Innovative Geosynthetic Saves 100 -Year-Old Panama Canal Locks

IFAI Geosynthetics Conference

1

IFAI Geosynthetics Conference

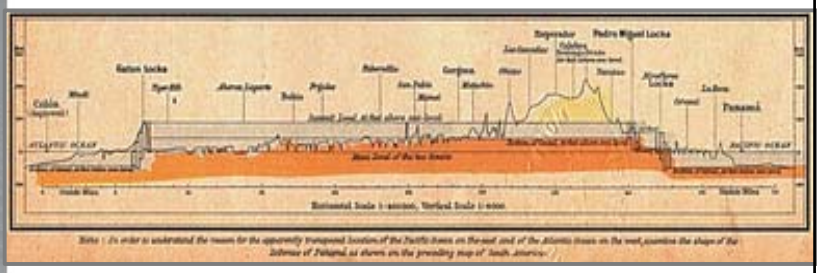
Dedicated to Bruce Lacina 1970 - 2019

2

Innovative Geosynthetic Saves 100 -Year-Old Canal

3

IFAI Geosynthetics Conference



The 1907 US Design for The Panama Canal

4

The Gatun Locks Under Construction in 1911
East Side Chamber Looking South

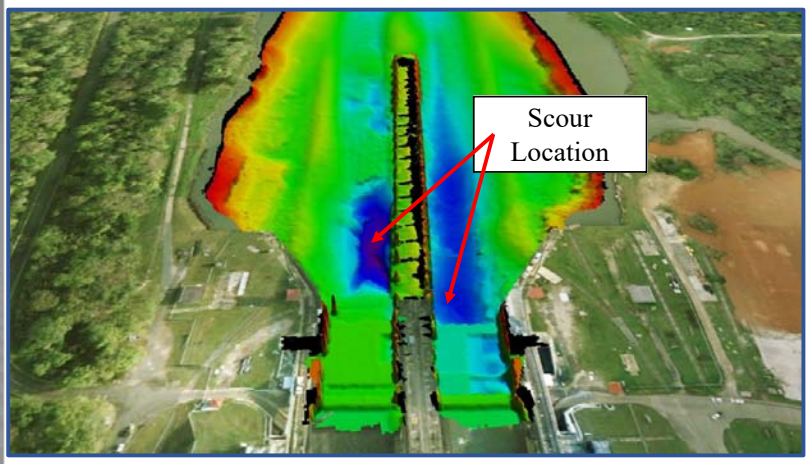
5

SS Ancon first ship to transit the Panama Canal Aug. 15, 1914
Gatun Locks East Chamber Looking North

6

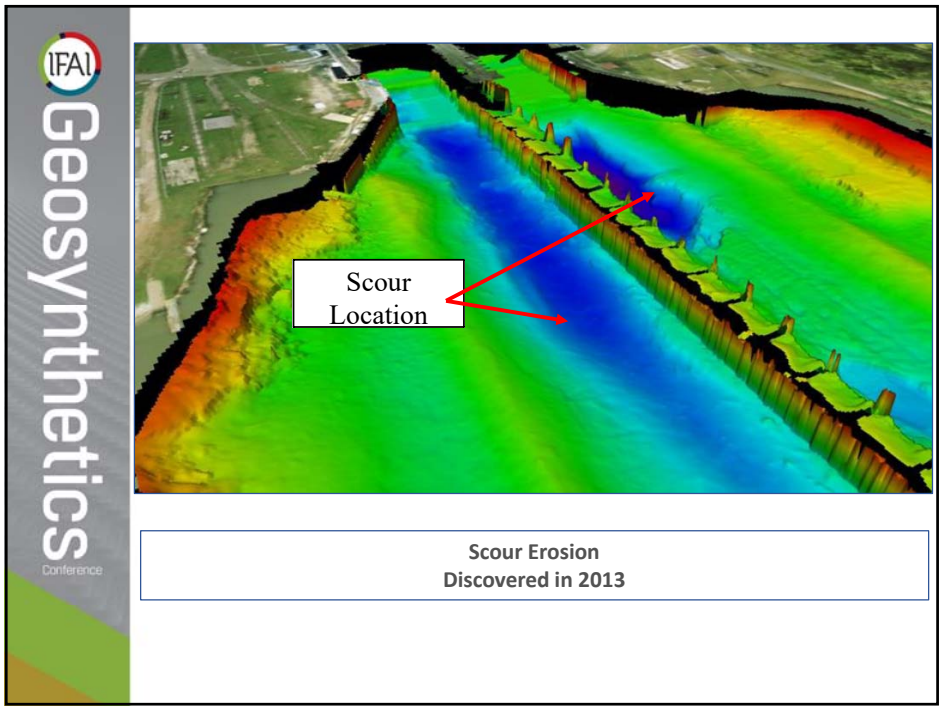
Gatun Locks
Atlantic Entrance

7



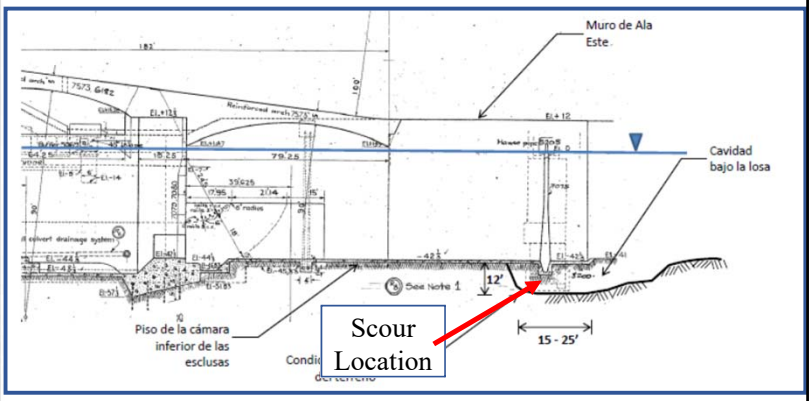
Scour Erosion
Discovered in 2013

8



Scour Erosion
Discovered in 2013

9



Scour Erosion
Discovered in 2013

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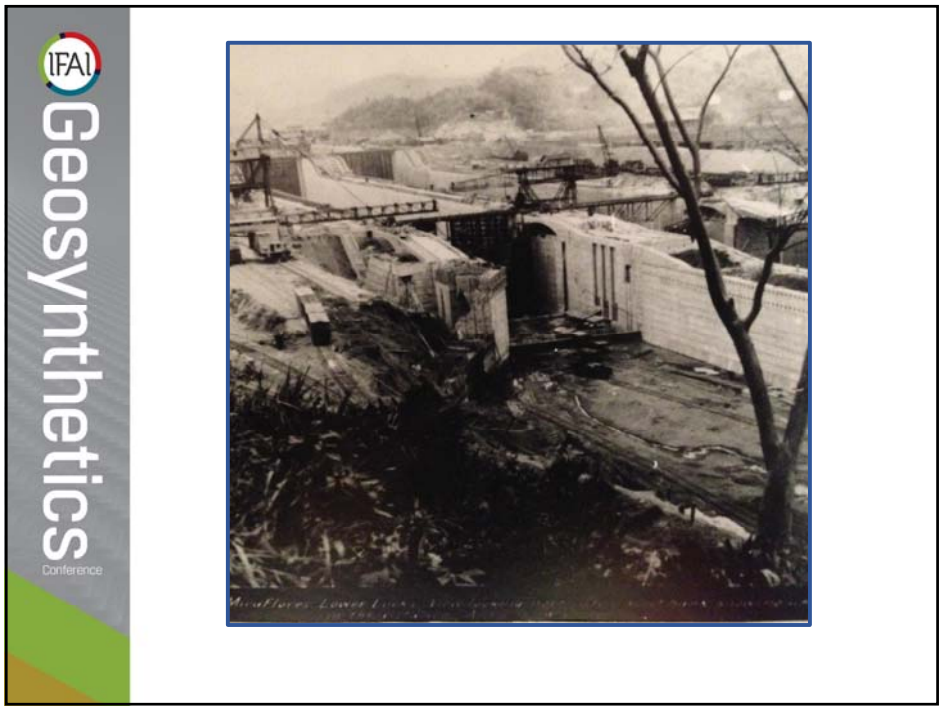

