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From:  
Kirk Lowery, P.E.

Date:  
July 18, 2017

Arcadis Project No.:  
LA003315.0000

Subject:  
July 2017 Final Summary Report of Inclinometer Readings  
Remediation Design of Levee Floodplain Failure within the  
Upper Brownsville Levee Reach Lower Rio Grande Flood  
Control Project – IBM15D0001 – IBM15T0015

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## 1. Introduction

Arcadis U.S., Inc. (Arcadis), is pleased to submit this summary technical memorandum including data charts of the slope inclinometer readings at the IBWC site. The baseline readings for the new inclinometers, ARC-1, ARC-2, ARC-3 and ARC-4, were taken in June 2016 and the eleventh set of readings were measured on July 12, 2017. Under the current scope of work, this month will be the last measurement to be taken for these inclinometers.

Exact readings for the existing inclinometers, I-32, I-33 and I-34, were not made when Arcadis visited the site July 12, 2017. However, the probe was placed in the inclinometer casings and the depth at which it would not pass was recorded. Arcadis measured the depth range in which the inclinometer probe could not pass through the constricted area of the pipe and are as follows:

I-32 (Top of the Levee): Depth Range: 32 feet

I-33 (Toe of the Levee): Depth Range: 38 feet

I-34 (Below Toe of Levee): Depth Range: 30 feet to 31 feet

In this month's visit to the IBWC site, several pins that were installed on June 14, 2017 on top of the levee near inclinometer ARC-1 and south of the existing retaining wall have been removed or disturbed due to the traffic on the levee roadway. In addition, recent rainfall has started to erode the surface tension cracks and they are becoming less apparent. All the pins that were removed, were set back to their original locations

to take this month's measurements. Over the last month, the tension cracks appear to have not changed except for the cracks that are located between the pins 18B and 19B. For those pins, there was a slight increase in width of 0.5 inch. The locations of the cracks and the pins are shown in Attachment B while Attachment C presents photos of the tension cracks.

Table 1 summarizes the pin flags location along the cracks.

**Table 1. Pin Flag Locations**

Pin Flag No.	Pin Location	Remarks
1B and 2B	3.33' south of inclinometer ARC-1. 8.5" between the two pin flags.	No Change
3B and 4B	11.25" south of inclinometer ARC-1. 9.5" between the two pin flags.	No Change
5B	GPS coordinates N25.898212°, W-97.496628°	-
6B and 7B	7' south of 5B. 9.0" between the two pin flags.	Pin 6B was removed
8B and 9B	16' south of 5B. 9.75" between the two pin flags.	Pins were removed
10B	24' south of 5B.	-
11B	GPS coordinates N25.897973°, W-97.496493°	-
12B and 13B	12' south of 11B. 11.0" between the two pin flags.	Pins were removed
14B and 15B	42' south of 11B. 10.5" between the two pin flags.	Pins were removed
16B	57' south of 11B.	-
17B	6' west of 14B and 15B.	-
18B and 19B	10.5' south of 17B. 12.25" between the two pin flags.	0.5 inch increase
20B	21' south of 17B.	
21B		-

	GPS coordinates N25.897669°, W-97.496309°	
22B and 23B	18' south of 21B. 9.75" between the two pin flags.	Pins were removed
24B and 25B	54' south of 21B. 10.0" between the two pin flags.	Pin 24B was removed
26B	72' south of 21B.	-

The readings for each inclinometer are reflected in the graphical displays provided in Attachment A. Attachment A includes both incremental and cumulative displacement plots. Attachment B shows the inclinometer locations on a Google Map.

The incremental displacement plot compares the mean deviation data to the baseline survey file. This plot reveals the exact depth where displacements are actually occurring. The cumulative displacement is the sum of the displacements from the base of the borehole. This plot shows the change in the position of the casing from the first set of readings.

The A-axis charts in the displacement plots show displacements in the plane perpendicular to the levee while the B-axis charts show displacements in the plane parallel with the levee. A positive reading in the A-axis chart indicates displacement to the west heading toward the Rio Grande, and a positive reading in the B-axis chart indicates displacement to the north heading toward the Gateway Bridge.

## 2. Digitilt AT Inclinometer

Digitilt AT system was used to survey the inclinometers. The system components include an inclinometer probe, control cable, a Bluetooth reel and the Digitilt Reader app for certified Android-based tablet computer. The equipment is shown in Figure 1.

Figure 1: Digitilt AT System Components.



### 3. July 2017 Inclinator Assessment

The depth of the casing restriction for the USACE installed inclinometers, I-32, I-33 and I-34 appears to be the same depth as the previous readings.

Data collected on July 12, 2017 followed the same trend as the baseline reading measured in June 2016. The monthly displacement plots recorded between July 2016 through July 2017 are presented in Attachment A. Data comparisons for each inclinometer are described below:

Inclinometer ARC-1: The base readings for inclinometer ARC-1 were collected on June 22, 2016. The ARC-1 cumulative plot in the A-Axis direction shows a slight progressive movement starting at depths between 28 and 30 feet. This depth corresponds with the interpreted Alluvium/Pleistocene interface presented in Figure 2 of Arcadis' December 2, 2016 *Draft Geotechnical Assessment Report*. Comparing the measurements taken in July 2016 to July 2017, the displacement is 0.12 inches towards the Rio Grande (A-Axis) at a depth of 28 feet. The displacement parallel to the levee does not show any sign of movement in this month's readings.

Inclinometer Arc-2: The base readings for inclinometer ARC-2 were collected on June 17, 2016. The ARC-2 cumulative displacement plot in the A-Axis direction shows a slight displacement between the depths of 38 feet to 40 feet. This depth corresponds with the interpreted Alluvium/Pleistocene interface presented in Figure 2 of Arcadis' December 2, 2016 *Draft Geotechnical Assessment Report*. Comparing the measurements taken in July 2016 to July 2017, the displacement is 0.13 inches towards the Rio Grande (A-Axis) at a depth of 38 feet. The displacement parallel to the levee does not show any sign of movement in this month's readings.

Inclinometer ARC-3: The base readings for inclinometer ARC-3 were collected on June 17, 2016. The ARC-3 cumulative and incremental displacement does not show any sign of movement on the plane perpendicular to the levee nor on the plane parallel to the levee.

Inclinometer ARC-4: The base readings for inclinometer ARC-4 were collected on June 22, 2016. The ARC-4 cumulative and incremental displacement does not show any sign of movement on the plane perpendicular to the levee nor on the plane parallel to the levee.

