

Multi-Sensor Inspection: 2D LIDAR & 3D LIDAR

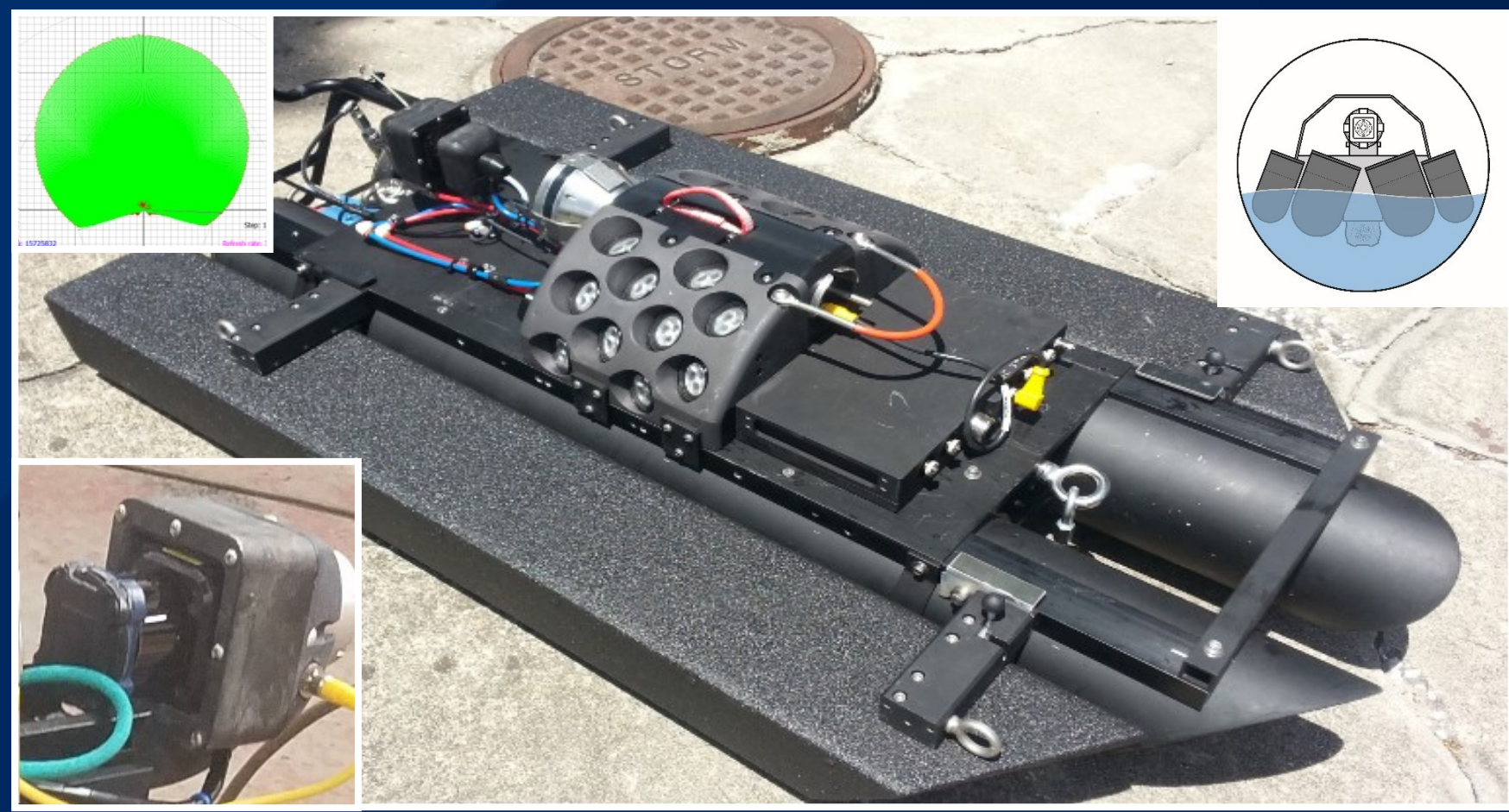
Adam Slifko

CUES / Pipeline Inspection Partners Corp.
Business Development Manager

Current Role: Manages the Multi-Sensor Inspection (MSI) line of business, with an emphasis on 2D and 3D LIDAR applications. Plans and coordinates multi-sensor jobs from field data collection to processing and report submittal.

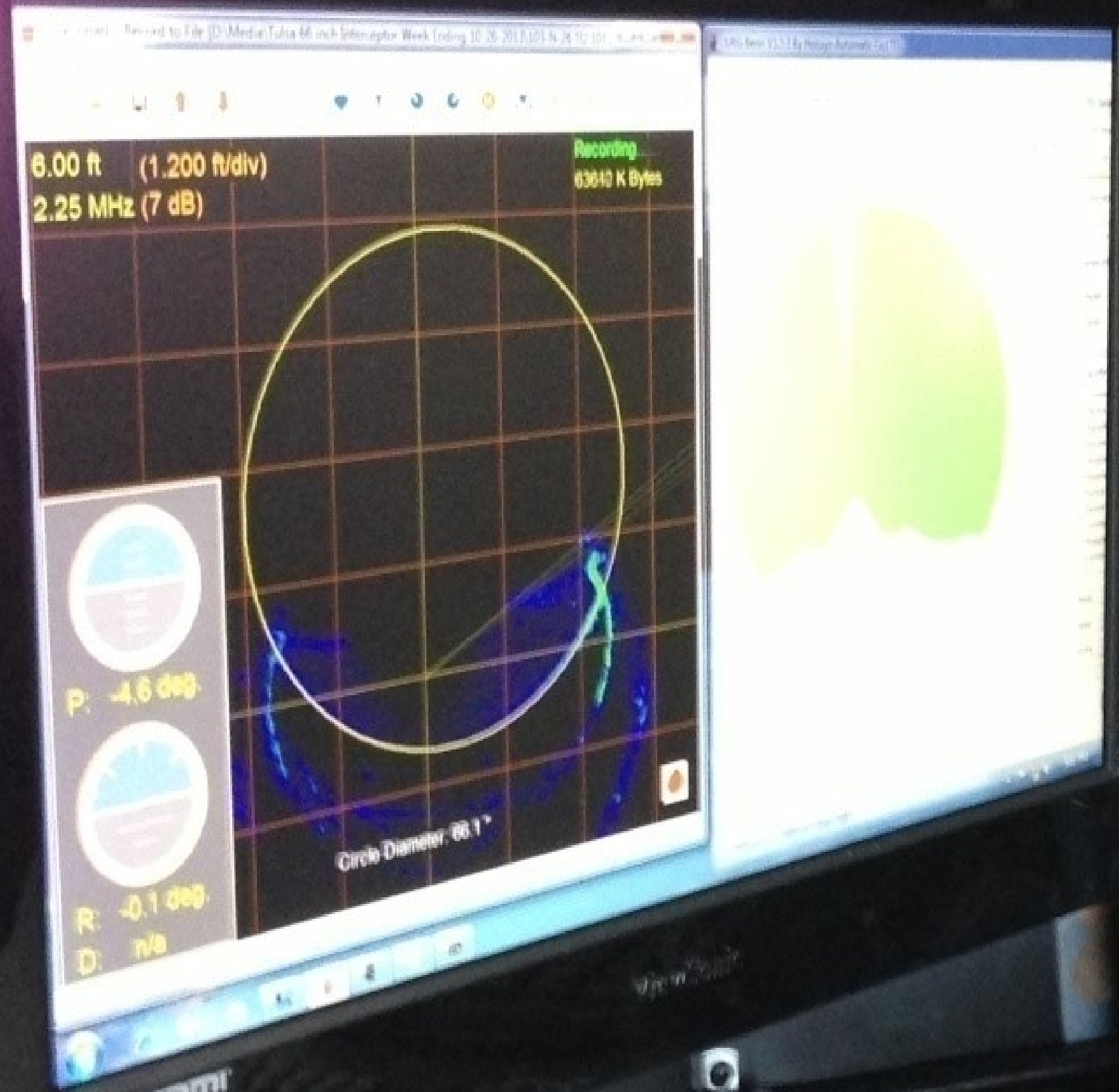
Background: Mechanical Engineering and Robotics

Multi-Sensor Inspection: 2D LIDAR & 3D LIDAR



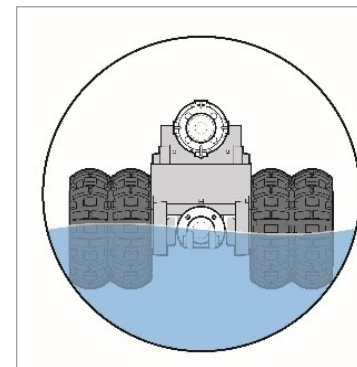
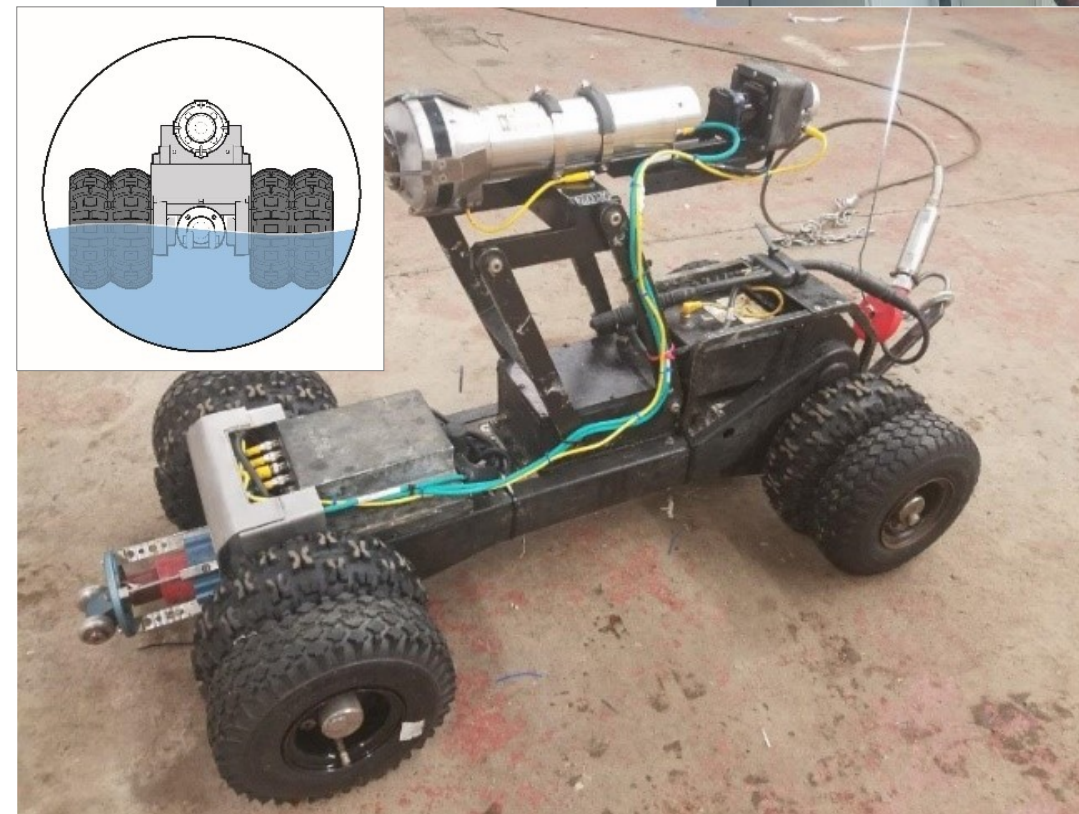
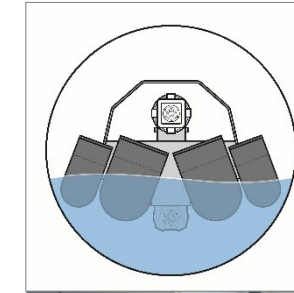
What Is **MSI**?

- Multiple Sensors
 - LIDAR
 - SONAR
 - Fisheye Video
 - H2S Gas & Temp - OPTIONAL
- **2D** LIDAR
- **3D** LIDAR
- Quantitative measureable data



SolidFX MSI Equipment

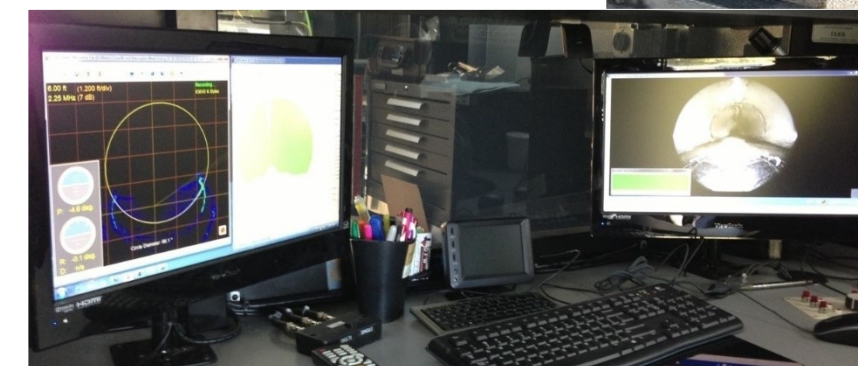
- State-of-the-Art 2D LIDAR Inspection
- FLOAT for 36" and larger pipe
 - Up to 5400 LF
- SMM for 24" and larger pipe
 - Up to 3000 LF
- View and verify data quality in real time
- Code in back office for QA/QC
- Lens cleaning for I&I



LIDAR view

DUC view

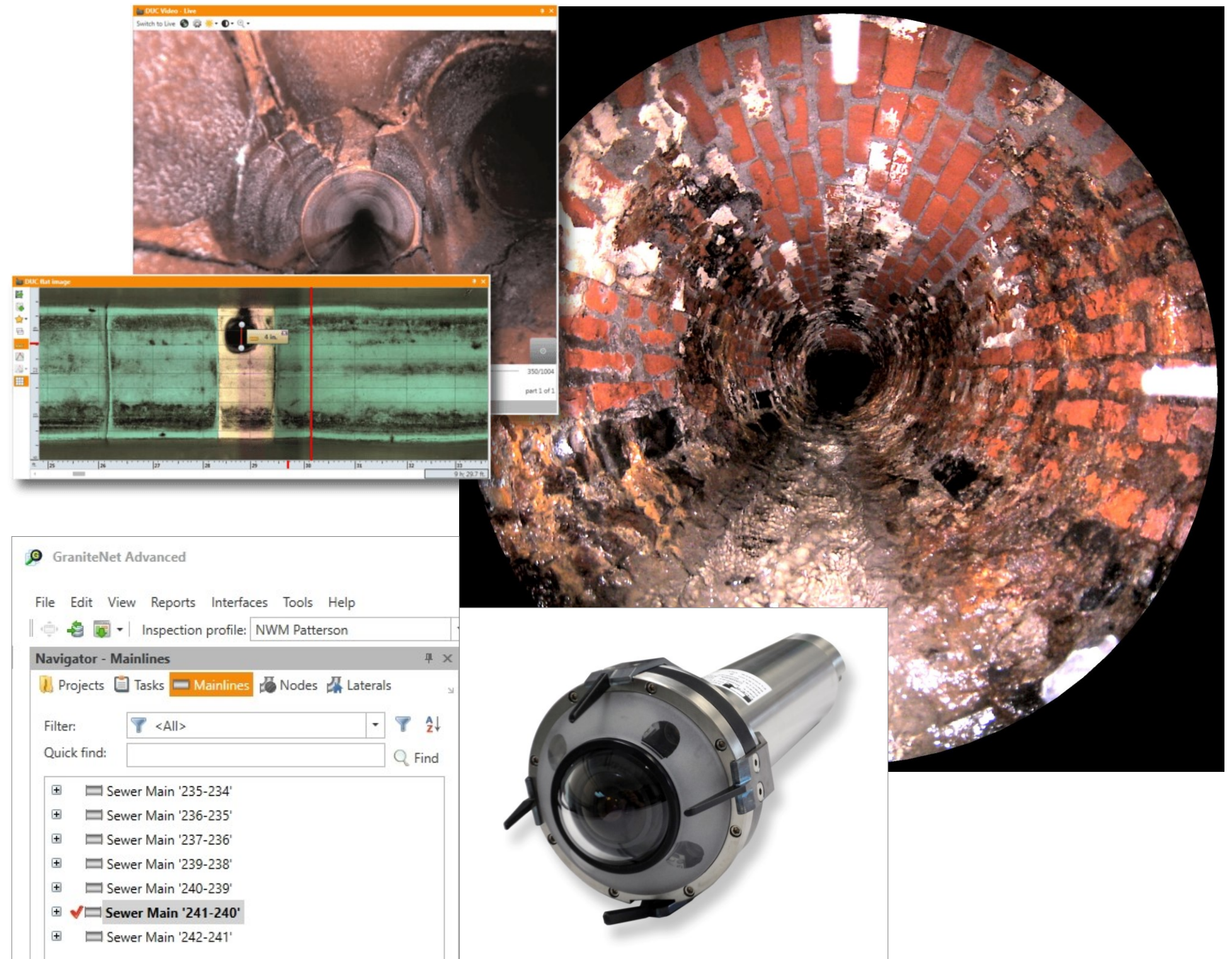
SONAR view



SFX-DUC Camera

Digital Universal Camera (DUC)