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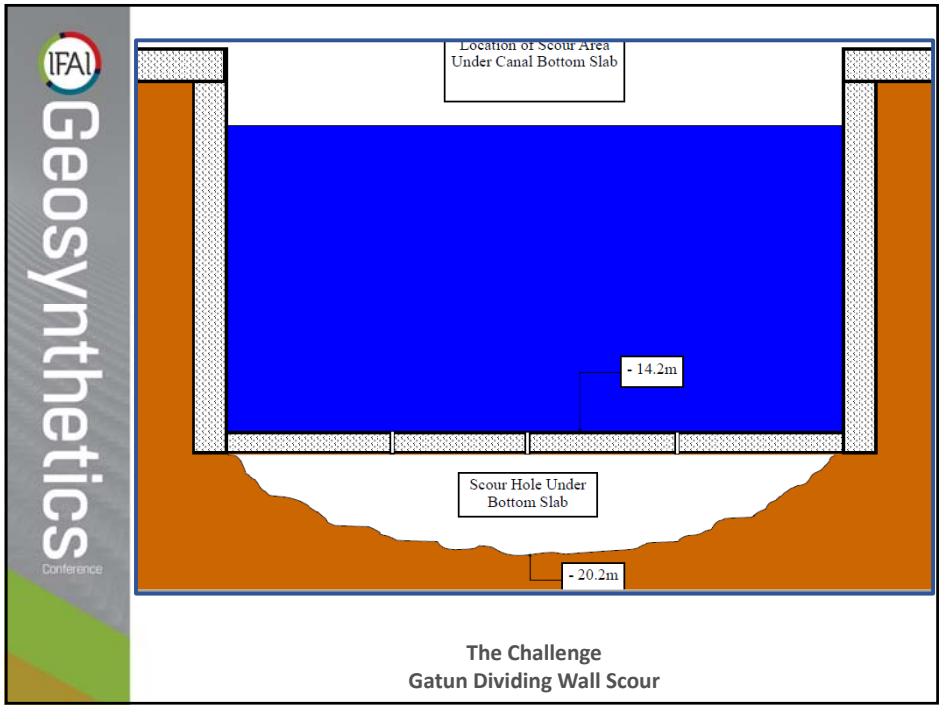
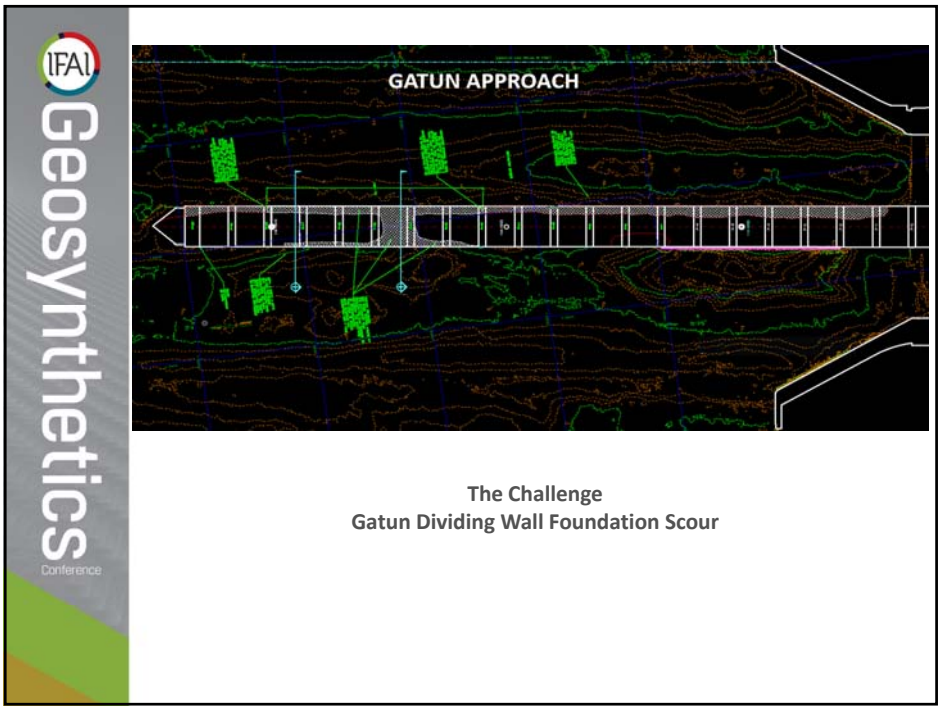


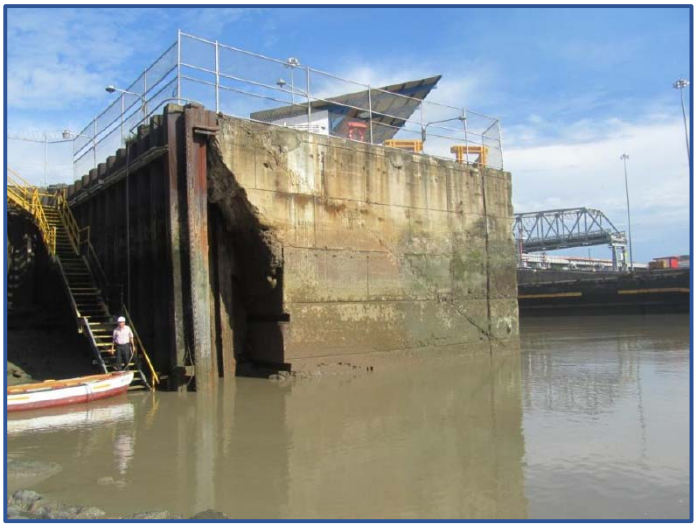
The Challenge
Gatun Dividing Wall Scour

12



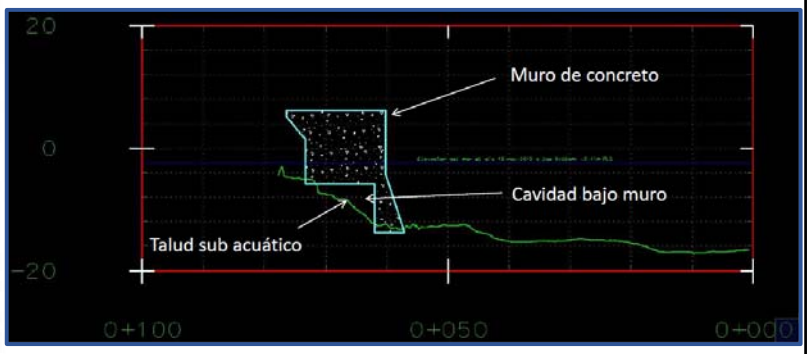
The Challenge
Gatun Dividing Wall Foundation Scour

13



The Challenge
Miraflores Locks Southwest Wing Wall

14



Miraflores Locks Southwest Wing Wall

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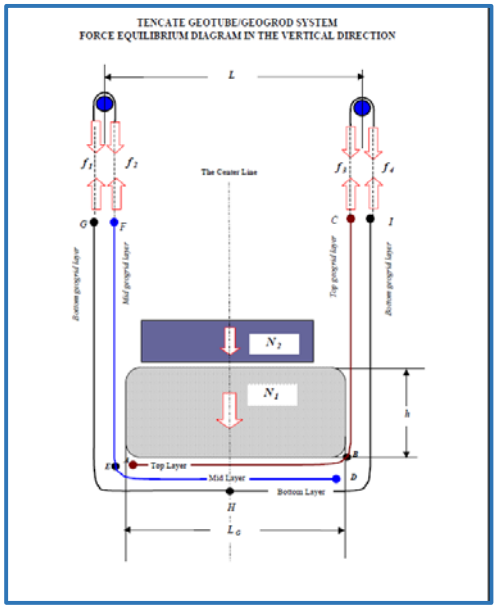
The Culprits

16

The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

17



The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

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Mechanical Properties	Test Method	Unit	Minimum Average Roll Value
			Machine Direction
Tensile Strength (at ultimate)	ASTM D 6637	kN/m (lbs/ft)	400.0 (27415)
Tensile Strength (at 5% strain)	ASTM D 6637	kN/m (lbs/ft)	102.1 (7000)
Creep Reduced Strength	ASTM D 5262	kN/m (lbs/ft)	253.2 (17351)
Long Term Allowable Design Load[1]	GRI GG-4(b)	kN/m (lbs/ft)	219.2 (15023)

[1] NOTE: Long Term Allowable Design values are for sand, silt and clay

Physical Properties	Test Method	Unit	Typical Value
Grid Aperture Size (machine direction)	--	mm (in)	35.6 (1.4)
Grid Aperture Size (cross machine direction)	--	mm (in)	12.7 (0.5)
Mass/Unit Area	ASTM D 5261	g/m^2 (oz/yd^2)	1119 (33)
Roll Dimensions (length x width)	--	m (ft)	3.6 (12) x 61 (200)
Roll Area	--	m^2 (yd^2)	220 (267)
Estimated Roll Weight	---	kg (lbs)	250 (551)

400 kN/m Woven PET / PVC Coated Geogrid
Lifting Harness

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Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Wide Width Tensile Strength (at ultimate)	ASTM D4595	lbs/in (kN/m)	1142 (200)	1142 (200)
Wide Width Tensile Elongation	ASTM D4595	%	20 (max.)	20 (max.)
Factory Seam Strength	ASTM D4884	lbs/in (kN/m)	913 (160)	
CBR Puncture Strength	ASTM D6241	lbs (kN)	4000 (17.8)[1]	
UV Resistance (% strength retained after 500 hrs)	ASTM D4355	%	85	

Hydraulic Properties	Test Method	Unit	Minimum Average Roll Value
Apparent Opening Size (AOS)	ASTM D4751	U.S. Sieve (mm)	30 (0.60)
Water Flow Rate	ASTM D4491	$gal/min/ft^2$ ($l/min/m^2$)	20 (815)
Permittivity	ASTM D4491	sec^{-1}	0.35

Physical Properties	Test Method	Unit	Typical Value[1]
Mass/Unit Area	ASTM D5261	oz/yd^2 (g/m^2)	33 (1119)