After critically reviewing the cumulative displacement plots, the graphical displays in Attachment A shows that in each month there is an increase in movement towards the Rio Grande (A-Axis direction) for the inclinometers ARC-1 and ARC-2. The displacement for these inclinometers are progressive but moving at a slow rate. This information will be summarized and used to finalize the *Draft Geotechnical Assessment Report*.

#### ATTACHMENTS:

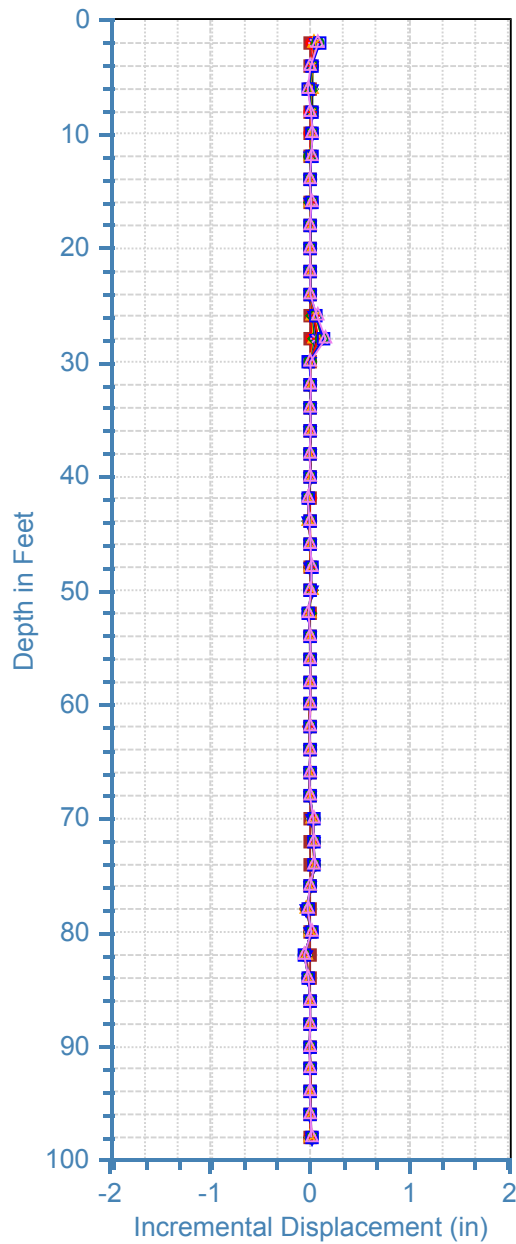
**A – Inclinometer Plots**

**B – Inclinometer and Levee Cracking Location Map**

**C – Photos of Surface Tension Cracks**

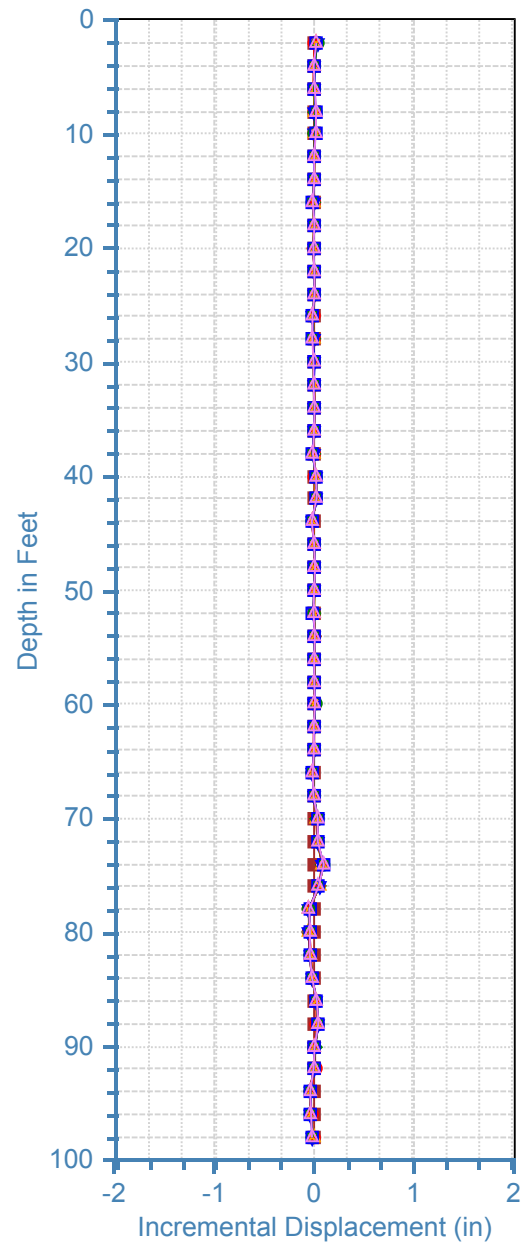
**ATTACHMENT A**  
**INCLINOMETER PLOTS**

IBWC Arc-1 A - Axis



6/22/2016 11:22:30 AM	7/25/2016 3:17:20 PM
8/25/2016 1:34:40 PM	9/22/2016 1:35:22 PM
10/27/2016 2:18:50 PM	11/14/2016 1:34:00 PM
12/22/2016 3:53:53 PM	2/8/2017 9:25:00 AM
3/17/2017 12:20:09 PM	4/10/2017 3:12:10 PM
5/9/2017 2:13:46 PM	6/14/2017 12:51:51 PM
7/12/2017 9:22:17 AM	

