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From:  
Kirk Lowery, P.E.

Date:  
April 12, 2017

Arcadis Project No.:  
LA003315.0000

Subject:  
April 2017 Summary Report of Inclinator 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 ninth set of readings were measured on April 10, 2017. These inclinometers will be measured every month until early July of 2017.

Exact readings for the existing inclinometers, I-32, I-33 and I-34, were not made when Arcadis visited the site April 10, 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 to 39 feet

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

In this month's visit to the IBWC site, tension cracks were observed on top of the levee near inclinometer ARC-1 and south of the existing retaining wall in two sections as shown in Attachment B. At the known surface cracks near ARC-1, there was no displacement with respect to the March 17, 2017 measurements for Pin 1 through Pin 5, however, the west outer edge of the wood frame to Pin 6 has decreased in length by 0.31 inches. It was noted that the form work for the concrete pad is expanding. The tension crack at the

northwest edge of the wood frame extended north for a length of approximately 3 inches and discontinued and showed no change from previous measurements. No other cracks were observed north of ARC-1. The ten pins located south of the retaining wall Pin 7 to Pin 12 and Pin 13 to Pin 16 exhibited no displacement with respect to previous measurements. These pin flags mentioned above will be used as a reference to measure over the next three months to observe if the cracks widen or extend either south or north. Table 1 summarizes the pin flags location along the cracks.

**Table 1. Pin Flag Locations**

| Pin Flag No. | Pin Location  |
|--------------|---|
| 1            | 14'-4" from center of inclinometer ARC-1 (southern edge of crack).                |
| 2 and 3      | 11' from center of inclinometer ARC-1.<br>10 and 1/16" between the two pin flags. |
| 4 and 5      | 6' from center of inclinometer ARC-1.<br>7 and 15/32" between the two pin flags.  |
| 6            | 5 and 3/4" from wood frame edge of the concrete pad.                              |
| 7            | GPS Coordinates N25.897884°, W97.496458°<br>(northern edge of crack)              |
| 8 and 9      | South 8' from Pin 7.<br>11.5" between the two pin flags.                          |
| 10 and 11    | South 23' from Pin 7.<br>14.0" between the two pin flags.                         |
| 12           | South 35' from Pin 7.   |
| 13           | GPS Coordinates N25.897672°, W97.496342°<br>(northern edge of crack)              |
| 14 and 15    | South 4' from Pin 13.<br>15.38" between the two pin flags.                        |
| 16           | South 8' from Pin 13.   |

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 River, 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. April 2017 Inclinometers 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 April 10, 2017 followed the same trend as the baseline reading measured in June 2016. The monthly displacement plots recorded between July through April 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 March 2017 to April 2017, the displacement increases 0.03 inches towards the Rio Grande (A-Axis) at a depth of 28 feet. This inclinometer will continue to be monitored on the normally scheduled frequency to determine if there is any increase in cumulative displacements. The displacement

parallel to the levee are comparatively smaller and 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 March 2017 to April 2017, the displacement increases 0.06 inches towards the Rio Grande (A-Axis) at a depth of 38 feet. This inclinometer will continue to be monitored on the normally scheduled frequency to determine if there is any increase in cumulative displacements. The displacement parallel to the levee are comparatively smaller and 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.

