FutureNet Group, Inc to obtain physical data and chemical data. Geotechnical testing was performed on nine samples – one each from Management Unit E1, E2, E3 and from Christiana Creek, as well as on all five samples from Management Unit E4.

17. Geotechnical testing included grain size analysis (ASTM D 422), moisture content (ASTM D 2216), Atterberg limits (ASTM D 4318), specific gravity (ASTM D 854), direct shear tests (ASTM D 3080), and soil classification (ASTM D 2488). All of the

geotechnical testing was performed by Test America Laboratories, Inc. except for the direct shear tests which were performed by Geotechnics. The geotechnical results were reviewed by USACE Chicago District TS-DG.

18. Most of the samples were classified as poorly graded sand with little fines. Sample ER2011-E4-05 was classified as well graded gravel. ER2011-E3-02 was incorrectly classified as SP-SM and should have been classified as SP since the amount of fines passing the #200 sieve was less that 5%. Sample ER2011-E4-04 is on the borderline between poorly graded sand and silty sand since the fines are between 5% to 12%. However, the fines are considered minimal. The results of the testing in shown in the table below.

Table B-1. Test Results

Sample	% Passing #200 Sieve	Soil Classification	Atterberg Limits	Specific Gravity	Direct Shear
ER2011-E1-02	3.70%	SP	NP	2.64	C = 1.38 psi, φ = 41.7°
ER2011-E2-02	1.20%	SP	NP	2.67	C = 0.39 psi, φ = 39.7°
ER2011-E3-02	3.40%	SP-SM	NP	2.71	C = 2.42 psi, φ = 42.1°
ER2011-E4-01	0.80%	SP	NP	2.70	N/A
ER2011-E4-02	1.20%	SP	NP	2.65	C = 1.46 psi, φ = 37.0°
ER2011-E4-03	1.70%	SP	NP	2.66	C = 2.13 psi, φ = 44.3°
ER2011-E4-04	5.20%	Sp-SM	NP	2.67	C = 0.00 psi, φ = 51.1°
ER2011-E4-05	1.10%	GW	NP	2.68	C = 2.12 psi, φ = 43.2°
CC2011-02	0.50%	SP	NP	2.69	C = 1.52 psi, φ = 39.6°

DESIGN ANALYSIS

19. Christiana Creek has fairly low velocities ranging from 0.5 to 5 ft/sec. The velocities are not expected to increase once the dam is removed. Although the soil in this area consists of sand which is susceptible to erosion, the slopes are gently sloped and nicely vegetated which help prevent against erosion and scour. There is sheetpile wall just upstream and along the right descending bank downstream of the dam. The left descending bank just downstream of the dam has some riprap. Stability and erosion issues are not expected at this location.

Figure B-9. Grassy slopes downstream of Christiana Dam

Figure B-10. Sheetpile on RDB, riprap on LDB

20. Elkhart River normally has velocities less than 4.5 ft/sec and may increase slightly with the removal of the dam. Although the soil in this area consists of sand which is susceptible to erosion, there is already slope protection in place along the downstream banks of the dam. There is a concrete retaining wall with riprap further downstream on the right descending bank that provides adequate protection against scouring. The left descending bank has riprap with concrete slope just downstream which provides stability and protection against erosion. The riprap slopes are moderately flat. No additional erosion protection is anticipated at this location.

Figure B-11. Riprap and concrete wall on right descending bank

Figure B-12. Riprap on left descending bank

21. There was a concern that the lower river level could potentially cause scour around the bridge upstream of the dam. The river sediment consists mostly of sand and gravel. A filter analysis was performed and INDOT CA-5 met all of the USACE and USBR filter criteria. At least 18 inches of CA-5 would be suitable. Based on the D50 at station 4604 for the 500 yr high flow, INDOT Class 1 riprap would be appropriate. INDOT recommends at least 24 inches for this gradation. Only the bottom of the piers would need to be protected.

RECOMMENDATIONS

22. The existing slope protection and conditions downstream of the dams will provide adequate protection against scour and instability. River conditions are not anticipated to change dramatically and no additional stabilization is needed. Flatter slopes and riprap can provide additional stabilization if required. Additional subsurface investigations and analyses are not anticipated to be required for development of plans and specifications.

23. Some things to consider for removal of the Elkhart Dam are that the concrete cap has been undercut and the dam contains voids that are passing water and fine material. Soundings taken at the south end of the dam indicated that there is a substantial amount of voids and it is recommended that repairs start at this end. Surface water, and even some groundwater, will likely pose major construction problems at the project site. It should be mentioned that fluctuations of the groundwater table should be expected to occur both seasonally and annually due to variations in rainfall, evaporation, transpiration, construction activities, and other site-specific factors. Additional variations may not become apparent until mass excavation commences. Riprap with bedding may be required around the upstream bridge piers to prevent scour.

REFERENCE

EM 1110-2-2504, Design of Sheet Pile Walls. 31 Mar 1994.

FutureNet Group. (2011) Elkhart River Dam and Christiana Creek Dam Sediment Sampling and Analysis. Prepared for the Corps of Engineers, Chicago District.

INDOT 2008 Standard Specifications.

Indiana Geological Survey, "Indiana Bedrock Geology", http://igs.indiana.edu/geology/maps/statebedrock/geology.cfm

Indiana Geological Survey, "Surficial Geology", Anthony Fleming and Robin Rupp http://igs.indiana.edu/allenCounty/surficialGeology.cfm

Indiana Geological Survey, "Water Resource Availability in the St. Joseph River Basin", http://www.in.gov/dnr/water/4106.htm

Natural Resources Conservation Service, Web Soil Survey. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

TesTech, Inc. (2011) Concrete Coring and Testing for Elkhart River Dams. Prepared for the Corps of Engineers, Chicago District.

WES 6-57, Stone Stability Tables, Sep 1970.

ATTACHMENT 1
NRCS Soil Map

Map Scale: 1:11,400 if printed on A size (8.5" x 11") sheet.

N

Meters: 0 100 200 400 600

Feet: 0 400 800 1,600 2,400

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Gully

Short Steep Slope

Other

Political Features

Cities

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:11,400 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 16N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

Date(s) aerial images were photographed: 7/19/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Elkhart County, Indiana (IN039)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AbhAN	Adrian muck, drained, 0 to 1 percent slopes	6.9	1.3%
Pxo	Psamments	136.8	25.6%
UdpA	Urban land-Bristol complex, 0 to 1 percent slopes	262.8	49.2%
UdrA	Urban land-Bronson complex, 0 to 1 percent slopes	30.7	5.7%
UglA	Urban land-Osolo complex, 0 to 1 percent slopes	4.3	0.8%
W	Water	76.1	14.2%
WcnAI	Waterford loam, 0 to 2 percent slopes, frequently flooded, long duration	16.5	3.1%
Totals for Area of Interest		**534.1**	**100.0%**

Elkhart County, Indiana

AbhAN—Adrian muck, drained, 0 to 1 percent slopes

Map Unit Setting

Elevation: 600 to 1,400 feet
Mean annual precipitation: 34 to 40 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 170 days

Map Unit Composition

Adrian, drained, and similar soils: 75 percent
Minor components: 25 percent

Description of Adrian, Drained

Setting

Landform: Depressions on outwash plains, depressions on terraces, depressions on till plains
Landform position (two-dimensional): Toeslope, footslope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Herbaceous organic material over sandy outwash

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 6.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 40 percent
Available water capacity: Very high (about 15.1 inches)

Interpretive groups

Land capability (nonirrigated): 3w
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Typical profile

0 to 9 inches: Muck
9 to 34 inches: Muck
34 to 80 inches: Sand

Minor Components

Antung, drained

Percent of map unit: 10 percent
Landform: Depressions on lake plains, depressions on outwash plains, depressions on till plains
Landform position (two-dimensional): Footslope, toeslope
Down-slope shape: Concave

Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Edwards, drained
Percent of map unit: 6 percent
Landform: Depressions on lake plains, depressions on outwash plains, depressions on till plains
Landform position (two-dimensional): Footslope, toeslope
Down-slope shape: Concave
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Houghton, drained
Percent of map unit: 6 percent
Landform: Depressions on lake plains, depressions on outwash plains, depressions on till plains
Landform position (two-dimensional): Footslope, toeslope
Down-slope shape: Concave
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Muskego, drained
Percent of map unit: 3 percent
Landform: Depressions on lake plains, depressions on outwash plains, depressions on till plains
Landform position (two-dimensional): Footslope, toeslope
Down-slope shape: Concave
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Data Source Information

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

Elkhart County, Indiana

Pxo—Psamments

Map Unit Setting

Mean annual precipitation: 34 to 40 inches
Mean annual air temperature: 47 to 51 degrees F
Frost-free period: 170 to 185 days

Map Unit Composition

Psamments and similar soils: 85 percent
Minor components: 15 percent

Description of Psamments

Setting

Landform: Outwash plains
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Sandy outwash

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Interpretive groups

Land capability (nonirrigated): 8
Other vegetative classification: Trees/Timber (Woody Vegetation)

Minor Components

Psammaquents

Percent of map unit: 15 percent
Landform: Outwash plains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Side slope
Down-slope shape: Concave
Across-slope shape: Concave
Other vegetative classification: Trees/Timber (Woody Vegetation)

Data Source Information

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

Elkhart County, Indiana

UdpA—Urban land-Bristol complex, 0 to 1 percent slopes

Map Unit Setting

Elevation: 570 to 1,540 feet
Mean annual precipitation: 32 to 42 inches
Mean annual air temperature: 46 to 50 degrees F
Frost-free period: 140 to 170 days

Map Unit Composition

Urban land: 50 percent
Bristol and similar soils: 40 percent
Minor components: 10 percent

Description of Urban Land

Setting

Landform: Outwash plains

Interpretive groups

Land capability (nonirrigated): 8
Other vegetative classification: Trees/Timber (Woody Vegetation)

Description of Bristol

Setting

Landform: Outwash plains, outwash terraces
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Sandy outwash over sandy and gravelly outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 40 to 70 inches to strongly contrasting textural stratification
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Available water capacity: Low (about 4.6 inches)

Interpretive groups

Land capability (nonirrigated): 3s
Other vegetative classification: Trees/Timber (Woody Vegetation)