IBWC Arc-1 B - Axis

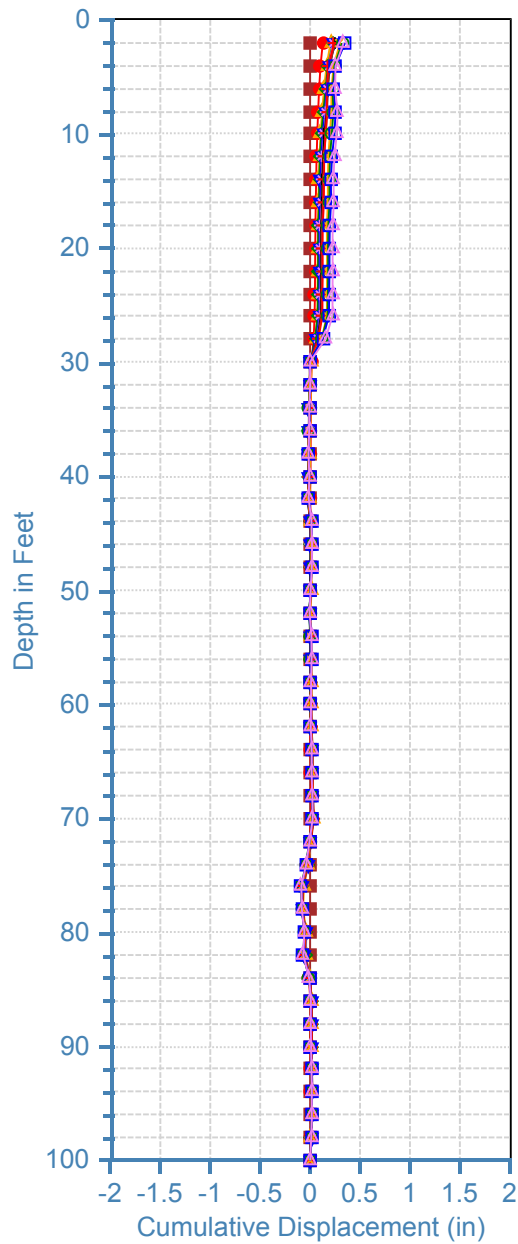


6/22/2016 11:22:30 AM	7/25/2016 3:17:20 PM
8/25/2016 1:34:40 PM	9/22/2016 1:35:22 PM
10/27/2016 2:18:50 PM	11/14/2016 1:34:00 PM
12/22/2016 3:53:53 PM	2/8/2017 9:25:00 AM
3/17/2017 12:20:09 PM	4/10/2017 3:12:10 PM
5/9/2017 2:13:46 PM	6/14/2017 12:51:51 PM
7/12/2017 9:22:17 AM	

Base reading on 6/22/2016

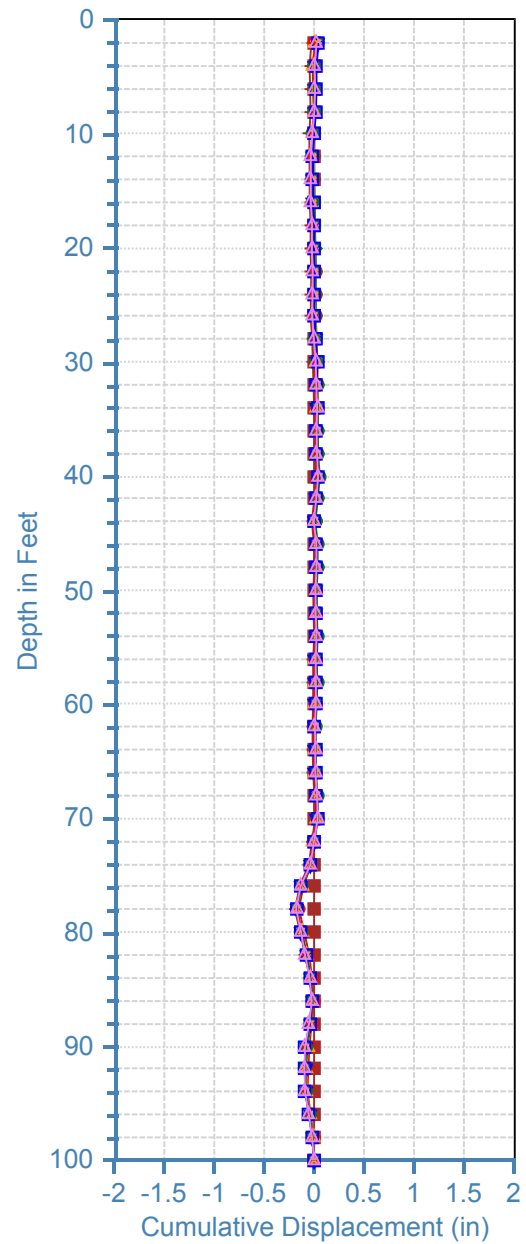


IBWC Arc-1 A - Axis



6/22/2016 11:22:30 AM	7/25/2016 3:17:20 PM
8/25/2016 1:34:40 PM	9/22/2016 1:35:22 PM
10/27/2016 2:18:50 PM	11/14/2016 1:34:00 PM
12/22/2016 3:53:53 PM	2/8/2017 9:25:00 AM
3/17/2017 12:20:09 PM	4/10/2017 3:12:10 PM
5/9/2017 2:13:46 PM	6/14/2017 12:51:51 PM
7/12/2017 9:22:17 AM	

IBWC Arc-1 B - Axis

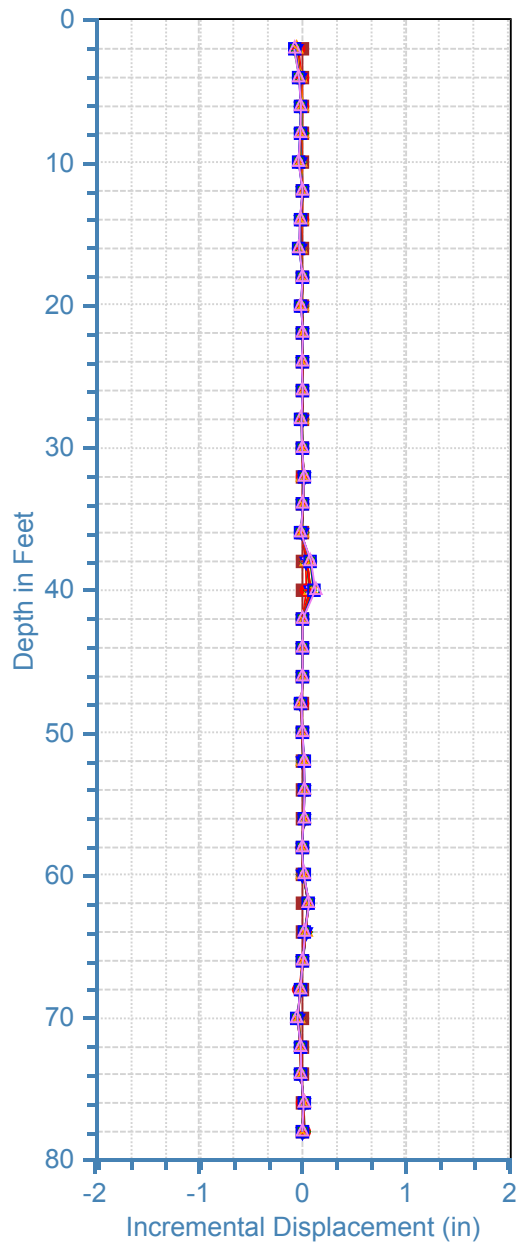


6/22/2016 11:22:30 AM	7/25/2016 3:17:20 PM
8/25/2016 1:34:40 PM	9/22/2016 1:35:22 PM
10/27/2016 2:18:50 PM	11/14/2016 1:34:00 PM
12/22/2016 3:53:53 PM	2/8/2017 9:25:00 AM
3/17/2017 12:20:09 PM	4/10/2017 3:12:10 PM
5/9/2017 2:13:46 PM	6/14/2017 12:51:51 PM
7/12/2017 9:22:17 AM	

