Geotechnical Design
for
Habitat Construction

Case Study:
Peoria Riverfront Development

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USACE, Rock Island

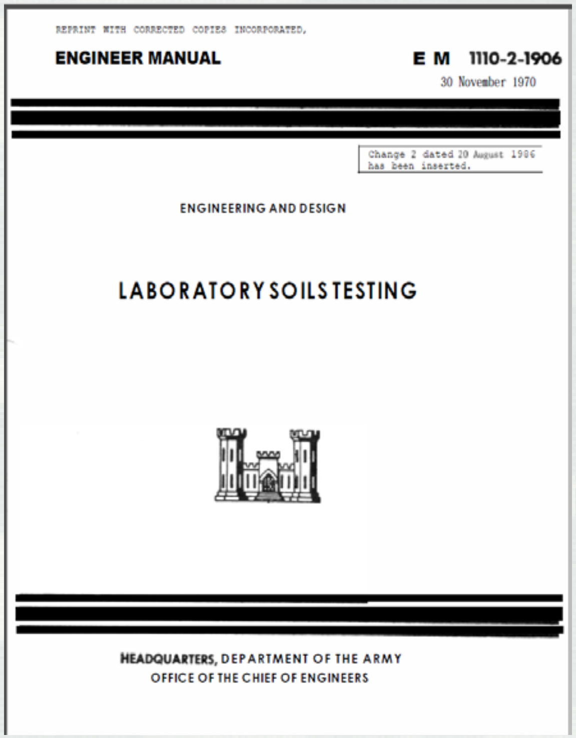
Topics

- **Traditional vs ‘Wet’ Geotechnical Engineering Design**
  Basic Differences

- **Peoria Riverfront Development**
  ‘Wet’ Geotechnical Engineering Design Case Study

- **Conclusions**
  ‘Take Home’ Points

Soil Characteristics



REPRINT WITH CORRECTED COPIES INCORPORATED.

ENGINEER MANUAL

EM 1110-2-1906

30 November 1970

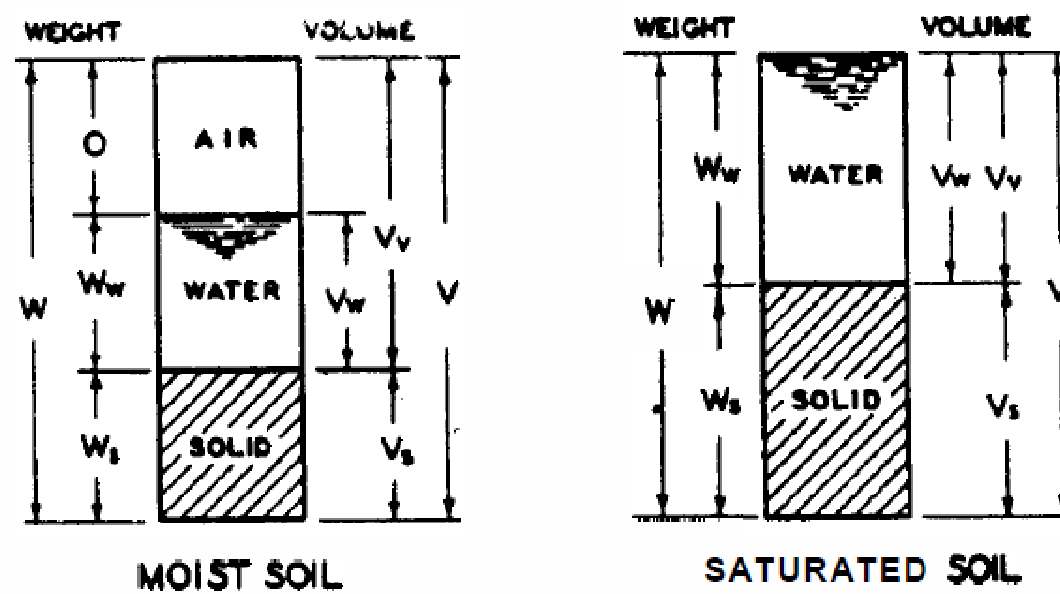
Change 2 dated 20 August 1986 has been inserted.