Typical profile

0 to 10 inches: Loamy sand
10 to 21 inches: Loamy sand

21 to 35 inches: Loamy coarse sand
35 to 55 inches: Sand
55 to 80 inches: Sand

Minor Components

Osolo

Percent of map unit: 4 percent
Landform: Outwash terraces, outwash plains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Other vegetative classification: Trees/Timber (Woody Vegetation)

Vistula

Percent of map unit: 4 percent
Landform: Outwash plains
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Other vegetative classification: Trees/Timber (Woody Vegetation)

Tyner

Percent of map unit: 2 percent
Landform: Outwash plains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Other vegetative classification: Trees/Timber (Woody Vegetation)

Data Source Information

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

Elkhart County, Indiana

UdrA—Urban land-Bronson complex, 0 to 1 percent slopes

Map Unit Setting

Elevation: 360 to 1,200 feet
Mean annual precipitation: 32 to 42 inches
Mean annual air temperature: 46 to 50 degrees F
Frost-free period: 140 to 170 days

Map Unit Composition

Urban land: 50 percent
Bronson and similar soils: 40 percent
Minor components: 6 percent

Description of Urban Land

Setting

Landform: Outwash plains

Interpretive groups

Land capability (nonirrigated): 8
Other vegetative classification: Trees/Timber (Woody Vegetation)

Description of Bronson

Setting

Landform: Outwash plains, moraines
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy outwash over sandy outwash

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 6.9 inches)

Interpretive groups

Land capability (nonirrigated): 2s
Other vegetative classification: Trees/Timber (Woody Vegetation)

Typical profile

0 to 9 inches: Sandy loam
9 to 20 inches: Sandy loam
20 to 43 inches: Sandy loam

43 to 56 inches: Loamy sand
56 to 80 inches: Sand

Minor Components

Brookston
Percent of map unit: 3 percent
Landform: Depressions on till plains
Landform position (two-dimensional): Toeslope, footslope
Down-slope shape: Linear
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Gilford
Percent of map unit: 3 percent
Landform: Depressions on outwash plains, drainageways on outwash plains
Landform position (two-dimensional): Footslope, toeslope
Down-slope shape: Linear
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Data Source Information

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

Elkhart County, Indiana

WcnAl—Waterford loam, 0 to 2 percent slopes, frequently flooded, long duration

Map Unit Setting

Elevation: 580 to 1,540 feet
Mean annual precipitation: 34 to 40 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 170 days

Map Unit Composition

Waterford and similar soils: 80 percent
Minor components: 20 percent

Description of Waterford

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Loamy alluvium over sandy alluvium

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 40 to 70 inches to strongly contrasting textural stratification
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Available water capacity: Low (about 5.7 inches)

Interpretive groups

Land capability (nonirrigated): 5w
Other vegetative classification: Trees/Timber (Woody Vegetation)

Typical profile

0 to 8 inches: Loam
8 to 41 inches: Fine sandy loam
41 to 46 inches: Loamy sand
46 to 50 inches: Loamy sand
50 to 80 inches: Gravelly coarse sand

Minor Components

Abscota

Percent of map unit: 10 percent
Landform: Flood plains
Landform position (two-dimensional): Backslope, shoulder, summit

Down-slope shape: Convex
Across-slope shape: Convex
Other vegetative classification: Trees/Timber (Woody Vegetation)

Gravelton
Percent of map unit: 5 percent
Landform: Depressions on flood plains, drainageways on flood plains
Landform position (two-dimensional): Toeslope, footslope
Down-slope shape: Linear
Across-slope shape: Concave
Other vegetative classification: Trees/Timber (Woody Vegetation)

Adrian, undrained
Percent of map unit: 5 percent
Landform: Depressions on lake plains, depressions on outwash plains, depressions on till plains
Landform position (two-dimensional): Toeslope, footslope
Down-slope shape: Concave
Across-slope shape: Concave
Other vegetative classification: Mixed/Transitional (Mixed Native Vegetation)

Data Source Information

Soil Survey Area: Elkhart County, Indiana
Survey Area Data: Version 14, Dec 9, 2011

ATTACHMENT 2
TesTech Report

TesTech

8(a) / DBE / MBE / EDGE Certified
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Ohio

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Geotechnical Investigation Concrete Coring & Testing

Elkhart River Dams, Section 506

Feasibility Study Project

Elkhart, Elkhart County, Indiana

TesTech file number: MI046M

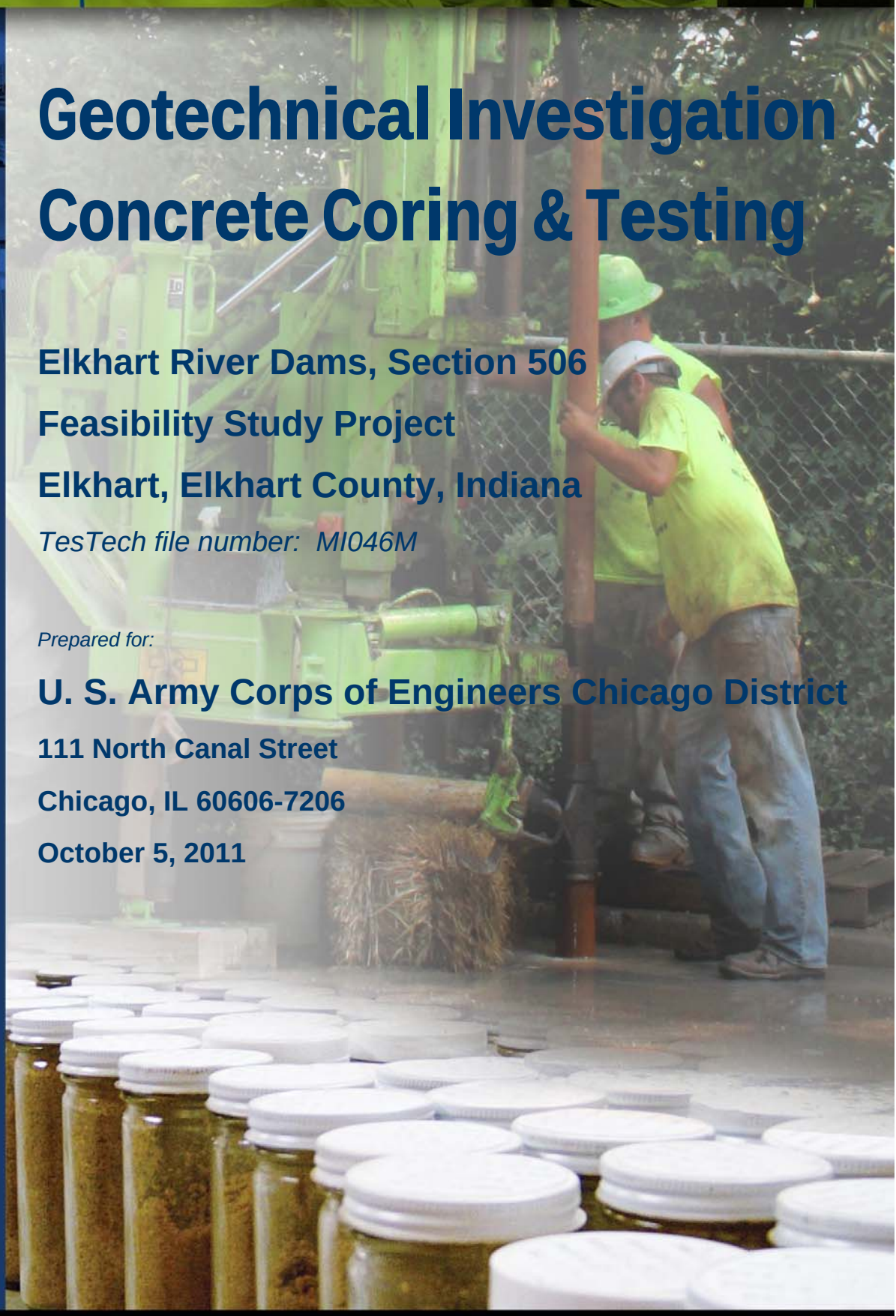
Prepared for:

U. S. Army Corps of Engineers Chicago District

111 North Canal Street

Chicago, IL 60606-7206

October 5, 2011



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Field Coring Notes
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1.0 Introduction

1.1 AUTHORIZATION

TesTech, Inc. *was contracted by the US Army Corps of Engineers (USACE) Chicago District under Contract Number W911XK-10-D-0004 and Delivery Order Number CX03 to perform geotechnical investigations consisting of Concrete Coring and Testing for the Elkhart Dams, Section 506 Feasibility Study Project. The notice to proceed for the Elkhart Dams project geotechnical investigation was issued by the Contracting Division of the Chicago District on July 25, 2011, under the revised Scope of Work dated 2 June 2011.*

1.2 PURPOSE OF INVESTIGATION

The geotechnical investigation consists of concrete coring to determine the thickness and strength of the existing concrete cap as well as determine the types of fill material below the cap.

The core holes, listed in Table 3.1 and shown in Appendix A, were to be drilled to a depth of 10 feet or until refusal was encountered. The investigation was to include literature research, site exploration (coring), laboratory testing of the concrete cores, and a brief report of the materials and conditions encountered at the site.

This report presents the field procedures, the laboratory testing procedures, the subsurface conditions encountered at each of the coring locations, the photos of the cores, and the laboratory test results consisting of the concrete core compressive strength results.

Assessment of site environmental conditions, including the detection of pollutants in the nearby soils or groundwater (which could not be clearly identified due to the constantly running water) and any environmental testing, was beyond the scope of this exploration. However, had any contaminated materials been encountered or any peculiar odors detected, the client would have been notified for immediate action.

The geotechnical exploration for the project was conducted in accordance with the US Army Corps of Engineers, Chicago District Geotechnical Investigation Scope of Work Requirements.

2.0 General Information

2.1 PROJECT LOCATION

The Elkhart River Dams, Section 506 Feasibility Study Project is a low-head hydraulic dam located along the Elkhart River in downtown city of Elkhart, Elkhart County, Indiana. The first dam in this location was constructed in 1832 and rebuilt in 1875. The exact dimension of the dam is unknown; however, preliminary survey information shows it to be approximately 10 feet tall and 147 feet long. The dam is located near the intersection of South Elkhart Avenue and Waterfall Drive. The site is accessible via the Studebaker Boat Ramp, located a few miles upstream from the dam across the Elkhart Central High School property by going under the railroad trestle on a steep incline, or directly adjacent to the dam by transversing down a very steep bank to the top of the dam. This steep slope connects the southern end of the dam or embankment to the main land. The dam runs in roughly a north and south direction across the Elkhart River. There is a nearby access road which starts from a point just west of the dam and continues east and northeast along a portion of the river. Access to this road (or path) is off of Waterfall Drive. Much of the embankment of the river is covered with grass, bushes, and trees. The embankment on the north side of the dam is retained by a vertical stone wall.