Base reading on 6/22/2016

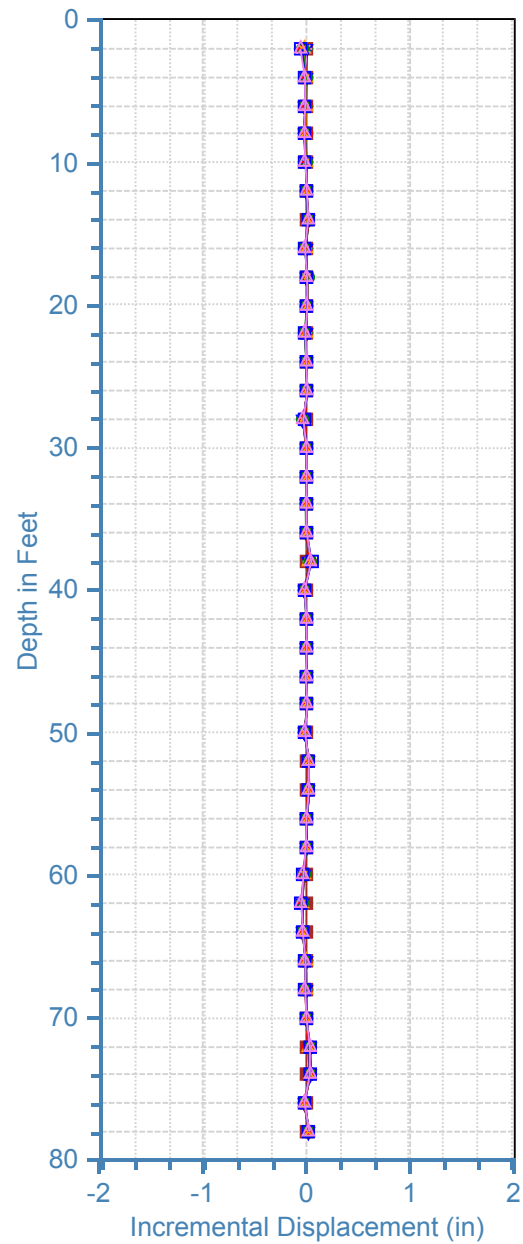


IBWC Arc-2 A - Axis



6/17/2016 6:27:13 PM	7/25/2016 3:57:11 PM
8/25/2016 2:02:22 PM	9/22/2016 2:05:40 PM
10/27/2016 2:44:45 PM	11/14/2016 1:57:25 PM
12/22/2016 4:18:54 PM	2/8/2017 9:52:21 AM
3/17/2017 11:58:39 AM	4/10/2017 2:47:48 PM
5/9/2017 1:53:54 PM	6/14/2017 1:13:37 PM
7/12/2017 8:38:59 AM	

IBWC Arc-2 B - Axis



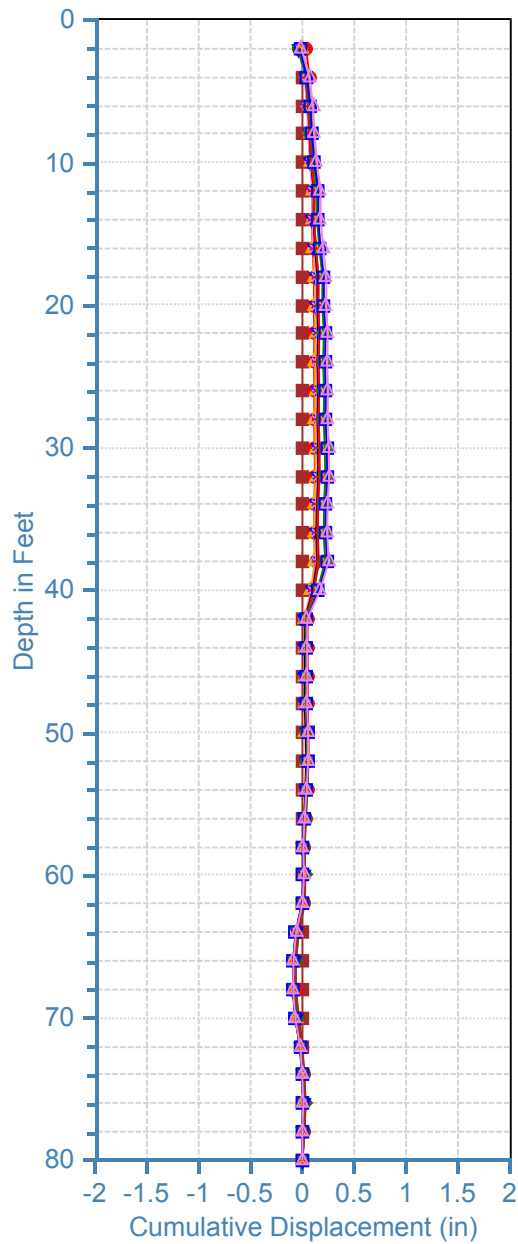
6/17/2016 6:27:13 PM	7/25/2016 3:57:11 PM
8/25/2016 2:02:22 PM	9/22/2016 2:05:40 PM
10/27/2016 2:44:45 PM	11/14/2016 1:57:25 PM
12/22/2016 4:18:54 PM	2/8/2017 9:52:21 AM
3/17/2017 11:58:39 AM	4/10/2017 2:47:48 PM
5/9/2017 1:53:54 PM	6/14/2017 1:13:37 PM
7/12/2017 8:38:59 AM	