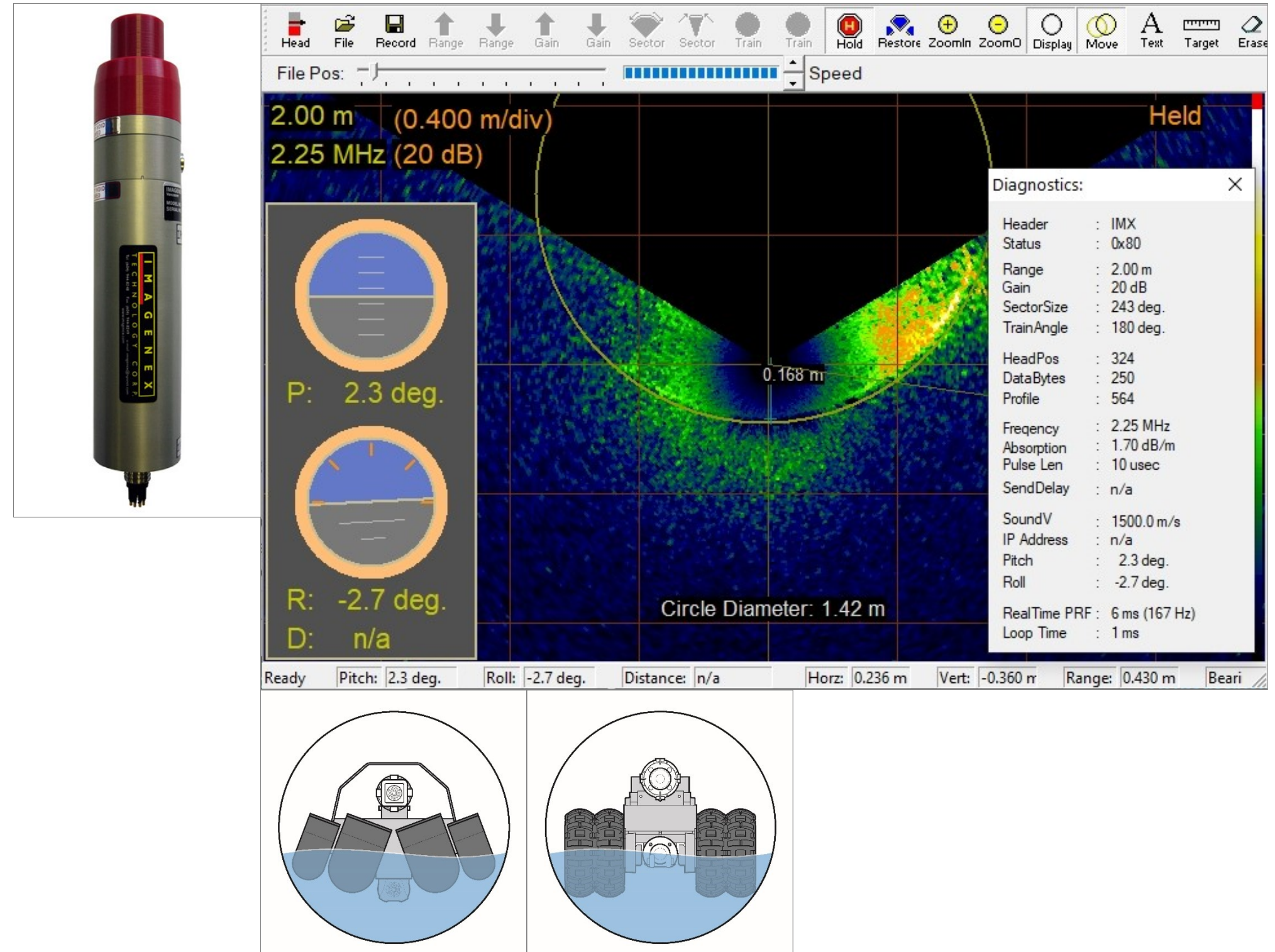
- Live video during inspection
- Digital pan-tilt-zoom
- Never miss a defect
- Integrated with GNet
- Code in truck or in office
- Flat images with measuring capabilities
- No moving parts



SFX-SONAR

Profiling SONAR

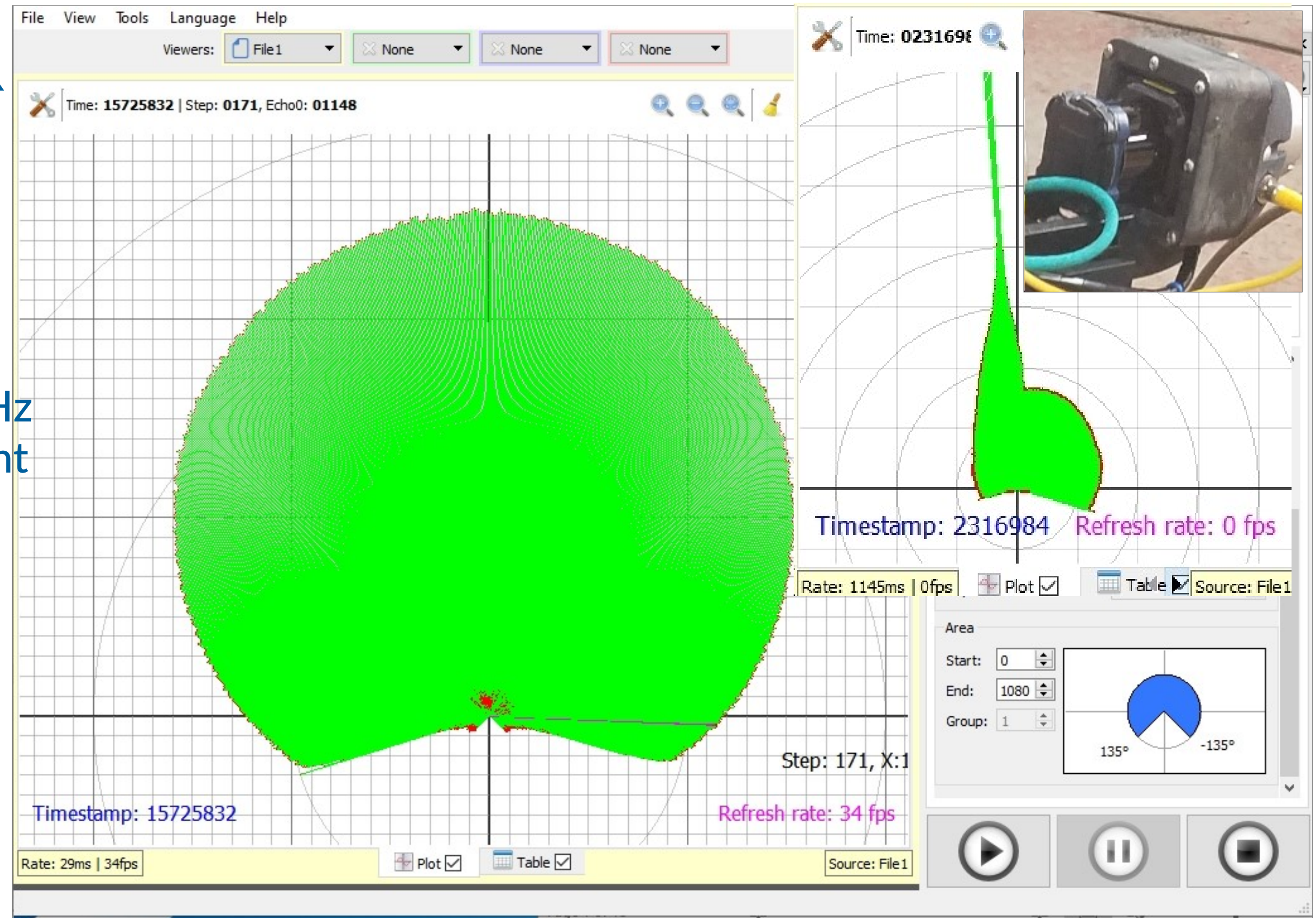
- Frequency = 2.25 MHz
- Beam = 1.4-deg conical
- RPM = 1 rev/sec
- Range = 6" - 180" (15 ft.)
- Pitch & Roll
- Debris level
- Water level
- Capacity Analysis
- On-screen measurements



SFX-2D LIDAR

2D Scanning LIDAR

- 2D SCANNING LIDAR
- Live view
- On screen measurements
- 270 degree sweep @ 40 Hz
- 1080 points @ 1/4 deg/point
- Height & Width
- Ovality
- Corrosion & Buildup



SFX-H2S Gas/Temp Sensor (optional)

H2S/TEMP-data logger

- H2S/TEMP – data logger
- Designed for sewers, manholes, and wet wells
- Wireless Bluetooth download of data
- Time synchronization with other MSI sensors
- Floats and self-righting

H2S Ranges	0-50, 0-200, 0-1000 and 0-2000ppm, Long Deployment (LD) or Short Deployment (SD) sensors available
Gas Accuracy at STP	+/- 2ppm at 20ppm gas (normal temperature and pressure)
Instrument Temp Range	-20C to 50C (-4F to 122F)
Relative Humidity Range	0-100% non-condensing
Ingress Protection	IP68
External Dimensions	Trilateral Diameter 58.3mm x 59.3mm Height 164mm (2.30" x 2.34" x 6.46")
Instrument Weight	300 grams (10.6oz)
Power Supply	3 x AA Alkaline Batteries (in adaptor) Or 1 x 3.6v D Lithium Battery
Logging Interval	1 second to 18 hours
Logging Capacity	3 million data points
Wireless Communication	Data download via <i>Bluetooth</i> [®]
Humidity Accuracy	+/- 5% RH @ 55% RH
Humidity Sensor Range	0-100%
Temperature Accuracy	+/- 0.3 @ 25C (77F)



SFX-Advantages

Live view of video and data

- Code in field or office
- Verify data quality in field
- Reduce re-work

Blow-off system for clearing lens

- No need to pull back
- DUC lens & LIDAR lens

No Shadowing

Accuracy is constant as pipe diameter gets larger

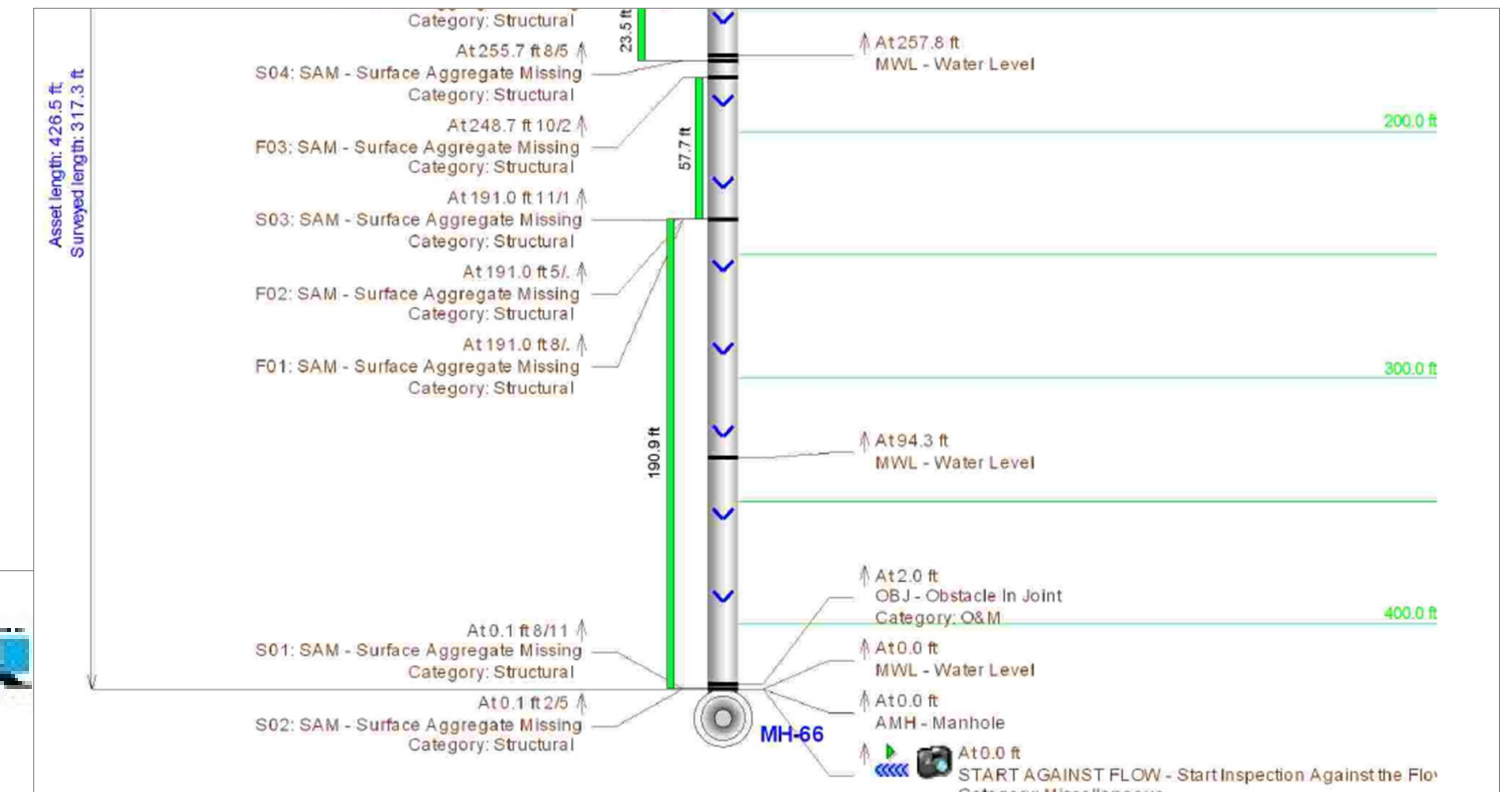
Factory calibration

2D Inspection Technology Comparison			
Feature	SOLID FX -2D	Rauch	Fly Eye
<i>Technology</i>	LiDAR	Spinning Laser Profiling	Laser Profiling with Wand
<i>Cross Sections Scan Rate</i>	45 /second	1.25 /second	12 /second
<i>Cross Section Measurement Density</i>	1080 points	20 -300 points	Function of Pipe diameter
<i>Effective Range</i>	6"- 30 meters	4"-48"	18"-100"
<i>Accuracy</i>	3 mm @ 10m	15mm @ 3m	3 mm @ 3mm
<i>Resolution</i>	1mm (constant)	+/- 0.5% (pipe diameter)	+/-0.1% (pipe diameter)
<i>Calibration</i>	Precision Factory	Automatic	Factory
<i>Limited by Shadowing</i>	No	No	Yes
<i>Requires Wand Change out</i>	No	No	Yes
<i>"Cork Screw" Distortion during Motion</i>	No	Yes	No
<i>Multiple Returns (fog resistance)</i>	Yes	No	No
<i>Sensor Cleaning during Inspection</i>	Yes	No	No
<i>Transport Mechanism</i>	Tractor/Float	Tractor Only	Float Only
<i>3D Option</i>	Yes	No	No
<i>Custom Reporting</i>	Yes	No	No
<i>Live Video</i>	Yes	Yes	No
<i>Sonar Available</i>	Yes	No	Yes
<i>Maximum Deployment Length (m)</i>	2000+	2000	2000+
<i>Data viewable during operations</i>	Yes	Yes	No
<i>Onsite PACP/WRC</i>	Yes	Yes	No



SFX-Reporting Deliverables

- Granite Net database and DUC video file
- 4:1 VIDEO – Synchronized sensor view (MP4)
- Condition Assessment Report (PDF)
- Tabular Data (Summary Info) (CSV)



Anytown, USA
Upstream Manhole: 104433
Downstream Manhole: 231533

SolidFX

Payout: 32.1
2017-11-30 09:02:33

Corrosion avg in: 0.27
Corrosion max in: 0.68

Water Height in: 17.0
Sediment Ht. in: 10.0

HD Video

Rollout View

Cross Section View

Height - in

Payout - ft

corrosion max

corrosion avg

Pipe Diameter - 54"


Water Level - inches

Sediment Height - inches


Payout - ft


Category: Miscellaneous				
0.013867596	2017_11_30_09_01_23198	86.66739156	2.147333956	5.123189999
0.014773519	2017_11_30_09_01_23224	86.74908718	2.168335546	5.33744858
0.015644599	2017_11_30_09_01_23249	88.60474504	2.21571583	5.488367359
0.016515679	2017_11_30_09_01_23274	90.71716059	2.181964199	5.488367359
0.01738676	2017_11_30_09_01_23299	89.73681304	2.147298754	5.33744858
0.01825784	2017_11_30_09_01_23324	78.48615785	2.103991424	4.948263487
0.042081633	2017_11_30_09_01_23349	89.620105	2.155747328	5.228985074
0.045142857	2017_11_30_09_01_23374	83.72634891	2.11037864	5.163934533
0.048326531	2017_11_30_09_01_23400	87.83447197	2.164946517	5.33744858
0.051020408	2017_11_30_09_01_23422	92.74788051	2.172976496	5.488367359
0.054326531	2017_11_30_09_01_23449	91.88424101	2.21507997	5.488367359
0.057510204	2017_11_30_09_01_23475	82.88605101	2.107107994	5.186547366
0.060571429	2017_11_30_09_01_23500	84.2632059	2.158815863	5.274763934
0.063632653	2017_11_30_09_01_23525	82.37253563	2.103689509	5.186235617
0.066693878	2017_11_30_09_01_23550	90.82219783	2.21888614	5.488367359
0.069755102	2017_11_30_09_01_23575	84.77672128	2.155203393	5.163934533
0.07295082	2017_11_30_09_01_23600	82.41921885	2.075084698	5.099194149
0.07602459	2017_11_30_09_01_23625	91.81421618	2.232759216	5.488367359
0.079221311	2017_11_30_09_01_23651	85.03347898	2.125692772	5.27402581