ENGINEERING AND DESIGN

LABORATORY SOILS TESTING

HEADQUARTERS, DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS

Moist vs Saturated



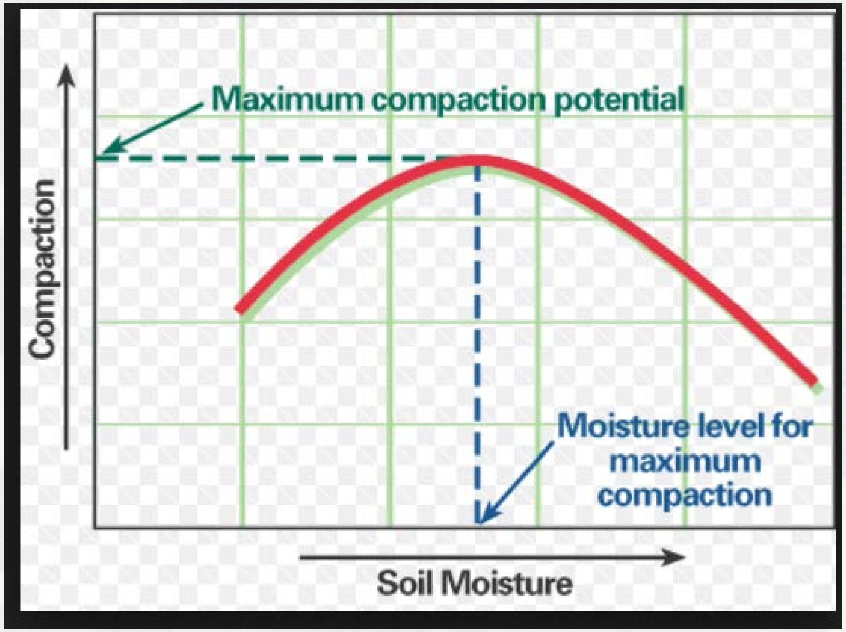
WATER CONTENT $w = \frac{W_w}{W_s}$

DRY UNIT WEIGHT (DRY DENSITY) $\gamma_d = \frac{W_s}{V}$

WET UNIT WEIGHT (WET DENSITY) $\gamma_m = \frac{W}{V}$

Typical Moist Soil Construction

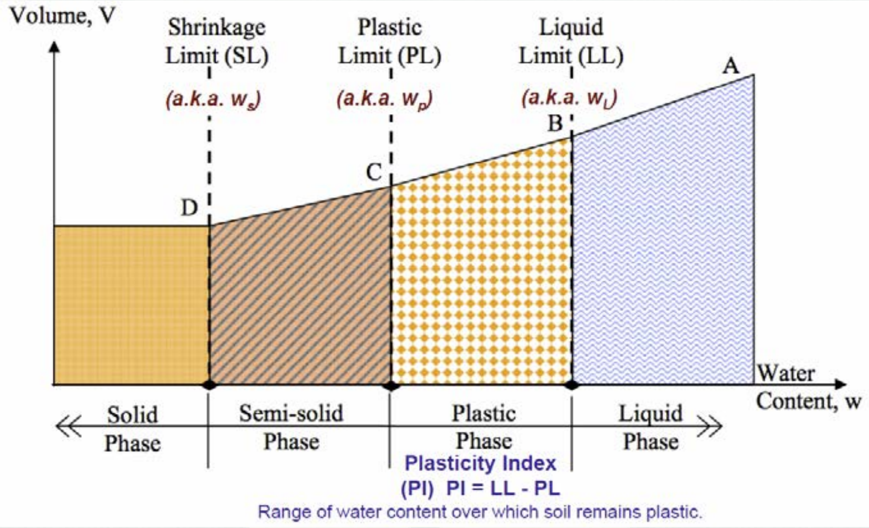
Optimum Moisture



Density Control

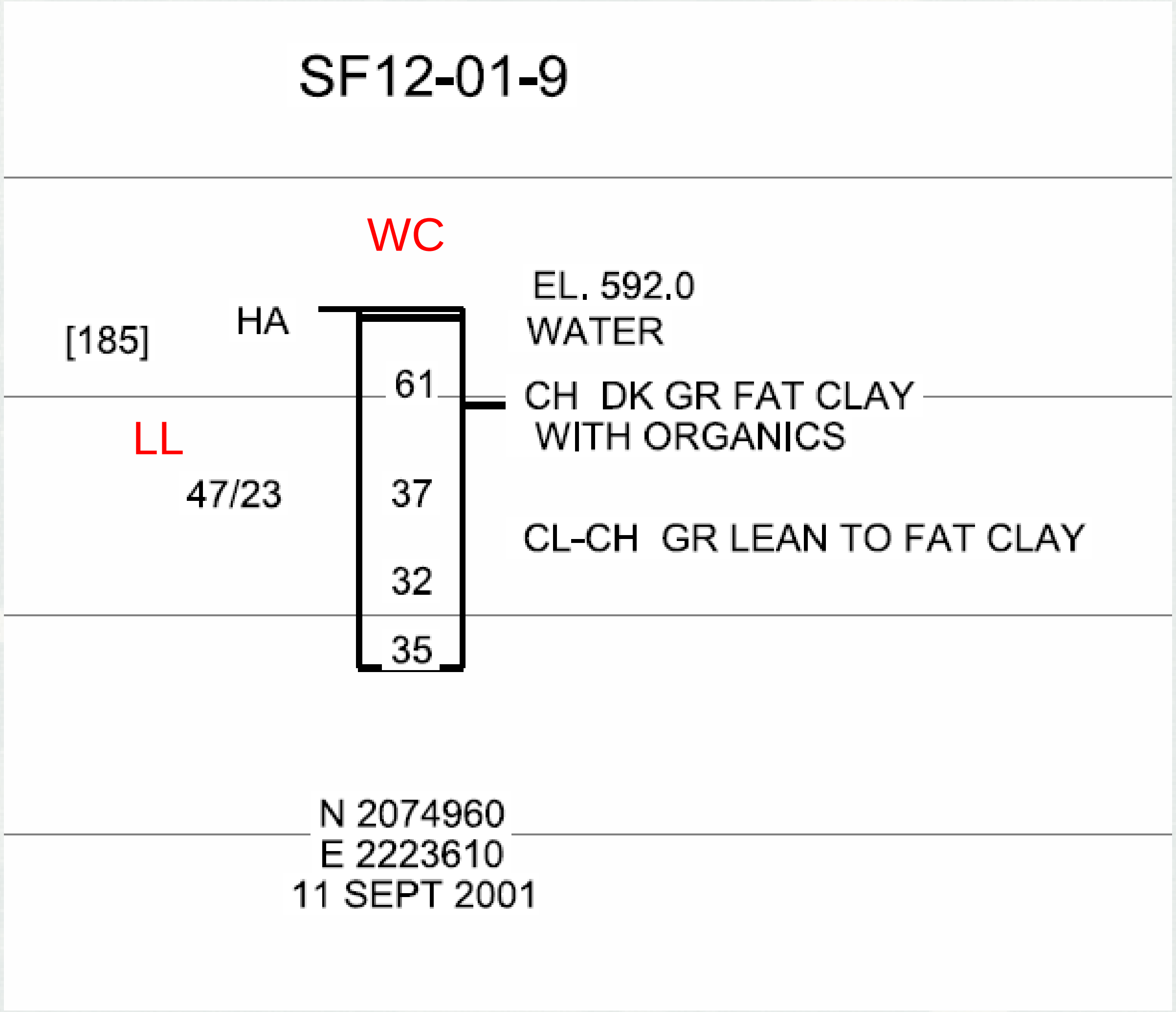
Atterberg Limit Testing

The *liquid limit* (LL) is conceptually defined as the *water content (WC)* at which the behavior of a clayey soil changes from plastic to liquid

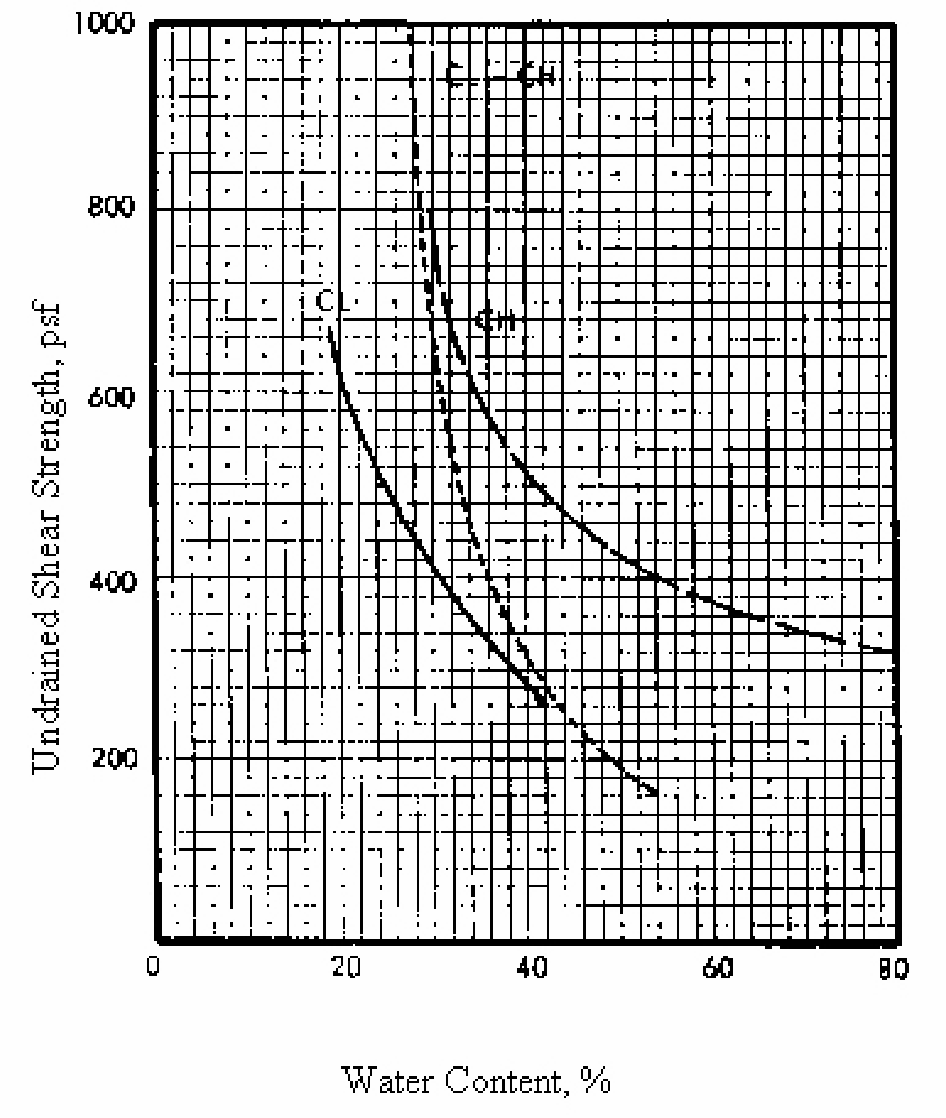


Typical Saturated Soil (Backwater Sediment)

high WC in upper 2-4 feet **lower WC with depth**



Rock Island Soil Water Content /Strength Correlation

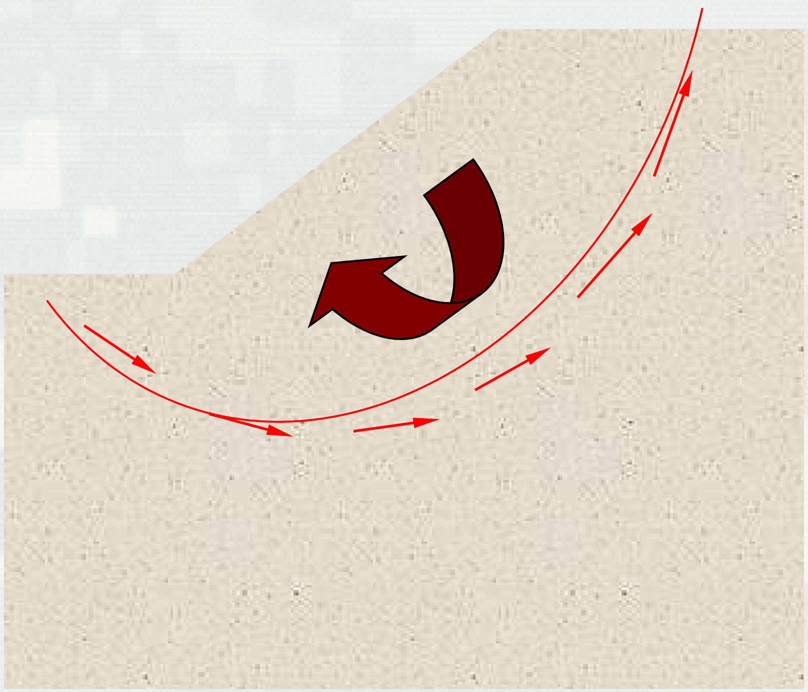


BUILDING STRONG®

Typical Moist Soil Design / Construction

Control Over Soil Compaction and Strength

Stable Cut and Embankment Fill Slopes



Principles are
Generally Applicable
to
Saturated Sediment
Design & Construction

Saturated Sediment
Main Geotechnical Design Outputs

Cut Slope Height and Steepness (Overwintering Habitat)