200 kN/m Woven PP Geotextile
Geobag Sand Filled Container

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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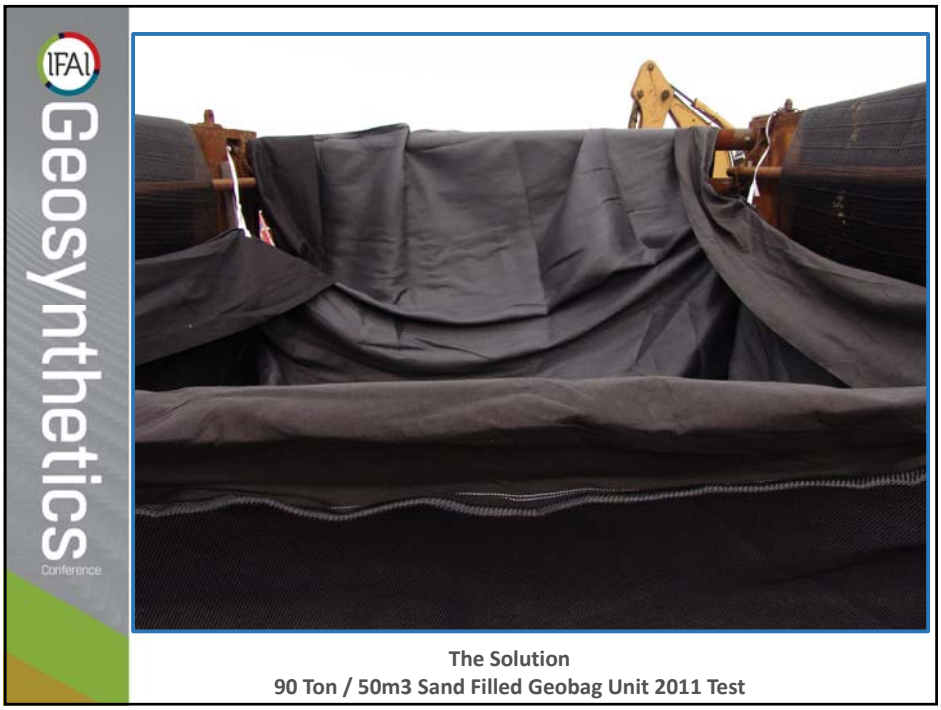

The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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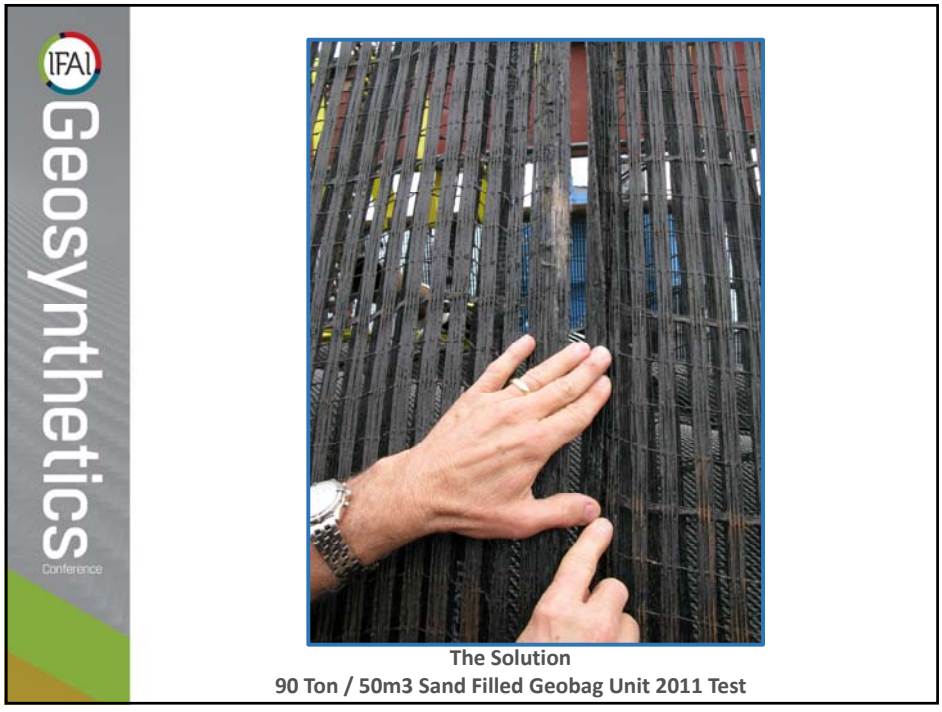
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

27



The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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The Solution
90 Ton / 50m3 Sand Filled Geobag Unit 2011 Test

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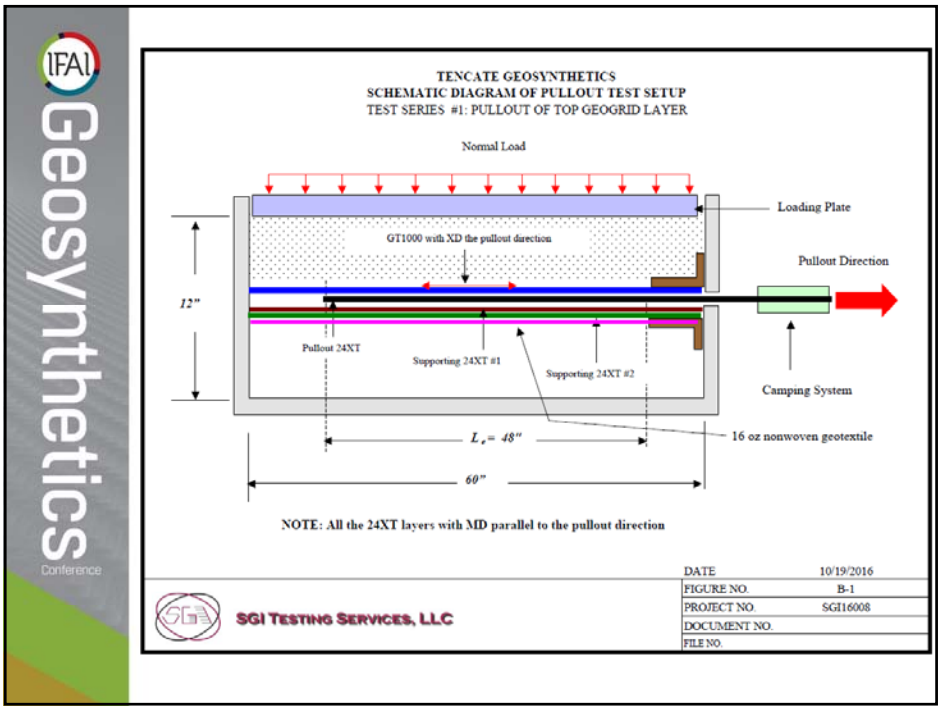
Load Cell S/N (QS791506), Units (Lbs)		30000				Crosshead Speed (Inches / min) or Rate 1			
Displacement Sensor		EHE 2-4 (4647)							
Test No	Specimen ID	ULTIMATE (LBS/FT)	TOTAL ELONG(%)	LBS/FT @ 2%	LBS/FT @ 5%	LBS/FT @ 10%	LBS/FT @ 1%	LBS/IN @ 12.5%	Testing Time
12586	1-1	26,687	13.1	4,883	8,512	19,071	2,557	25,551	102.32
12587	1-2	27,917	13.8	5,578	8,840	21,273	3,674	26,241	108.82
12588	1-3	27,038	13.1	4,809	8,155	19,342	2,681	25,966	106.78
12589	1-4	26,851	14.4	6,102	8,982	19,328	4,904	24,936	104.77
12590	1-5	25,953	12.4	5,255	8,459	20,589	3,476	24,606	98.30
12591	1-6	25,258	11.6	5,313	8,519	21,422	3,410		107.14
12592	1-7	25,361	12.0	5,633	8,730	20,360	3,905	23,616	107.89
	Mean	26,438	12.9	5,368	8,600	20,198	3,515	25,153	105.14
	Median	26,687	13.1	5,313	8,519	20,360	3,476	24,936	106.78
	Std Dev	963	1.0	451	275	965	789	971	3.71
	Maximum	27,917	14.4	6,102	8,982	21,422	4,904	26,241	108.82
	Minimum	25,258	11.6	4,809	8,155	19,071	2,557	23,616	98.30
	Range	2,659	2.8	1,294	827	2,351	2,347	2,624	10.51
	Specification (min)	27,415	10.0	4,500	7,000	13,000			
	(max)								

3.6% Reduction in Ultimate Strength

30


TENCATE GEOSYNTHETICS
SCHEMATIC DIAGRAM OF PULLOUT TEST SETUP
TEST SERIES #1: PULLOUT OF TOP GEOGRID LAYER
Normal Load
Loading Plate
GT1000 with XD the pullout direction
Pullout Direction
12"
Pullout 24XT
Supporting 24XT #1
Supporting 24XT #2
Camping System
16 oz nonwoven geotextile
L_e = 48"
60"
NOTE: All the 24XT layers with MD parallel to the pullout direction
SGI TESTING SERVICES, LLC
DATE 10/19/2016
FIGURE NO. B-1
PROJECT NO. SGI16008
DOCUMENT NO.
FILE NO.