Base reading on 6/17/2016



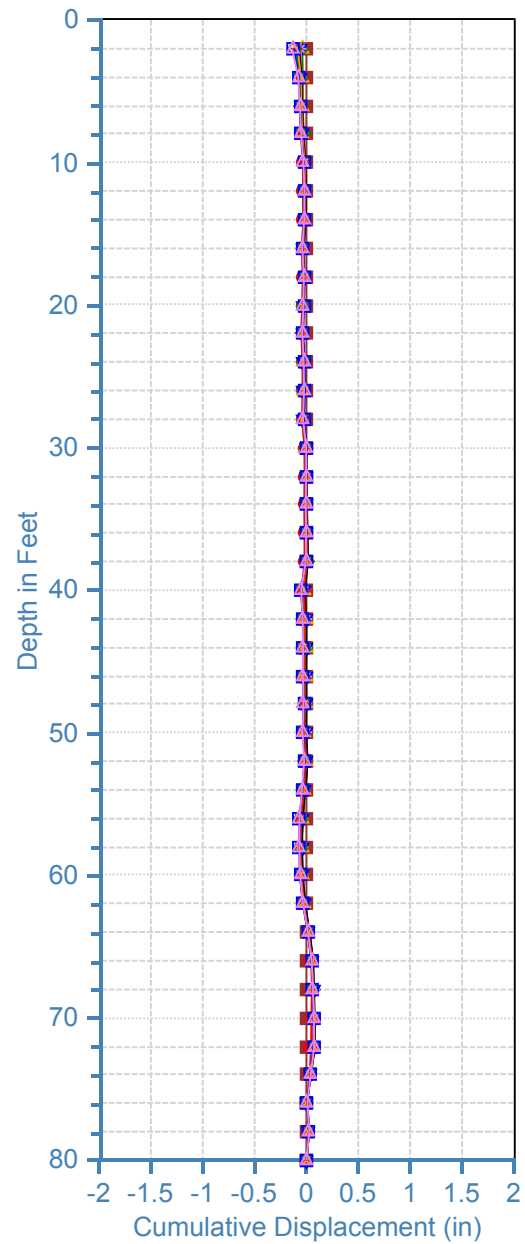


IBWC Arc-2 A - Axis



6/17/2016 6:27:13 PM	7/25/2016 3:57:11 PM
8/25/2016 2:02:22 PM	9/22/2016 2:05:40 PM
10/27/2016 2:44:45 PM	11/14/2016 1:57:25 PM
12/22/2016 4:18:54 PM	2/8/2017 9:52:21 AM
3/17/2017 11:58:39 AM	4/10/2017 2:47:48 PM
5/9/2017 1:53:54 PM	6/14/2017 1:13:37 PM
7/12/2017 8:38:59 AM	

IBWC Arc-2 B - Axis

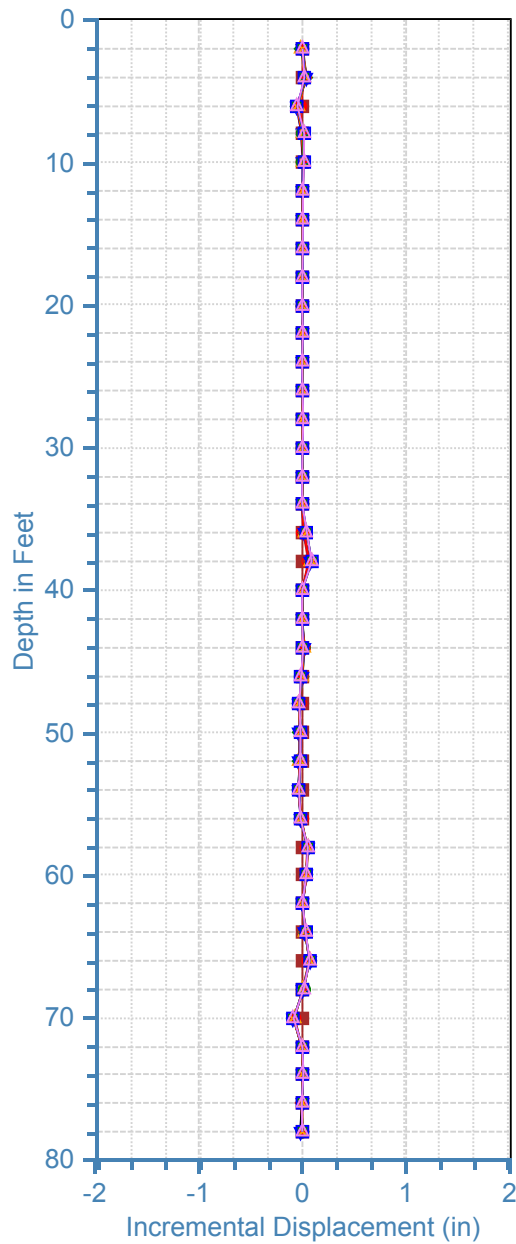


6/17/2016 6:27:13 PM	7/25/2016 3:57:11 PM
8/25/2016 2:02:22 PM	9/22/2016 2:05:40 PM
10/27/2016 2:44:45 PM	11/14/2016 1:57:25 PM
12/22/2016 4:18:54 PM	2/8/2017 9:52:21 AM
3/17/2017 11:58:39 AM	4/10/2017 2:47:48 PM
5/9/2017 1:53:54 PM	6/14/2017 1:13:37 PM
7/12/2017 8:38:59 AM	

Base reading on 6/17/2016

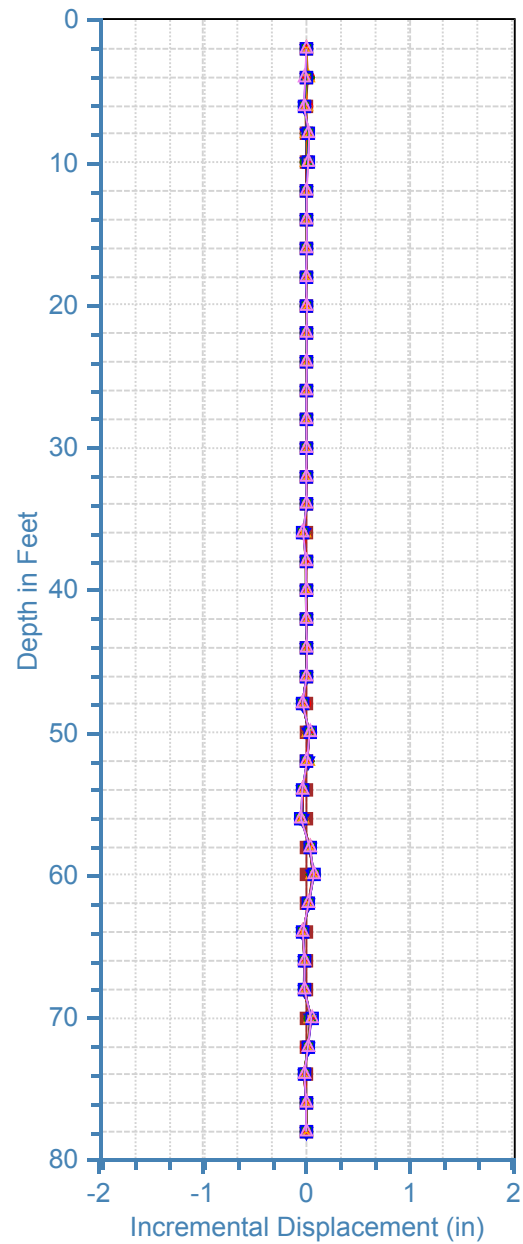


IBWC Arc-3 A - Axis



6/17/2016 7:05:22 PM	7/25/2016 4:28:56 PM
8/25/2016 2:41:46 PM	9/22/2016 2:36:13 PM
10/27/2016 3:17:17 PM	11/14/2016 2:27:09 PM
12/22/2016 4:38:15 PM	2/8/2017 10:12:24 AM
3/17/2017 11:40:50 AM	4/10/2017 2:26:29 PM
5/9/2017 1:36:04 PM	6/15/2017 3:53:45 PM
7/12/2017 8:22:33 AM	