Embankment Slope Height and Steepness (Elevation Diversity)

Cut / Embankment Fill Slope Offset Distance (Slope Stability)

Dredge Bucket Size and Type

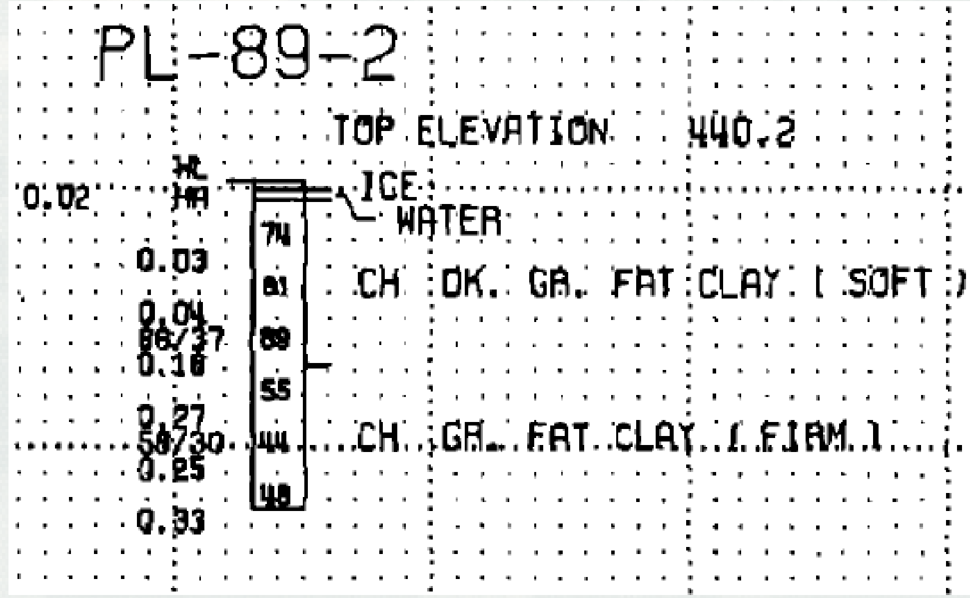
Contract Duration to Achieve Final Geometry

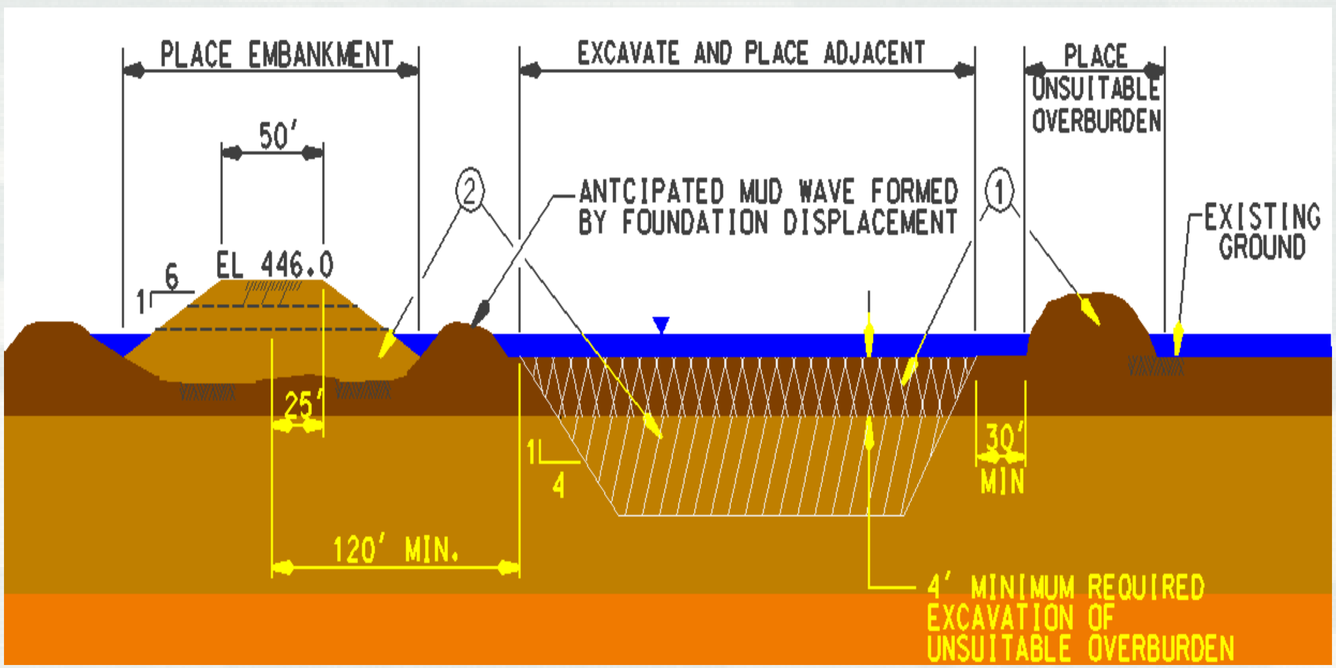
Saturated Sediment Geotechnical Design Examples

▪ Peoria Lake	1991
▪ Lake Chautauqua	1997
▪ Pool 11 Islands	2005

Peoria Lake - 1991

Sidecast Mechanical Dredging

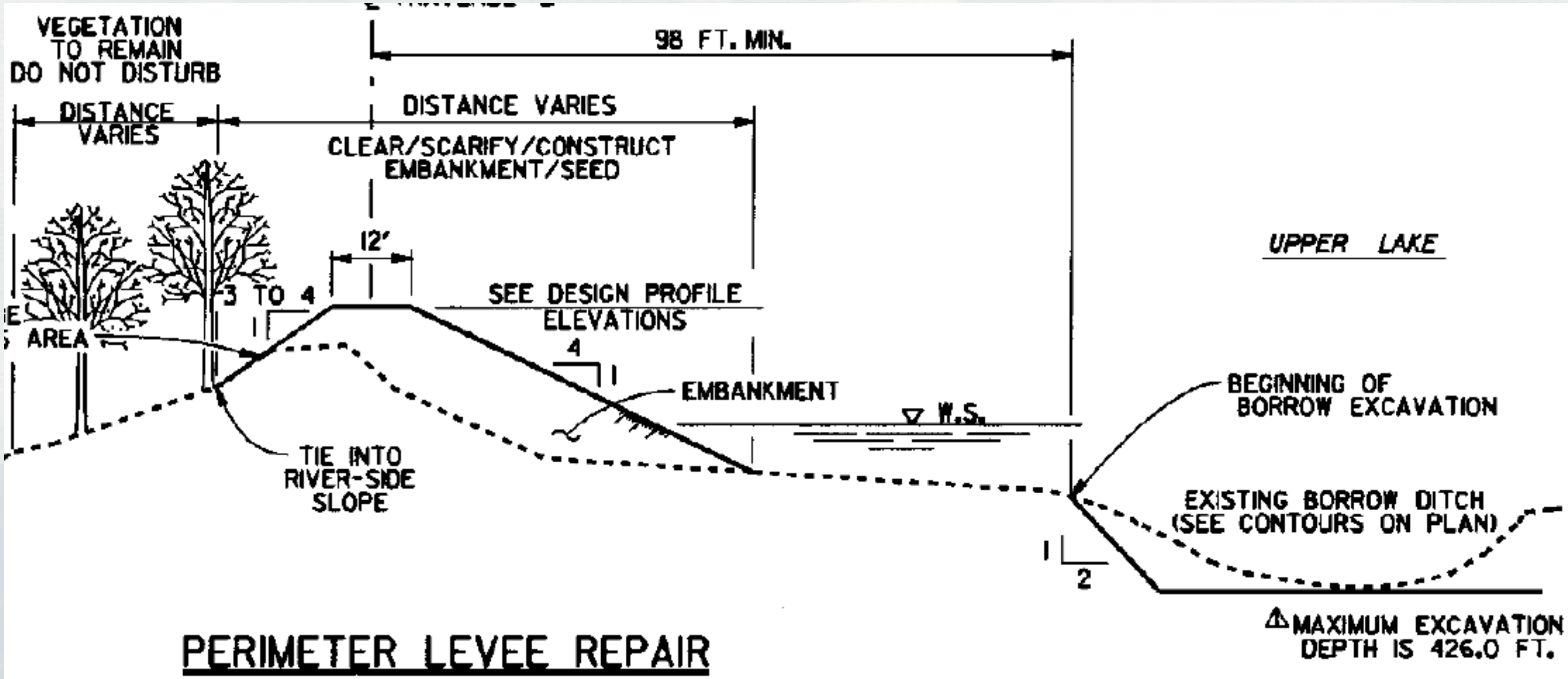

PL-89-2
TOP ELEVATION 440.2
0.02
ICE
WATER
0.03
CH DK. GR. FAT CLAY (SOFT)
0.04
86/37
0.16
0.27
58/30
0.25
CH GR. FAT CLAY (FIRM)
0.33
74
81
89
55
44
48