Corings CC-01 thru CC-03 are located across the top of the dam starting at the north end of the dam and being located at approximately along the quarter points of the dam leading southward. A site location map of the project site is included in Appendix A.

2.2 REGIONAL GEOLOGY

Indiana is a large anticline that plunges to the northwest strongly affected by the Cincinnati Arch. Northern Indiana was repeatedly covered by continental ice sheets during the past one million years or so, which produced a thick section of unconsolidated sediments that mantle the bedrock in varying depths across the state. The bulk of the glacial sediments were deposited during the most recent period of glacial activity known as the late Wisconsin Stage. As far as is known, all of the important unconsolidated aquifers and confining units date from this most recent period of glacial activity.

During this time, approximately two-thirds of the state was covered by glacier ice that originated in northern Canada. As the ice sheets expanded and moved south, they carved up the pre-glacial landscape beneath; therefore, much of the sediment we find in Indiana has origins in Canada and Michigan. In the northern portion of Indiana, these deposits range from 250 to 500 feet in thickness.

This glaciation, including the sediments borne by the ice sheets, resulted in a mixture of sand, silt, clay, and boulders as the glaciers advanced across Indiana filling the bedrock valleys and covered the bedrock hills of northern Indiana to produce the flat to gently rolling landscape. It's strength and durability make it ideal aggregate material for asphalt and concrete.

These resulting boulders provided the rock that was used locally to produce the concrete cap, and individual rock, cobbles, and boulders were apparently used to make up the cores of the original Elkhart River Dams.

3.0 Subsurface Exploration

The geotechnical field exploration was conducted by **TesTech, Inc.** *on September 13 and September 14, 2011. The field investigations program consisted of the core drilling of three (3) core holes designated as CC-01 through CC-03. CC-01 thru CC-03 (labeled in this report as C-1 thru C-3) were performed across the top of the dam, beginning at the northern end of the dam and proceeding to the south end of the dam, approximately one fourth of the way across the dam for each coring location.*

Table 3.1 Core Depths and Coordinates

Core No.	*Depth (ft)*	*Northing (Y) (NAD83)*	*Easting (X) (NAD83)*	*Date Drilled*	*Borehole Status*
CC-01	*2.75*	*2344778.080*	*245864.781*	*09/13/11*	*Grouted/sealed**
CC-02	*1.75*	*2344735.416*	*245873.646*	*09/13/11*	*Grouted/sealed**
CC-03	*5.0*	*2344701.143*	*245879.535*	*09/14/11*	*Grouted/sealed**

**Backfilled with 4500psi concrete grout*

Prior to the start of the coring operations, a 3.5 foot high safety cable was installed across the top of the dam. This installation was approximately 18 inches from the downstream vertical face of the spillway. The length of the cable was approximately 145 feet. When drilling the four 5/8-inch diameter holes for the rod anchor for the safety cable (at approximately the center of the dam or spillway) clay was encountered at depths varying from 4 to 6 inches. Apparently there was a previous cable or railing across the top of the dam as small (1½") holes spaced approximately 5 feet apart extended from one end to the other across the structure.

Once the safety cable was placed, the corings were conducted utilizing a standard portable coring machine powered by a portable generator utilizing a standard 4-inch outside diameter (3.72-inch diameter core) core barrel. The corings were drilled to depths varying from 1.75 to 5.0-feet below the existing surface of the dam.

Core samples were taken immediately at the ground surface and down to the bottom of the core, including any cores taken through existing cobbles or boulders within the interior of the dam.

Samples were logged and individual pieces were numbered to insure that the core could be re-assembled in the laboratory to facilitate the requirement for taking pictures of the cores. The top and bottom of the cores were labeled for future reference as required for providing digital photos of the individual cores.

Corings CC-01 to CC-03 were tremie backfilled with 4500 psi concrete grout from the bottom of the core hole to the top of the existing dam. Due to the holes drawing water, as described later in this report, the holes were sealed off to eliminate the surface water, and the bottom of the holes were plugged with small rock. Core CC-01 had a strong water draw. The bottom had to

be plugged with a rock core (taken from a nearby boulder) and the hole then was sealed with concrete grout.

Coring frequency, location, spacing, and depth for the field investigations were assigned by the USACE prior to the fieldwork. The actual locations of corings were staked on-site by the **TesTech** *drill crew. The core locations for CC-01 to CC-03 as shown on the location map were located in the field using a hand held GPS locator and were later converted in the TesTech survey office to northing and easting coordinates. The core locations are presented in Indiana State Plane North America Datum 1983 (NAD83), East Zone 1301.*

The subsurface exploration for the Elkhart River Dams, Section 506 Project was conducted in accordance with the US Army Corps of Engineers, Chicago District Geotechnical Investigation Scope of Work Requirements.

Elkhart River Dam, Section 506

4.0 Evaluation of Subsurface Conditions

The subsoil conditions at the project site were explored by coring a total of three (3) core holes. Generalized descriptions of the materials encountered in the corings are given below, in no specific order. More detailed descriptions of the cores are provided in the photos taken of the individual cores and in the attached Laboratory Report for the Compressive Strength Breaks on the samples taken out of each coring. (Report provided in Appendix B). It should be noted that any stratification lines visible on the cores do not represent exact geological or construction planes but approximate transitions between rock types and the concrete, whether the rock is a part of the core of the dam, or was a part of the concrete placed as an outer protective shell for the dam. In-situ stratum changes could occur gradually, but are more apt to occur abruptly and at greatly differing elevations.

4.1 SUBSURFACE CONDITIONS

Concrete was encountered in all of the cores at the surface. The thickness of this cap varied, and as measured at the downstream face of the dam, appeared to be between 3 inches and 8 inches at CC-01 and CC-02, and was approximately one foot thick at CC-03. In the individual cores, there were several large rock or cobbles encountered that could have been a part of the original concrete, or original core rocks that were surrounded by the concrete during initial placement. The rock was cored and became a part of the solid portions of the cores that were retrieved.

Clay

Clay soils were encountered in some of the holes used to install the safety cable. No significant clay was found or encountered during the actual coring; however most of the loose soils that might have been in the interior of the dam were washed away as soon as the core hole was opened up. There were some small quantities of silty clay found in one of the cores, CC-03. It is impossible to know if this clay was a part of the original central core of the dam, or has been washed into voids within the dam as a result of high-water flood events which would carry large volumes of suspended silt and clay.

Clay Contained In Concrete ►

Sand

Brown sand was observed all around the dam; however, during the actual coring operations, no definable sand layers or trapped sand was clearly identified. During the coring operations, sand that was placed in close proximity to the core holes would be drawn down into the hole rather than flowing over the top of the spillway. This would indicate that the voids within the dam are large enough, and there is enough water flowing through the dam, that little if any sand would be caught or remain in the core of the dam.

Full photographs of the rock cores are included in Appendix B.

Voids

Voids were encountered in all of the corings, CC-01 to CC-03, below the existing concrete cap which forms the surface of the dam or spillway. The drilling core barrel encountered the voids after passing through the concrete cap, through large rock or cobbles, and possibly larger stone. The voids were identified when the encountered rock started to spin as a result of the down pressure of the core barrel. Once these loose boulders or rocks were encountered, the voids around them allowed them to spin with the core barrel rather than allow the drill to push the barrel through the rock. It was this combination of voids and rocks that prevented the coring operation from continuing to the originally designed depths. There was no visible cave in of the holes, due to the top concrete cap, but a large volume of water was being sucked through the holes once the core was removed. It was possible to reach down into the core hole and rotate the loose rock or cobbles, but the stones were too large to be removed through the top of the core hole.

A smaller core barrel was used to try and core through the loose rock, but even with very little down pressure, the rock would spin within the holes. Attempts were made to wedge rock in and around the larger stones, but due to the large amount of water flowing through the holes, these attempts were also unsuccessful. There was no evidence that any of the rock interior to the dam, below the immediate top of the dam, had been locked in or that any mortar, grout, or concrete had been used around those rock.

4.2 SURFACE AND GROUNDWATER CONDITIONS

Surface water was present at each coring location and across the entire top of this dam, as the entire top of the dam acts as both the principle and the emergency spillways for the dam. The water depth across the surface of the dam at the time of the investigation was on the average 10-inches. This water depth will of course vary based on the flow rate of the river, as there is no bypass for any of the water flowing down the Elkhart River. If any work is to be considered for the repair or maintenance of this dam, the surface water will have to be carefully controlled, with provisions made for increased flows as a result of upstream rainfall events.

Groundwater, as normally defined in a geotechnical report, was not encountered and/or measured in any the corings, mainly due to the continual presence of the surface flows.

However, during the backfilling of the holes, a 10-inch PVC pipe was placed over the hole, and was sealed with plumber's putty. Water was bailed out of the holes, but complete removal of the water was not possible due to the water being recharged from the bottom of the hole from within the interior of the dam (from water within the rock and cobble core). Details of the groundwater conditions as observed were recorded in the narrative provided by the drillers on-site Geologist.

The groundwater conditions observed, or lack thereof, reflect the conditions at the time of our exploration only. Fluctuations of the groundwater table should be expected to occur both seasonally and annually due to variations in rainfall, evaporation, transpiration, construction activities, and other site-specific factors. Contractors should be prepared to control both the surface water and groundwater during construction at all times at a minimum with a sump and pump system. Major repairs may require a more extensive water removal program.

5.0 Engineering Properties

The concrete core samples obtained during the drilling operations were placed in boxes, labeled, and transported to the **TesTech** *Corps-validated laboratory for further identification, photographs, and strength testing of a selected portion of the concrete caps. The Geotechnical Engineer, in accordance with originally agreed upon Geotechnical Investigation Revised Scope of Work, reviewed each core individually, identified pieces of steel from the imbedded welded wire mesh, and selected specific sections of the cores to be included in the laboratory testing.*

In an effort to miss the embedded steel, to not use the large rock which might not have been in the original designed mix, and to ensure a good quality sample, some of the samples were smaller in height than the preferred 2:1 ratio. Therefore, the strengths of the individual samples have been adjusted using a standard height to width (length to diameter) ratio formula in accordance with ASTM Standards. The strengths provided in Table 5.2 on the following page are the adjusted strengths for each sample. There was wire mesh observed in each of the concrete core samples. The wire mesh was located approximately 1 to 1.5-inches from the surface elevation in each of the three cores (CC-01 to CC-03).