IBWC Arc-3 B - Axis

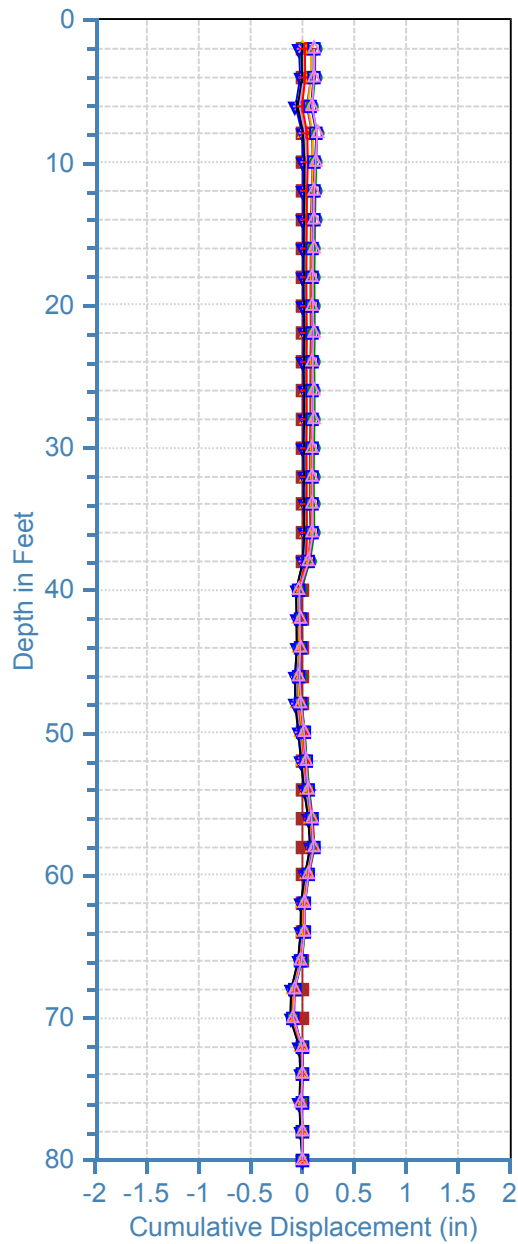


6/17/2016 7:05:22 PM	7/25/2016 4:28:56 PM
8/25/2016 2:41:46 PM	9/22/2016 2:36:13 PM
10/27/2016 3:17:17 PM	11/14/2016 2:27:09 PM
12/22/2016 4:38:15 PM	2/8/2017 10:12:24 AM
3/17/2017 11:40:50 AM	4/10/2017 2:26:29 PM
5/9/2017 1:36:04 PM	6/15/2017 3:53:45 PM
7/12/2017 8:22:33 AM	

Base reading on 6/17/2016

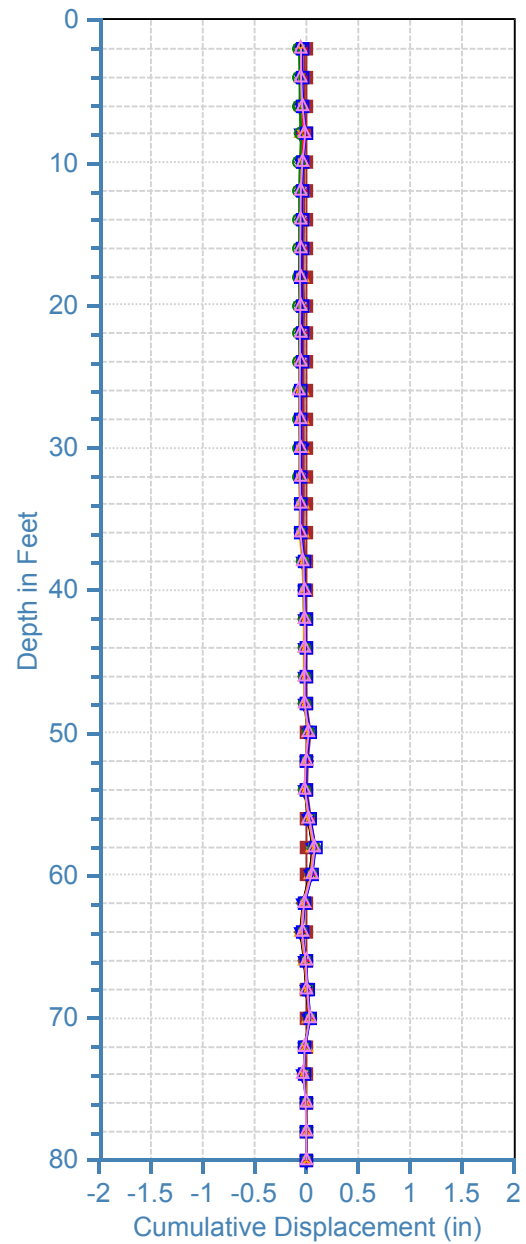


IBWC Arc-3 A - Axis



6/17/2016 7:05:22 PM	7/25/2016 4:28:56 PM
8/25/2016 2:41:46 PM	9/22/2016 2:36:13 PM
10/27/2016 3:17:17 PM	11/14/2016 2:27:09 PM
12/22/2016 4:38:15 PM	2/8/2017 10:12:24 AM
3/17/2017 11:40:50 AM	4/10/2017 2:26:29 PM
5/9/2017 1:36:04 PM	6/15/2017 3:53:45 PM
7/12/2017 8:22:33 AM	