PLACE EMBANKMENT
EXCAVATE AND PLACE ADJACENT
PLACE UNSUITABLE OVERBURDEN
50'
EL 446.0
1
6
2
ANTCIPATED MUD WAVE FORMED BY FOUNDATION DISPLACEMENT
1
EXISTING GROUND
25'
1
4
30' MIN
120' MIN.
4' MINIMUM REQUIRED EXCAVATION OF UNSUITABLE OVERBURDEN

Peoria Lake – 10 cuyd Clamshell Bucket

Lake Chautauqua – 1997

Backhoe Dredging Bankline Placement



Pool 11 Islands – 2005

Sidecast Mechanically Dredged Containment Embankment

Hydraulically Dredged Overwintering Habitat Channels

Containment Embankment Placement

Low Ground Pressure Equipment

Hydraulic Dredging Design Tools

ERDC/TN EEDP-06-12
November 2004

DREDGING OPERATIONS TECHNICAL SUPPORT PROGRAM

The Automated Dredging and Disposal Alternatives Modeling System (ADDAMS)

by Paul R. Schroeder, Michael R. Palermo, Tommy E. Myers, and Cheryl M. Lloyd

EM 1110-2-5027
30 September 1987

US Army Corps of Engineers

Engineering Manual

Confined Disposal of Dredged Material

Hydraulic Dredging Design

Inputs:

Excavation Volume Excavated Material Types Hydraulic Dredge Size

Lab Settling and Consolidation Test Data

Effluent Water Quality Requirements

Outputs:

Containment Area and Depth Effluent Weir Dimensions

Thickness and Elevation of Multiple Lifts of Dredged Material Placed at Given Time Intervals (Long Term Storage Capacity)

Additional Design Tools
for
Hydraulic Dredging and Sediment Containment

Sediment Dewatering

Chemical Flocculant Addition

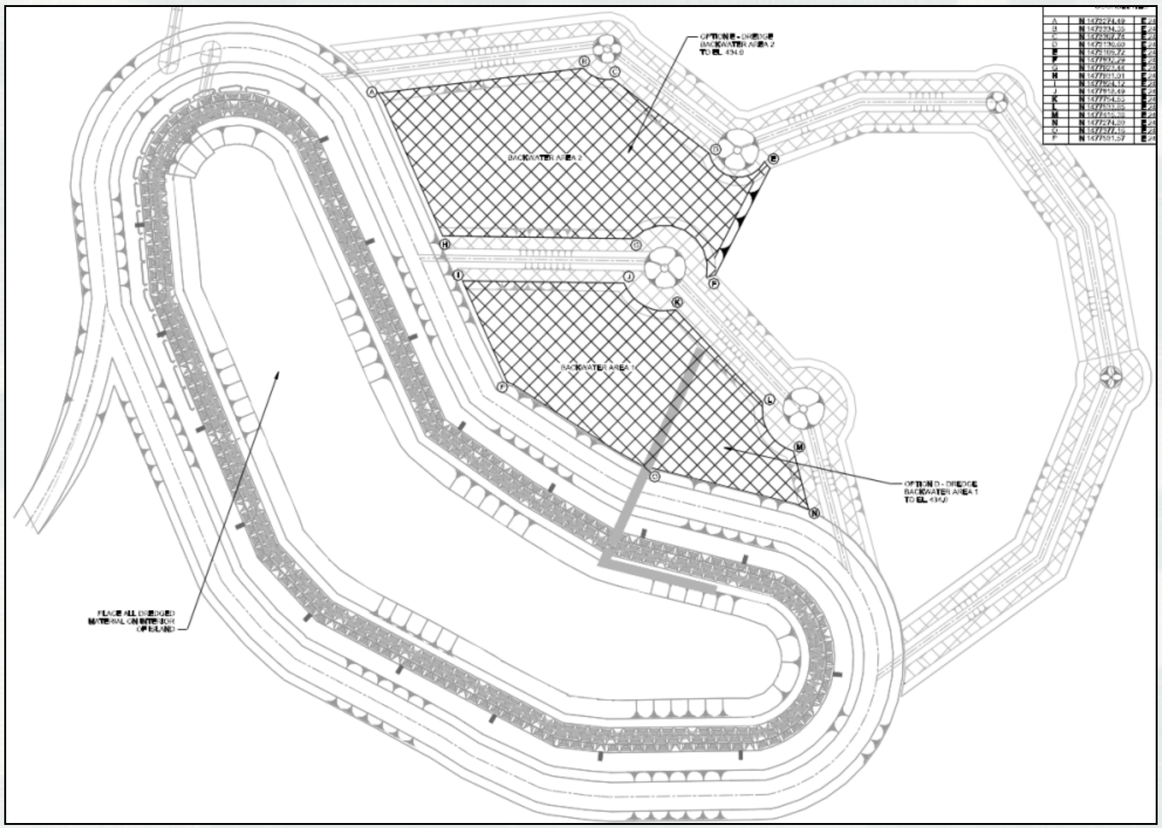
Background Complete
for
Rock Island District's
State of Geotechnical Design
for
Habitat
through 2003

Ready to Begin Case Study

Peoria Riverfront – 2008 to 2012

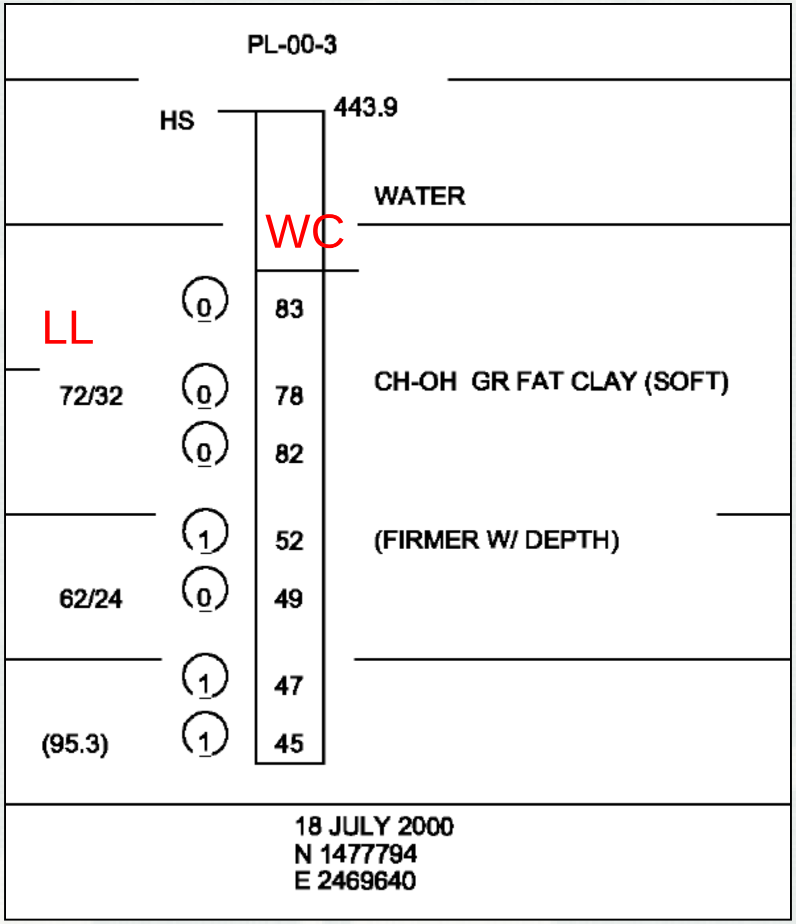
Original Plan

Mechanically-Dredged Containment Embankment and Hydraulically-Dredged Overwintering Habitat