SFX-4:1 Viewer



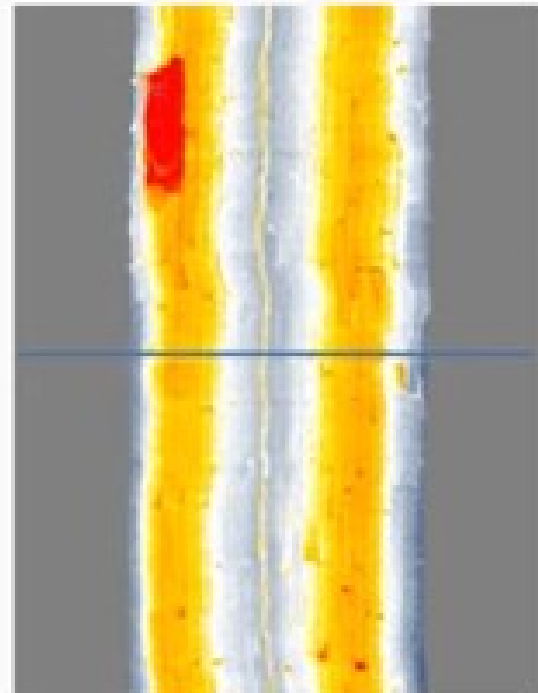
PIPC
Upstream Manhole: GIS123
Downstream Manhole: GIS456



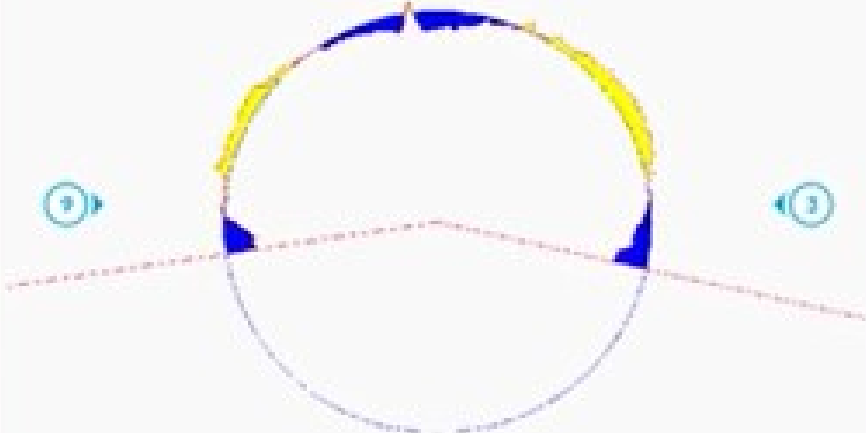


Payout: 29.7 Corrosion avg in: 0.27 Buildup avg in: 0.33
 2016-02-29 10:56:02 Corrosion max in: 1.27 Buildup max in: 2.53

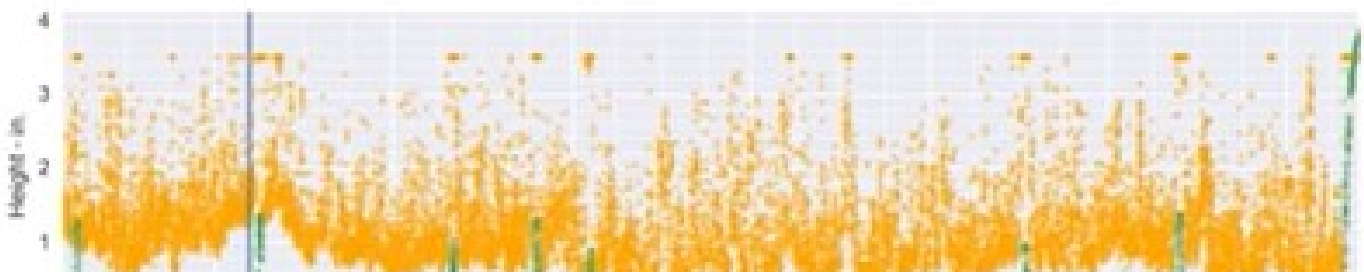

HD Video




Rollout View





Cross Section View

SFX-4:1 Viewer (cont.)

 **PIP**
Upstream Manhole: GIS123
Downstream Manhole: GIS456



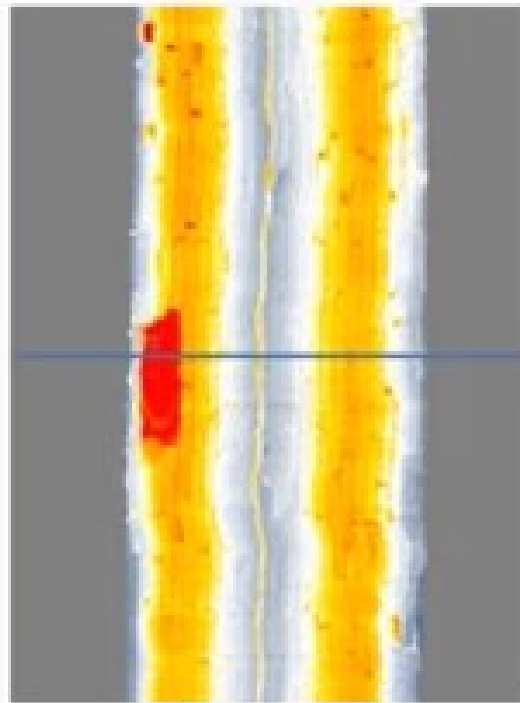


Payout: 31.4
2016-02-29 10:56:08

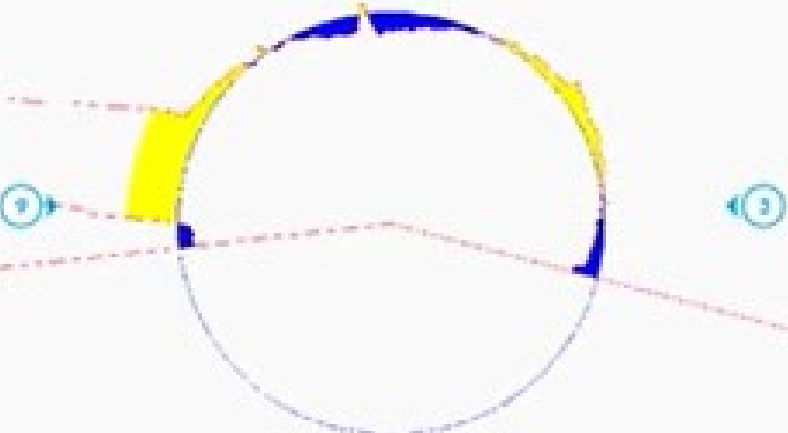
Corrosion avg in: 1.33
Corrosion max in: 3.5

Buildup avg in: 0.27
Buildup max in: 1.98

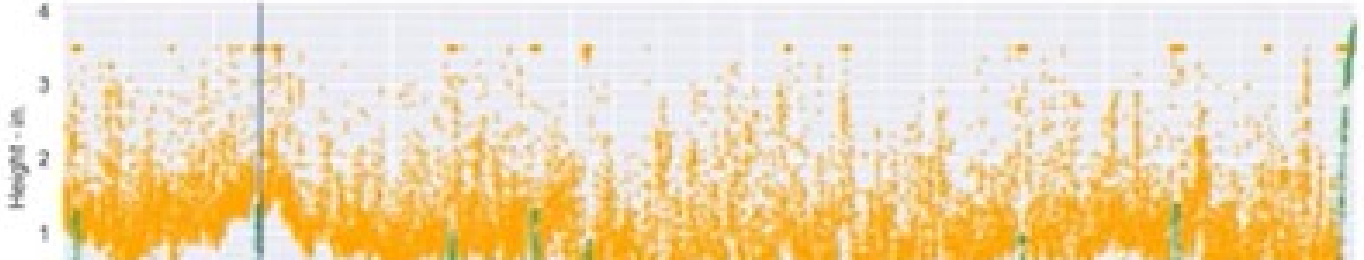
HD Video




Rollout View






Cross Section View





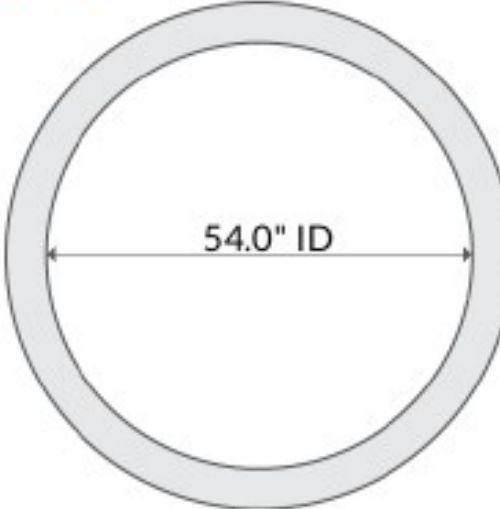
SFX-Condition Assessment Report



Anytown, USA 104433
 Inspected November 30, 2017 231533

As-Built Dimensions



54.0" ID

Document Details

Report Prepared February 15, 2018
 Source Reference 52305

Inspection Information

Transport
Float



Sensor(s)
LIDAR
HD
SONAR

Inspection Details


Service Area:	AREA 3
Segment Reference:	167020
Upstream Manhole:	104433
Downstream Manhole:	231533
Direction:	Downstream
Distance:	406.0
Scan Date:	November 30, 2017
Operator Notes:	None
Processing Notes:	None

Table of Contents



Technology Comparison	3
Inspection Information	4
Sediment and Corrosion Summary Metrics	5
Sediment and Corrosion Graphs	6
Pipe Ovality Graphs	9
Summary Table	10
Distributed Cross-Sections	13





SFX-Condition Assessment Report *(cont.)*



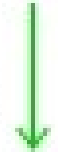
The Standard of the Industry



Anytown, USA 104433

Inspected November 30, 2017 231533



Sediment and Corrosion Summary Metrics

Sediment/Sonar Metrics

Sediment Volume (cubic yard):	10.1
As-is Capacity/As-built Capacity (%):	95.7
Average cross-sectional restriction (%):	4.3

Corrosion/Lidar Metrics

Corroded Volume (cubic in):	42126.5
Wall/As-built (%):	99.2
Average Wall Loss (%):	0.8



Table of Contents

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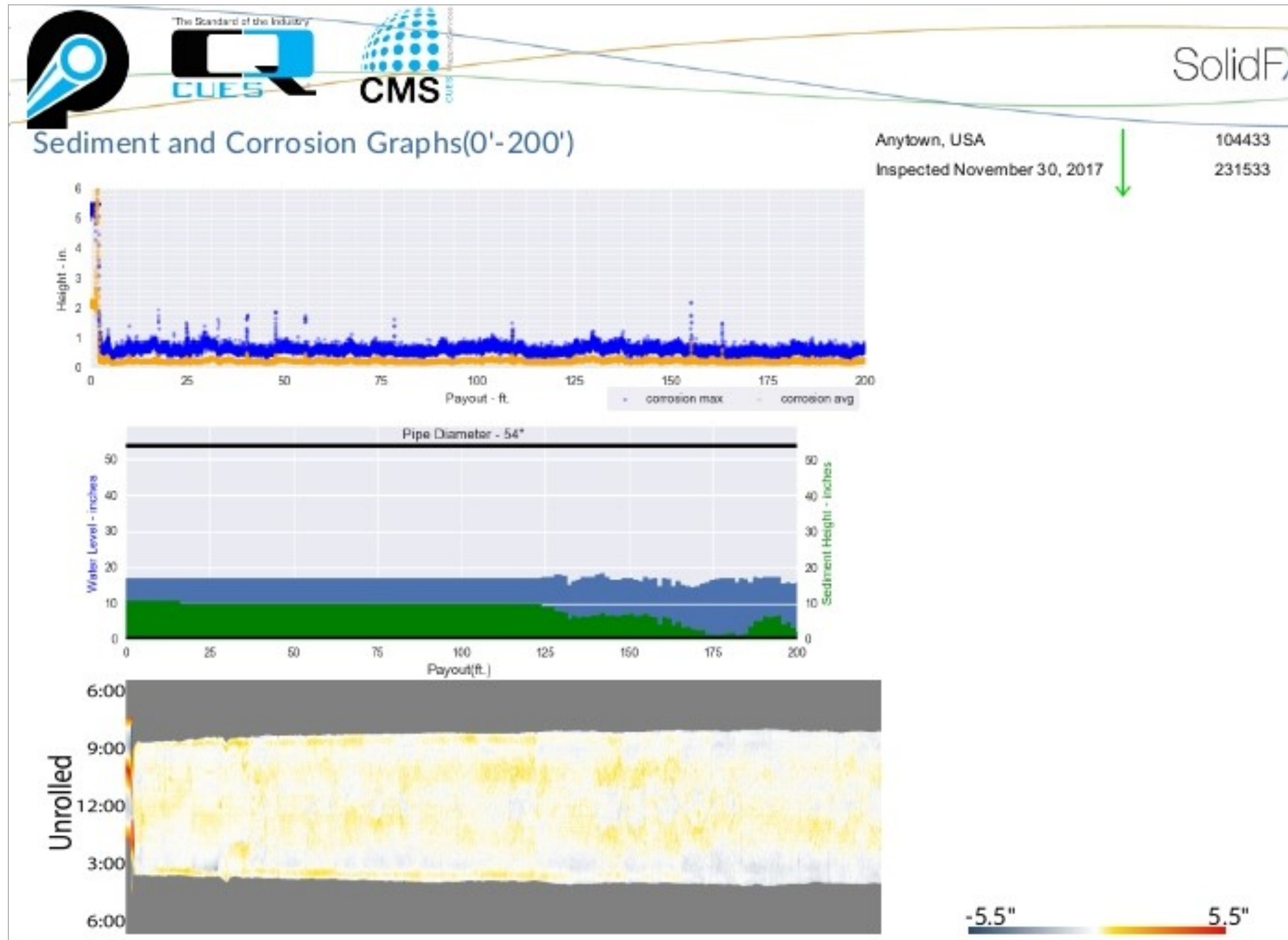
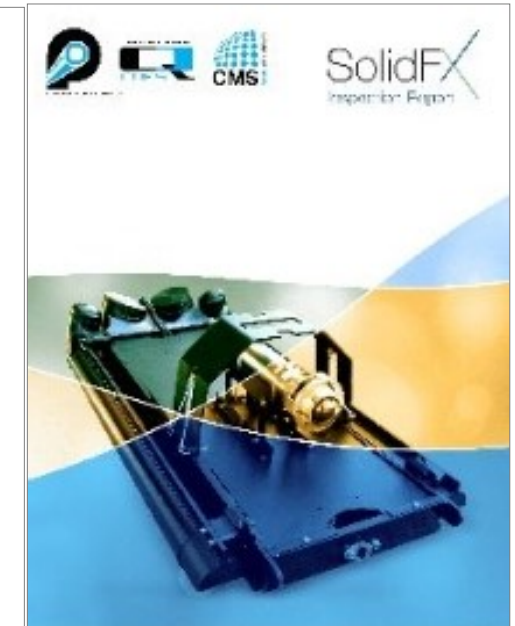


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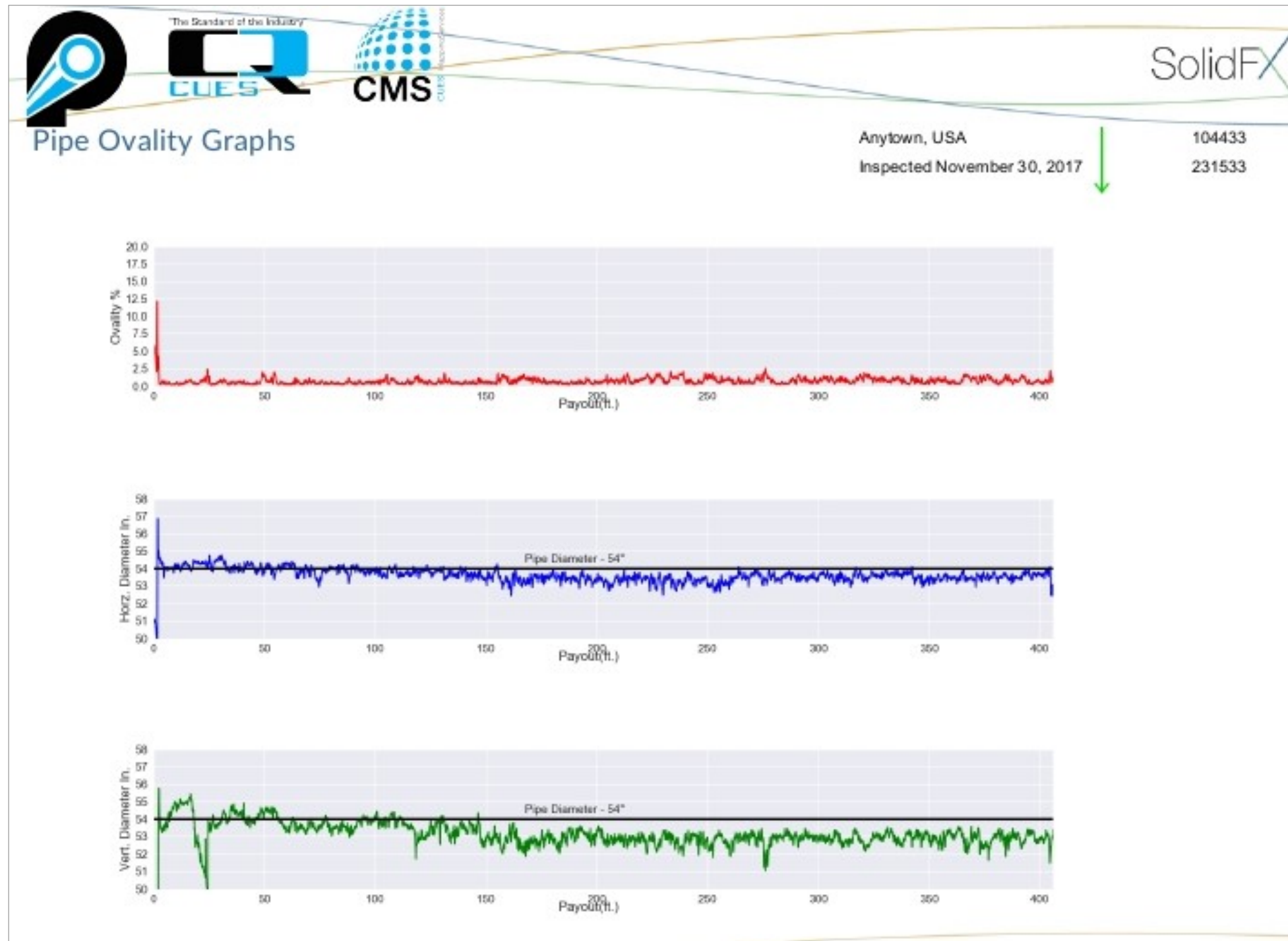