One of the concrete cores had a large percentage of voids in the concrete. This may be easily identified by its mass. This may be a result of the concrete being placed in water, a result from lack of adequate mixing in the initial placement, or a result of erosion of the weaker material within the concrete due to the extended exposure to the constant flow of water over the spillway. In any case, the lower strength of the concrete in the sample taken from the core at CC-02 is more of a direct result of the voids in the concrete than the height to width ratio.

The testing items and related ASTM standards are listed in Table 5.1.

Table 5.1 Laboratory Test Items and Related ASTM Standards

Test Items	*Standard Name*
Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens	*ASTM C 39*
Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete	*ASTM C 42*

The laboratory test results are provided in the table on the following page and are also included in Appendix C.

Table 5.2 Concrete Strength Test Results

Boring No.	*Length (in)*	*Diameter (in)*	*Max Load (lbf)*	*Compressive Strength (psi)*
CC-01	*7.364*	*3.71*	*51530*	**4780**
CC-02	*4.788*	*3.72*	*25530*	**2209**
CC-03	*5.169*	*3.72*	*63060*	**5849**

6.0 Geotechnical Analyses

The following discussions and conclusions are based on the previously discussed project information, results of the field investigations and laboratory tests, observations at the site and our experiences with similar subsurface conditions.

6.1 ANALYSIS OF THE SITE CONCRETE CAP AND DAM CORE

Based on our evaluation of the core results and an interpretation of the concrete strength tests, the strength of the concrete appears to vary inconsistently across the dam site from weak to relatively strong. However, it is not necessarily the actual strength of the concrete that is so important but rather how that concrete is working effectively as both a cap for the structure and a method of tying the rock core together to ensure the long term stability of the structure.

Across most of the inside face of the dam, the stream bed rises to the top, or almost to the top of the dam. This embankment material acts as a partial support to the dam preventing water from flowing freely through those portions of the dam and providing stability to the dam, as additional embankment.

At the north end of the structure, where the dam ties into the somewhat vertical wall, the depth of the water increases to a depth of approximately four (4) feet. This would indicate that water is passing through this portion of the dam or the adjacent wall carrying the fines that have been deposited and retained (similar to what is taking place across the central portion of the dam). This apparent erosion is hampered by both the dam and its contents, as well as the adjacent wall.

At the south end of the dam, where the sloping bank occurs (on the upstream side), the water is even deeper (approximately 6-7 feet in depth). The concrete cap has also been undercut in this area, and an opening that was measured to be approximately eight (8) feet across and roughly one foot in height, and extending an unknown distance into the dam. Rough soundings taken by the drilling crew while on site seemed to indicate that this void probably extends to the downstream concrete face of the dam. If this is in fact the case, there is some danger of the whole opening becoming larger in high flow situations where the pressure on the concrete face would be increased.

Whether the dam is to be repaired, replaced, or removed completely, this end of the dam would be the ideal place to start due to the immediate lack of substantial material within the dam structure.

Surface water, and even some groundwater, will likely pose major construction problems at the project site. It should be mentioned that fluctuations of the groundwater table should be expected to occur both seasonally and annually due to variations in rainfall, evaporation, transpiration, construction activities, and other site-specific factors. The site should be dewatered for site preparation and any other excavations during repair, rehabilitation, re-construction, or demolition, in accordance with the project dewatering specifications.

7.0 Limitations of Liability

Discussions and conclusions presented in this report are based upon the available soil information, currently accepted engineering principles, and available information provided by the Detroit District Corps of Engineers. **TesTech** *should be notified of any revisions to the scope of this project so that these revisions may be evaluated against the known subsurface conditions. Should it be necessary to revise the discussions and conclusions outlined in this report,* **TesTech** *will submit a written report to address any necessary changes to the discussions and conclusions. No other warranties, expressed or implied, are made.*

Discontinuities in soil and rock types and geology may exist, including abrupt strata changes and soil and rock strength variations. The extent of these variations may not be fully determined from the borings or site reconnaissance. Additional variations may not become apparent until mass excavation commences.

Assessment of site environmental conditions, including the detection of pollutants in the soil or groundwater, and environmental testing was beyond the scope of this exploration.

8.0 Appendices

APPENDICES:

A. Site Location Map

B. Concrete Core Photographs

C. Laboratory Test Results
Laboratory Analysis of Drilled Concrete Cores

D. Field Data
Field Photographs

Appendix A:

Site Location Map

Boring location Map
C-1
C-2
C-3
© 2011 Google
Image Indiana Map Framework Data
41°41'06.23" N 85°58'03.63" W elev 722 ft
©2010
Eye alt

Appendix B:

Concrete Core Photographs

CC-01

CC-02

CC-03

Appendix C:

Laboratory Test Results

Laboratory Analysis of Drilled Concrete Cores

Geotechnical Engineering
Materials Testing/Inspection
TESTECH
Professional Surveying and Environmental Services

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LABORATORY REPORT

AASHTO R18

U.S. Army Corps of Engineers – Chicago District
111 North Canal Street
Chicago, IL 60606-7206

TT Project No. MI046M
TT Report No. 0661
Date September 26, 2011

Attn: Mr. Yuki Galisanao

RE: Laboratory Analysis of Drilled Concrete Cores from the Elkhart River Dams, Section 506 Feasibility Study Project in Elkhart, Indiana

On September 23, 2011, three concrete cores were tested for laboratory determination of compressive strength. Testing was performed in accordance with the following procedures:

ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens"
ASTM C42, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete"

Results are summarized below.

Core ID	Length as Cut (in)	Diameter (in)	Mass (g)	L/D Ratio	Max Load (lbf)	Corrected Compressive Strength (psi)
1	7.364	3.71	2790.6	2.01	51530	4780
2	4.788	3.72	1722.6	1.33	25530	2209
3	5.169	3.72	2091.5	1.43	63060	5849

Should you have any questions, please do not hesitate to call.

Respectfully submitted,

TesTech, Inc.

Sheila Sennet, CET #94321
Laboratory Operations

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1-file

Results Contained In This Report Reflect Only The Items Tested. All Reports Will Remain The Confidential Property Of TesTech, Inc. No Publication Or Distribution Of Reports May Be Made Without TesTech, Inc.'s Express Written Consent, Except As Authorized By Contract. Unless Otherwise Agreed, Samples and/or Specimens Will Be Discarded at TesTech, Inc.'s discretion.

Appendix D:

Field Data

Field Photographs

Looking South to North

Looking East

Downstream

Upstream

Safety Cable Installed

Coring Operation

Coring Operation

Retrieved Core

Second Core (Note: voids in concrete)

Third Core (Note: Mud trapped in core)

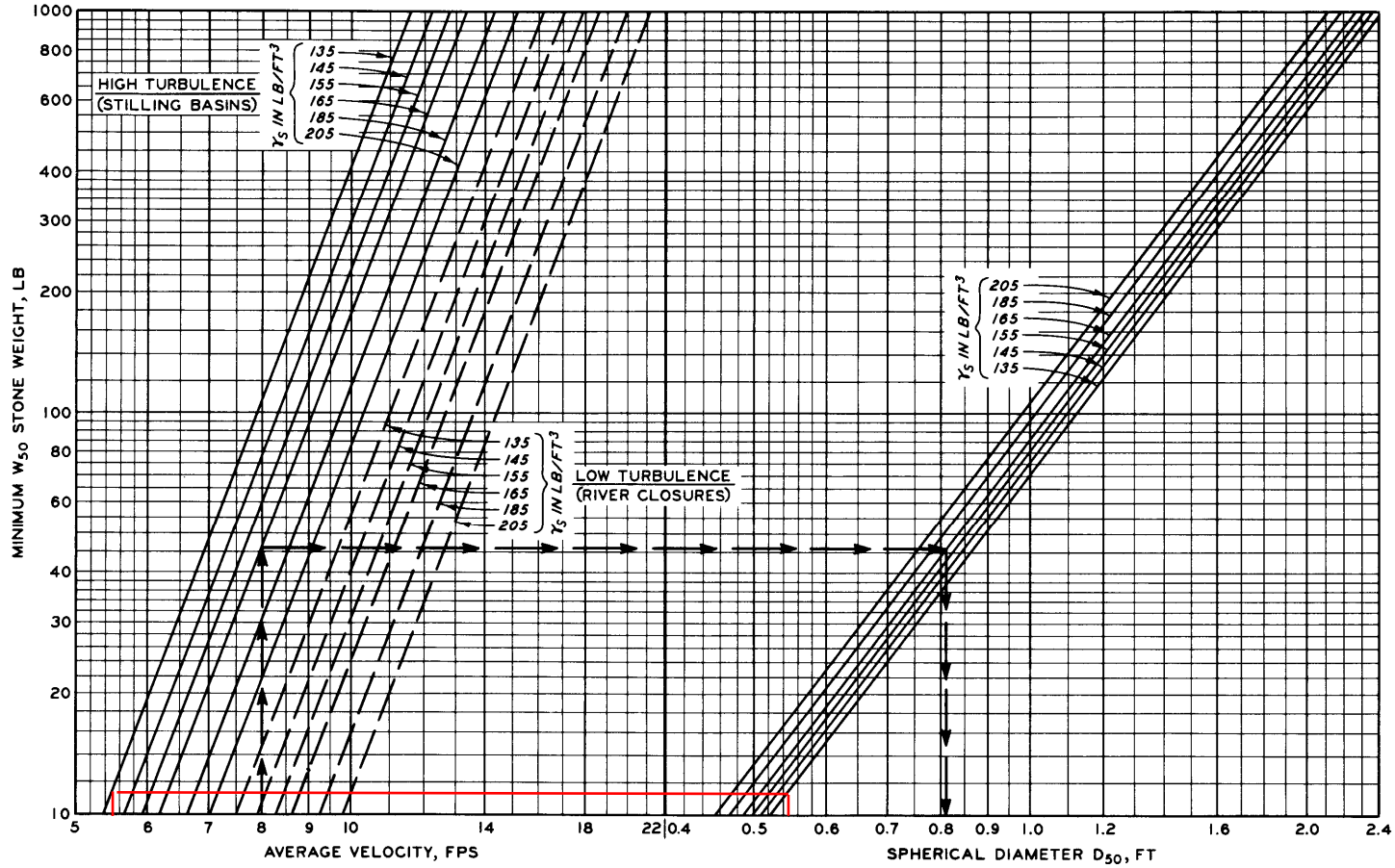
Exposed Face

Exposed Concrete Cap

Exposed concrete caps in both photos show how the thickness of the cap varies across the top of the dam. The thickness of the cap as measured by the tape in each photo is approximately 12-inches. Note in the photo to the right, the water spewing from between the rock across the exposed face of the