IBWC Arc-3 B - Axis

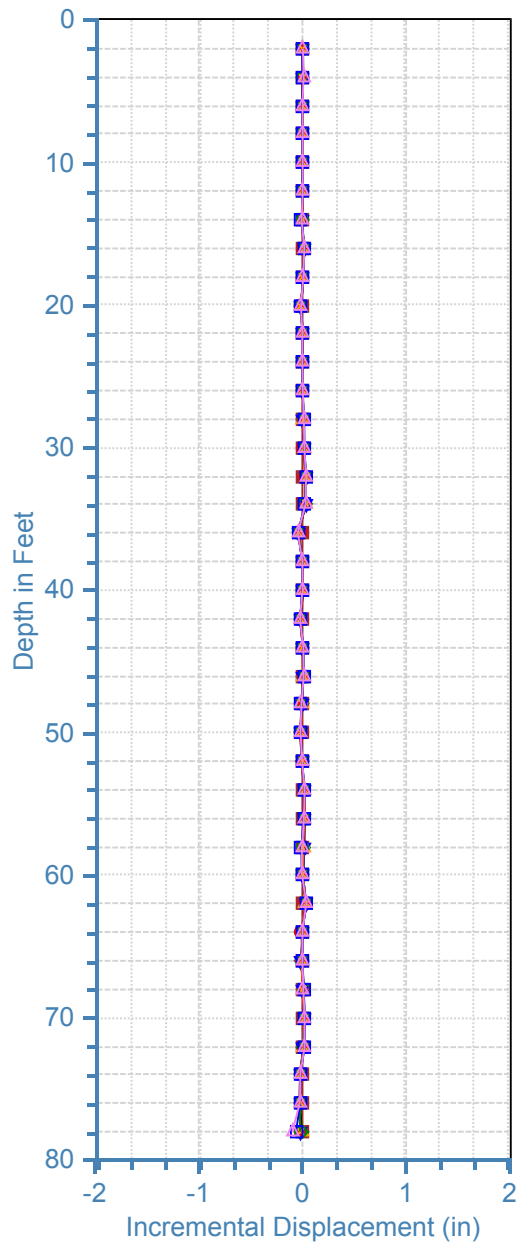


6/17/2016 7:05:22 PM	7/25/2016 4:28:56 PM
8/25/2016 2:41:46 PM	9/22/2016 2:36:13 PM
10/27/2016 3:17:17 PM	11/14/2016 2:27:09 PM
12/22/2016 4:38:15 PM	2/8/2017 10:12:24 AM
3/17/2017 11:40:50 AM	4/10/2017 2:26:29 PM
5/9/2017 1:36:04 PM	6/15/2017 3:53:45 PM
7/12/2017 8:22:33 AM	

Base reading on 6/17/2016

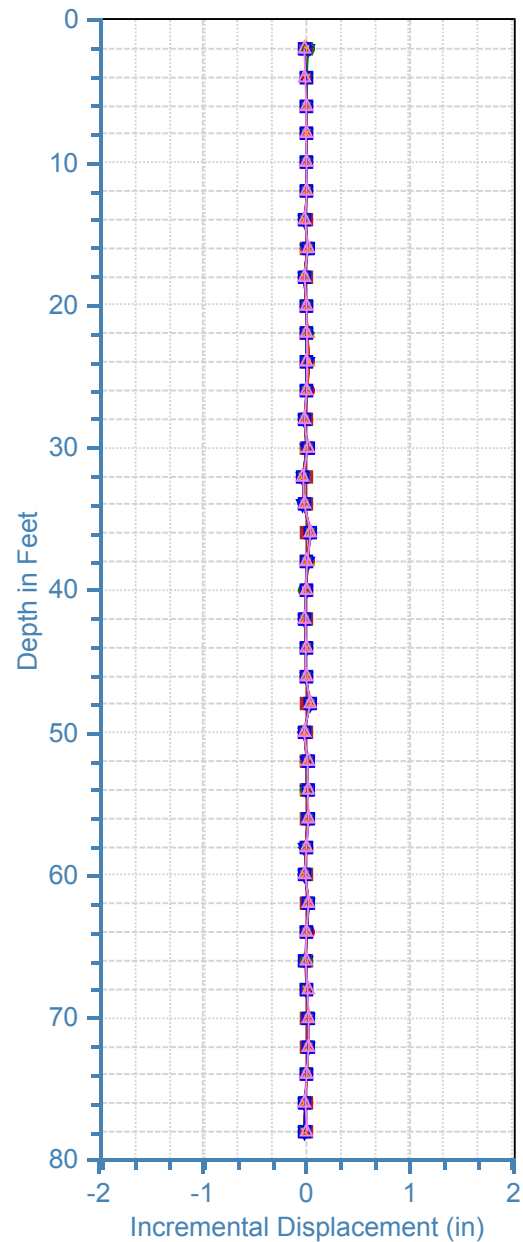


IBWC Arc-4 A - Axis



6/22/2016 10:48:04 AM	7/25/2016 5:08:42 PM
8/25/2016 3:15:23 PM	9/22/2016 3:09:20 PM
10/27/2016 3:58:37 PM	11/14/2016 3:00:46 PM
12/22/2016 5:00:01 PM	2/8/2017 10:34:24 AM
3/17/2017 11:22:03 AM	4/10/2017 2:04:56 PM
5/9/2017 1:18:23 PM	6/14/2017 1:48:14 PM
7/12/2017 8:06:31 AM	