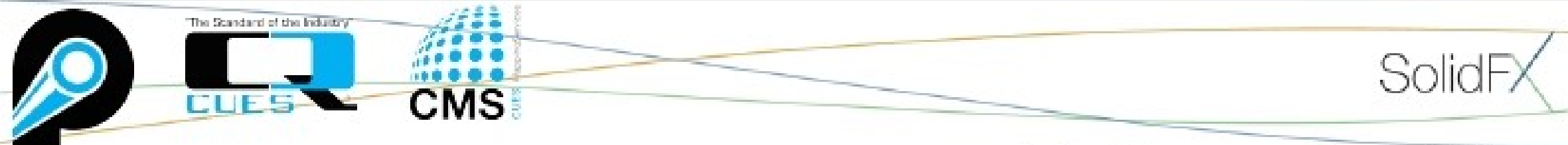
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$$\text{Ovality} = \frac{(\text{Horizontal Diameter} - \text{Vertical Diameter})}{(\text{Horizontal Diameter} + \text{Vertical Diameter})}$$

Horizontal Diameter is width at maximum.
Vertical Diameter is 2 * Vertical Radius.
Vertical Radius is vertical distance from center of Horizontal Diameter to peak of circle

SFX-Condition Assessment Report (cont.)



Anytown, USA
 Inspected November 30, 2017

104433
 231533

Summary Table

Payout	Type	Note	Av. Corr.	3s Corr.	Max Corr.	Av. Buildup	Max Buildup	Sed. Max Ht.	Sed. Restriction %
0.0'	Start	Start of inspection	2.1"	4.5"	5.5"	0.9"	1.5"	10.8"	9.8%
40.5'	Material Loss	Material Loss at Joint	0.4"	1.3"	1.8"	0.2"	0.7"	10.0"	9.4%
47.8'	Material Loss	Material Loss at Joint	0.4"	1.3"	1.6"	0.2"	0.5"	10.0"	9.4%
50.0'	Regular Interval		0.3"	0.4"	0.7"	0.3"	0.8"	10.0"	9.4%
55.5'	Material Loss	Material Loss at Joint	0.5"	1.5"	1.8"	0.2"	0.6"	10.0"	9.4%
100.0'	Regular Interval		0.2"	0.4"	0.6"	0.3"	0.8"	10.0"	9.4%
145.7'	Sediment	Sediment (0-205 lf.)	0.3"	0.4"	0.8"	0.3"	0.9"	6.7"	5.9%
150.0'	Regular Interval		0.3"	0.5"	0.7"	0.3"	0.9"	7.2"	7.3%
155.0'	Material Loss	Material Loss at Joint	0.7"	1.8"	2.2"	0.4"	1.4"	7.2"	7.5%
200.0'	Regular Interval		0.3"	0.5"	0.8"	0.3"	0.9"	2.2"	1.2%





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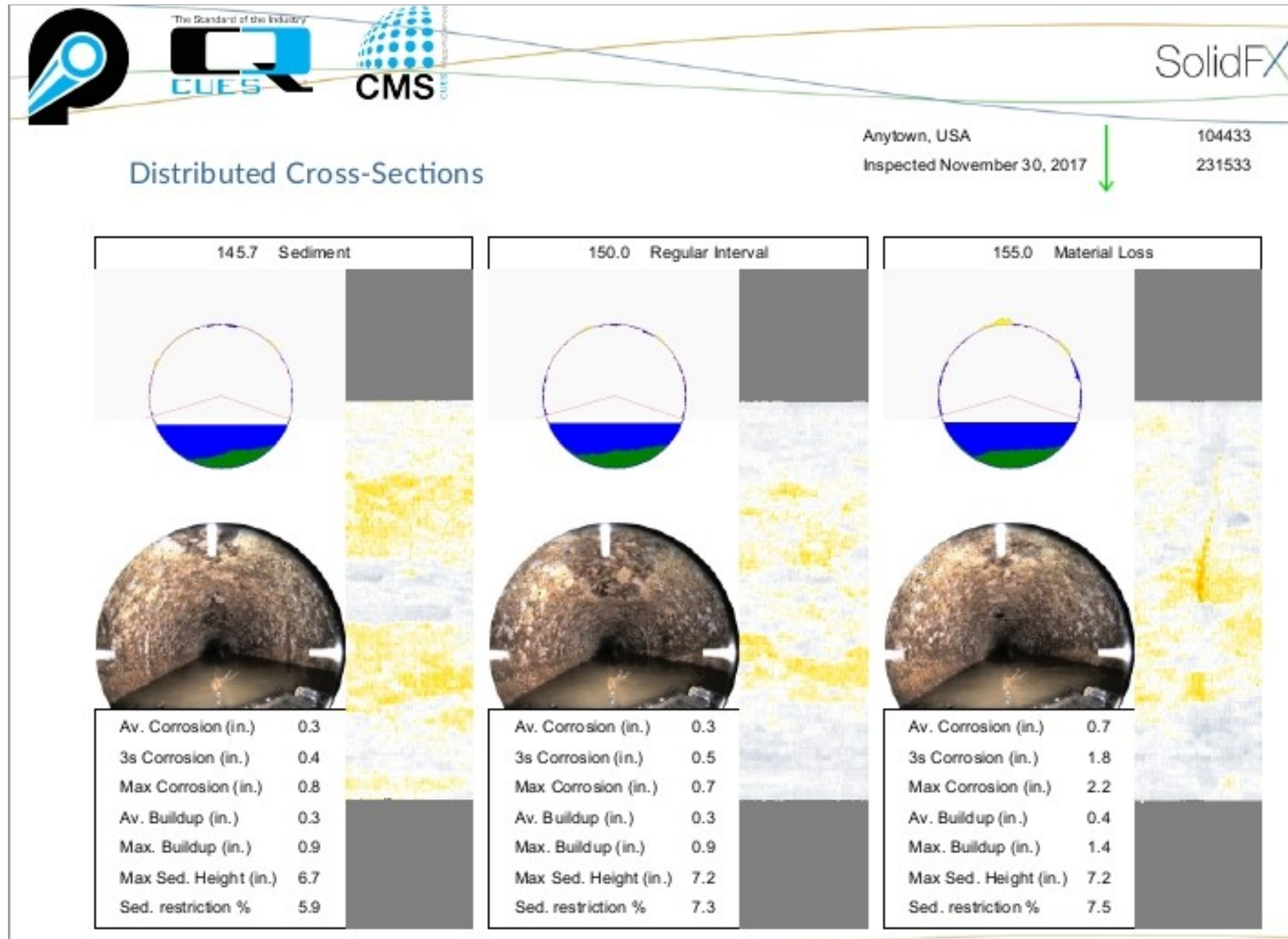


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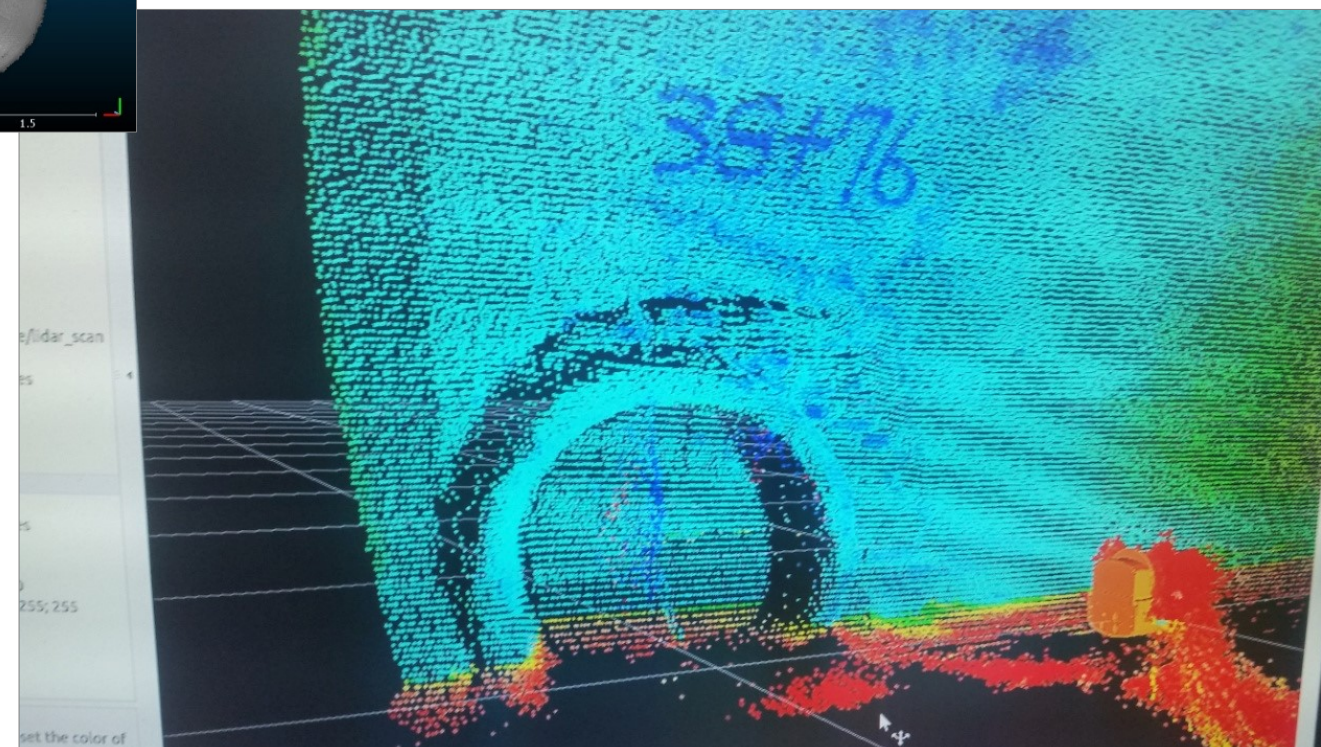
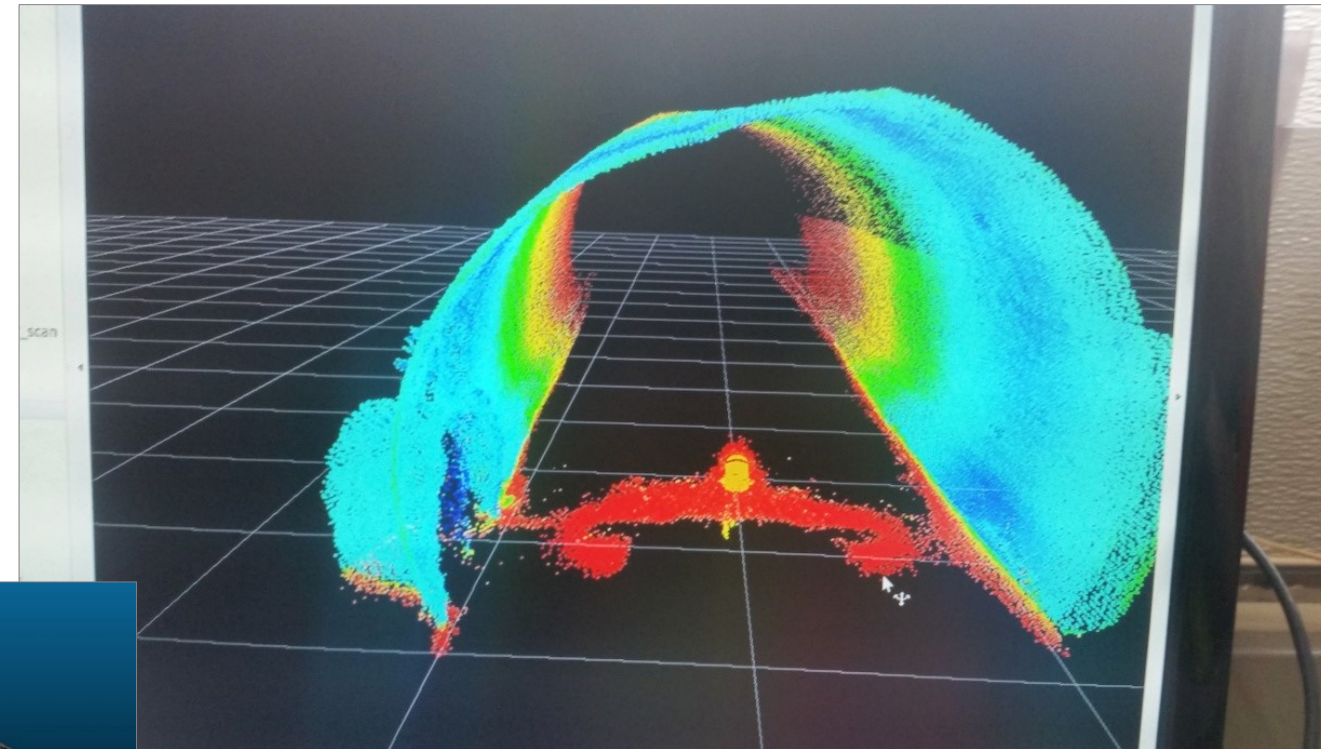
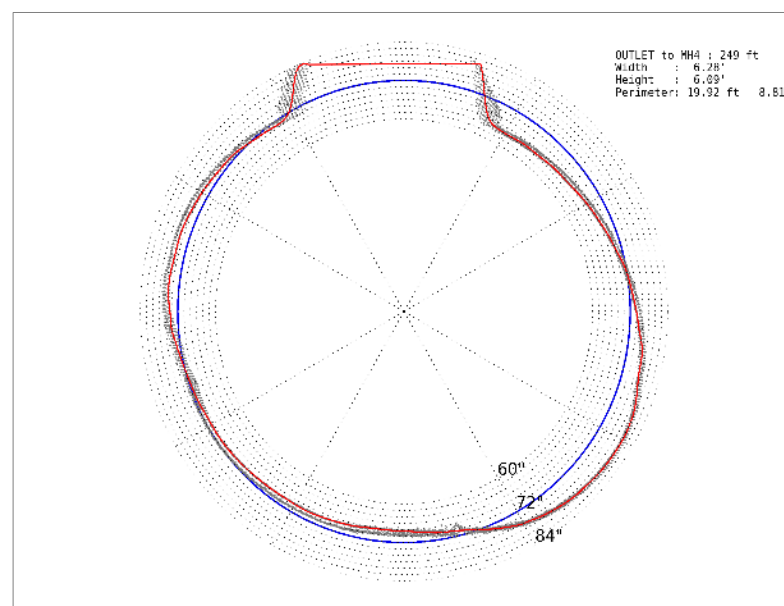
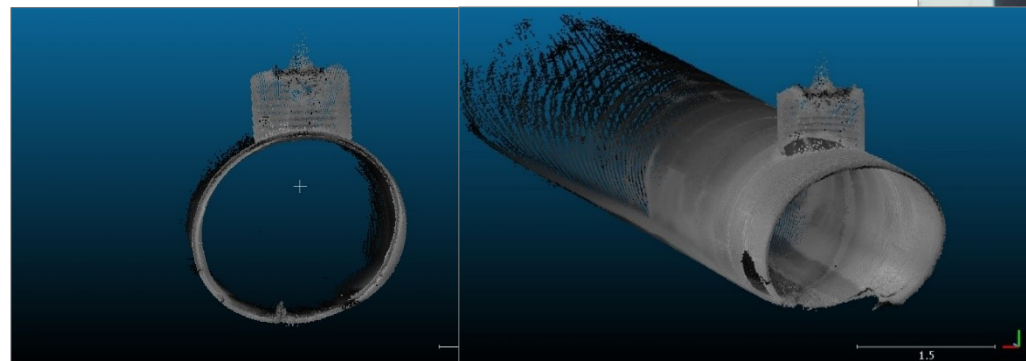


SFX-3D
Multi-Sensor Inspection



SFX-3D

Condition Assessment
 Rehab Planning
 Geo-Location



3D LiDAR

THE CUES SOLIDFX 3D MULTI-SENSOR PLATFORM

Used for condition assessment, rehabilitation planning, and geo-location mapping.