ATTACHMENT 3
Riprap Gradation

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
DS	4604	50YR	EX_HI	7350	722.74	734.87	728.58	735.14	0.000328	4.25	2016.24	237.34	0.23
DS	4604	50YR	PR_ST_HI	7350	722.74	733.87	728.58	734.2	0.000464	4.73	1783.1	224.91	0.27
DS	4604	50YR	PR_LT_HI	7350	721.47	732.69	728.1	733.09	0.000622	5.18	1592.35	218.84	0.31
DS	4604	100YR	EX_HI	8100	722.74	735.28	728.86	735.58	0.000348	4.5	2114.63	240.51	0.24
DS	4604	100YR	PR_ST_HI	8100	722.74	734.34	728.86	734.71	0.000477	4.95	1892.47	234.13	0.28
DS	4604	100YR	PR_LT_HI	8100	721.47	733.31	728.39	733.73	0.000593	5.3	1730.08	221.78	0.31
DS	4604	500YR	EX_HI	9350	722.74	735.91	729.32	736.26	0.000382	4.89	2266.38	514.56	0.26
DS	4604	500YR	PR_ST_HI	9350	722.74	735.13	729.32	735.55	0.000487	5.27	2079.36	239.54	0.28
DS	4604	500YR	PR_LT_HI	9350	721.47	734.33	728.84	734.78	0.000555	5.49	1960.51	234.08	0.3
DS	4516	10YR	EX_HI	5650	721.86	733.41	728.52	733.91	0.000683	5.73	1140.03	623.68	0.33
DS	4516	10YR	PR_ST_HI	5650	721.86	732.09	728.52	732.78	0.00115	6.72	919.63	151.42	0.42
DS	4516	10YR	PR_LT_HI	5650	721.03	730.01	728.38	731.22	0.002849	8.86	660.4	121.52	0.63
DS	4516	25YR	EX_HI	6600	721.86	733.94	729.08	734.53	0.000767	6.29	1239.95	777.64	0.35
DS	4516	25YR	PR_ST_HI	6600	721.86	732.64	729.08	733.46	0.001254	7.33	1004.68	278.42	0.44
DS	4516	25YR	PR_LT_HI	6600	721.03	730.73	728.88	732.05	0.002675	9.23	750.16	126.06	0.62
DS	4516	50YR	EX_HI	7350	721.86	734.28	729.46	734.97	0.000843	6.75	1310.55	1127.54	0.37
DS	4516	50YR	PR_ST_HI	7350	721.86	733.04	729.46	733.96	0.001331	7.78	1072.84	511.45	0.46
DS	4516	50YR	PR_LT_HI	7350	721.03	731.32	729.26	732.7	0.002521	9.47	827.52	137.22	0.61
DS	4516	100YR	EX_HI	8100	721.86	734.63	729.83	735.39	0.000908	7.16	1381.5	1273.95	0.39
DS	4516	100YR	PR_ST_HI	8100	721.86	733.43	729.83	734.44	0.001393	8.19	1143.87	629.67	0.47
DS	4516	100YR	PR_LT_HI	8100	721.03	731.91	729.64	733.34	0.002366	9.64	911.89	148.53	0.6
DS	4516	500YR	EX_HI	9350	721.86	735.13	730.42	736.04	0.00102	7.82	1487.09	1442.39	0.41
DS	4516	500YR	PR_ST_HI	9350	721.86	734.09	730.42	735.25	0.001463	8.78	1270.43	1031.99	0.49
DS	4516	500YR	PR_LT_HI	9350	721.03	732.9	730.24	734.38	0.002121	9.86	1068.49	455.6	0.58
DS	4430	10YR	EX_HI	5650	720.86	733.43	727.52	733.83	0.000481	5.15	1247.99	741.89	0.28
DS	4430	10YR	PR_ST_HI	5650	720.86	732.12	727.52	732.66	0.000764	5.93	1051.99	468.25	0.35
DS	4430	10YR	PR_LT_HI	5650	720.86	730.01	727.52	730.94	0.001876	7.8	762.68	125.43	0.52
DS	4430	25YR	EX_HI	6600	720.86	733.96	728.07	734.45	0.000553	5.7	1331.24	848.39	0.3
DS	4430	25YR	PR_ST_HI	6600	720.86	732.67	728.07	733.32	0.000852	6.51	1133.19	595.35	0.37
DS	4430	25YR	PR_LT_HI	6600	720.86	730.74	728.07	731.78	0.00183	8.23	856.63	132.18	0.52
DS	4430	50YR	EX_HI	7350	720.86	734.31	728.46	734.87	0.000616	6.14	1388.19	1257.32	0.32



BASIC EQUATIONS

$$V = C\left[2g\left(\frac{\gamma_S - \gamma_W}{\gamma_W}\right)\right]^{1/2}\left(D_{50}\right)^{1/2}$$

$$D_{50} = \left(\frac{6W_{50}}{\pi\gamma_S}\right)^{1/3}$$

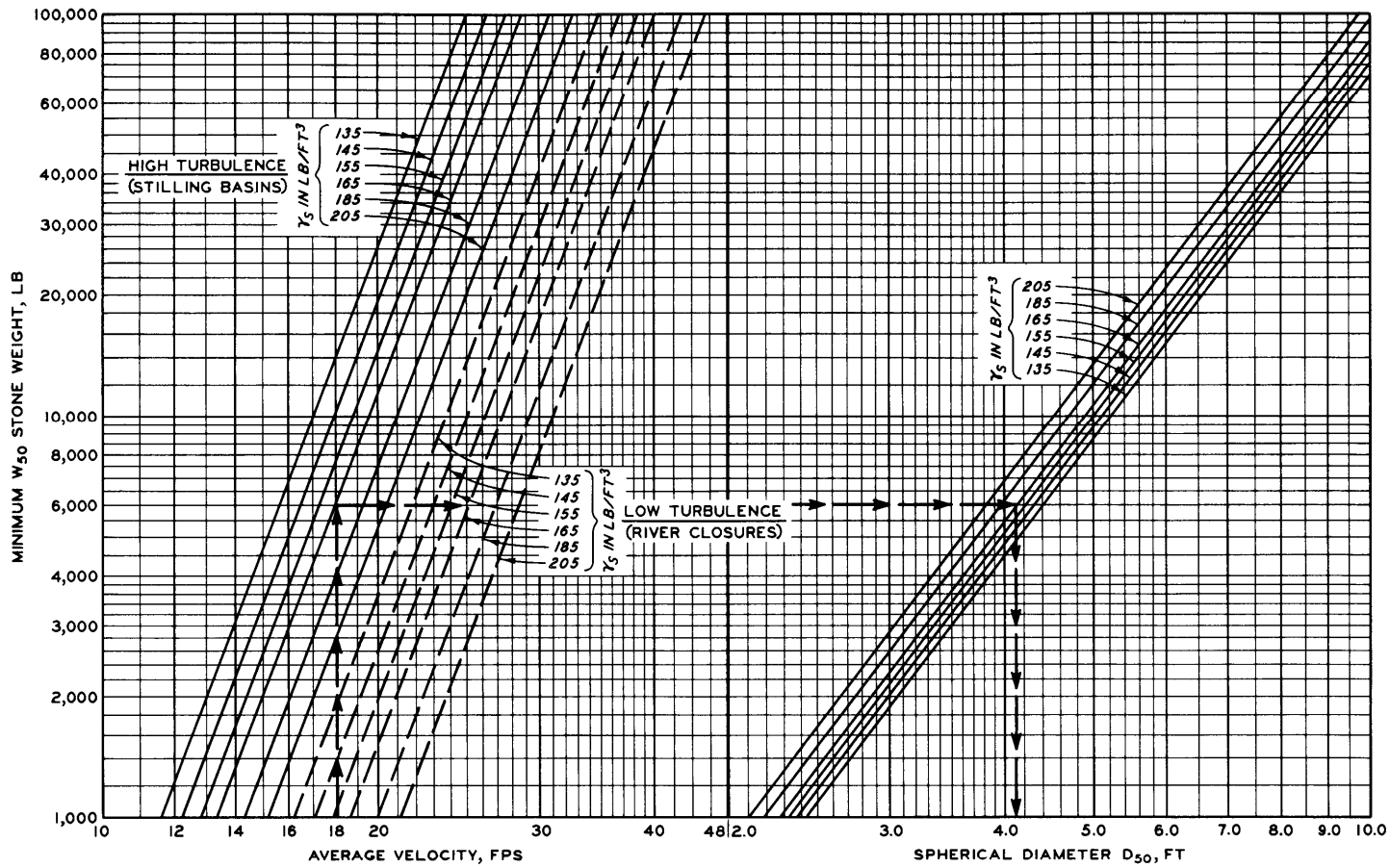
WHERE:
- V = VELOCITY, FPS
- γ_S = SPECIFIC STONE WEIGHT, LB/FT^3
- γ_W = SPECIFIC WEIGHT OF WATER, 62.5 LB/FT^3
- W_{50} = WEIGHT OF STONE. SUBSCRIPT DENOTES PERCENT OF TOTAL WEIGHT OF MATERIAL CONTAINING STONE OF LESS WEIGHT.
- D_{50} = SPHERICAL DIAMETER OF STONE HAVING THE SAME WEIGHT AS W_{50}
- C = ISBASH CONSTANT (0.86 FOR HIGH TURBULENCE LEVEL FLOW AND 1.20 FOR LOW TURBULENCE LEVEL FLOW)
- g = ACCELERATION OF GRAVITY, FT/SEC^2

STONE STABILITY
VELOCITY VS STONE DIAMETER

HYDRAULIC DESIGN CHART 712-1
(SHEET 1 OF 2)