IBWC Arc-4 B - Axis

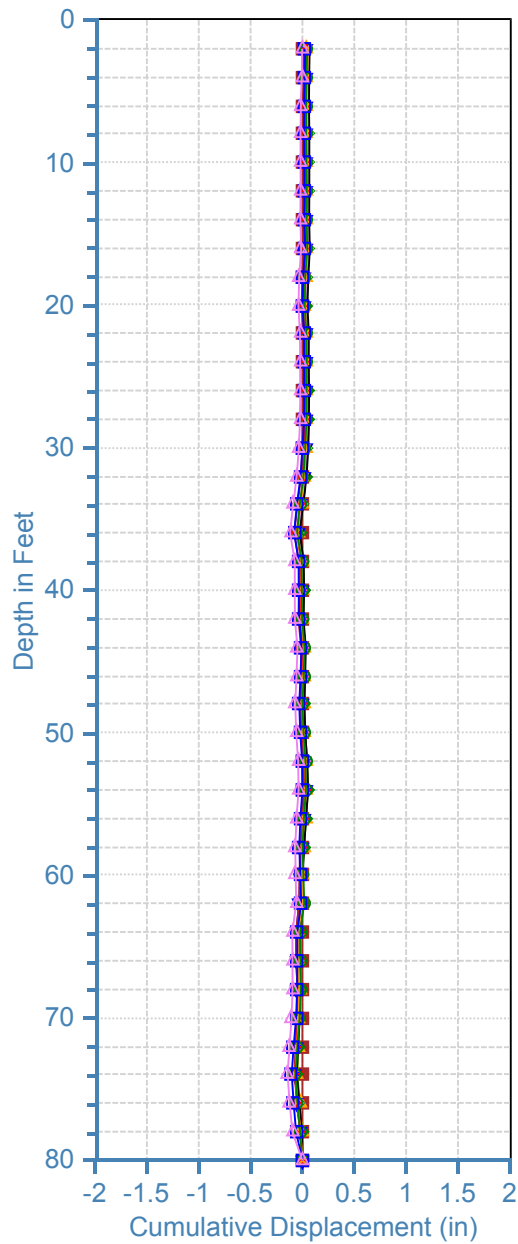


6/22/2016 10:48:04 AM	7/25/2016 5:08:42 PM
8/25/2016 3:15:23 PM	9/22/2016 3:09:20 PM
10/27/2016 3:58:37 PM	11/14/2016 3:00:46 PM
12/22/2016 5:00:01 PM	2/8/2017 10:34:24 AM
3/17/2017 11:22:03 AM	4/10/2017 2:04:56 PM
5/9/2017 1:18:23 PM	6/14/2017 1:48:14 PM
7/12/2017 8:06:31 AM	

Base reading on 6/22/2016

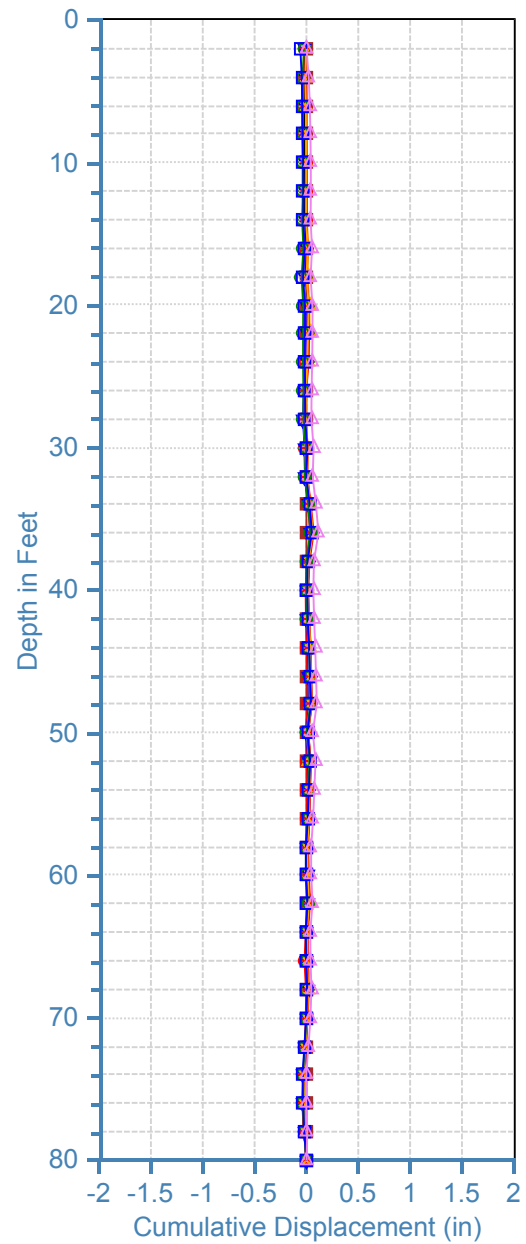


IBWC Arc-4 A - Axis



6/22/2016 10:48:04 AM	7/25/2016 5:08:42 PM
8/25/2016 3:15:23 PM	9/22/2016 3:09:20 PM
10/27/2016 3:58:37 PM	11/14/2016 3:00:46 PM
12/22/2016 5:00:01 PM	2/8/2017 10:34:24 AM
3/17/2017 11:22:03 AM	4/10/2017 2:04:56 PM
5/9/2017 1:18:23 PM	6/14/2017 1:48:14 PM
7/12/2017 8:06:31 AM	

IBWC Arc-4 B - Axis



6/22/2016 10:48:04 AM	7/25/2016 5:08:42 PM
8/25/2016 3:15:23 PM	9/22/2016 3:09:20 PM
10/27/2016 3:58:37 PM	11/14/2016 3:00:46 PM
12/22/2016 5:00:01 PM	2/8/2017 10:34:24 AM
3/17/2017 11:22:03 AM	4/10/2017 2:04:56 PM
5/9/2017 1:18:23 PM	6/14/2017 1:48:14 PM
7/12/2017 8:06:31 AM	

Base reading on 6/22/2016



**ATTACHMENT B**  
**INCLINOMETER AND LEVEE CRACKING LOCATION MAP**





**LEGEND:**

**B-1:** 100 FEET BOREHOLE DRILLED AT THE TOP OF THE LEVEE

**ARC-1:** 98 FEET INCLINOMETER CASING INSTALLED WITHIN BORING B-1

**B-2:** 80 FEET BOREHOLE DRILLED AT THE TOE OF THE LEVEE

**ARC-2:** 78 FEET INCLINOMETER CASING INSTALLED WITHIN BORING B-2

**B-3:** 80 FEET BOREHOLE DRILLED AT THE THE EDGE OF THE RIVERBANK

**ARC-3:** 78 FEET INCLINOMETER CASING INSTALLED WITHIN BORING B-3

**B-4:** 80 FEET BOREHOLE DRILLED NEAR THE NORTH ABUTMENT OF THE GATEWAY BRIDGE

**ARC-4:** 78 FEET INCLINOMETER CASING INSTALLED WITHIN BORING B-4

IBWC  
SUMMARY REPORT OF INCLINOMETER READINGS

REMEDATION DESIGN OF LEVEE FLOODPLAIN FAILURE  
WITHIN THE UPPER BROWNSVILLE LEVEE REACH  
LOWER RIO GRANDE FLOOD CONTROL PROJECT

INCLINOMETER & LEVEE CRACKING LOCATION

**ARCADIS**

ATTACHMENT

**B**

NOT TO SCALE



## **ATTACHMENT C**

### **PHOTOS OF SURFACE TENSION CRACKS**





Photo 1 - Looking North - Surface Tension Crack of Pin Flags 1B through 4B.



Photo 2 - Looking North - Surface Tension Crack of Pin Flags 5B through 10B.





Photo 3 - Looking South - Surface Tension Crack of Pin Flags 11B through 20B.



Photo 4 - Looking South - Surface Tension Crack of Pin Flags 21B through 26B.