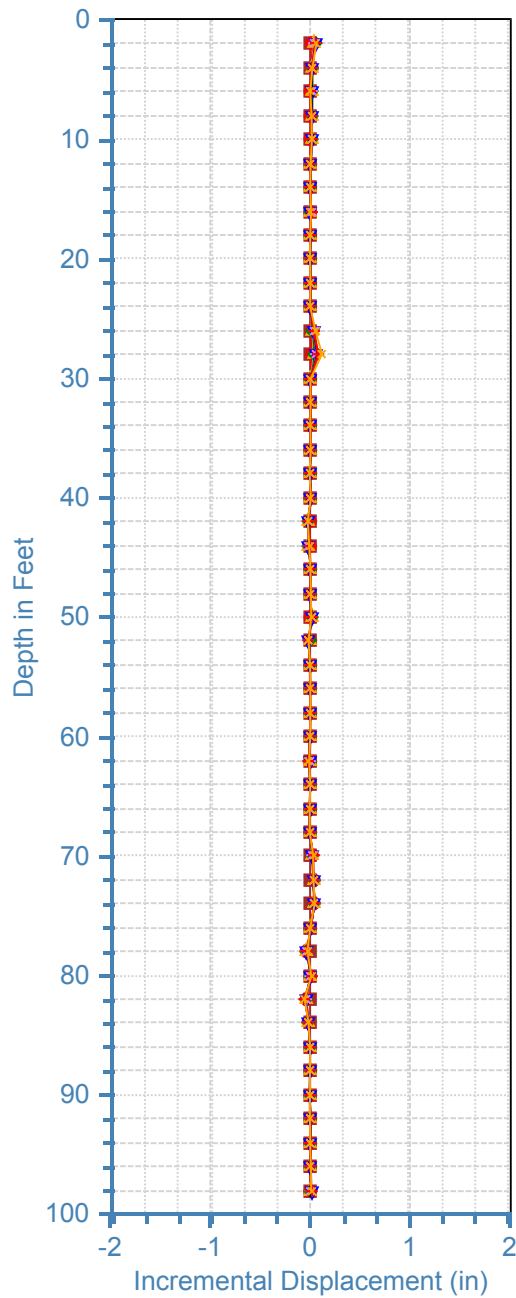
**ATTACHMENTS:**

**A – Inclinometer Plots**

**B – Inclinometer Location Map**

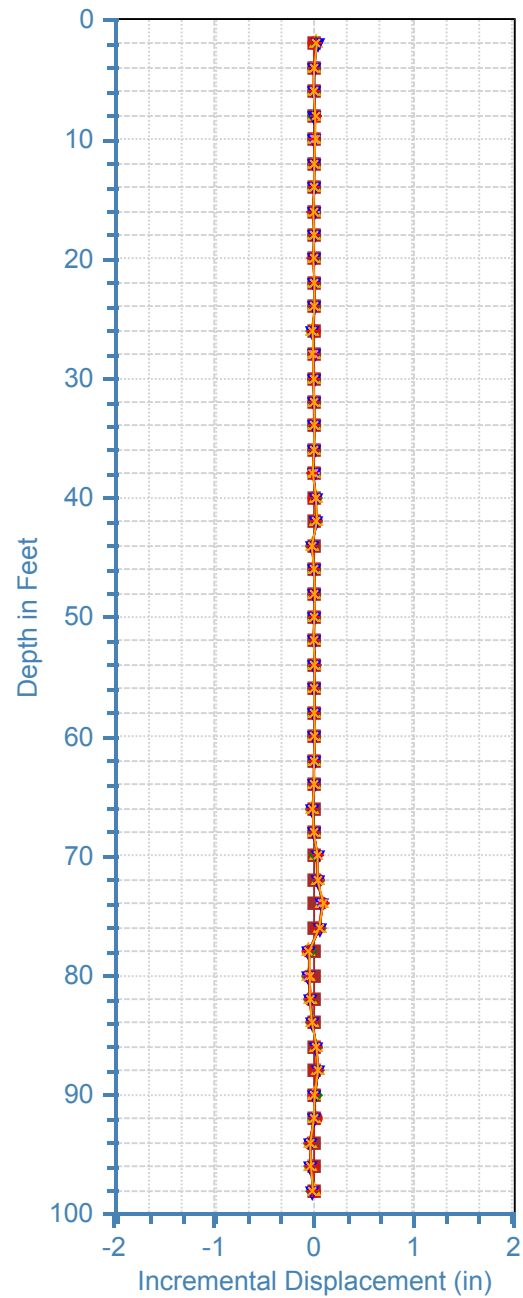
**ATTACHMENT A**  
**INCLINOMETER PLOTS**

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  |

IBWC Arc-1 B - Axis

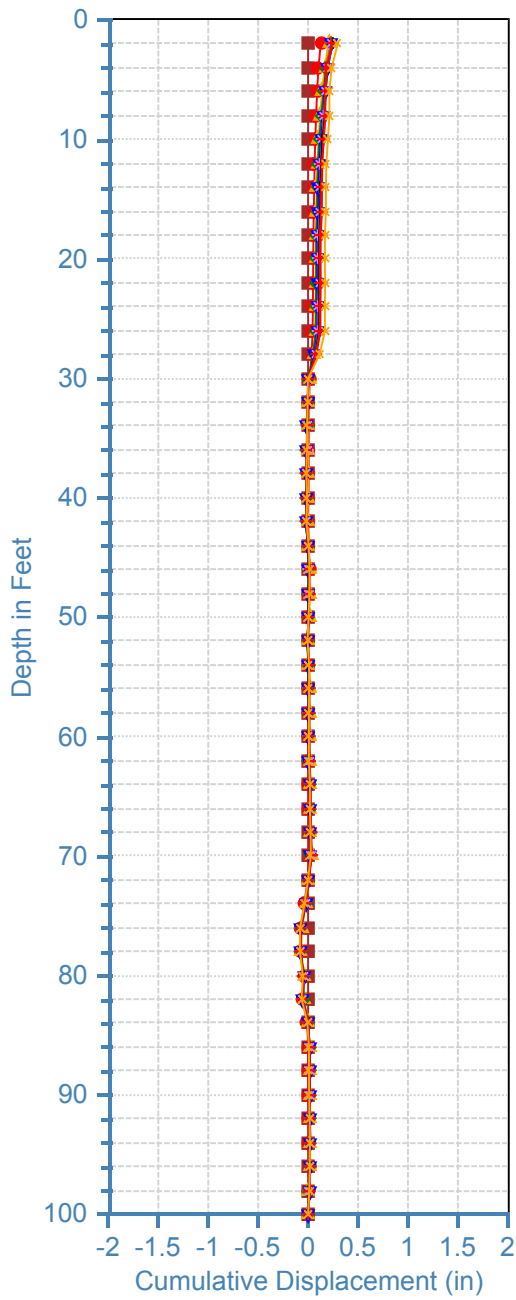


|                       |                       |
|-----------------------|-----------------------|
| 6/22/2016 11:22:30 AM | 7/25/2016 3:17:20 PM  |
| 8/25/2016 1:34:40 PM  | 9/22/2016 1:35:22 PM  |
| 10/27/2016 2:18:50 PM | 11/14/2016 1:34:00 PM |
| 12/22/2016 3:53:53 PM | 2/8/2017 9:25:00 AM   |
|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