REV 8-58, 9-70 WES 6-57

PREPARED BY U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI



BASIC EQUATIONS

$$V = C\left[2g\left(\frac{\gamma_S-\gamma_W}{\gamma_W}\right)\right]^{1/2}\left(D_{50}\right)^{1/2}$$

$$D_{50} = \left(\frac{6W_{50}}{\pi\gamma_S}\right)^{1/3}$$

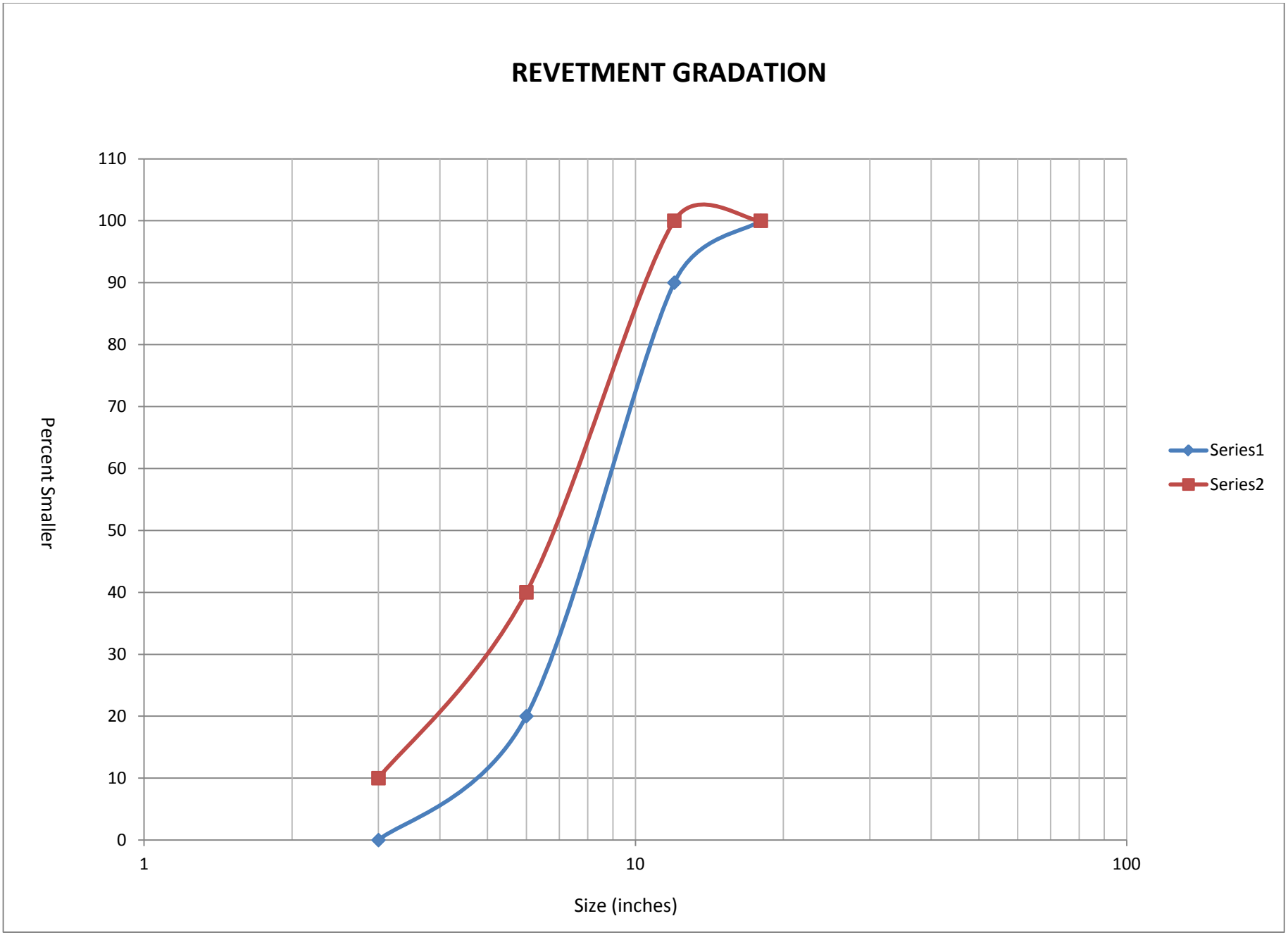
WHERE:
- V = VELOCITY, FPS
- γ_S = SPECIFIC STONE WEIGHT, LB/FT^3
- γ_W = SPECIFIC WEIGHT OF WATER, 62.5 LB/FT^3
- W_{50} = WEIGHT OF STONE. SUBSCRIPT DENOTES PERCENT OF TOTAL WEIGHT OF MATERIAL CONTAINING STONE OF LESS WEIGHT.
- D_{50} = SPHERICAL DIAMETER OF STONE HAVING THE SAME WEIGHT AS W_{50}
- C = ISBASH CONSTANT (0.86 FOR HIGH TURBULENCE LEVEL FLOW AND 1.20 FOR LOW TURBULENCE LEVEL FLOW)
- g = ACCELERATION OF GRAVITY, FT/SEC^2

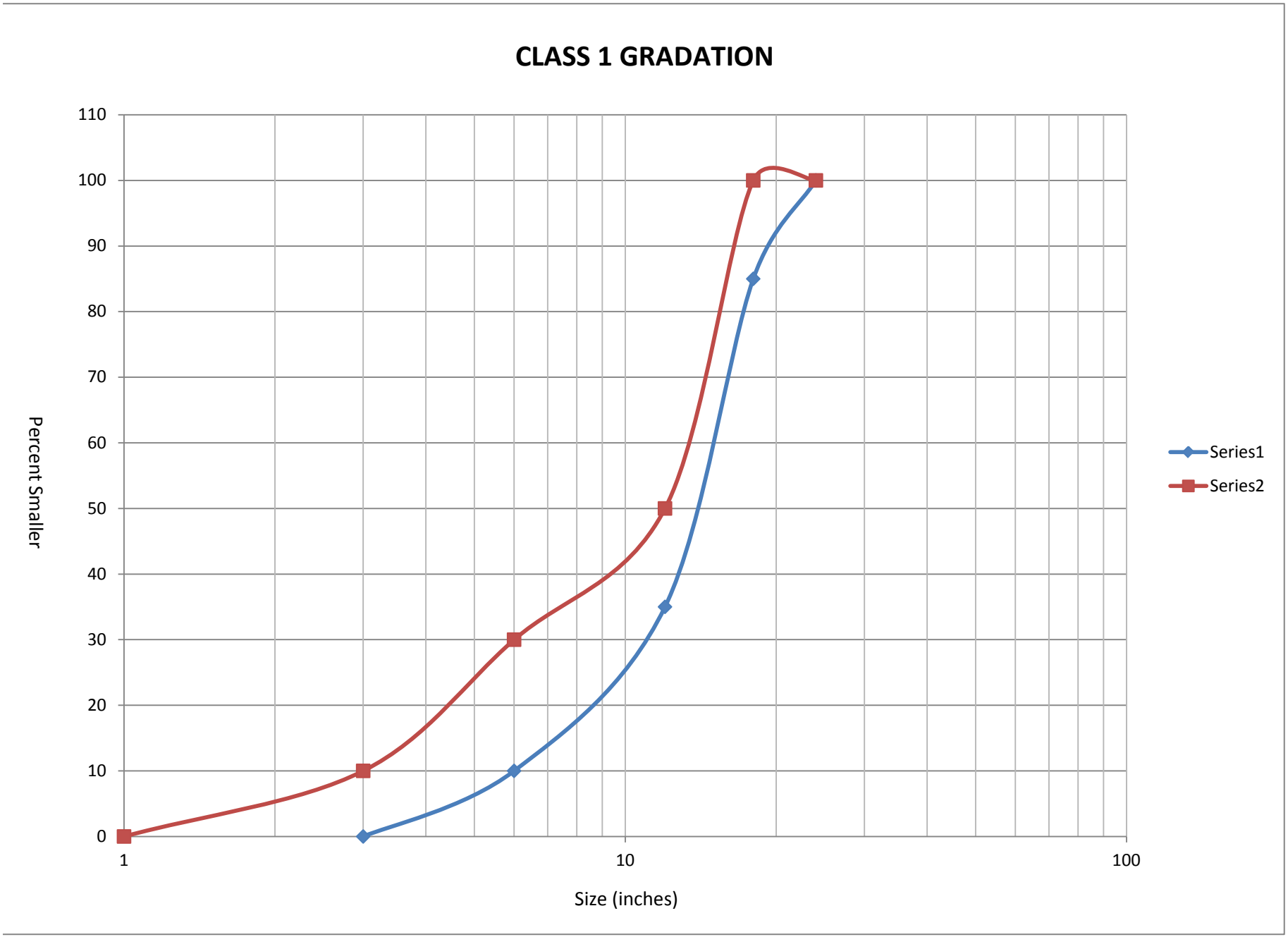
STONE STABILITY
VELOCITY VS STONE DIAMETER

HYDRAULIC DESIGN CHART 712-1
(SHEET 2 OF 2)

REV 8-58, 9-70 WES 6-57

PREPARED BY U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI


REVETMENT GRADATION
110
100
90
80
70
60
50
40
30
20
10
0
Percent Smaller
1
10
100
Size (inches)
Series1
Series2


CLASS 1 GRADATION
110
100
90
80
70
60
50
40
30
20
10
0
Percent Smaller
1
10
100
Size (inches)
Series1
Series2

CLASS 2 GRADATION
110
100
90
80
70
60
50
40
30
20
10
0
Percent Smaller
1
10
100
Size (inches)
Series1
Series2

(d) Uniform Riprap

The material shall be coarse aggregate, Class F or higher in accordance with 904.03(a). Gradation shall be in accordance with 904.04(f). Either type A or type B may be utilized.

(e) Precast Concrete Riprap

Precast concrete riprap shall consist of unreinforced concrete units of the thickness specified and shall be in accordance with the details shown on the plans. The precast concrete units shall be in accordance with ASTM C 139 except the fine aggregates shall be in accordance with 904.02(a) and the coarse aggregates, class A or higher, shall be in accordance with 904.03. The minimum compressive strength shall be 2500 psi (17 MPa) for an average of three units and 2300 psi (16 MPa) for individual units. The maximum water absorption shall be 12 lb/cu ft (190 kg/m^3) for an average of three units.