- 55 acres of dredging
  - ► Dredge backwater 5’ deep
  - ► Dredge channels 9’ deep
  - ► Dredge holes
  - ► 450,000 CY
- 21 acres of island

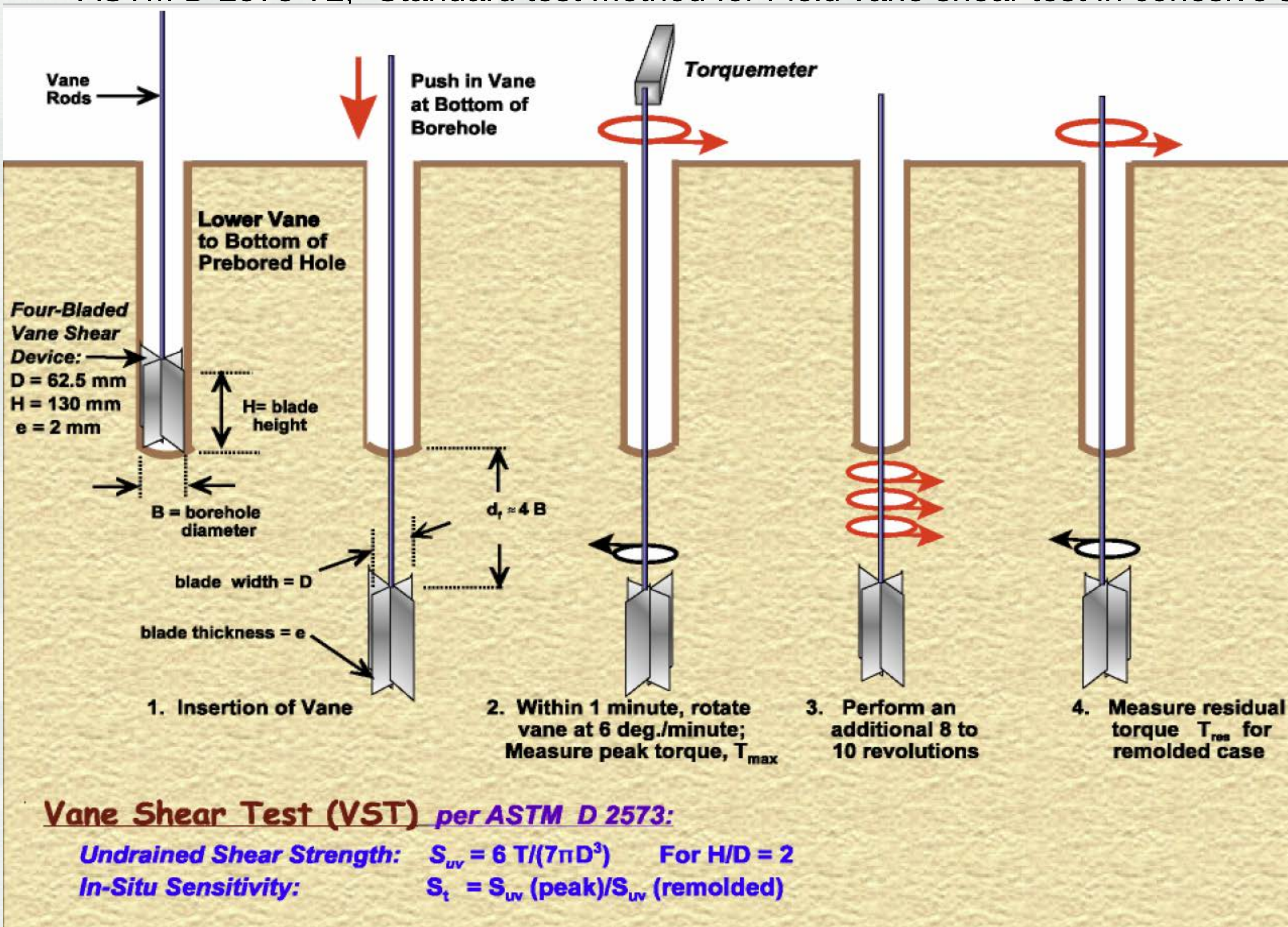
High Water Contents to 10-20 foot Depths



- High WC close to LL
- Low vane shear strengths
- Weakest sediment to date in Rock Island District

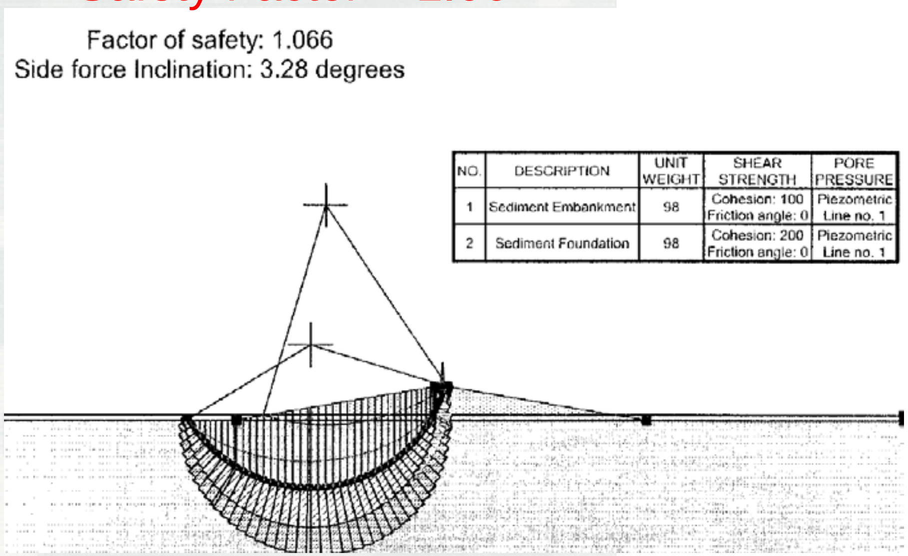
Soil Strength Testing - Vane Shear Test

ASTM D 2573-72, "Standard test method for Field vane shear test in cohesive soil".

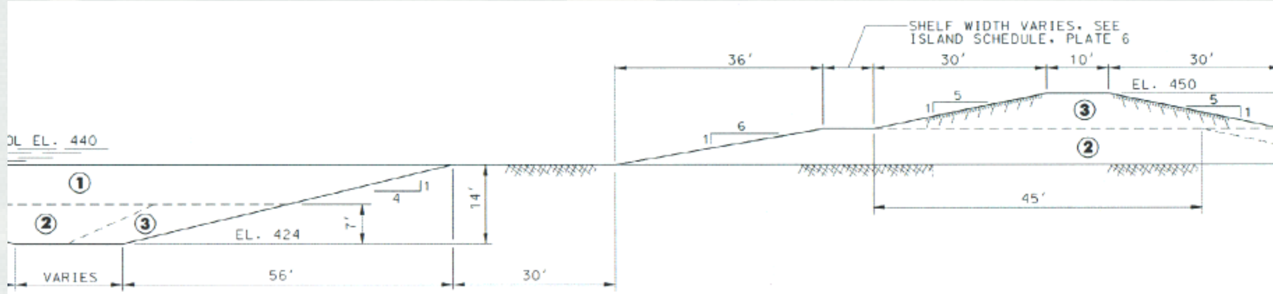


Low Confidence in Stability
Complicated and Lengthy Construction

Safety Factor = 1.06



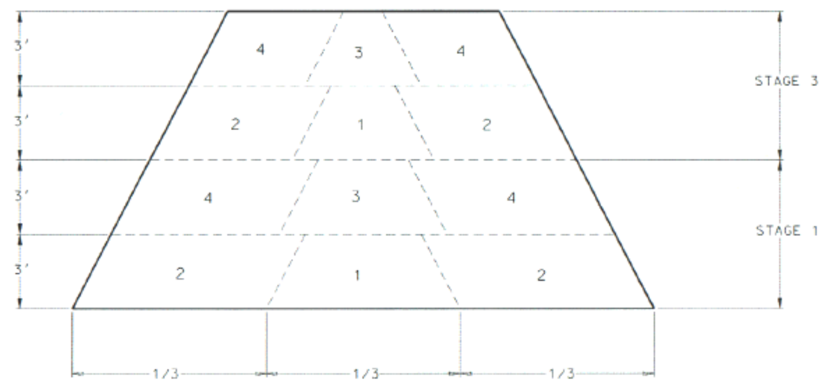
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Sediment Embankment	98	Cohesion: 100 Friction angle: 0	Piezometric Line no. 1
2	Sediment Foundation	98	Cohesion: 200 Friction angle: 0	Piezometric Line no. 1