Base reading on 6/22/2016

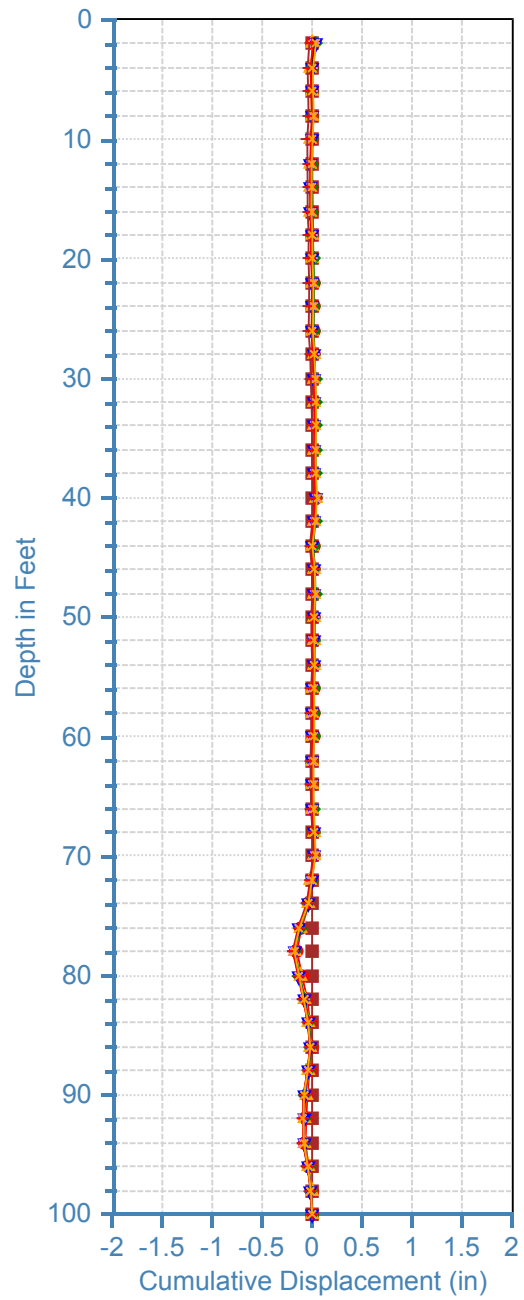


IBWC Arc-1 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

IBWC Arc-1 B - Axis

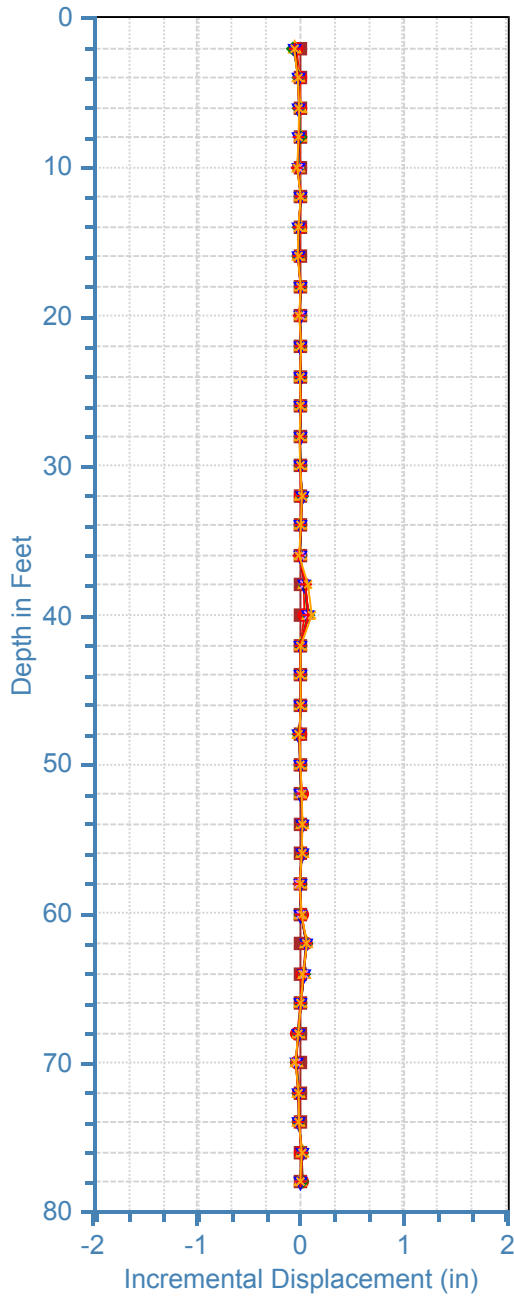


|                       |                       |
|-----------------------|-----------------------|
| 6/22/2016 11:22:30 AM | 7/25/2016 3:17:20 PM  |
| 8/25/2016 1:34:40 PM  | 9/22/2016 1:35:22 PM  |
| 10/27/2016 2:18:50 PM | 11/14/2016 1:34:00 PM |
| 12/22/2016 3:53:53 PM | 2/8/2017 9:25:00 AM   |
|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