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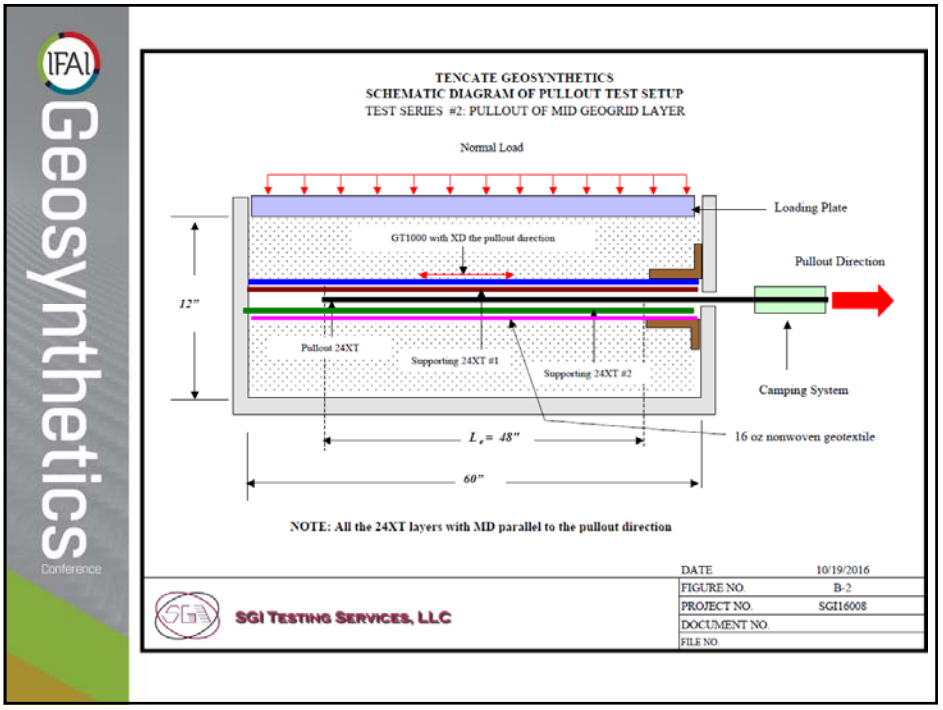
TENCATE GEOSYNTHETICS
SCHEMATIC DIAGRAM OF PULLOUT TEST SETUP
TEST SERIES #2: PULLOUT OF MID GEOGRID LAYER
Normal Load
Loading Plate
GT1000 with XD the pullout direction
Pullout Direction
12"
Pullout 24XT
Supporting 24XT #1
Supporting 24XT #2
Camping System
16 oz nonwoven geotextile
L_e = 48"
60"
NOTE: All the 24XT layers with MD parallel to the pullout direction
SGI TESTING SERVICES, LLC
DATE 10/19/2016
FIGURE NO. B-2
PROJECT NO. SGI16008
DOCUMENT NO.
FILE NO.

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IFAI
Geosynthetics
Conference

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IFAI
Geosynthetics
Conference

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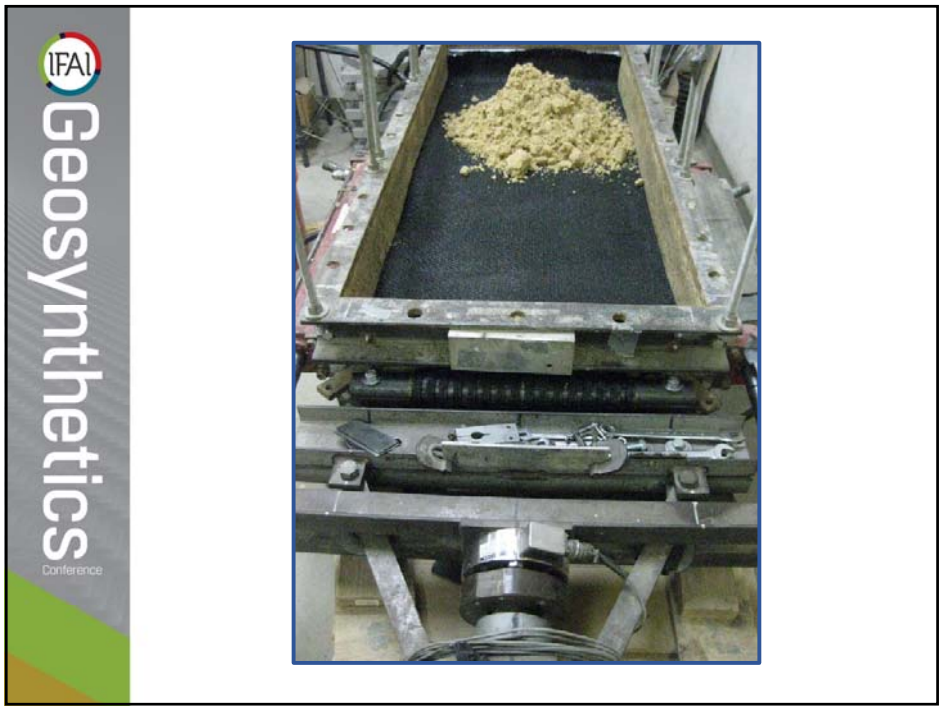

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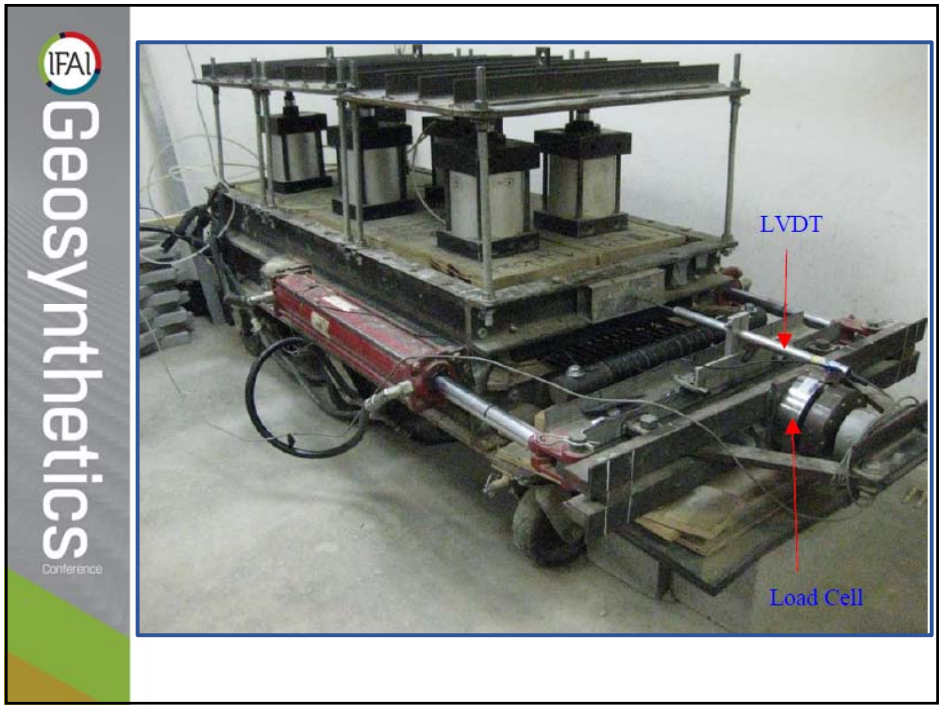

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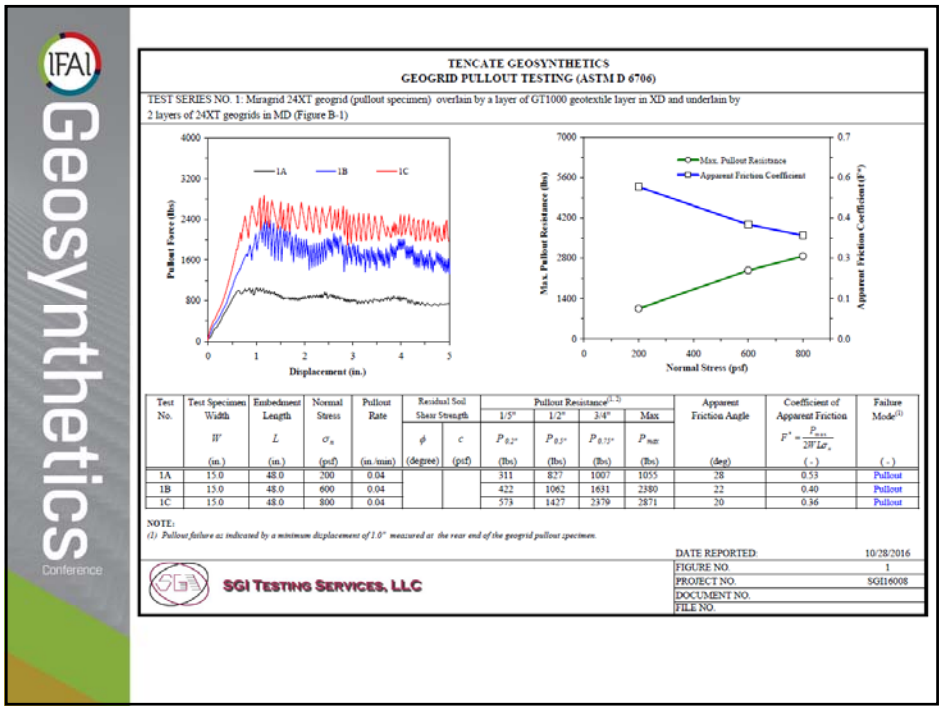