- Deployed from a stable skid or tractor
- Never miss a defect with the DUC camera
- Suitable for pipelines ranging from 36" to 240"
- The digital SONAR and DUC are complimented by 3D LiDAR
- LiDAR accurately measures cross sections & bends in the pipe
- Use LiDAR data and detailed scans to determine pipe centerline
- Collect high-density point clouds to accurately determine pipe size

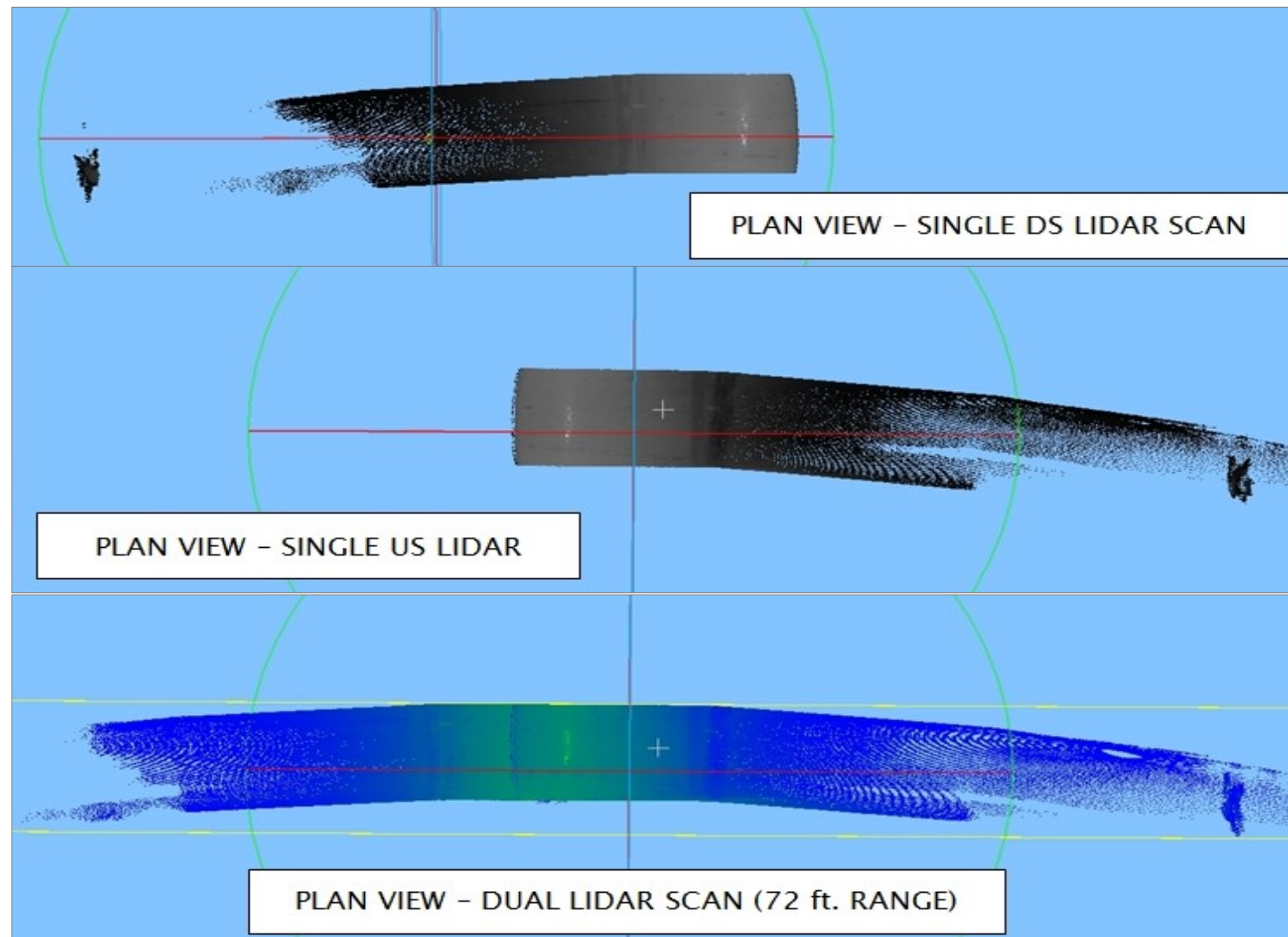
CUES Inc.

www.cuesinc.com | salesinfo@cuesinc.com

Dual LIDAR Technology

Combine Data From Two Sensors

One SCAN Covers 40-70 Feet



DUAL LIDAR Technology

Longer Point Cloud
More Accurate
Measurements

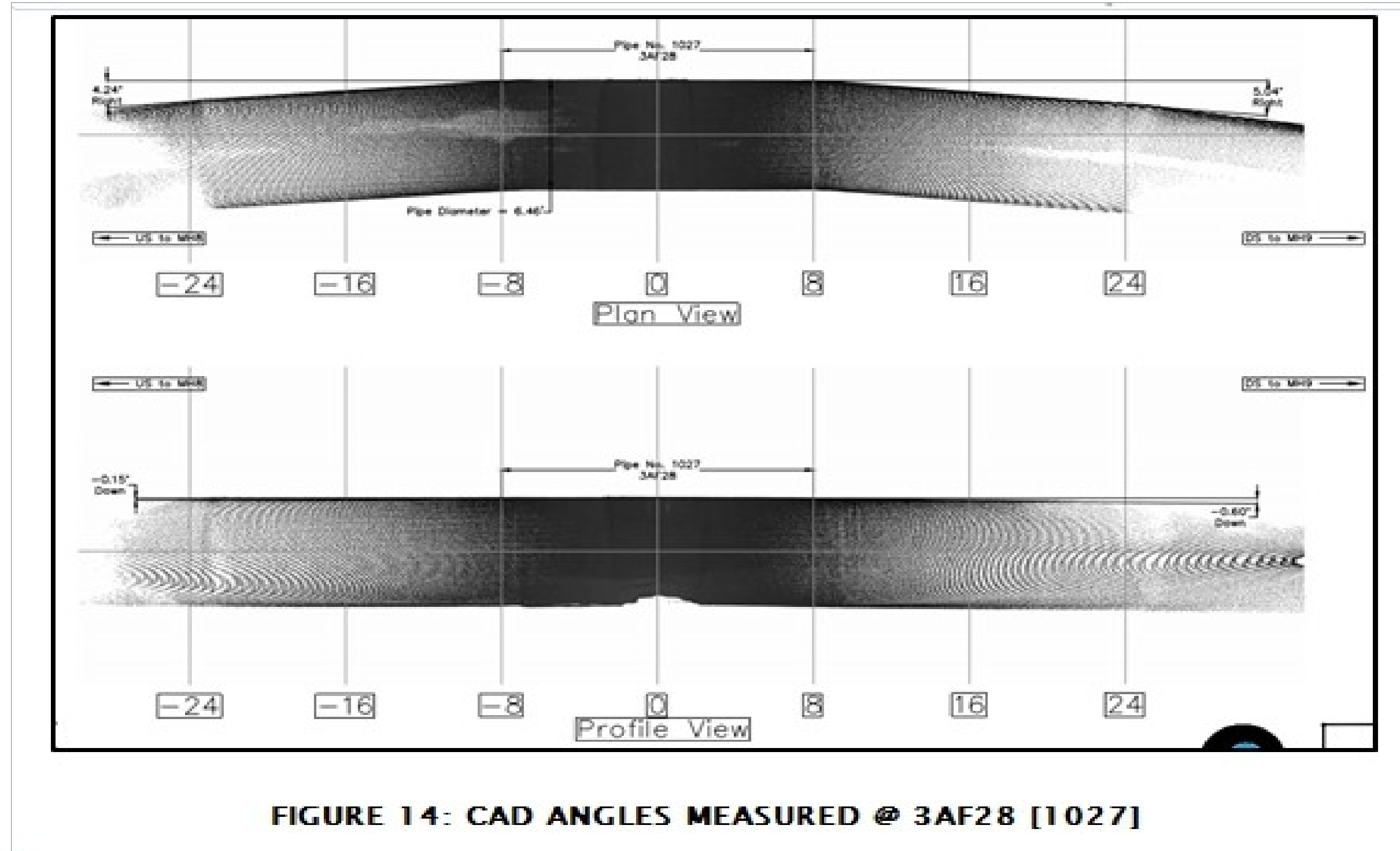
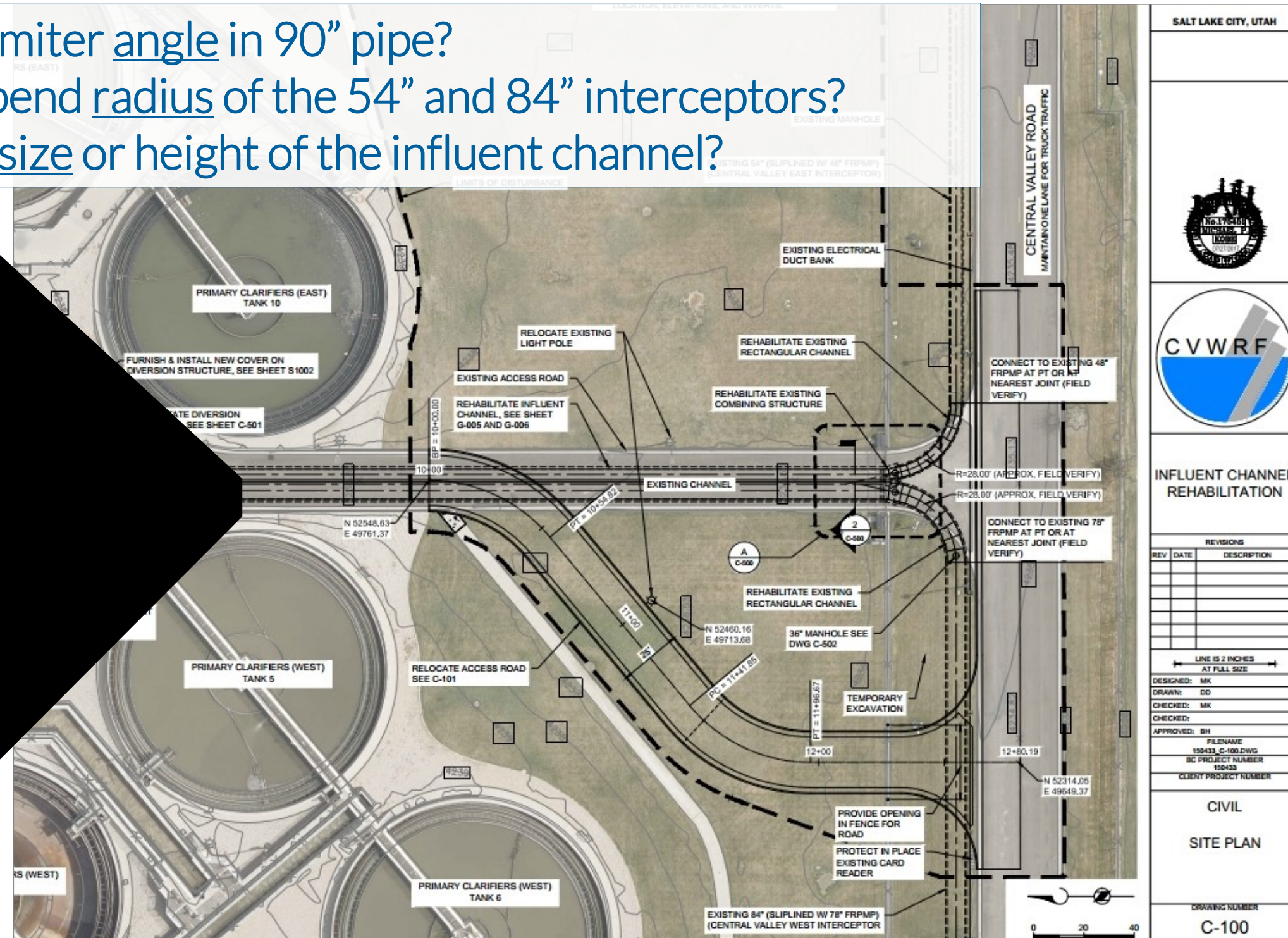
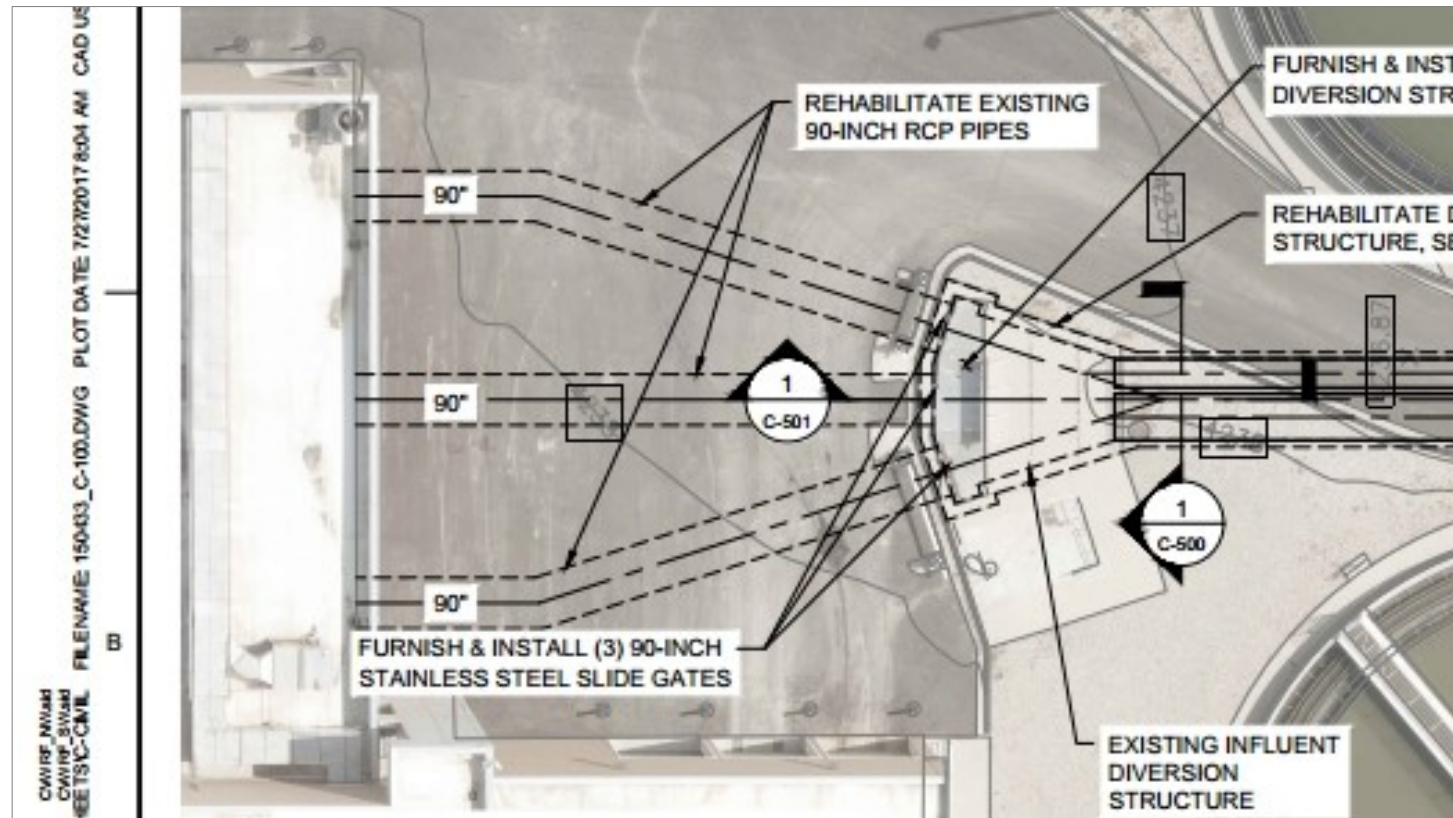


FIGURE 14: CAD ANGLES MEASURED @ 3AF28 [1027]

Salt Lake, UT

Influent Structure Rehab Size and Bend Analysis

What is the miter angle in 90" pipe?
 What is the bend radius of the 54" and 84" interceptors?
 What is the size or height of the influent channel?