Base reading on 6/22/2016

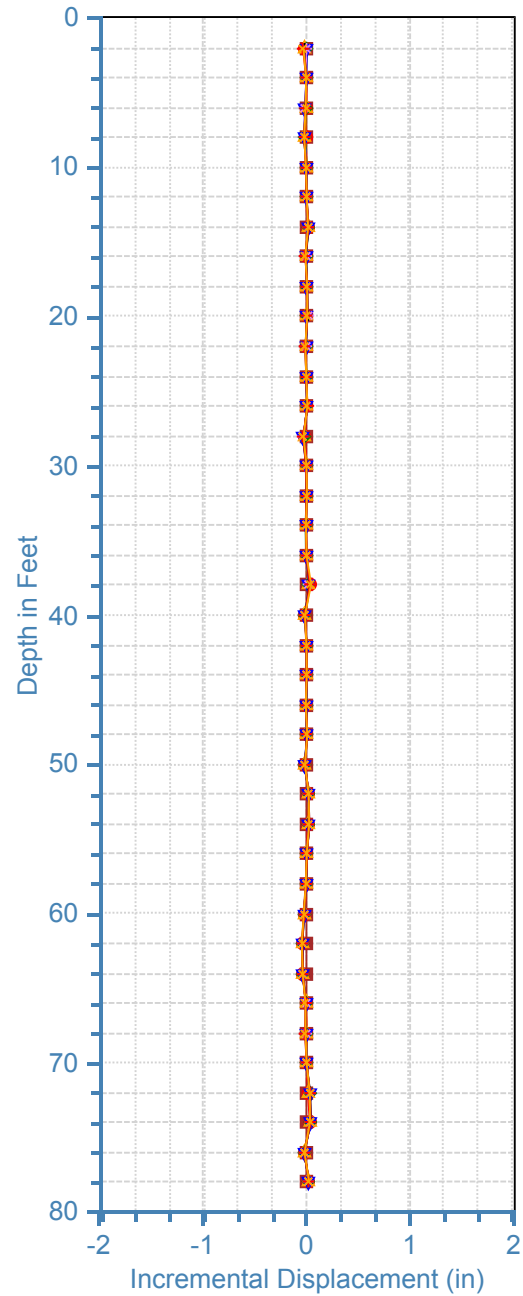


IBWC Arc-2 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

IBWC Arc-2 B - Axis



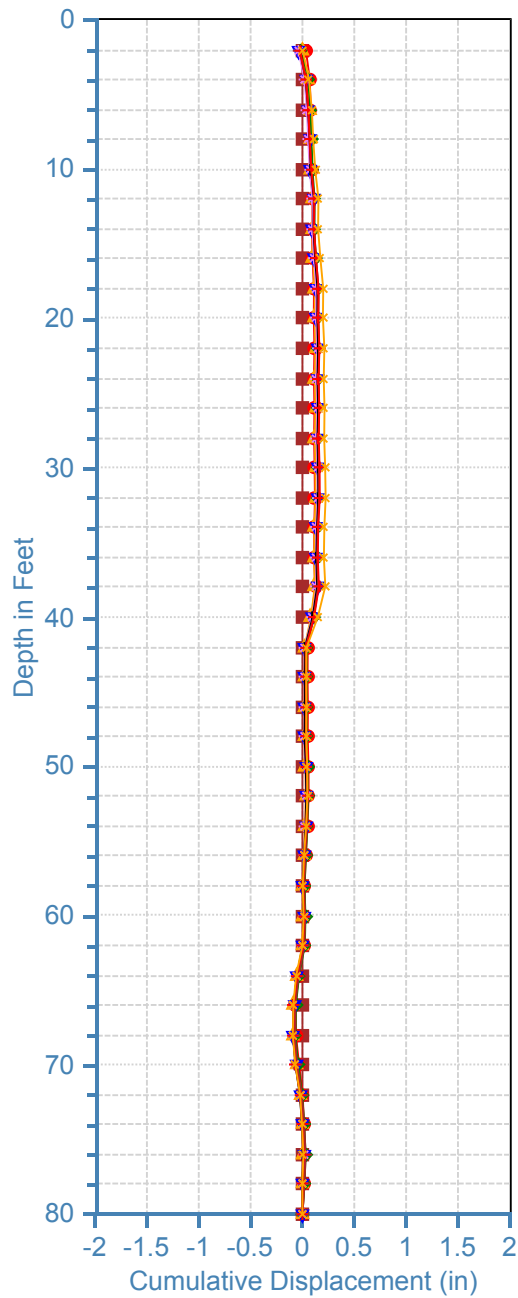
|                       |                       |
|-----------------------|-----------------------|
| 6/17/2016 6:27:13 PM  | 7/25/2016 3:57:11 PM  |
| 8/25/2016 2:02:22 PM  | 9/22/2016 2:05:40 PM  |
| 10/27/2016 2:44:45 PM | 11/14/2016 1:57:25 PM |
| 12/22/2016 4:18:54 PM | 2/8/2017 9:52:21 AM   |
|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