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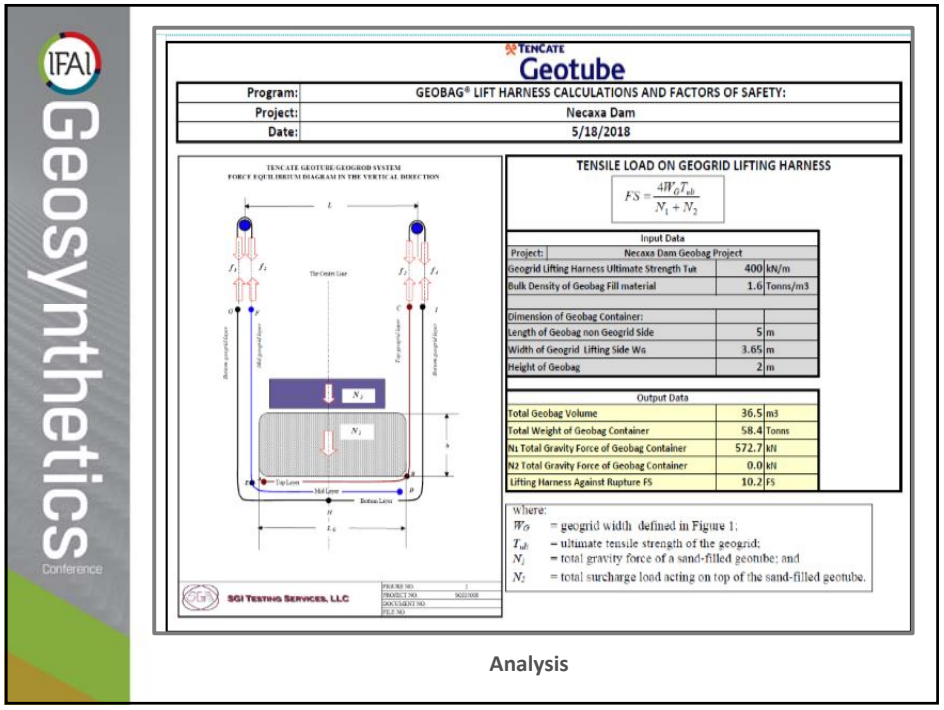

Analysis

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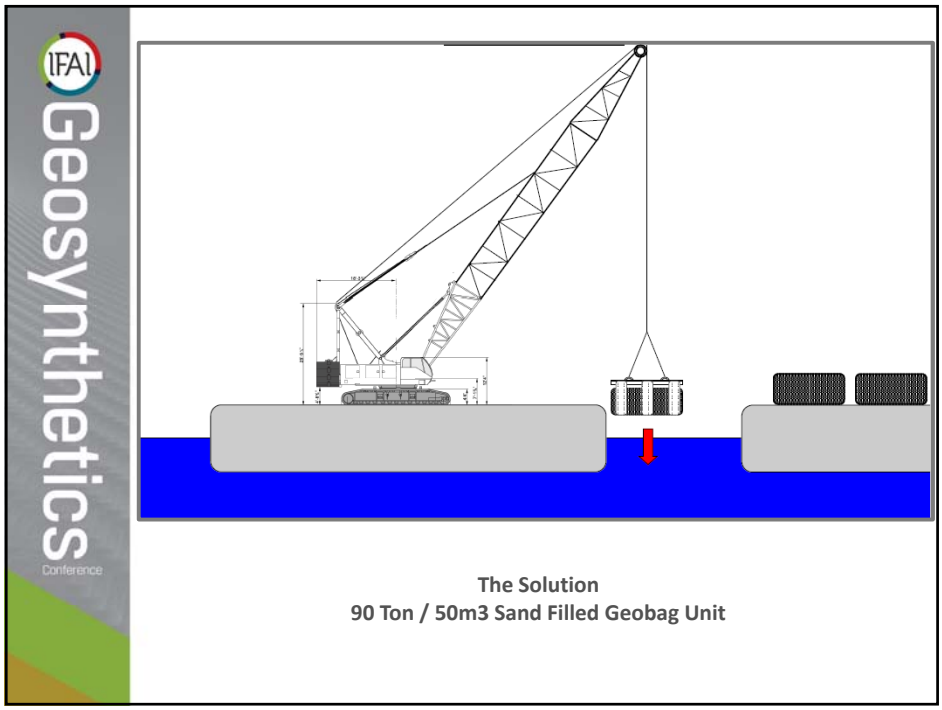
IFAI
Geosynthetics
Conference
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

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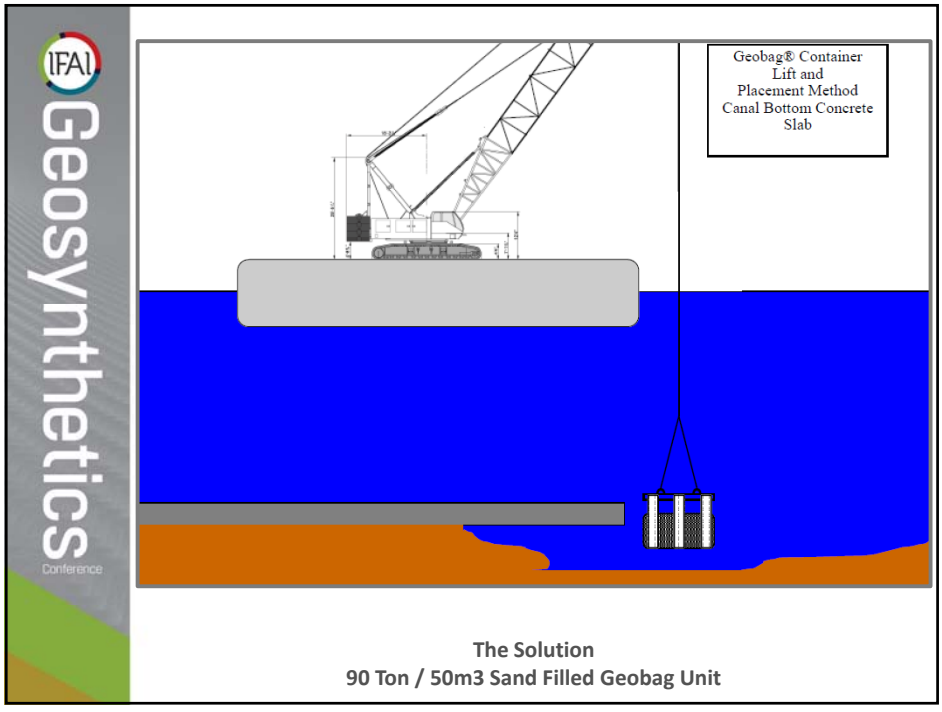
IFAI
Geosynthetics
Conference
Geobag® Container
Lift and
Placement Method
Canal Bottom Concrete
Slab
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

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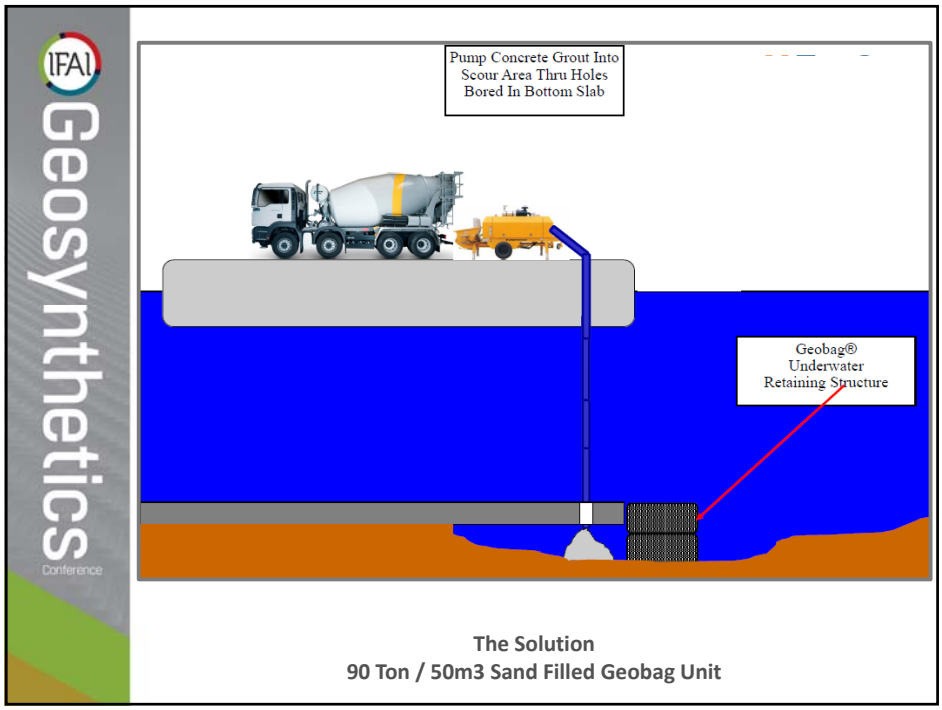
IFAI
Geosynthetics
Conference
Pump Concrete Grout Into
Scour Area Thru Holes
Bored In Bottom Slab
Geobag®
Underwater
Retaining Structure
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