(f) Sizes of Riprap

GRADATION REQUIREMENTS					
Percent Smaller					
Size, in. (mm)	Revetment	Class 1	Class 2	Uniform A	Uniform B
30 (750)			100		
24 (600)		100	85-100		
18 (450)	100	85-100	60-80		
12 (300)	90-100	35-50	20-40		
8 (200)				100	
6 (150)	20-40	10-30	0-20	35-80	95-100
3 (75)	0-10	0-10	0-10		35-80
1 (25)				0-20	0-20
Depth of Riprap, minimum	18 in. (450 mm)	24 in. (600 mm)	30 in. (750 mm)		

The maximum dimension of individual pieces shall not be greater than three times the minimum dimension. The riprap will be visually inspected for size, shape, and consistency.

904.05 Structure Backfill

The material shall be of acceptable quality, free from large or frozen lumps, wood, or other extraneous matter. It shall consist of suitable sand, gravel, crushed stone, ACBF, or GBF. Structure backfill shall be in accordance with one of the following gradations or No. 8, No. 9, No. 11, No. 53, or No. 73 coarse aggregate in accordance with the gradation requirements of 904.03(e). Coarse aggregate No. 8, No. 9, No. 11, No. 53, or No. 73 shall be crushed stone or ACBF, class D or higher.

(e) Sizes of Coarse Aggregates

Sieve Sizes	COARSE AGGREGATE SIZES (PERCENT PASSING)									
	COARSE GRADED								DENSE GRADED	
	2	5	8	9	11	12	43(1)	91	53[1]	73[1]
4 in. (100 mm)										
3 1/2 in. (90 mm)										
2 1/2 in. (63 mm)	100									
2 in. (50 mm)	80-100									
1 1/2 in. (37.5 mm)		100					100		100	
1 in. (25 mm)	0-25	85-98	100				70-90	100	80-100	100
3/4 in. (19 mm)	0-10	60-85	75-95	100			50-70		70-90	90-100
1/2 in. (12.5 mm)	0-7	30-60	40-70	60-85	100	100	35-50		55-80	60-90
3/8 in. (9.5 mm)		15-45	20-50	30-60	75-95	95-100				
No. 4 (4.75 mm)		0-15	0-15	0-15	10-30	50-80	20-40		35-60	35-60
No. 8 (2.36 mm)		0-10	0-10	0-10	0-10	0-35	15-35		25-50	
No. 30 (600 µm)						0-4	5-20		12-30	12-30
No. 200 (75 µm)[2]							0-6.0		5.0-10.0[4]	5.0-12.0
Decant (PCC)[3]		0-1.5	0-1.5	0-1.5	0-1.5	0-1.5		0-1.5		
Decant (Non-PCC)	0-2.5	0-2.5	0-3.0	0-2.5	0-2.5	0-2.0		0-2.5		

Notes:
1. The liquid limit shall not exceed 25 (35 if slag) and the plasticity index shall not exceed 5. The liquid limit shall be determined in accordance with AASHTO T 89 and the plasticity index in accordance with AASHTO T 90.
2. Includes the total amount passing the No. 200 (75 µm) sieve as determined by AASHTO T 11 and T 27.
3. Decant may be 0-2.5 for stone and slag.
4. When slag is used for separation layers as defined in 302.01, the total amount passing the No. 200 (75 µm) sieve shall be 10.0 to 12.0.

Base Material

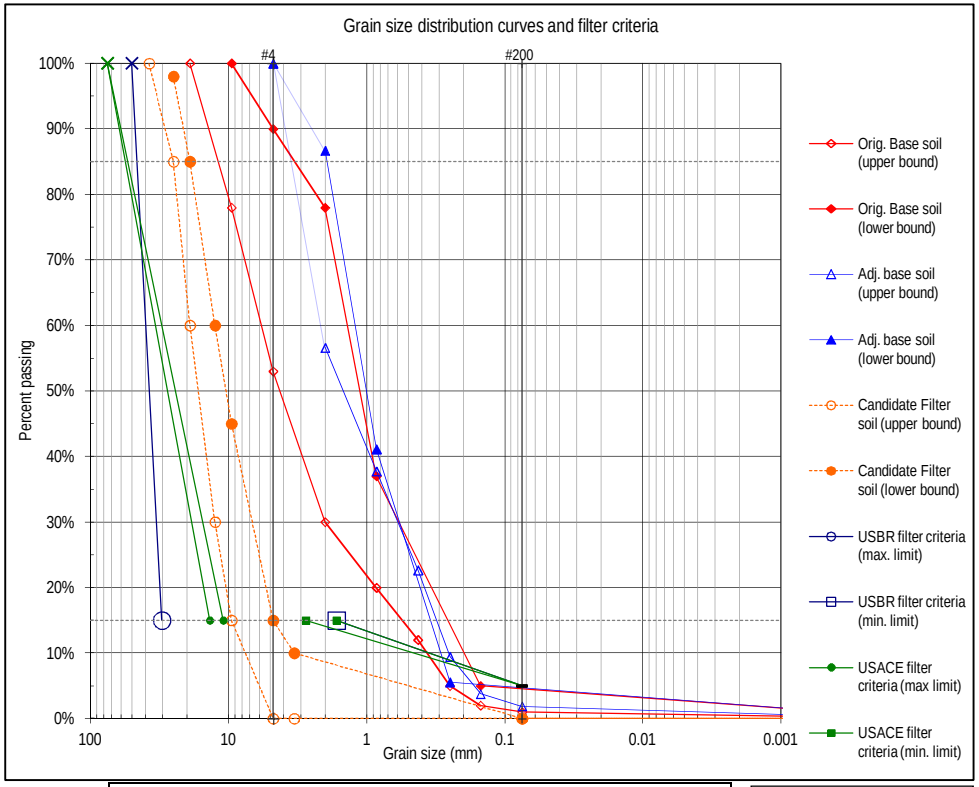
Determine the gradation curves of the base soil. Use enough samples to define the range of grain size for the base soil. Design the filter gradation based on the base soil that requires the smallest D_{15F} size. If soil has particles larger than the #4 sieve, an adjusted gradation is calculated. Input values below for the base soil (original) gradation (in red):

Project: CA5 Name: YG
Date: 3/12/13

Particle size (mm)	Sieve #	Base soil (original), % passing (upper bound)	(lower bound)	Adjusted gradation, % passing upper bound	lower bound
75	-				
37.5	-				
19.0	-	100.0%			
9.5	-	78.0%	100.0%		
4.75	4	53.0%	90.0%	100.0%	100.0%
4.00	5				
3.35	6				
2.80	7				
2.36	8				
2.00	10	30.0%	78.0%	56.6%	86.7%
1.70	12				
1.40	14				
1.18	16				
1.00	18				
0.850	20	20.0%	37.0%	37.7%	41.1%
0.710	25				
0.600	30				
0.500	35				
0.425	40	12.0%		22.6%	
0.300	50				
0.250	60	5.0%	5.0%	9.4%	5.6%
0.212	70				
0.180	80				
0.150	100	2.0%	5.0%	3.8%	5.6%
0.125	120				
0.106	140				
0.090	170				
0.075	200	1.0%	5.0%	1.9%	5.6%
0.053	270				
0.037	-				
0.019	-				
0.009	-				
0.005	-				
0.002	-				
0.001	-				
0.0001	-	0.0%	0.0%	0.0%	0.0%

Required entry values are defined below. *

Average % passing #200 after regarding (if any) = A = 3.7%



Properties of base soil	Upper bound	Lower bound
D_{85B} of original base soil =	11.844 mm	3.313 mm
D_{85B} of adjusted base soil =	3.522 mm	1.938 mm
D_{15B} of original base soil =	0.5512 mm	0.2579 mm
D_{15B} of adjusted base soil =	0.3126 mm	0.3460 mm
D_{60B} of adjusted base soil =	2.140 mm	1.212 mm
D_{10B} of adjusted base soil =	0.2558 mm	0.2913 mm
C_u of adjusted base soil =	8.4	4.2

Fixed points on graph:
- <5% passing #200
- 50mm max. grain size (USBR)
- 75mm max. grain size (USACE)

Filter Material

Filter criteria required by the USBR as published in *Design Standards - Embankment Dams No. 13 (1994):*

D_{85B} used in filter design	7.578
Average Passing #200 sieve of base soil (from adjusted gradation)	3.7%
Base soil category	4
Base soil description	Sands and gravels
Filter criteria (mm)	Maximum: $D_{15F} \leq$ 30.31 To ensure sufficient permeability: Minimum: $D_{15F} \geq$ 1.65
Maximum particle size of filter (mm)	50
Maximum % passing # 200 sieve	5%
PI of material passing #40	0 when tested in accordace with USBR 5360, Earth Manual on material passing #40

Filter criteria required by the US Army Corps of Engineers as published in EM 1110-2-2300 (31 Jul 94):

D_{85B} used in filter design	2.730
Average Passing #200 sieve of base soil (from adjusted gradation)	3.7%
Base soil category	4**
Filter criteria (mm)	Maximum: $D_{15F} \leq$ 10.92 to 13.65 To ensure sufficient permeability: Minimum: $D_{15F} \geq$ 1.65 to 2.76
Maximum particle size of filter (mm)	75
Maximum % passing # 200 sieve	5%
PI of material passing #40	0 when tested in accordance with EM 1110-2-1906

**If the base soil is in category 4, use the lower of the two 'max. D_{15F}' values when the filter is beneath riprap subject to wave action or beneath drains which may be subject to violent surging and/or vibration.

*Required entry values for base soil & candidate filter gradations:

1. Particle size for 100% passing.
2. % Passing the #4 sieve.
3. % Passing the #200 sieve.
4. One point in the 85% - 90% range and another point in the 80% - 85% range, or the 85% point.
5. One point in the 15% - 20% range and another point in the 10% - 15% range, or the 15% point.
6. No duplicate entries; if D100<#4, enter 101% for #4 and 100% for appropriate size.

USBR filter gradation limits:

Maximum limit	
Grain size (mm)	% Passing
50.00	100.0%
30.31	15.0%

Minimum limit	
Grain size (mm)	% Passing
1.65	15.0%
0.075	5.0%

USACE filter gradation limits:

Maximum limit	
Grain size (mm)	% Passing
75.00	100.0%
13.65	15.0%
10.92	15.0%

Minimum limit	
Grain size (mm)	% Passing
1.65	15.0%
2.76	15.0%
0.075	5.0%

Candidate filter soil gradation. Values shown in red in the left column, and all values in the two right columns, can be changed.