Base reading on 6/17/2016



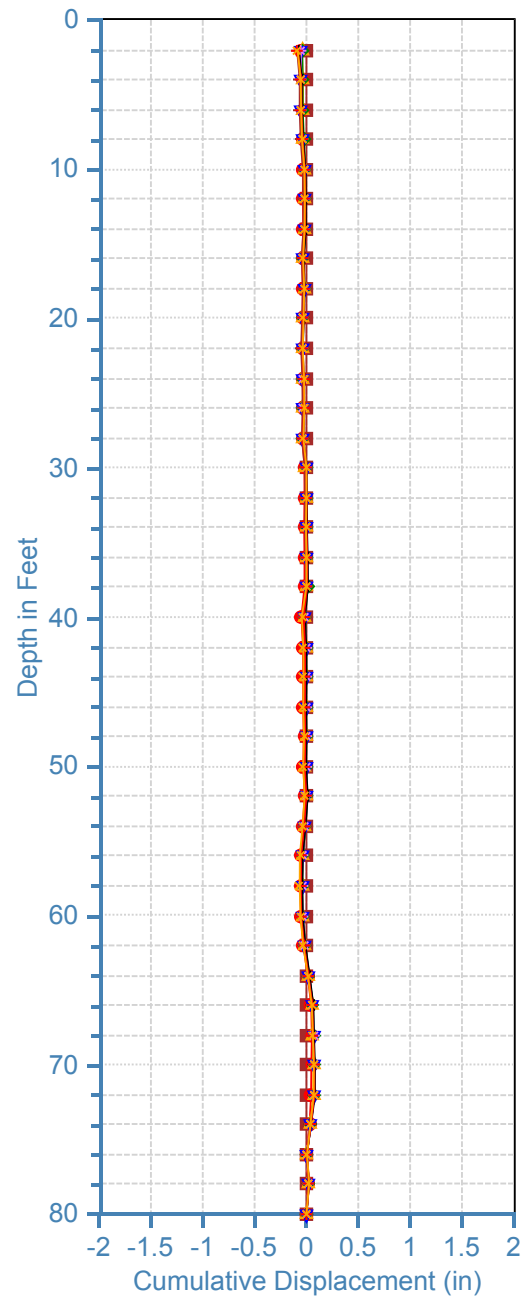


IBWC Arc-2 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

IBWC Arc-2 B - Axis

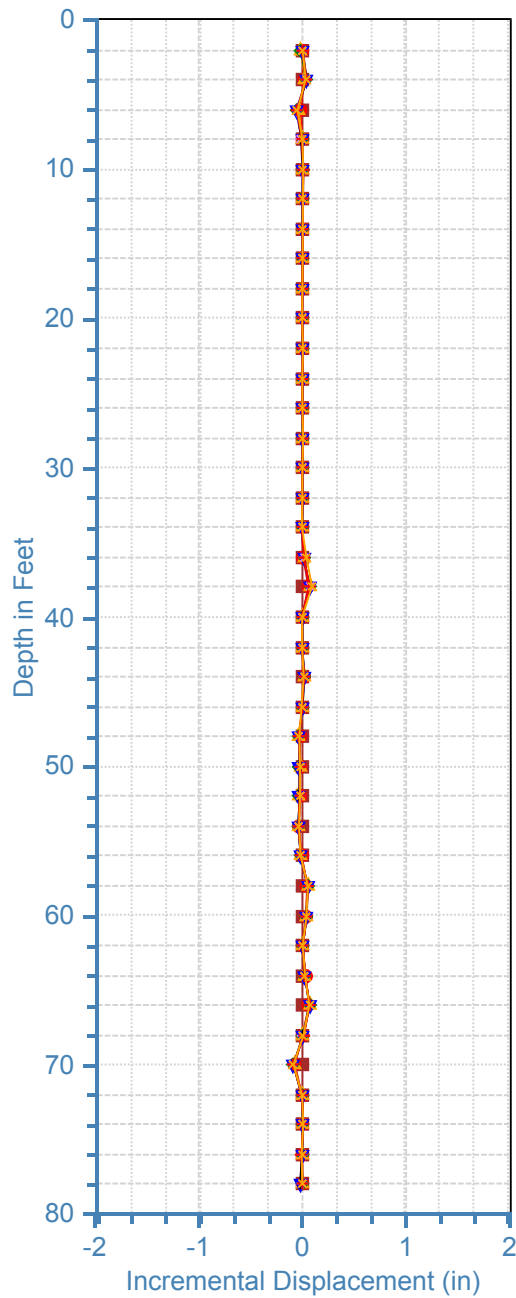


|                       |                       |
|-----------------------|-----------------------|
| 6/17/2016 6:27:13 PM  | 7/25/2016 3:57:11 PM  |
| 8/25/2016 2:02:22 PM  | 9/22/2016 2:05:40 PM  |
| 10/27/2016 2:44:45 PM | 11/14/2016 1:57:25 PM |
| 12/22/2016 4:18:54 PM | 2/8/2017 9:52:21 AM   |
|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