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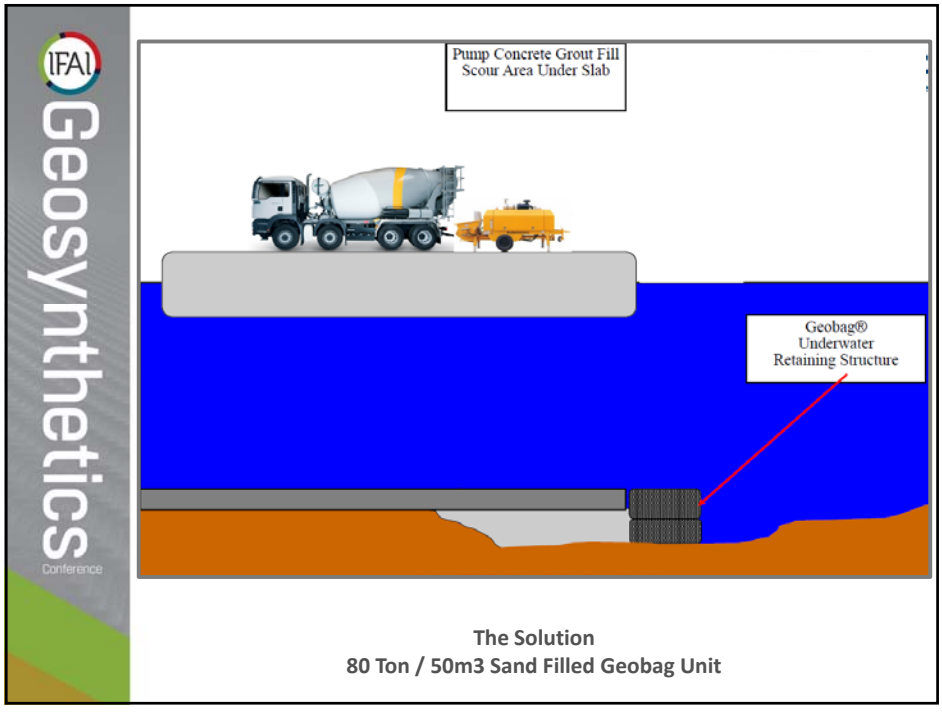
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Pump Concrete Grout Fill
Scour Area Under Slab
Geobag®
Underwater
Retaining Structure
The Solution
80 Ton / 50m3 Sand Filled Geobag Unit

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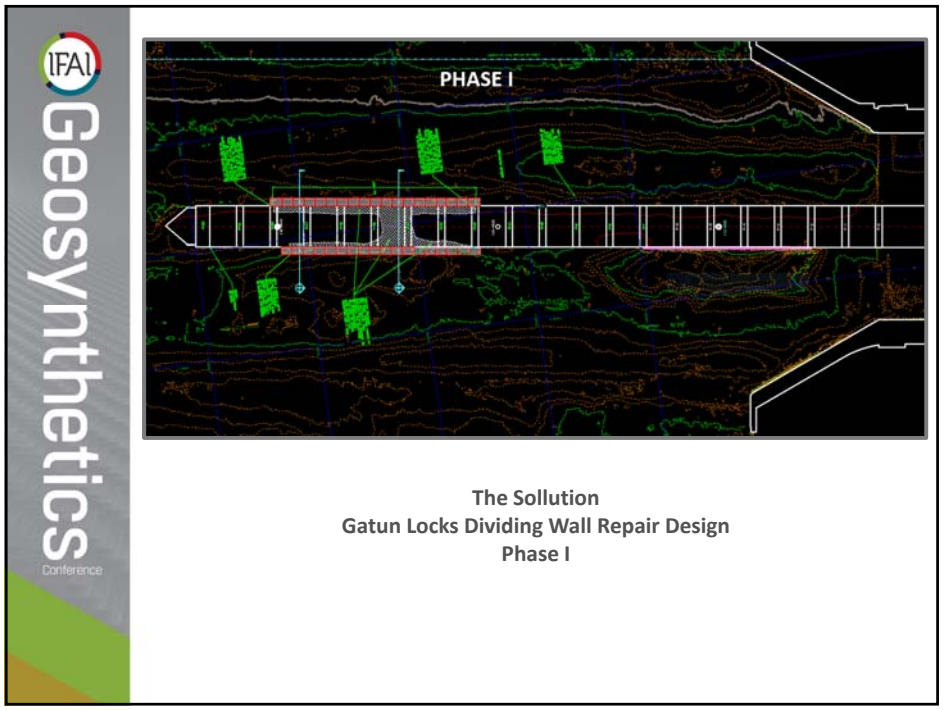
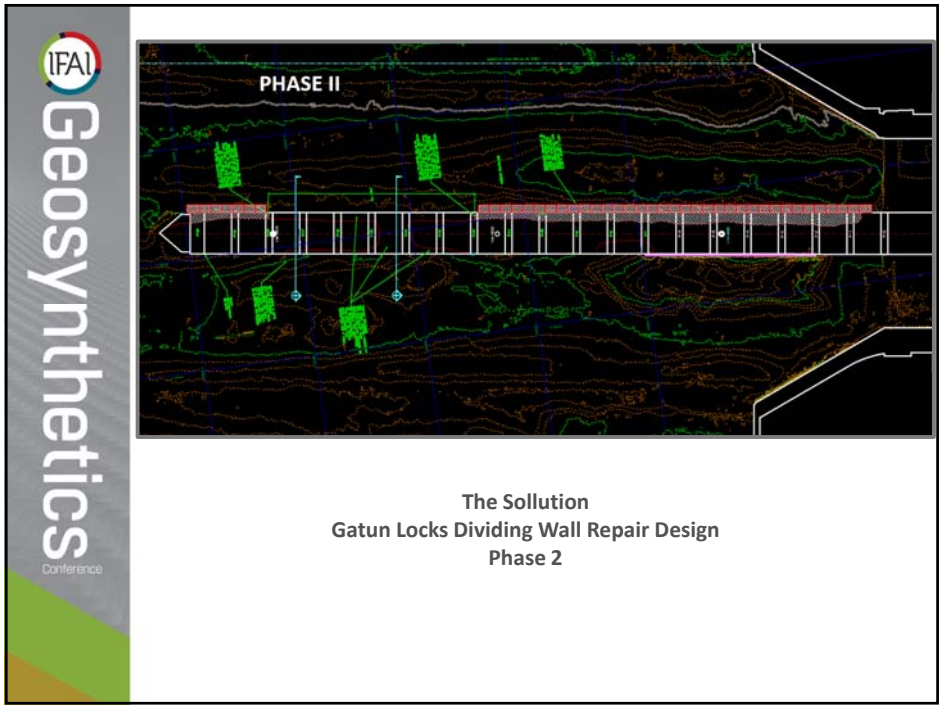


The Sollution
Gatun Locks Dividing Wall Repair Design
Phase I

43



The Sollution
Gatun Locks Dividing Wall Repair Design
Phase 2

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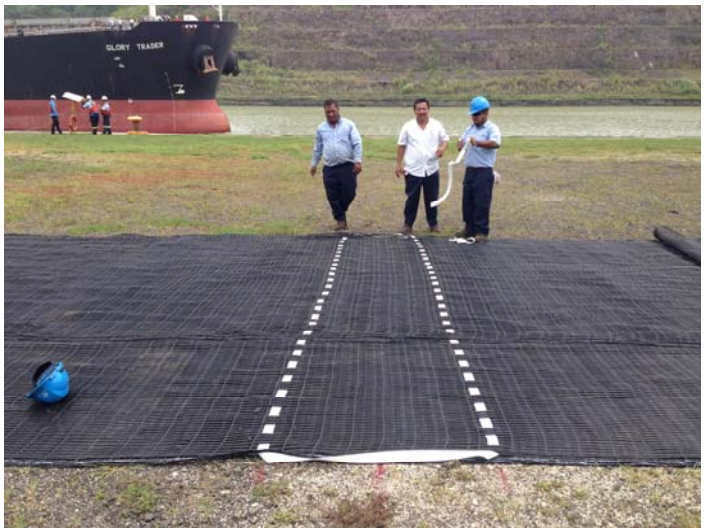
The Operation
350 Ton Titan Crane

45



The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

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The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

47

The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

48

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90 Ton / 50m3 Sand Filled Geobag Unit

49

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90 Ton / 50m3 Sand Filled Geobag Unit

50

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90 Ton / 50m3 Sand Filled Geobag Unit

51

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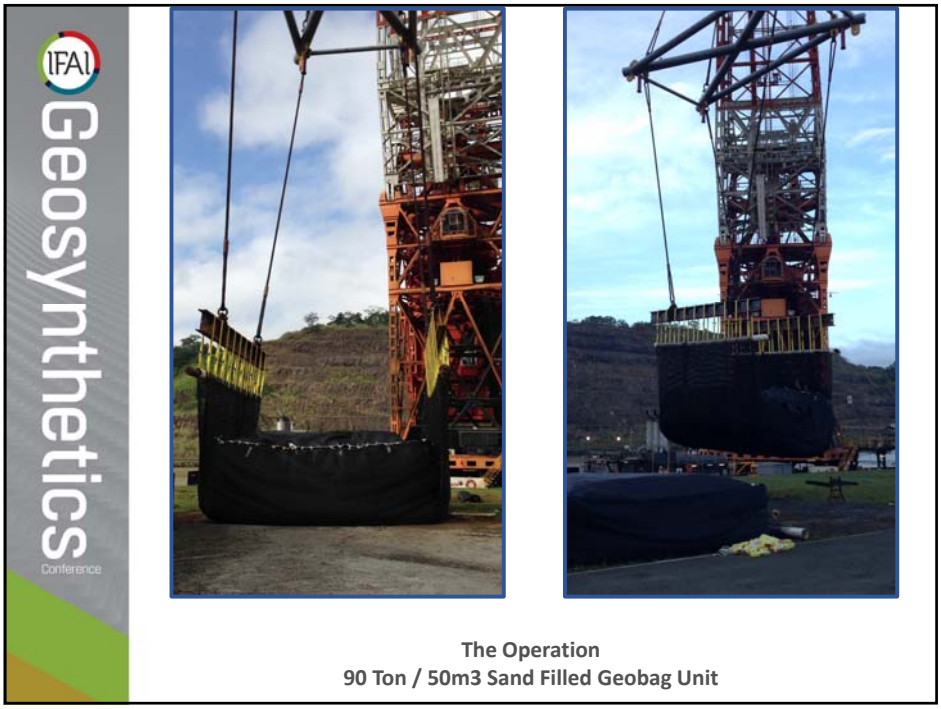
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