EMBANKMENT DREDGING AND PLACEMENT SEQUENCE

NO SCALE

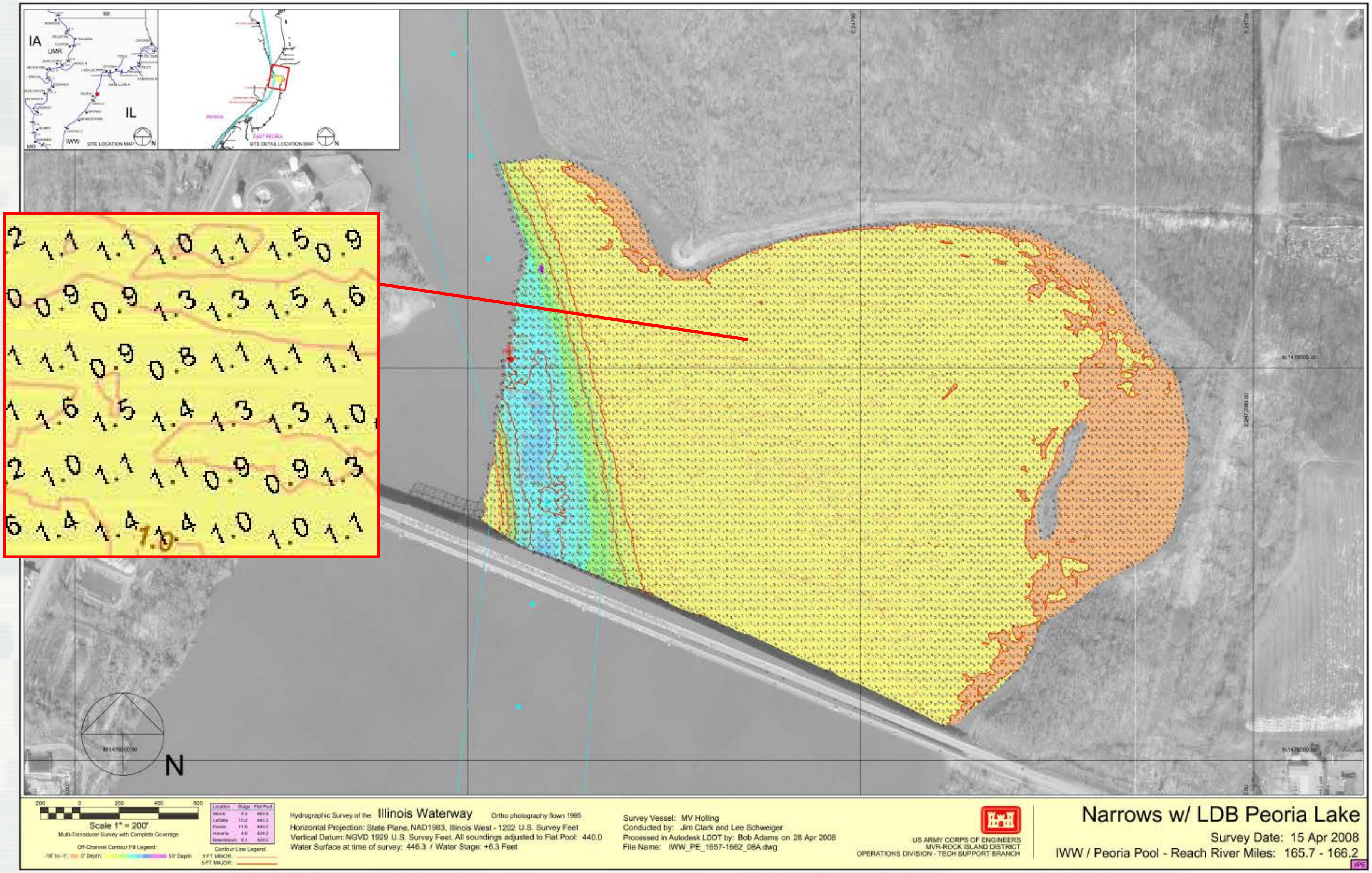
ISLAND SCHEDULE	
ISLAND	SHELF WIDTH
1	40'
2	40'
3	20'



TYPICAL ISLAND EMBANKMENT CONSTRUCTION SEQUENCE

Extreme Low-Strength Sediment to 20-foot depth

Field Conditions – Shallow Water



BUILDING STRONG®

Mechanical Dredging Constraints

- Large distance between excavation and placement areas

  resulting in double handling of dredged material

- Sediment too weak to ‘stack’, requiring multiple passes and years to build containment embankment
- Foundation too weak to support embankment
- Erosion potential during construction

Hydraulic Dredging Constraints

- Small Dredged Containment Area Size
- Less Habitat Diversity – flat
- Hydraulically dredged fine sediment does not drain from geotextile container fabric quickly, resulting in ‘flat’ containers

RISK OF BAD OUTCOME TOO HIGH

BEGIN EXPLORING ALTERNATIVES

Benefits of Geotextile Containers

- Adds lateral confinement to a otherwise difficult to use, low stiffness, high WC fine grained sediment
- Water quality
- Advantageous onsite water depths
- Reduced stress on underlying soils, uniformly distributing weight
- Durability

New Design Tools

- Drake's Creek – USACE, Nashville
- Soil / Water relationships – material balances
- Geotextile Container Stability
- Geotextile Container Design

Drake’s Creek

US Army Corps of Engineers
Nashville District

High Solids Dredging

- High solids content achieved by mechanical dredging.
- The goal of 40% solids was rarely achieved.

Material Balance Tool

Table 4. Dredged Material Soil Properties Before, During and After Dredging											
In Situ Dredged Material Soil Properties Prior To Dredging											
Specific	Water	Void	Percent	Wet Bulk	Dry Bulk	Wet Bulk	DryBulk	Wet Bulk	Dry	Shrinkage	Volume
Gravity	Content	Ratio	Solids	Density	Density	Density	Density	Density	Density	or Bulking	In Situ
of	Ww/Ws	e=Vv/Vs	S%=	(Gs+e)/	Gs/(1+e)	Wt/Vt	Wt/Vt	Wt/Vt	Ws/Vt	Factor	to be
Solids			Ws/Wt	(1+e)	Ws/Vt					(e+1)/	Dredged
				Wt/Vt						(e+1)	
	%		%	gr/ml	gr/ml	pcf	pcf	tons/cy	tons/cy	SF	Wet cy
2.65	69	1.8	59	1.581	0.933	101.2	59.69	1.366	0.8058		120,000
Soil Properties Bulked in Geotextile Tubes and in Disposal Area After Initial Placement											
2.65	100	2.7	50	1.452	0.726	90.6	45.30	1.223	0.6116	1.28	154,143
Soil Properties After Consolidation and Dewatering in Tubes and Disposal Area											
2.65	59	1.6	63	1.645	1.037	102.7	64.7	1.39	0.87	1.43	107,957

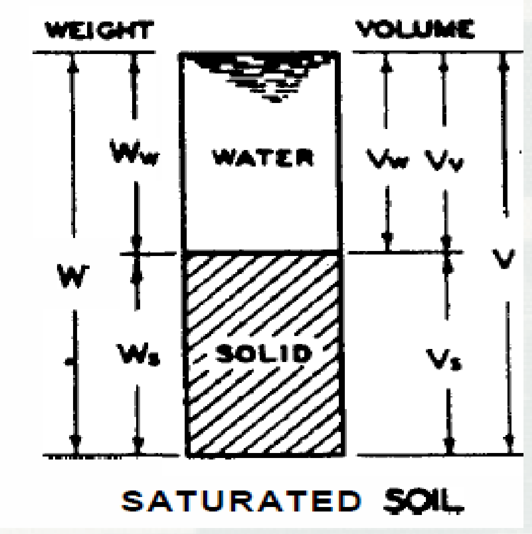
Estimated Volume Decrease (%) = 0.10

Specific	Water	Void	Percent
Gravity	Content	Ratio	Solids
of	Ww/Ws	e=Vv/Vs	S%=
Solids			Ws/Wt
	%		%
2.65	62	1.6	61

(Used DOER Program ERDC TN-DOER-D1 page 10 to get S% in D23)

SAMPLE DATE		23-Sep				
Sample #	Date	Station	Specific	Water	Void	Percent
	Filled		Gravity	Content	Ratio	Solids
			of	Ww/Ws	e=Vv/Vs	S%=
			Solids			Ws/Wt
				%		%
1	16-Aug	2 + 00	2.65	50	1.3	66
2	16-Jul	54 + 49	2.65	56	1.5	64
3	22-Sep	37 + 04	2.65	71	1.9	58
					AVG =	63

- Balance dredge cut / fill
- Predict bulking
- Set reasonable % solids requirement
- Control Quality



Key Contract Requirement From Material Balance Tool

1.4.4 **Dredge Plant Requirements**

The Contractor shall select a dredging system that provides the required concentration of effluent solids. The Corps of Engineers requires *no less than 50 percent (by weight) average effluent solids prior to placement in either geotextile containers, or the designated placement area*, in order to ensure that the geotextile containers retain their intended heights.