Base reading on 6/17/2016

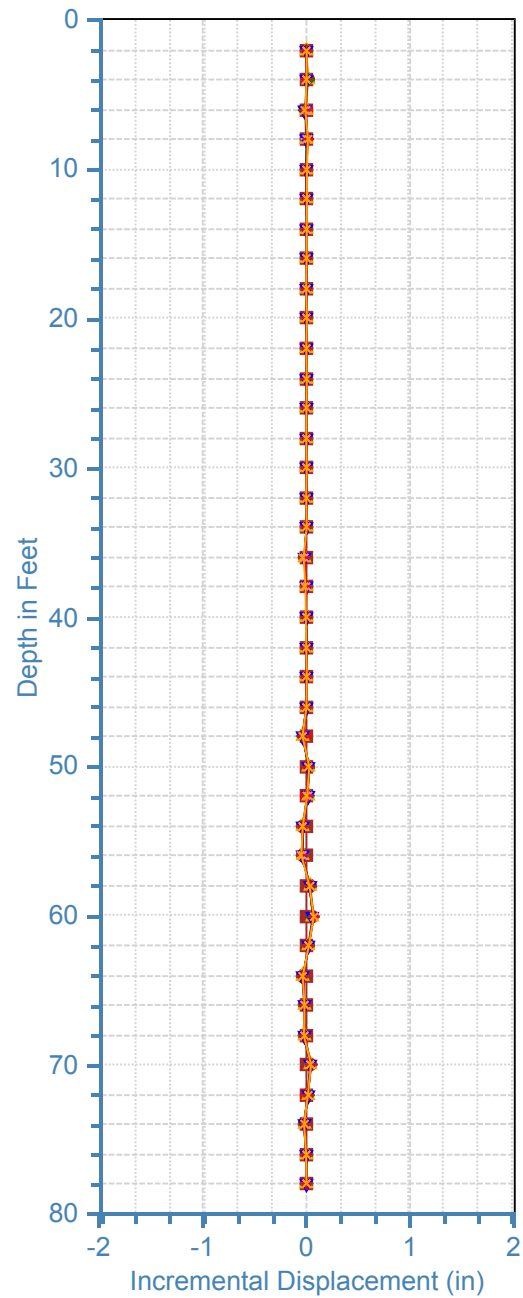


IBWC Arc-3 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

IBWC Arc-3 B - Axis

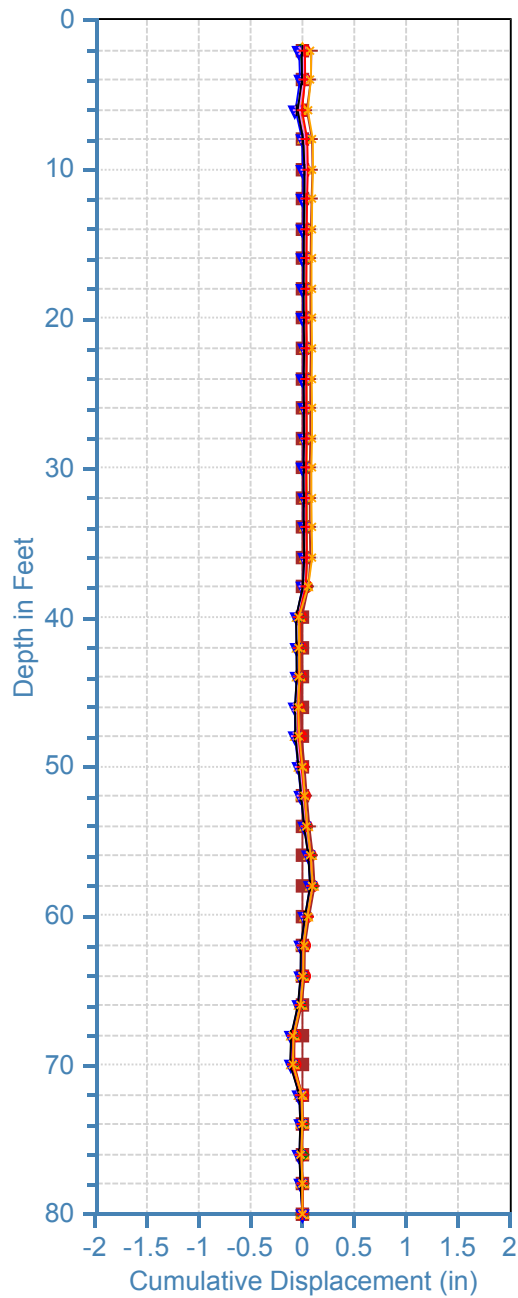


|                       |                       |
|-----------------------|-----------------------|
| 6/17/2016 7:05:22 PM  | 7/25/2016 4:28:56 PM  |
| 8/25/2016 2:41:46 PM  | 9/22/2016 2:36:13 PM  |
| 10/27/2016 3:17:17 PM | 11/14/2016 2:27:09 PM |
| 12/22/2016 4:38:15 PM | 2/8/2017 10:12:24 AM  |
|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