56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Geosynthetics
Conference
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

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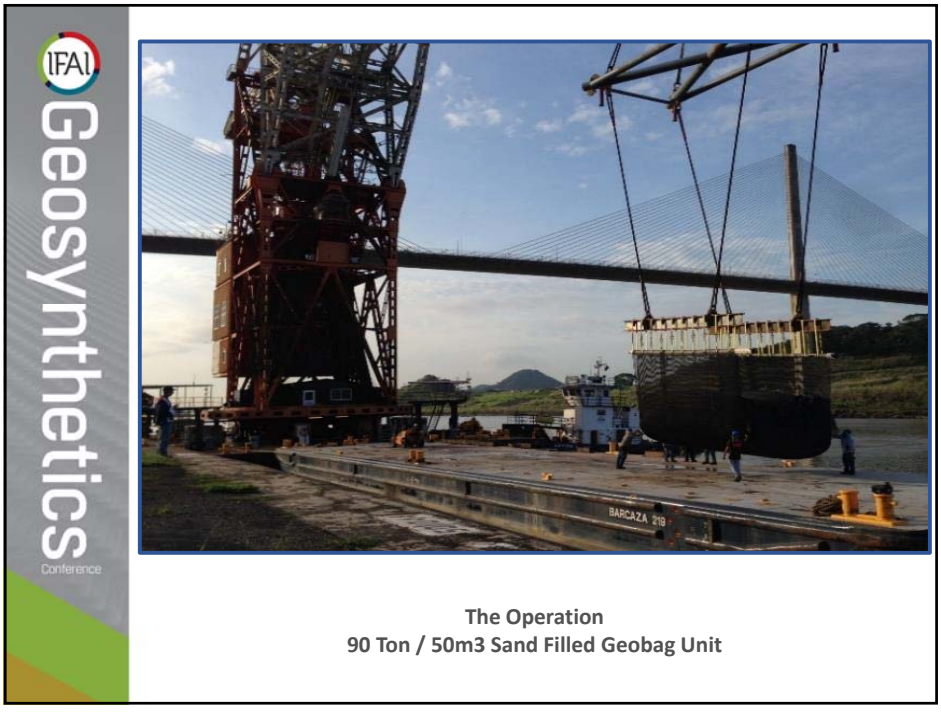
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Conference
BARCAZA 219
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

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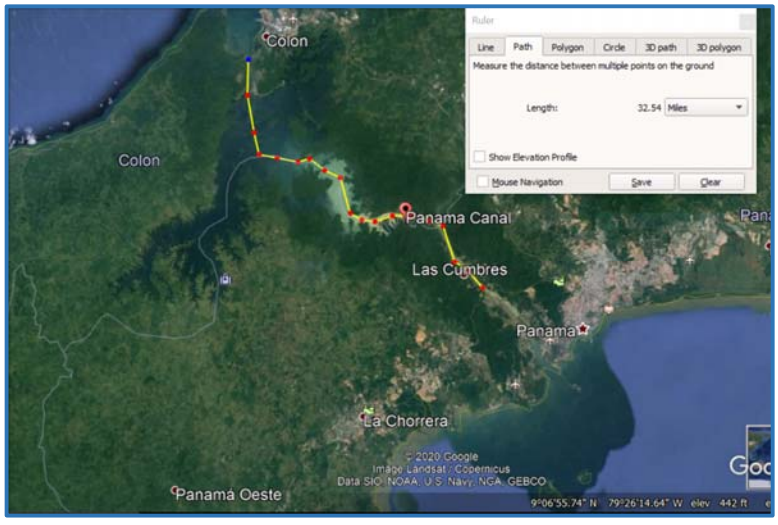
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

59



The Operation
Transit From Work Site To Gatun Locks

60

The Operation
90 Ton / 50m3 Sand Filled Geobag Unit
East Side Chamber Looking North

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The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

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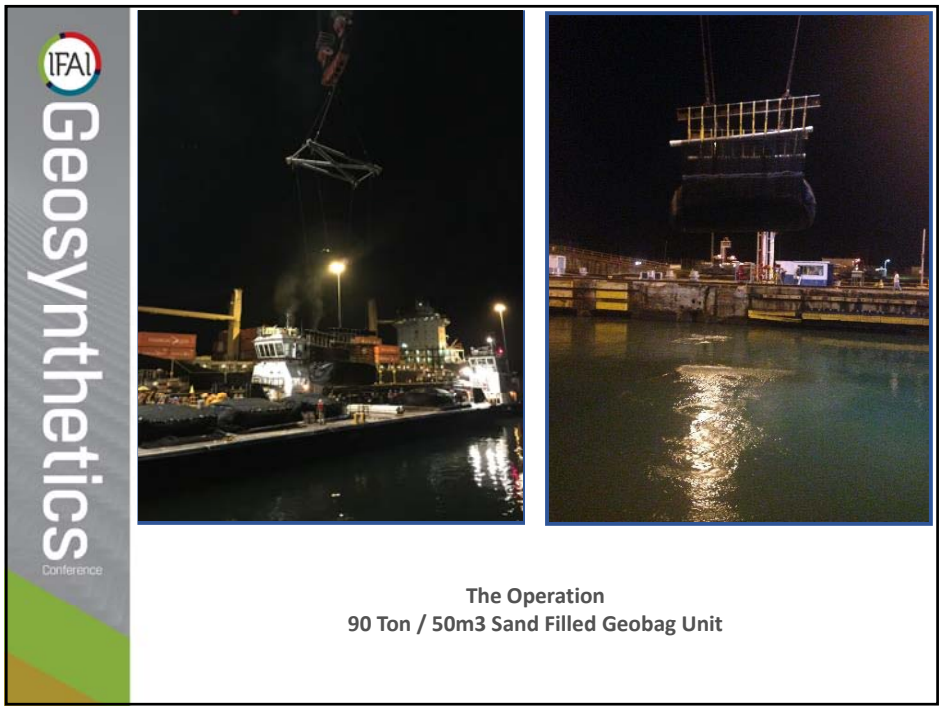
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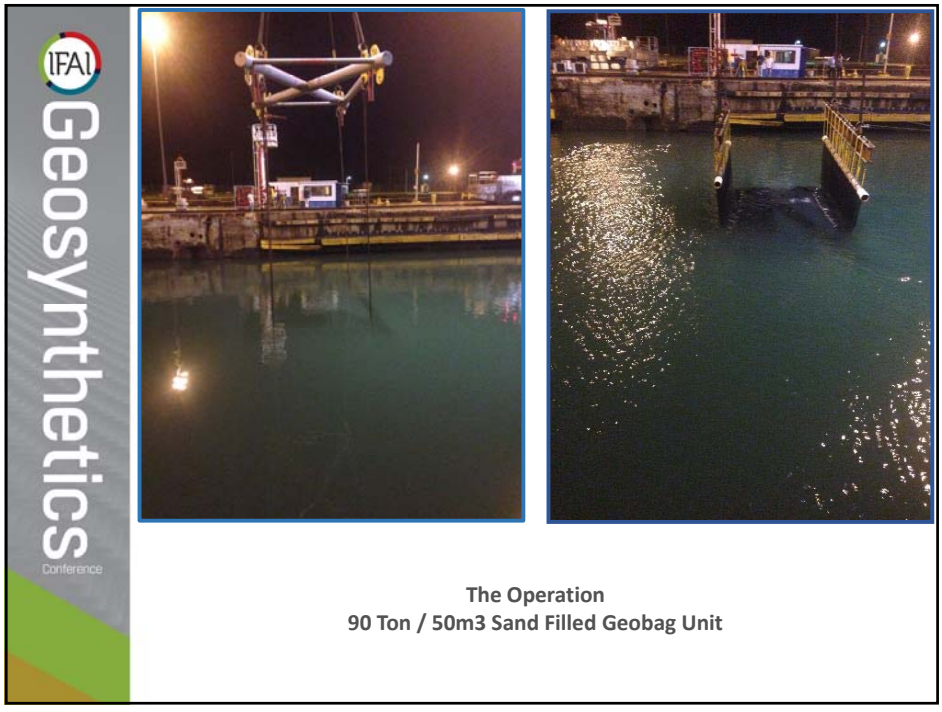
Geosynthetics
Conference
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