SALT LAKE CITY, UTAH

CVWRF

INFLUENT CHANNEL REHABILITATION

REVISIONS	
REV	DESCRIPTION

DESIGNED: MK
 DRAWN: DD
 CHECKED: MK
 APPROVED: BH

FILENAME: 150433_C-100.DWG
 BC PROJECT NUMBER: 150433
 CLIENT PROJECT NUMBER:

CIVIL
 SITE PLAN

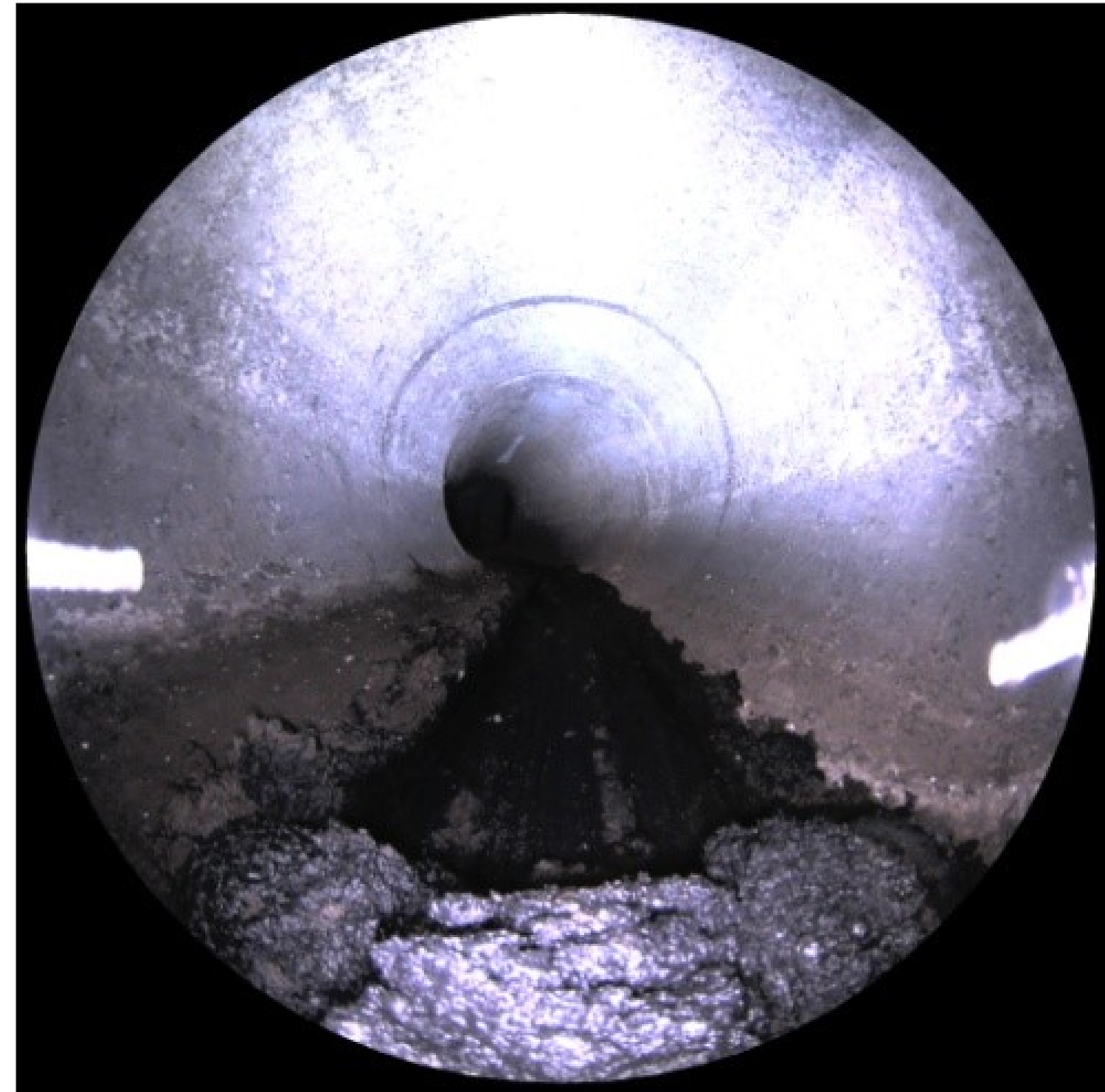
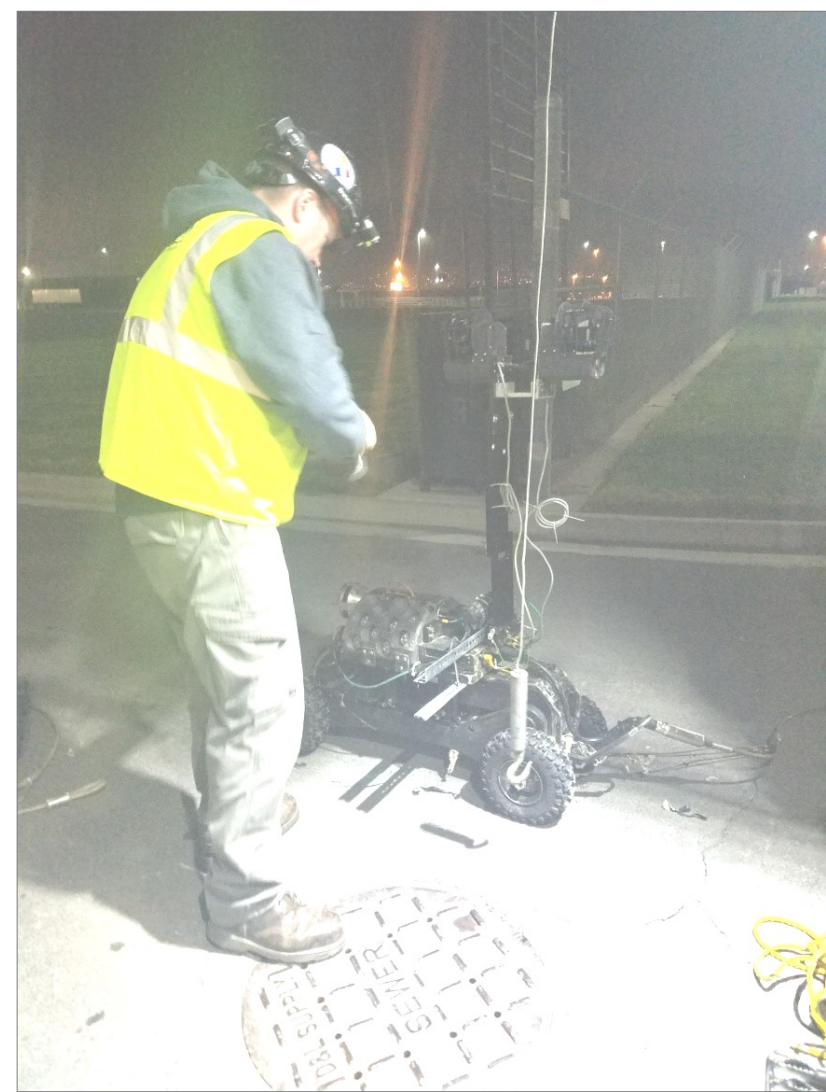
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Salt Lake, UT (cont.)

Influent Structure Rehab

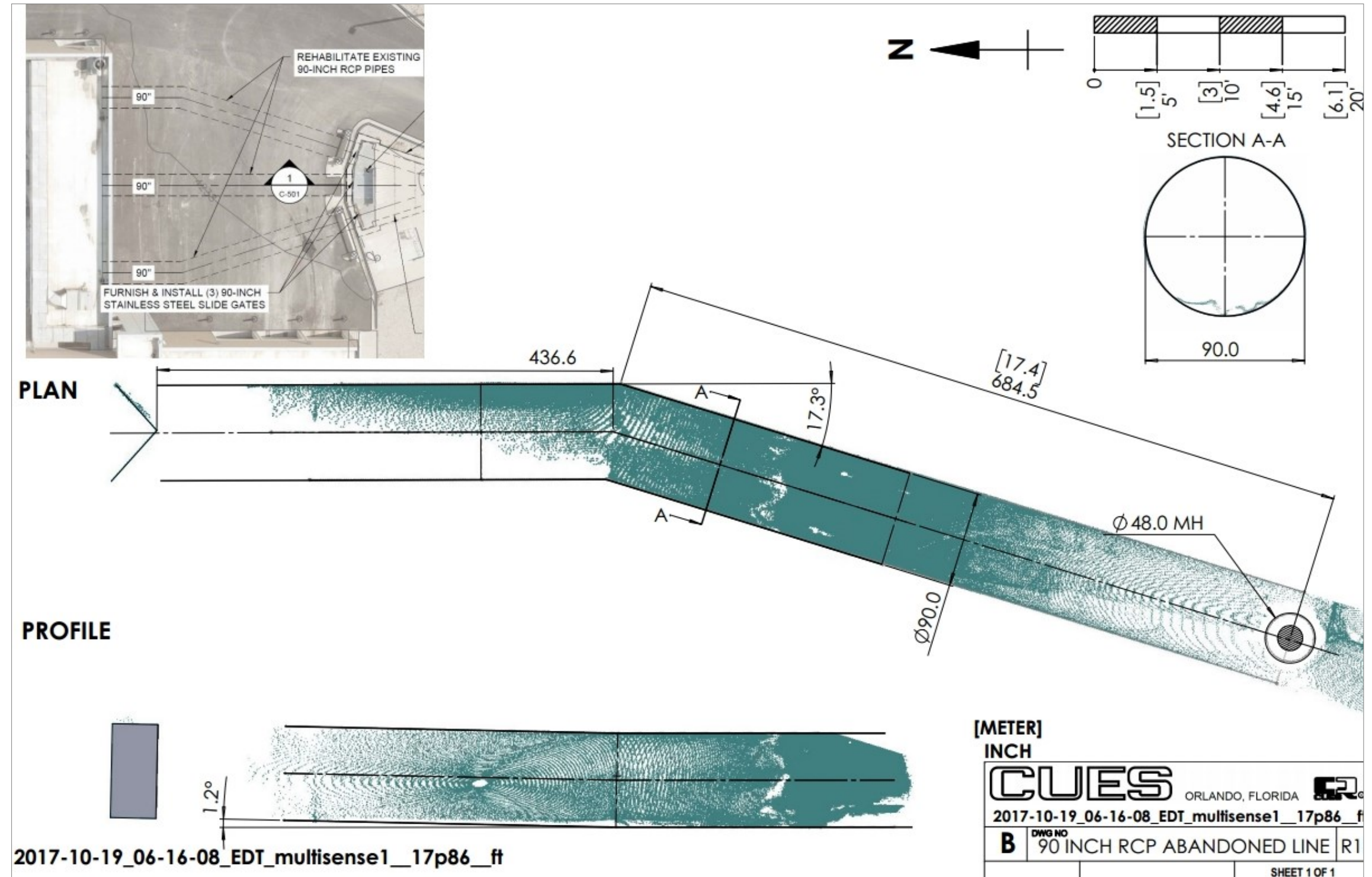
SMM Setup

90" Diversion Pipe



Salt Lake, UT (cont.)

Influent Structure Rehab 90" Diversion Pipe CAD Drawing



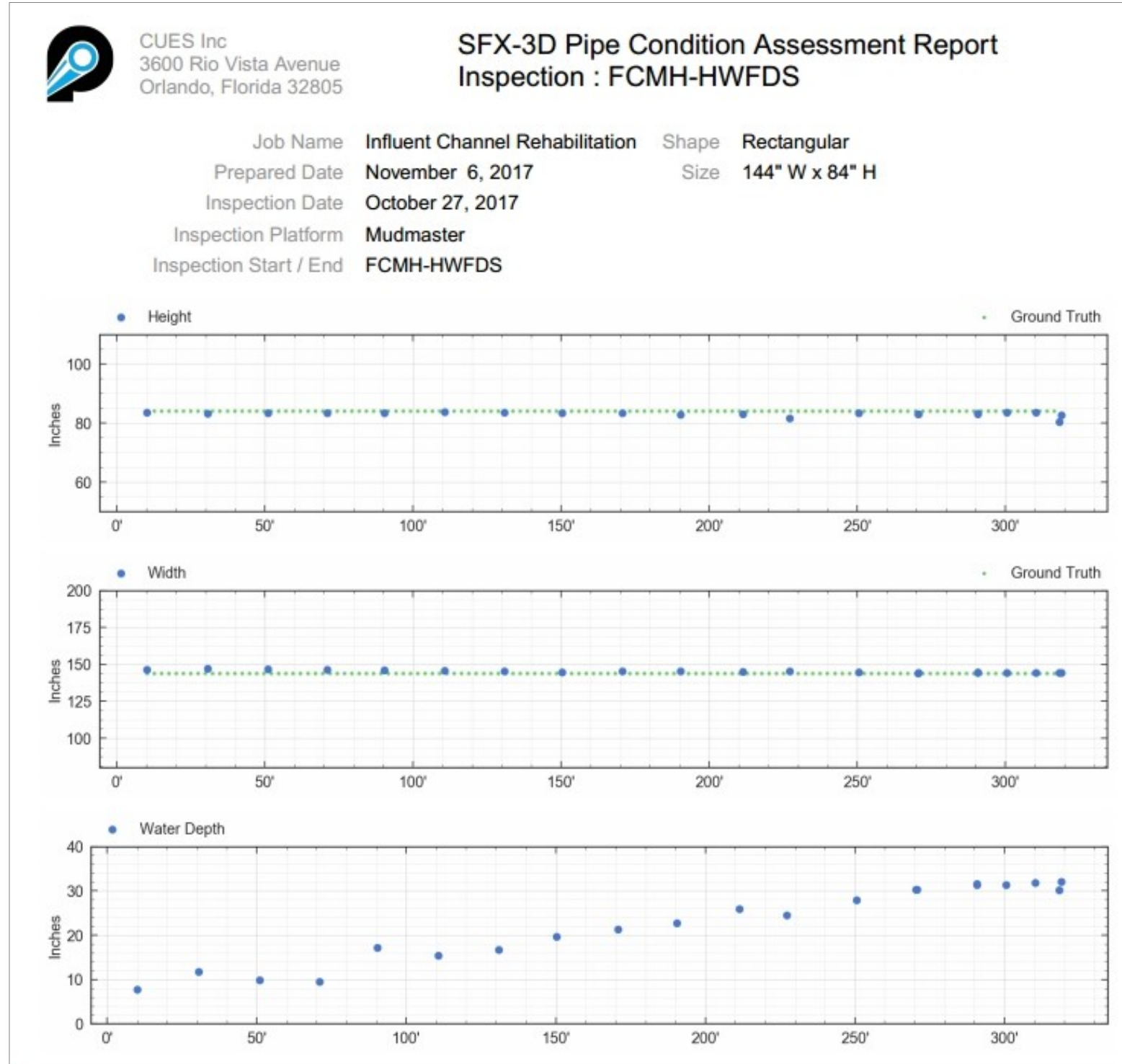
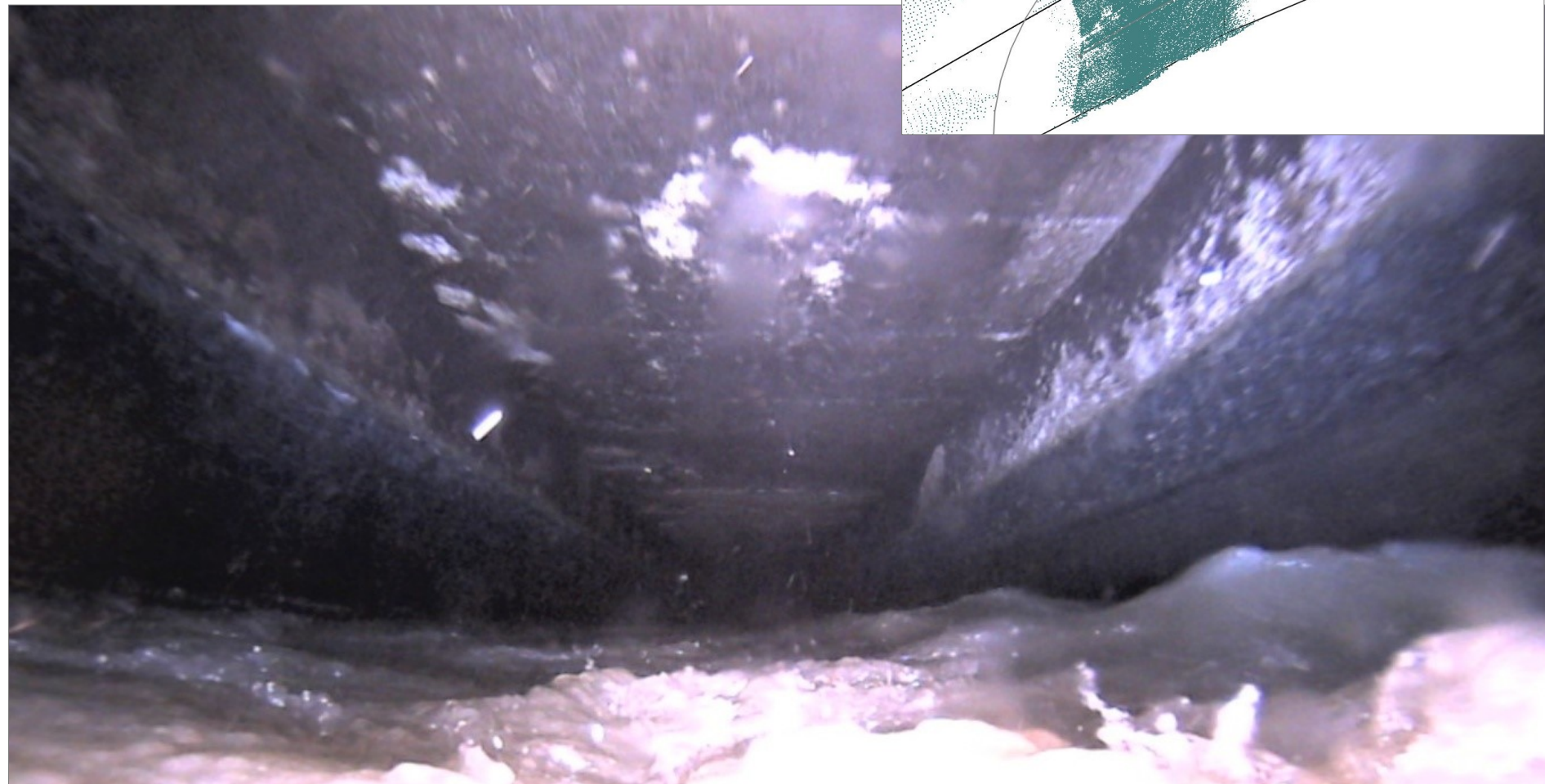
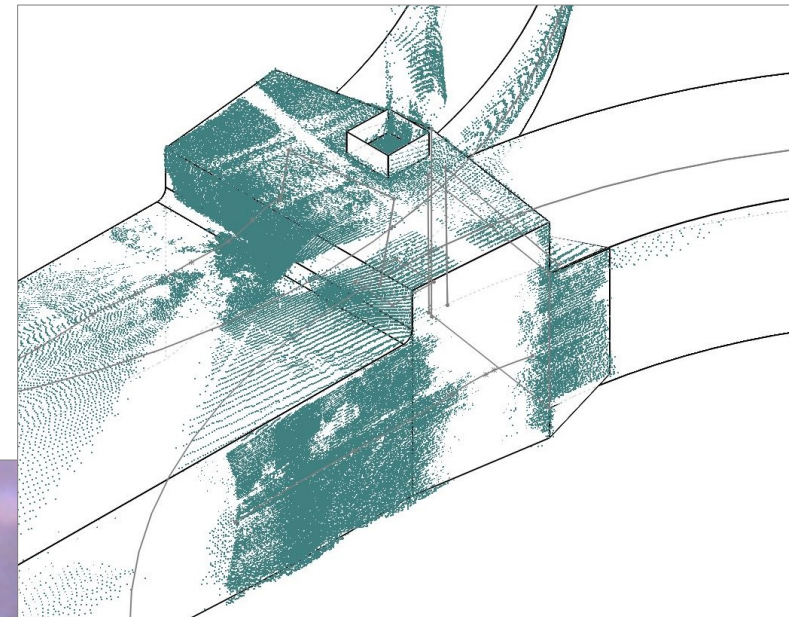
Salt Lake, UT (cont.)