Base reading on 6/17/2016

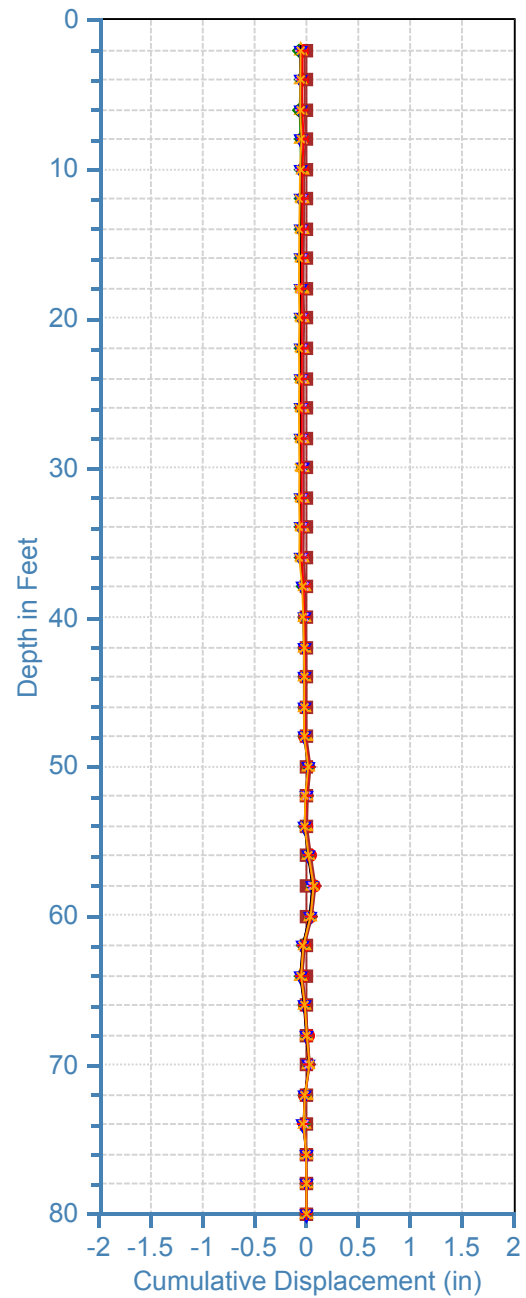


IBWC Arc-3 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

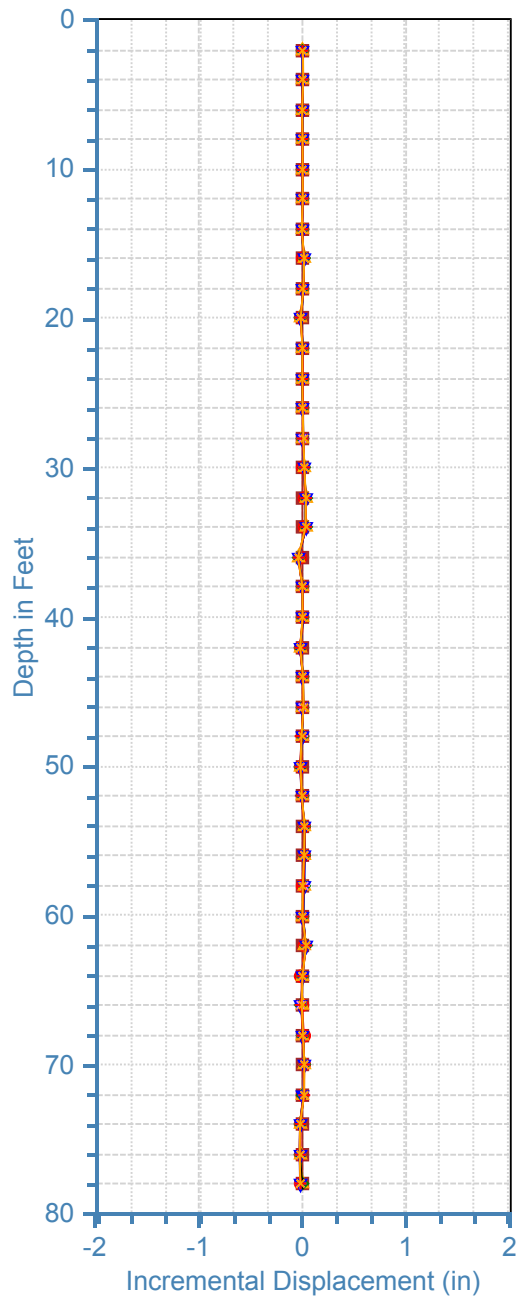
IBWC Arc-3 B - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