Particle size *mm*	Sieve #	% Passing (upper bound)	% Passing (lower bound)
150.0	-		
100.0	-		
90.0	-		
75.0	-		
63.0	-		
50.0	-		
37.5	-	(100.0%)	
25.0	-	(85.0%)	(98.0%)
19.0	-	(60.0%)	(85.0%)
12.5	-	(30.0%)	(60.0%)
9.5	-	15.0%	(45.0%)
4.75	4	0.0%	15.0%
3.35	6	(0.0%)	(10.0%)
2.36	8		
2.00	10		
1.70	12		
1.40	14		
1.18	16		
0.850	20		
0.600	30		
0.425	40		
0.300	50		
0.250	60		
0.212	70		
0.180	80		
0.150	100		
0.125	120		
0.106	140		
0.090	170		
0.075	200	(0.0%)	(0.0%)
0.053	270		
0.037	-		
0.019	-		
0.009	-		
0.0001	-	0.0%	0.0%

Required entry values are defined above. *

Properties of candidate filter soil (CF). D sizes are in mm:					
	D_{85CF}	D_{15CF}	D_{60CF}	D_{10CF}	C_u
upper bound	25.00	9.50	19.00	7.54	2.52
lower bound	19.00	4.75	12.50	3.35	3.73

Acceptibility of candidate filter (CF) soil:

USBR criteria	Upper bound	Lower bound
Max % passing #200:	OK	OK
Max particle size (mm):	OK	OK
Maximum D_{15CF}:	OK	OK
Minimum D_{15CF}:	OK	OK
To minimize segregation (from *Table 2*)***		
Max allowable D_{90CF} =	40	OK
Max D_{90CF} =	28.62	

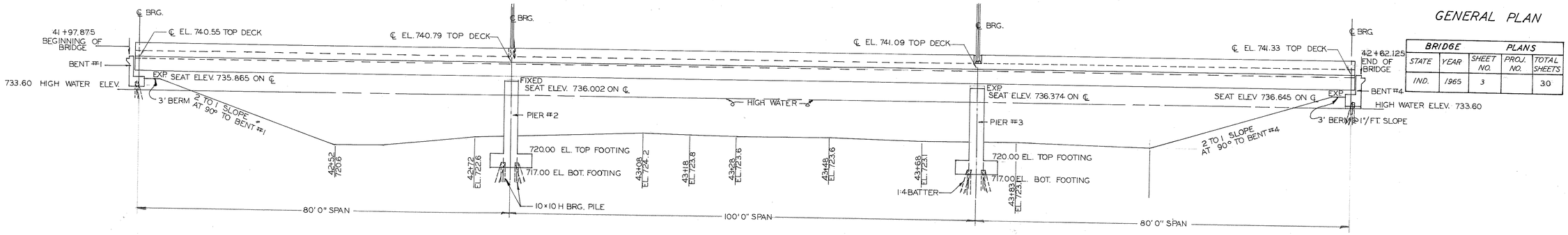
USACE criteria	Upper bound	Lower bound
Max % passing #200:	OK	OK
Max particle size (mm):	OK	OK
Maximum D_{15CF}:	OK	OK
Minimum D_{15CF} ($3 \times D_{15B}$):	OK	OK
Minimum D_{15CF} ($5 \times D_{15B}$):	OK	OK
To minimize segregation (from *Table B-3*)***		
Max allowable D_{90CF} =	40	OK
Max D_{90CF} =	28.62	

Filters should be relatively uniform (see the C_u value of the candidate filter soil.). Also, filters should not be gap-graded.

*** Generally, this requirement is only necessary for coarse filters and gravel zones that serve as both filters and drains. For sand filters with D_{90} < ~20mm, these limitations are usually not necessary.

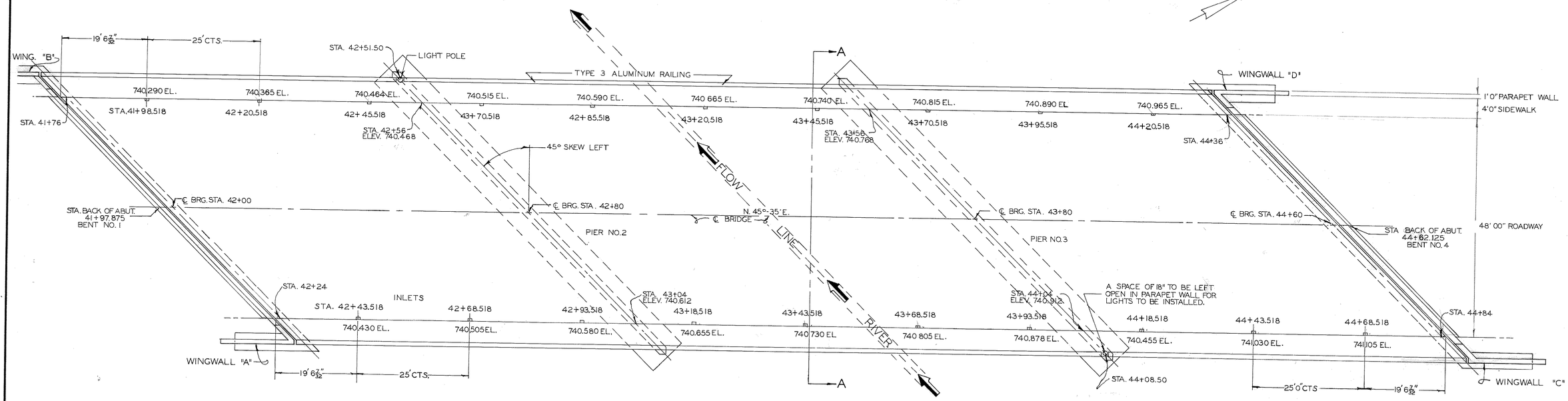
GENERAL PLAN

BRIDGE		PLANS		
STATE	YEAR	SHEET NO.	PROJ. NO.	TOTAL SHEETS
IND.	1965	3		30



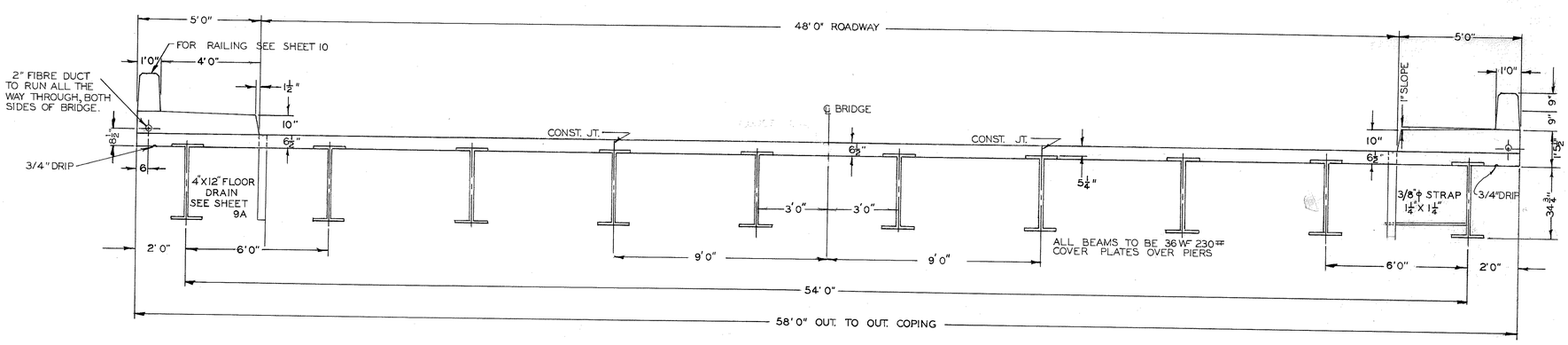
SECTIONAL ELEVATION

SCALE 3/32"=1'0"



PLAN

SCALE 3/32"=1'0"



SECTION A-A

SCALE 3/8"=1'0"

GENERAL NOTES

SPECIFICATIONS IN ACCORDANCE WITH INDIANA STATE HIGHWAY COMMISSION STANDARD 1963.
ALL STRUCTURAL STEEL TO BE A-36 AND REINFORCING A-15
NO PRESENT STRUCTURE AT PROPOSED BRIDGE SITE.
CONCRETE IN FOOTINGS AND PIER STEMS BELOW CONSTRUCTION JOINT TO BE CLASS "E".
CONCRETE IN SUPERSTRUCTURE INCLUDING PARAPET AND CONCRETE RAILING, AND ALL CONCRETE IN END BENTS AND PIER CAP ABOVE CONST. JT. TO BE CLASS "F".
CONCRETE CONTINUOUS POURS SHALL BE REQUIRED BETWEEN CONSTRUCTION JOINT AS SHOWN ON DETAIL PLANS.
FIELD CONNECTIONS – ALL FIELD CONNECTIONS TO BE FRICTION TYPE WITH HIGH-STRENGTH BOLTS AND WASHERS. ALL BOLTS A-325 AND 7/8" ϕ.
PILING TO BE USED 10×10 H 57# BEARING PILE, DRIVEN TO BEARING CAPACITY OF 50 TONS.
WATERPROOF BACK OF MUDWALL AND WINGS ON END BENTS IN ACCORDANCE WITH SPECIFICATIONS.
BEVEL FORMS 3/4" UNDER COPINGS, AND CHAMFER EXPOSED EDGES 3/4" UNLESS NOTED.
I & M ELECTRIC TO FURNISH ALL MATERIAL FOR LIGHTS AND CONTRACTOR TO INSTALL.
FOR PAINTING SEE SHEET NO. 7

DESIGN DATA

DESIGNED IN ACCORDANCE WITH A.A.S.H.O. SPECIFICATION, 1961 EDITION, H 20-S 16-44 LOADING AND INDIANA STATE HIGHWAY COMMISSION STANDARD 1963.

UNIT STRESSES: FC = 1200 #/IN.², FS = 20,000 #/IN.² (REINF.), FS = 20,000 #/IN.² (STRUCTURAL)
SLAB DESIGNED OF DEAD LOAD INCREASED 35 #/FT.² OF ROADWAY FOR FUTURE WEARING SURFACE.

GENERAL PLAN
CONTINUOUS STEEL BEAM BRIDGE

3 SPANS: 80'0" – 100'0" – 80'0"
45° SKEW, 48'0" ROADWAY