Sediment Foundation Failure Under Geotextile Container Load

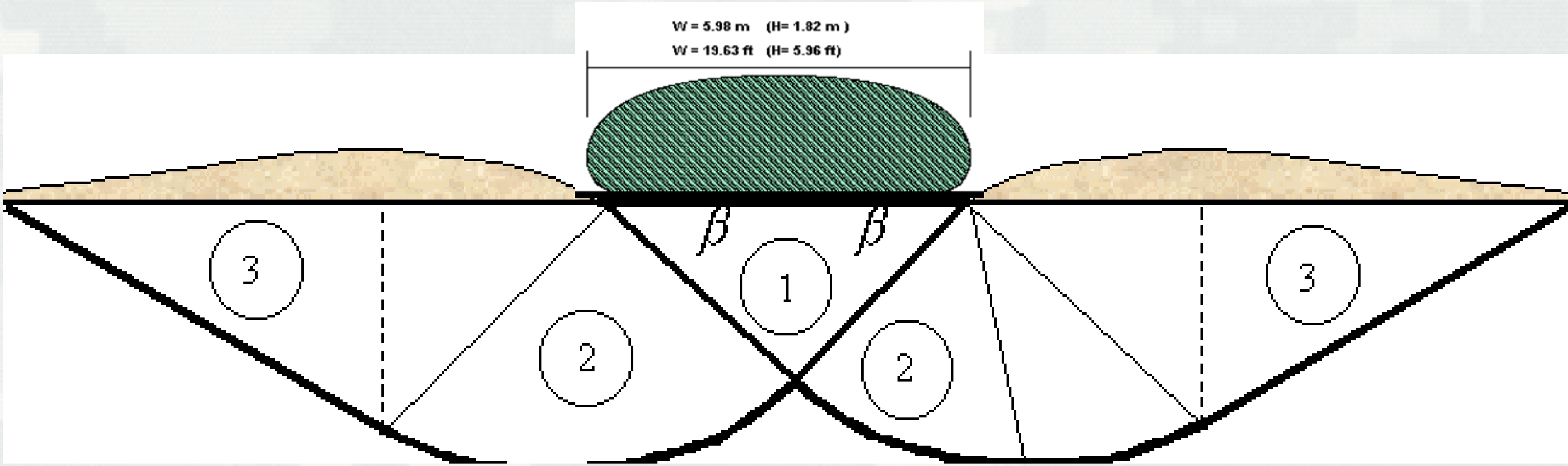
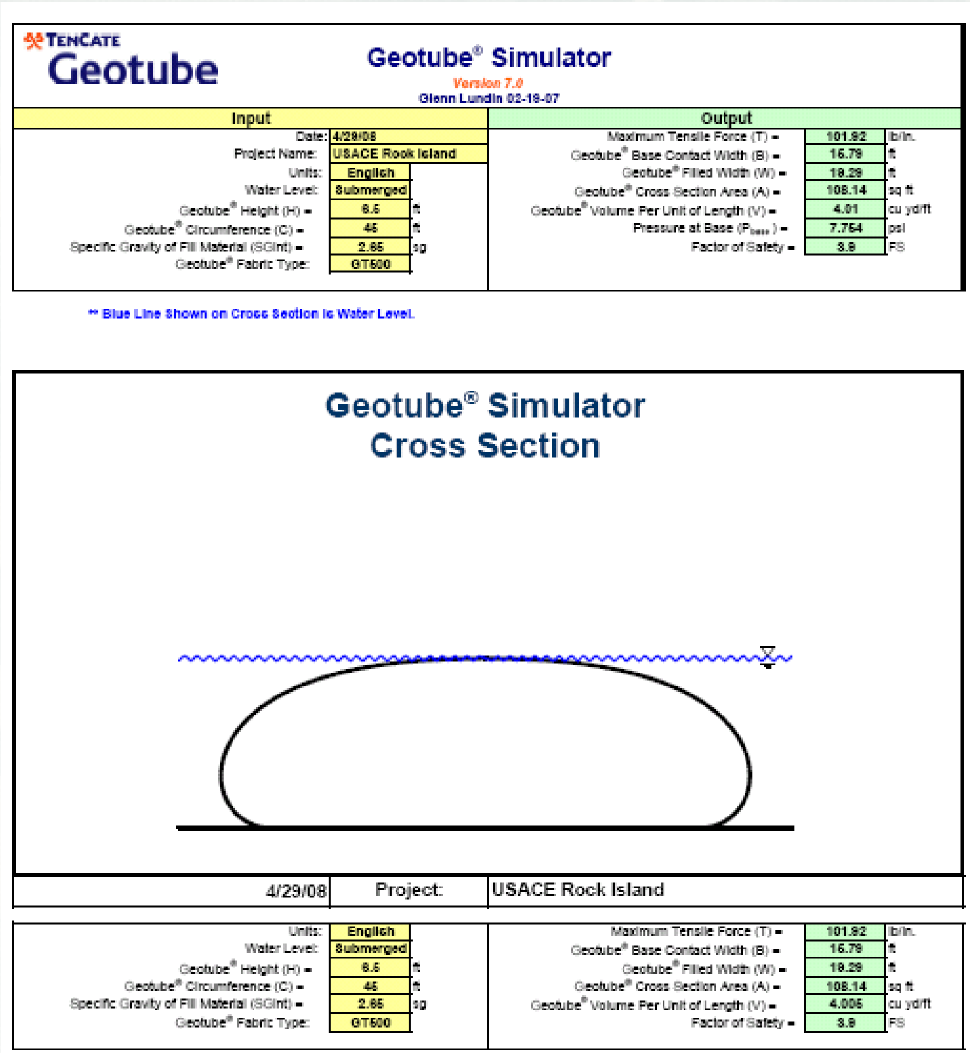


TABLE C-4 Sediment Embankment Bearing Capacity		
Depth (ft)	qallow	FS
1	98	5.24
2	196	2.62
3	294	1.75
4	392	1.31
5	490	1.05
6	588	0.87
cohesion (psf)=		100
qult=(5.14)*(cohesion)=		514

Height = 5ft
Factor of Safety =1.05

Geotextile Container *Fabric* Design



TENCATE Geotube

Geotube® Simulator

Version 7.0

Glenn Lundin 02-18-07

Input			Output		
Date:	4/29/08		Maximum Tensile Force (T) =	101.92	lb/in.
Project Name:	USACE Rock Island		Geotube® Base Contact Width (B) =	16.79	ft
Units:	English		Geotube® Filled Width (W) =	18.29	ft
Water Level:	Submerged		Geotube® Cross Section Area (A) =	108.14	sq ft
Geotube® Height (H) =	6.5	ft	Geotube® Volume Per Unit of Length (V) =	4.01	cu yd/ft
Geotube® Circumference (C) =	45	ft	Pressure at Base (P_{base}) =	7.764	psi
Specific Gravity of Fill Material (SGinf) =	2.65	sg	Factor of Safety =	3.8	FS
Geotube® Fabric Type:	GT500				