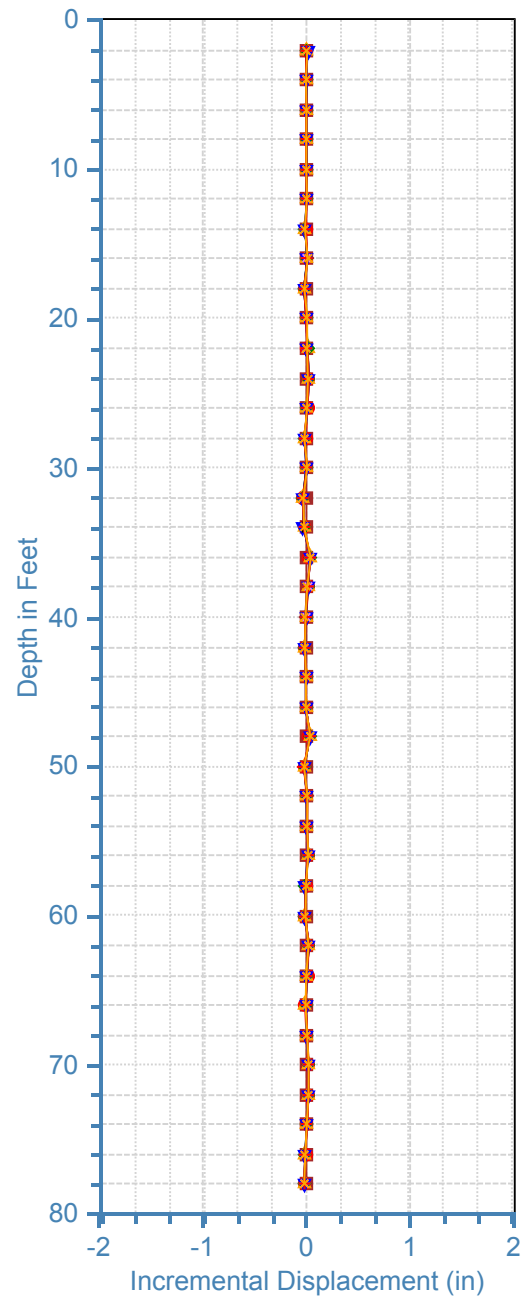
Base reading on 6/17/2016

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  |

IBWC Arc-4 B - Axis

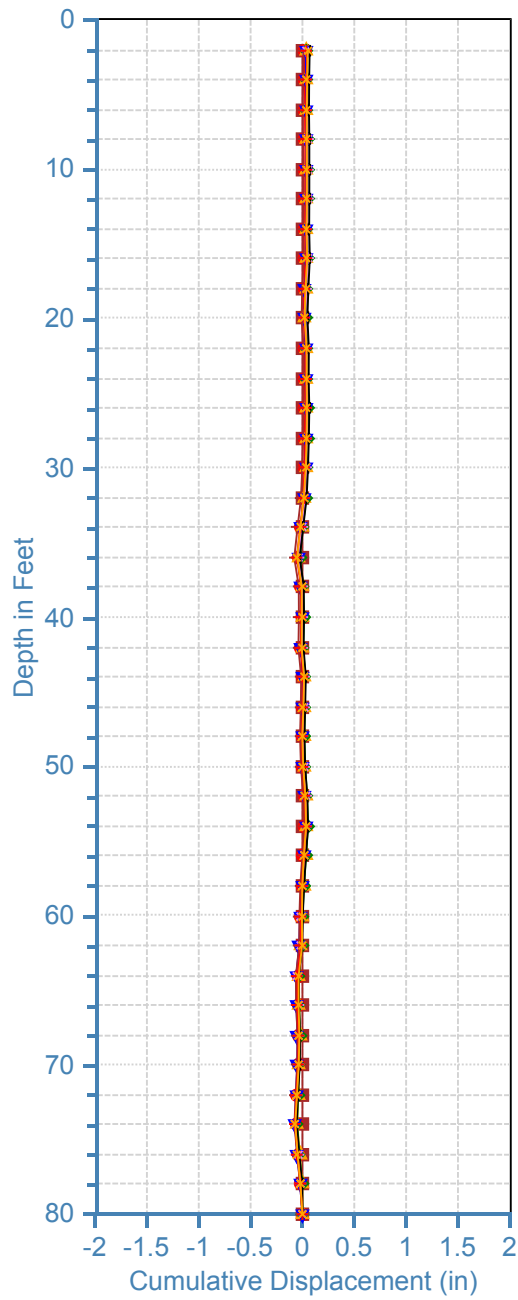


|                       |                       |
|-----------------------|-----------------------|
| 6/22/2016 10:48:04 AM | 7/25/2016 5:08:42 PM  |
| 8/25/2016 3:15:23 PM  | 9/22/2016 3:09:20 PM  |
| 10/27/2016 3:58:37 PM | 11/14/2016 3:00:46 PM |
| 12/22/2016 5:00:01 PM | 2/8/2017 10:34:24 AM  |
|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

Base reading on 6/22/2016

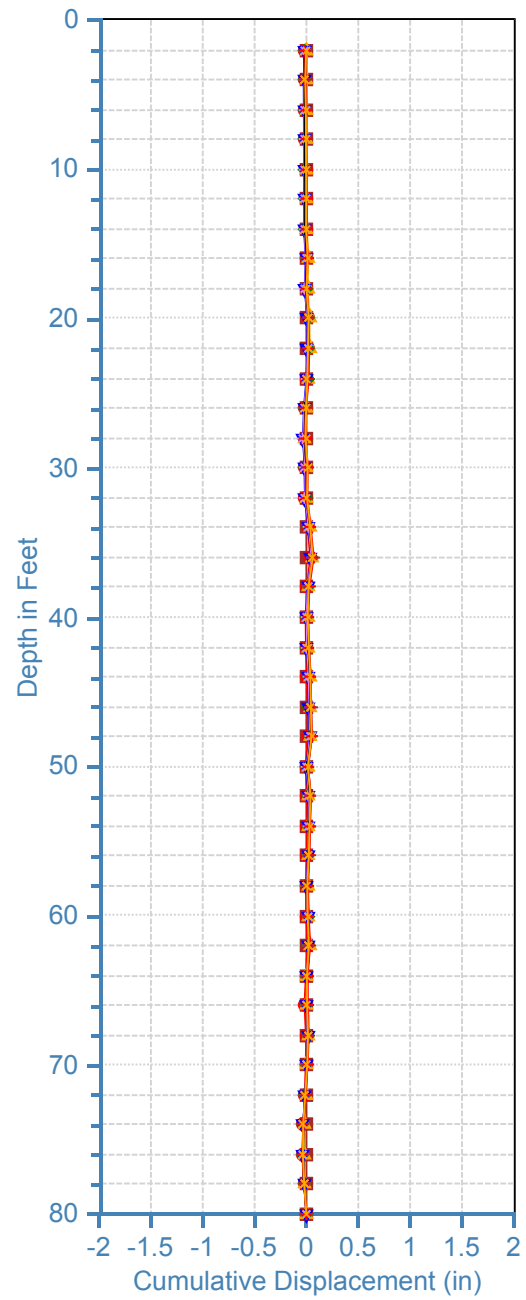


IBWC Arc-4 A - Axis



|                       |                       |
|-----------------------|-----------------------|
| 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  |

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  |

Base reading on 6/22/2016



## **ATTACHMENT B**

### **INCLINOMETER AND LEVEE CRACKING LOCATION MAP**