Influent Structure Rehab Custom Liner Installation



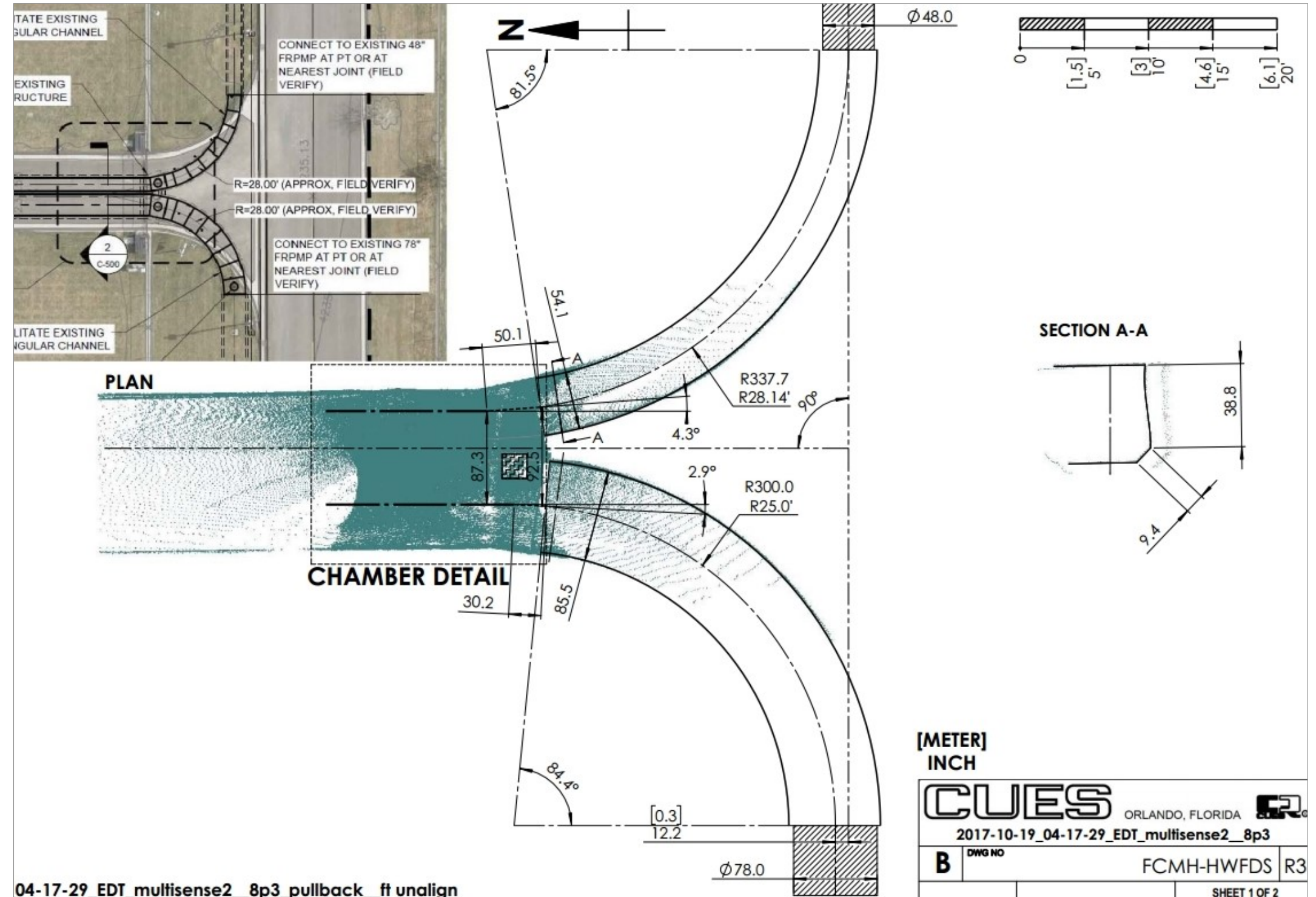
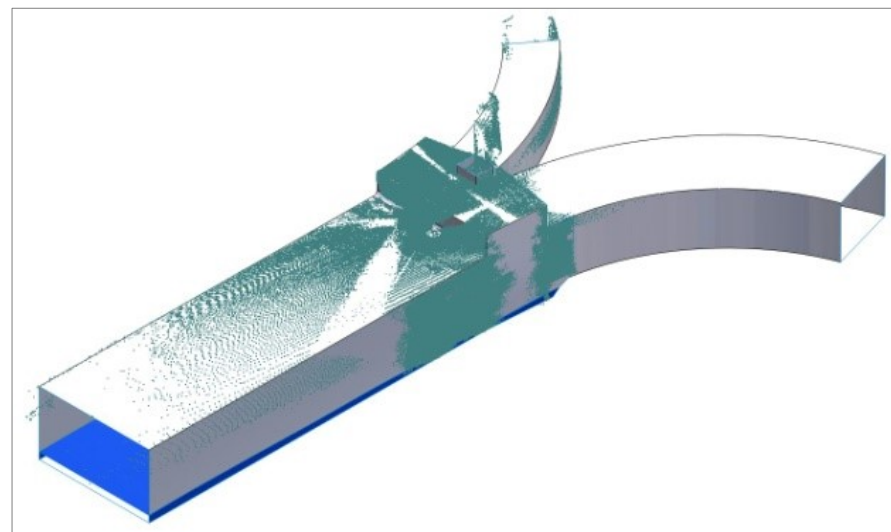
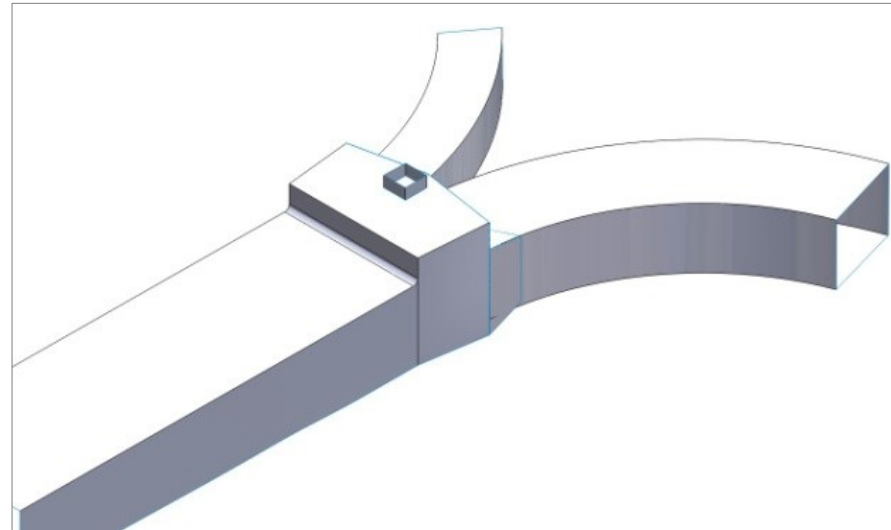
Salt Lake, UT (cont.)

Influent Structure Rehab
 Influent Channel Size?
 Does the height change?



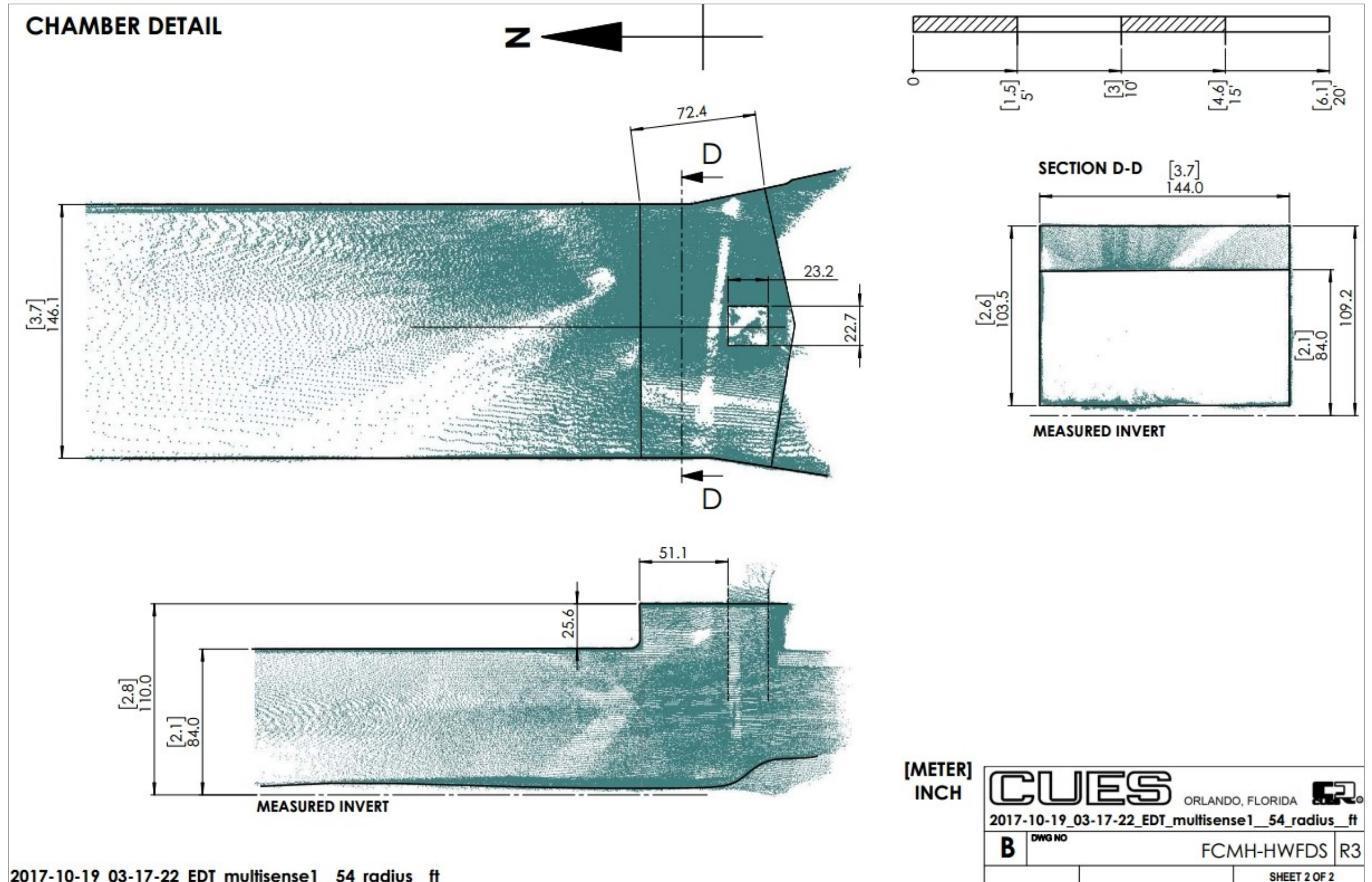
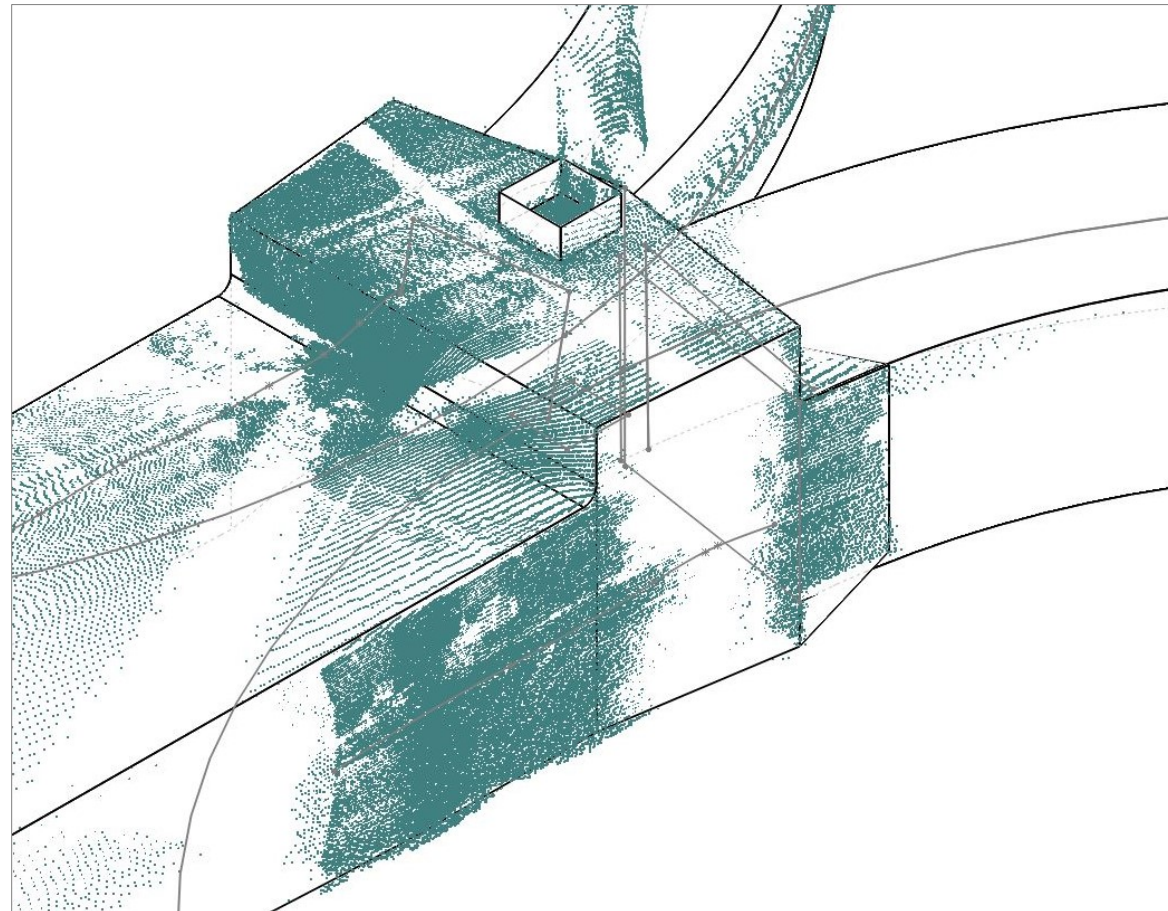
Salt Lake, UT (cont.)

Influent Structure Rehab Combining Structure – Radii?



Salt Lake, UT (cont.)