** Blue Line Shown on Cross Section is Water Level.

Geotube® Simulator
Cross Section

4/29/08	Project:	USACE Rock Island

Units:	English		Maximum Tensile Force (T) =	101.92	lb/in.
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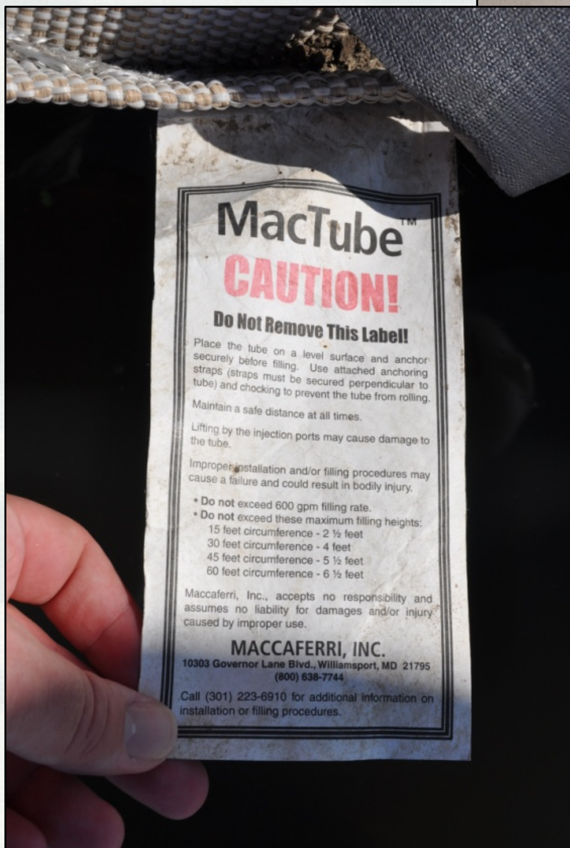
Specific Gravity of Fill Material (SGinf) =	2.65	sg	Geotube® Volume Per Unit of Length (V) =	4.005	cu yd/ft
Geotube® Fabric Type:	GT500		Factor of Safety =	3.8	FS

- Based on *Advanced Strength of Materials*, Hartog
- Iterative solution which balances tension in fabric and slurry density

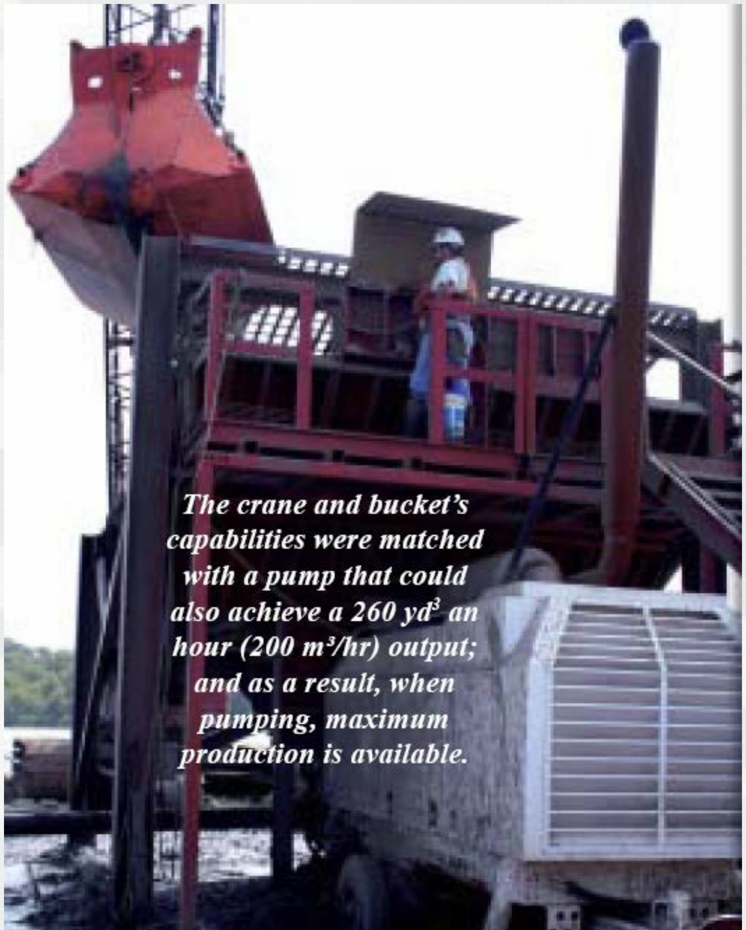
Geotextile Container Specifications



- High strength woven polypropylene fibers to resist calculated tensile forces
- 45’ Circumference
- 100’ long and 60’ long- shorter ones used for curves
- 6’ high after initial filling
- 5’ high after a year
- UV resistant

Contractor's Response to Specifications

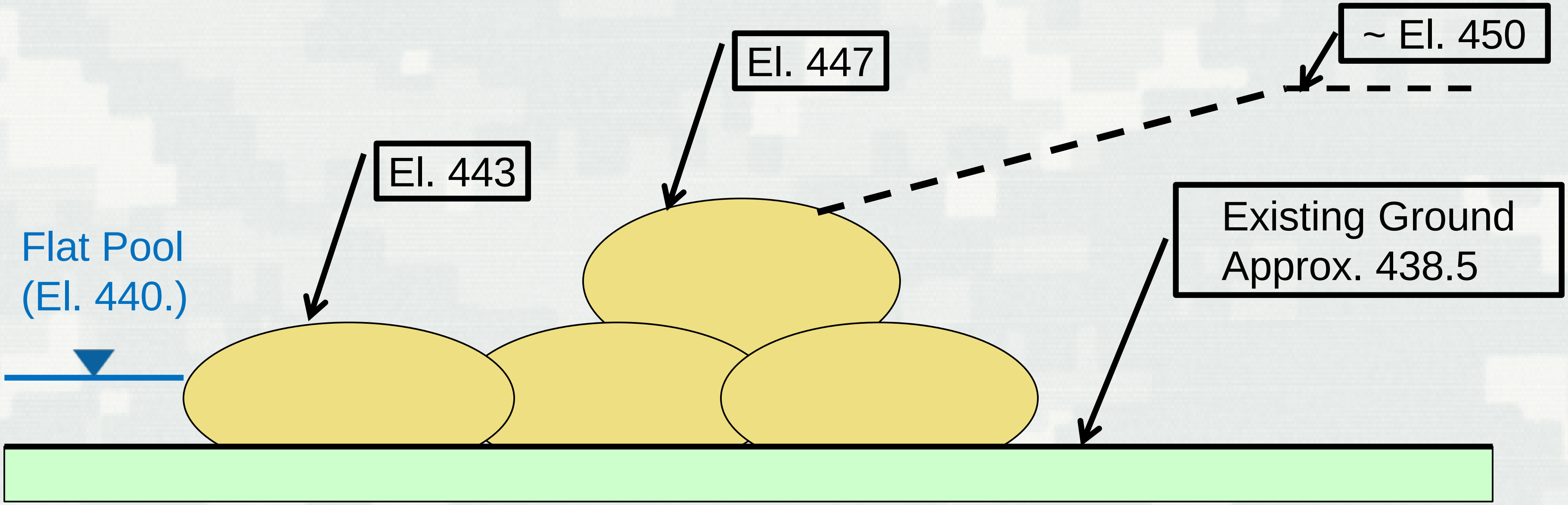
World Dredging, Mining, & Construction, Vol. 45



- 6 cuyd *vented* crane bucket
- 'big mouth' screened hopper
- 260 cuyd/hr concrete pump

Dredge line leading from concrete pump to geotextile containers

Successful ‘Stacked’ Test Section Stability



- After completion of the first layer, most geotubes are 5’ high (EL 443.5)
- A second layer test section was added for applicability to future projects

Minor displacement of sediment beneath geotextile containers (FS = 1.06)

Stage I Construction

- 135-100’ geotextxtile containers filled, 25 - 60’ geotextile containers filled
- 14,715’ of bags
- Entire CDF/island perimeter finished
- Approximately 49,400 CY of material dredged
- Rip Rap placed for erosion protection

Stage II – Fill ‘Island’ Interior

Inside View

Outside View

Spring 2014

Containers remain intact and above the sediment surface
Containers achieved goal of sediment confinement
Interior sediment from overwintering habitat dredging has some topography

Take Home Points

- Start with ‘classical’ geotechnical engineering design principles
- Adapt principles appropriately and recognize limitations
- Incorporate new ideas appropriately
- Do not ‘overspecify’ contractor’s means and methods
  - limits ingenuity
- Take advantage of opportunities to test concepts for future applications
- Involve geotechnical designers early in planning process to help screen alternatives early

QUESTIONS ??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