63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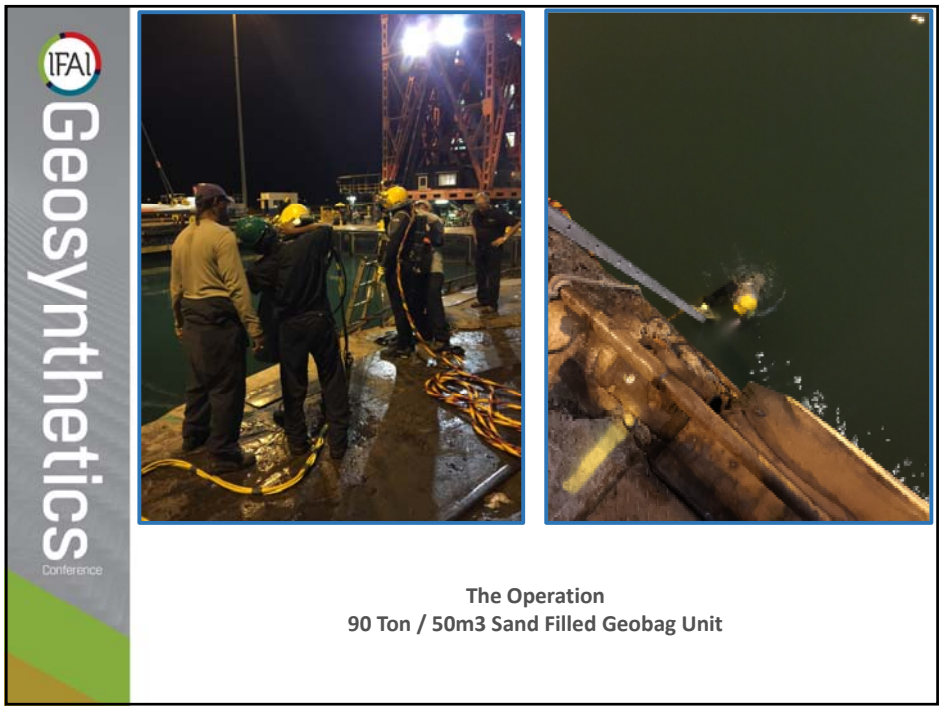
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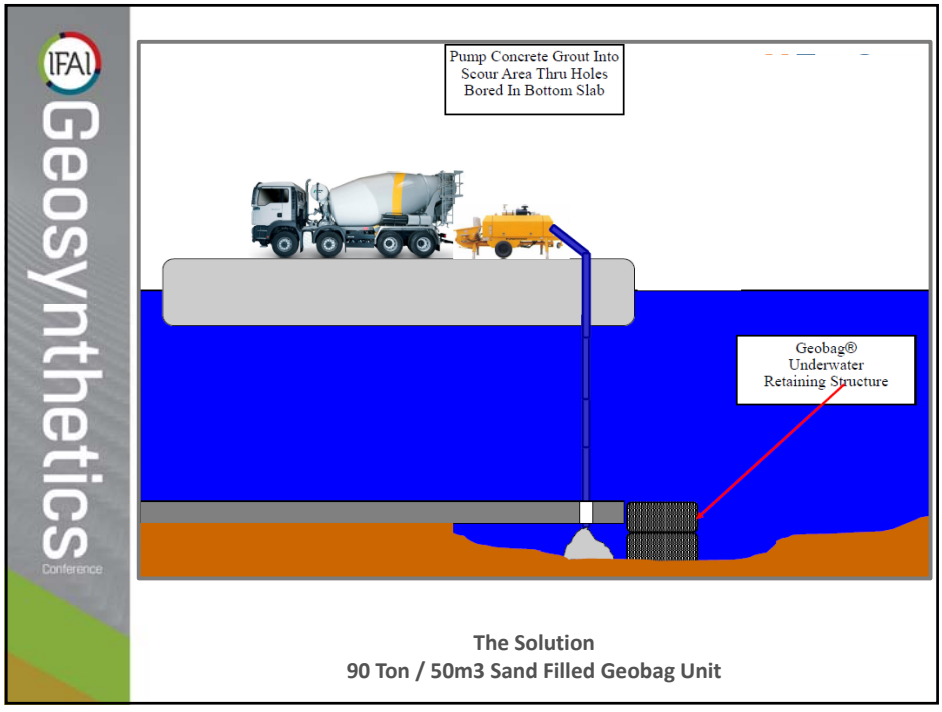
Conference
The Operation
90 Ton / 50m3 Sand Filled Geobag Unit

65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Bored In Bottom Slab
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90 Ton / 50m3 Sand Filled Geobag Unit

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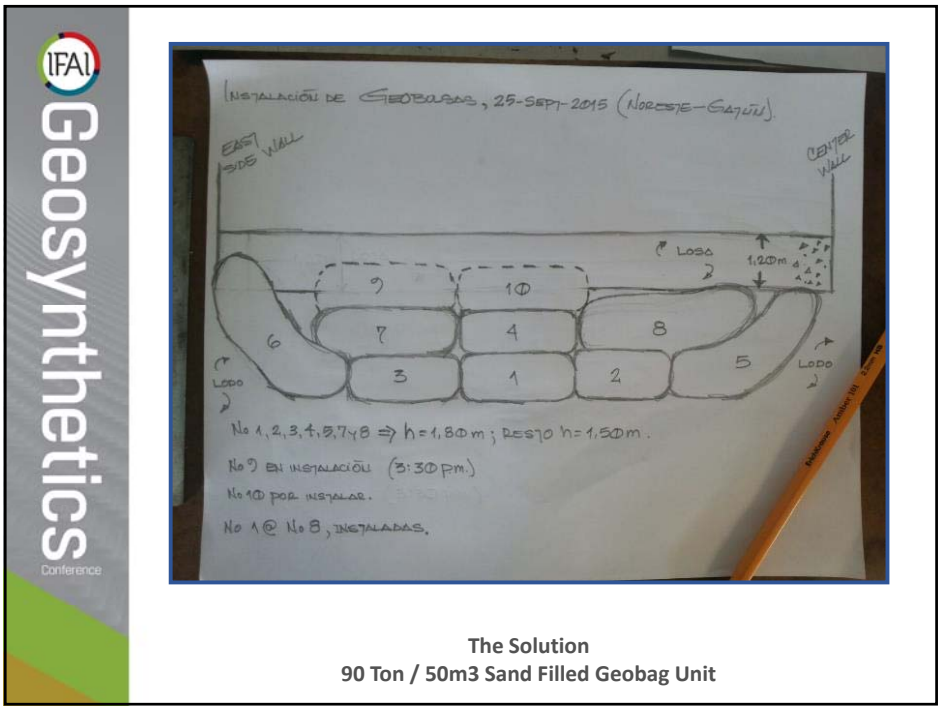

The Solution
90 Ton / 50m3 Sand Filled Geobag Unit

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The Operation
Dividing Wall Phase 1
90 Ton / 50m3 Sand Filled Geobag Unit

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To Date More Than 500 of the 90 Ton Geobag Units
Have Been Installed In The Panama Canal and Other Projects

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Other Challenging Marine Projects
Have Adapted This Solution

70

Conclusions:

- Innovative Solutions Require A Multidiscipline Collaborative Approach
- Geobag Containers Allowed for Rapid Response and Deployment
- Geobag Containers Were Flexible Enough to Conform to The Irregular Eroded Bottom of The Canal
- Geobag Containers Had The Mass to Not Be Moved When Subjected to High Velocity Water Flow or Prop Wash.
- Geobag Containers Performed as the Underwater Coffer Dam to Retain the Concrete Pumped Under The Canal Lock Structures
- Geobag Containers Are Performing as Long Term Weighted Erosion Control Mattresses

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THANK YOU

QUESTIONS?

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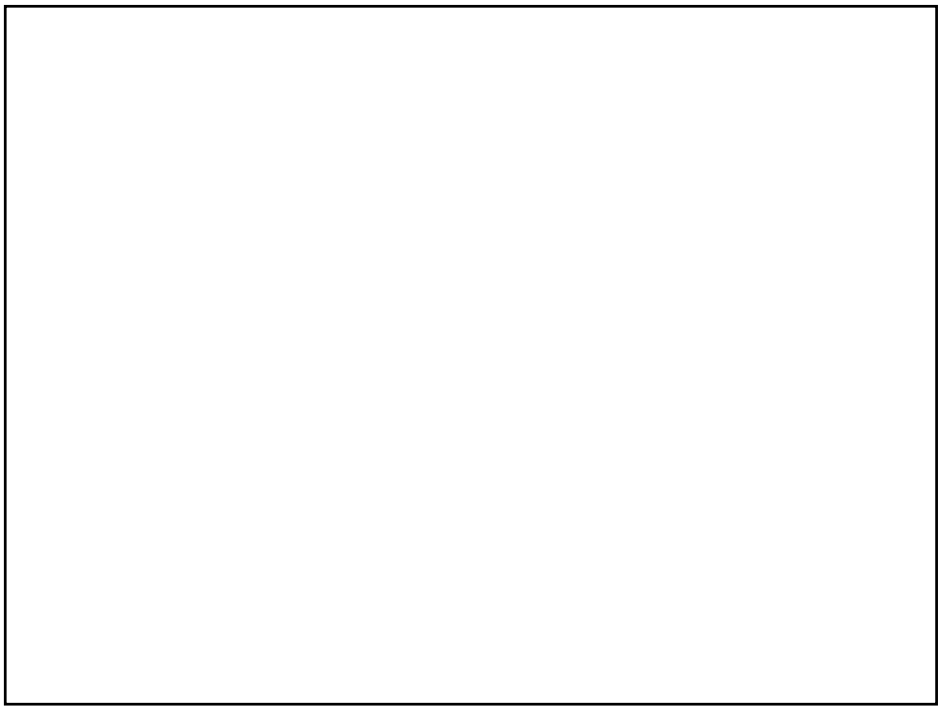

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