List of Figures

Figure 2-1: Release Drain Installed on Two New Tubes................................. 9
Figure 2-2: Release Drain Installed on Existing Tube.................................. 10
Figure 2-3: End Cap and Connecting Hose Used in Leveling Trough............... 11
Figure 2-4: Inflow Drip Line with Adjustable Valve.................................... 12
Figure 2-5: Outflow Drip Line with Fixed Head Location............................ 12
Figure 2-6: Aligning of the Measurement Beam in Vertical Direction............. 13
Figure 2-7: Measurement Tool for Obtaining Measurements Under the Tubes... 14
Figure 2-8: Measurement Procedure Using Plumb Bob.............................. 15
Figure 2-9: Typical Cross Section of Three-Tube Configuration................... 16
Figure 2-10: Locations of Straps along Longitudinal Length of Tubes............. 17
Figure 2-11: Cross Section of Trial 1 Setup........................................... 20
Figure 2-12: Strapping System for Trial 1............................................ 20
Figure 2-13: Tube #2 Rolling Away from Headwater at 7.5-Inch Water Height in Trial 1................................................................. 21
Figure 2-14: Cross Section of Trial 2 Setup.......................................... 22
Figure 2-15: Rotation of Tube #2 Against Sidewall of Box at 10-Inch Water Height in Trial 2................................................................. 23
Figure 2-16: Strapping System for Trial 3............................................ 25
Figure 2-17: Bentonite Paste Applied to Tube #2 and Tube #3 in Trial 3.......... 26
Figure 2-18: Valve on Tube #2 Nearly Sheared Off by Tube #3 in Trial 3....... 27
Figure 2-19: Strapping System for Trial 4............................................ 28
Figure 2-20: No-Slip Buckle................................................................. 28
Figure 2-21: Ratcheting Device............................................................ 28
Figure 2-22: Bentonite Paste Applied to Strap Locations on Tube #2 and Tube #3 in Trial 4................................................................. 28
Figure 2-23: Foam Material under Strapping System in Trial 5.................... 30
Figure 2-24: Piping Failure at Strap Locations in Trial 5............................ 31
Figure 2-25: Flat Plate Hand Compactor in Operation............................... 32
Figure 4-4: Tension vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
\[ h_{\text{int}} = 0.2 \] is Constant

Figure 4-5: \( y_E \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
\[ h_{\text{int}} = 0.2 \] is Constant

Figure 4-6: Tube with Apron Attached and \( h_{\text{int}} = 0.3 \) is Constant

Figure 4-7: Tube with Apron Attached and \( h_{\text{int}} = 0.4 \) is Constant

Figure 4-8: Tube with Apron Attached and \( h_{\text{int}} = 0.5 \) is Constant

Figure 5-1: Freestanding Tube

Figure 5-2: Tube With an Apron Attached and \( \theta_E < \theta_J < \pi/2 \)

Figure 5-3: Tube With an Apron Attached and \( \theta_E < \pi/2 \) and \( \theta_J > \pi/2 \)

Figure 5-4: Tube With an Apron Attached and \( \theta_J > \theta_E > \pi/2 \)

Figure 5-5: Tube With an Apron Attached and Drain Directly Beneath

Figure 5-6: Free Body Diagram of the Apron

Figure 5-7: Tube with Apron Attached; Constant Area, Initial \( h_{\text{int}} = 0.2 \)

Figure 5-8: \( h_{\text{int}} \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached; Constant Area,
Initial \( h_{\text{int}} = 0.2 \)

Figure 5-9: \( h \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached; Constant Area,
Initial \( h_{\text{int}} = 0.2 \)

Figure 5-10: Tension vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
Constant Area, Initial \( h_{\text{int}} = 0.2 \)

Figure 5-11: \( y_E \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
Constant Area, Initial \( h_{\text{int}} = 0.2 \)

Figure 5-12: Tube with Apron Attached; Constant Area,
Initial \( h_{\text{int}} = 0.31903 \)

Figure 5-13: \( h_{\text{int}} \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
Constant Area, Initial \( h_{\text{int}} = 0.31903 \)

Figure 5-14: Tension vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
Constant Area, Initial \( h_{\text{int}} = 0.31903 \)

Figure 5-15: \( y_E \) vs. \( h_{\text{ext}} \) for a Tube with Apron Attached;
Constant Area, Initial \( h_{\text{int}} = 0.31903 \)
Figure 6-1: Tube with Apron Attached: initial hint = 0.31903,
    hext = 0.05172 (3 in.)………………………………………………………………………………… 88

Figure 6-2: Tube with Apron Attached: initial hint = 0.31903,
    hext = 0.10345 (6 in.)………………………………………………………………………………… 89

Figure 6-3: Tube with Apron Attached: initial hint = 0.31903,
    hext = 0.15517(9 in.)………………………………………………………………………………… 89

Figure 7-1: Typical Cross Section of Trial Setup………………………………………………. 91
Figure 7-2: Critical Headwater Height vs. Location of Drain………………………………….. 91