Influent Structure Rehab Chamber Detail

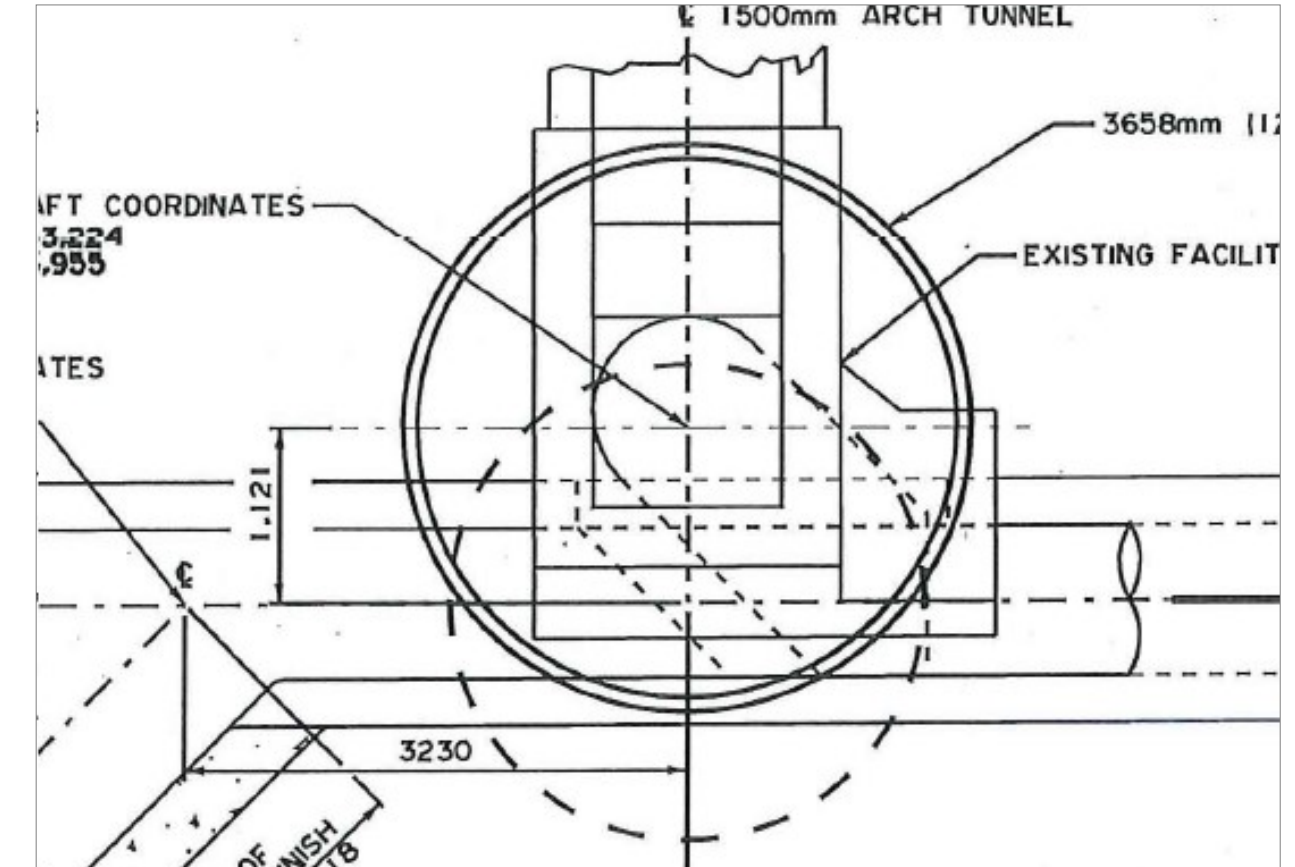
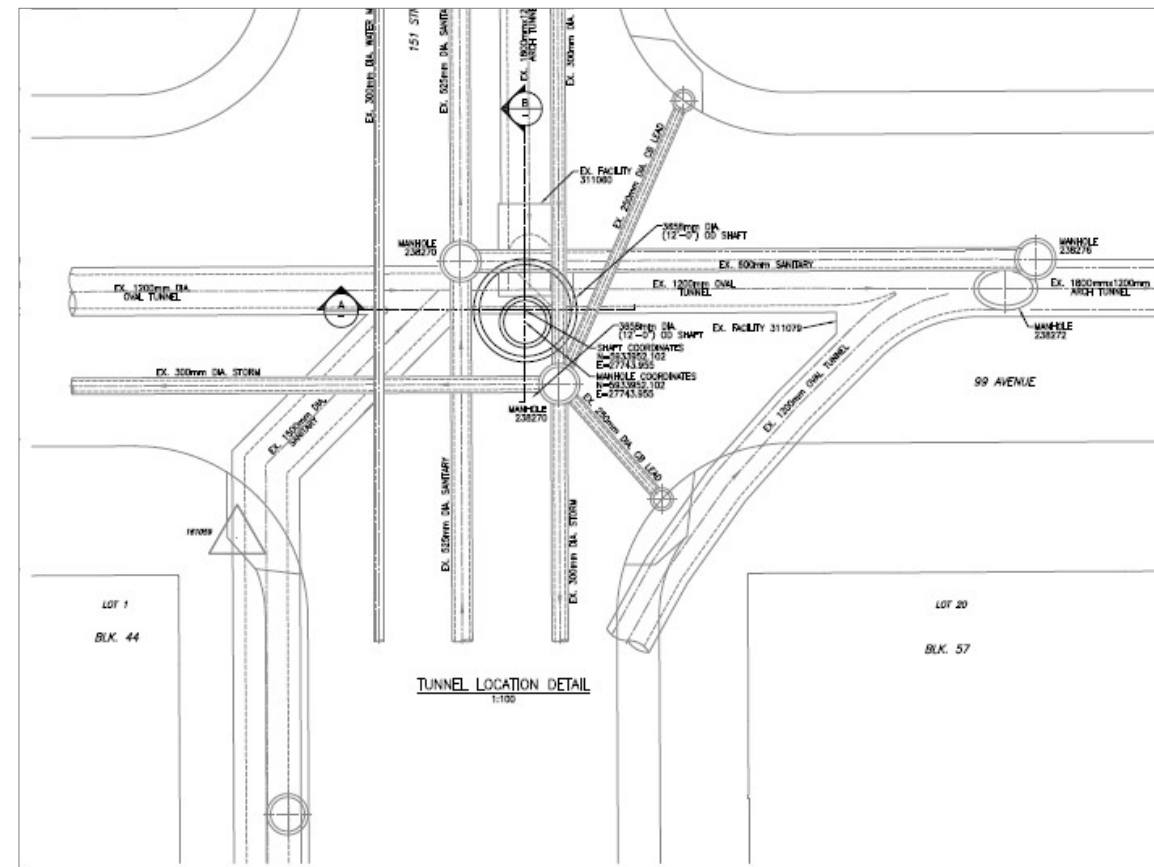


Edmonton Alberta, CA

Drill and Rehab Project

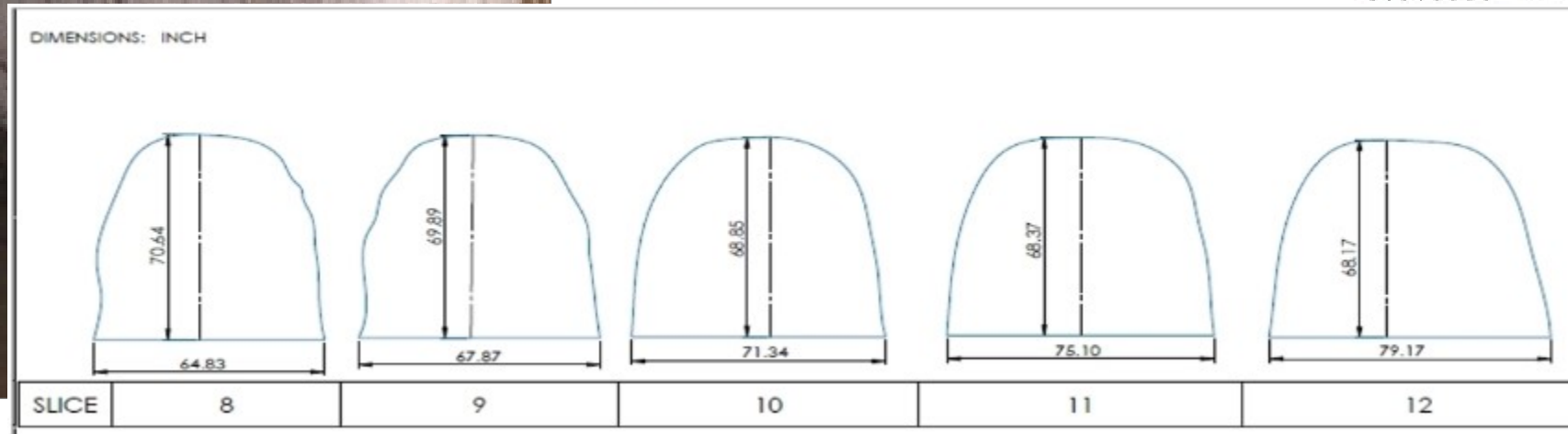
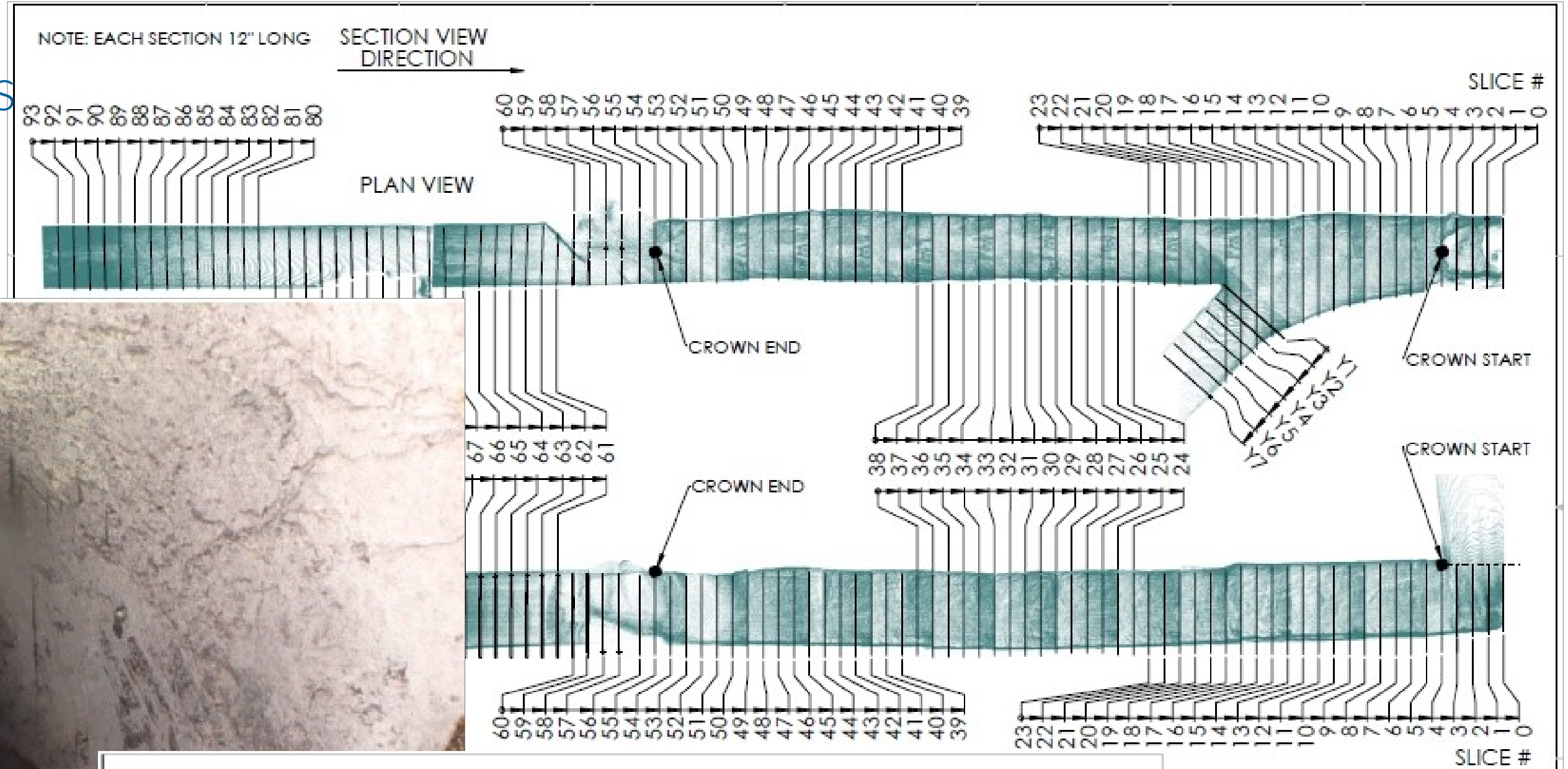
Geo Location & Cross Section Report

- What is smallest cross section of the E-W tunnel?
- Where should be dig our 10' diameter, 100 ft. deep rehab/maintenance shaft?



Edmonton Alberta, CA (cont.)

Drill and Rehab Project Deliverable - Cross Sections



CUES ORLANDO, FLORIDA 

Cross Sections - Anytown USA

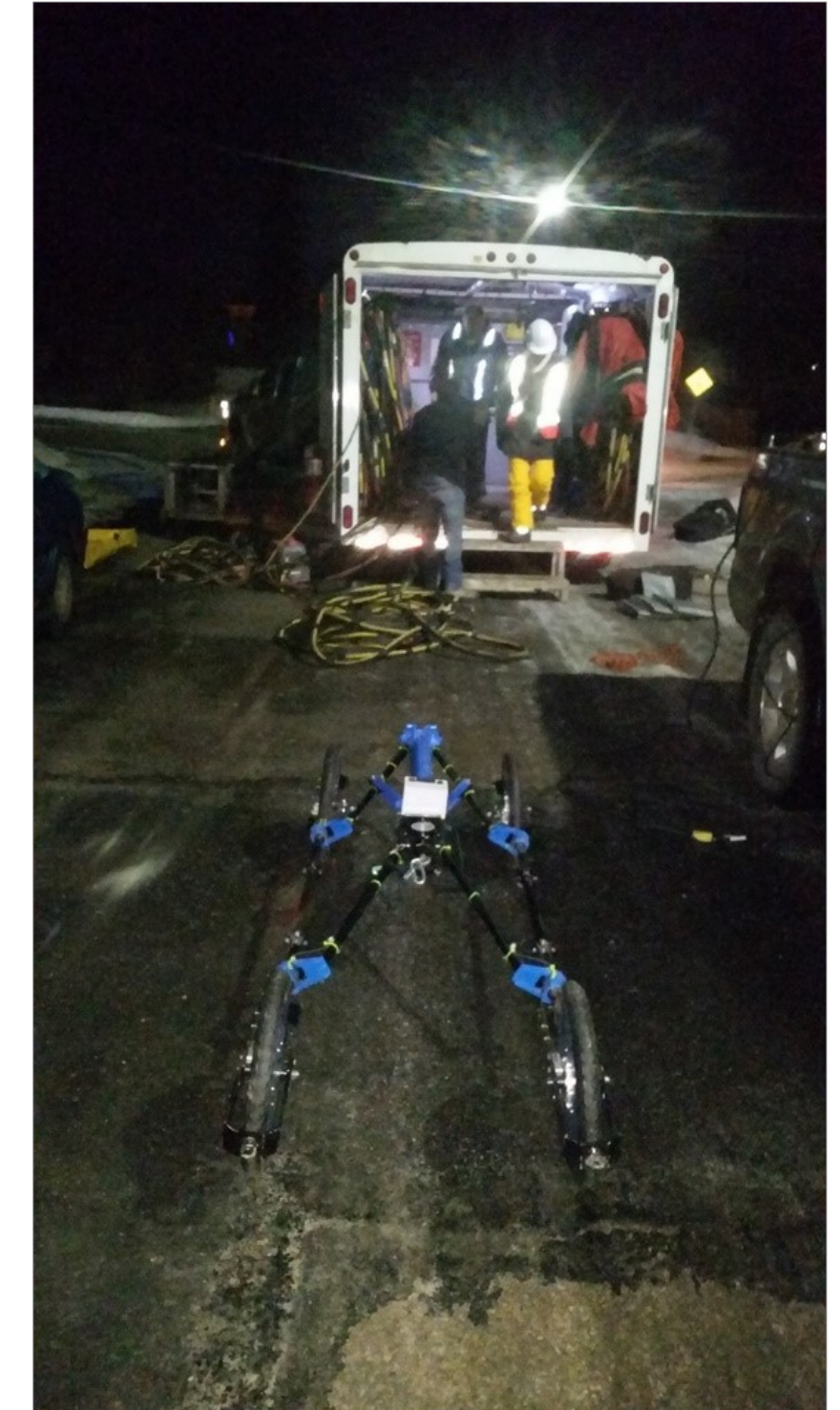
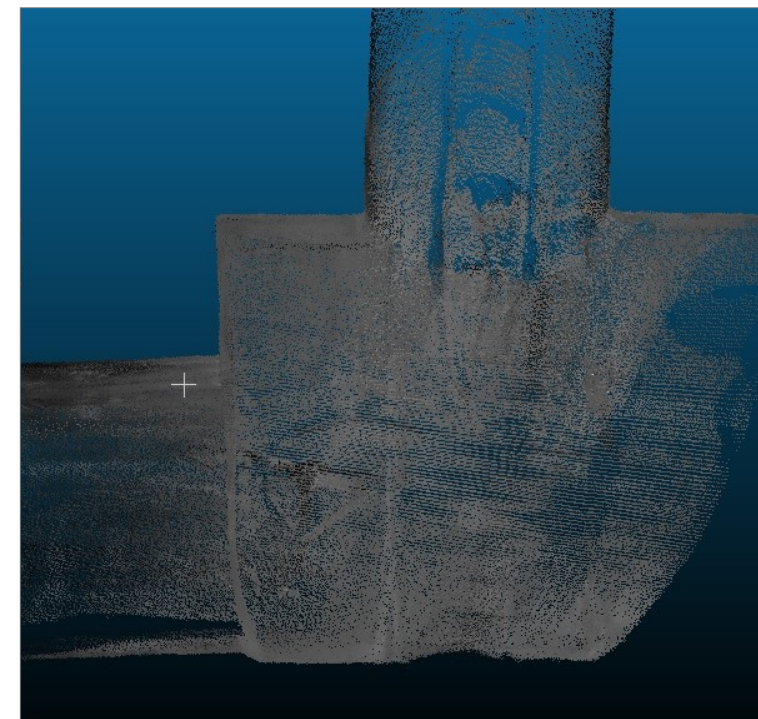
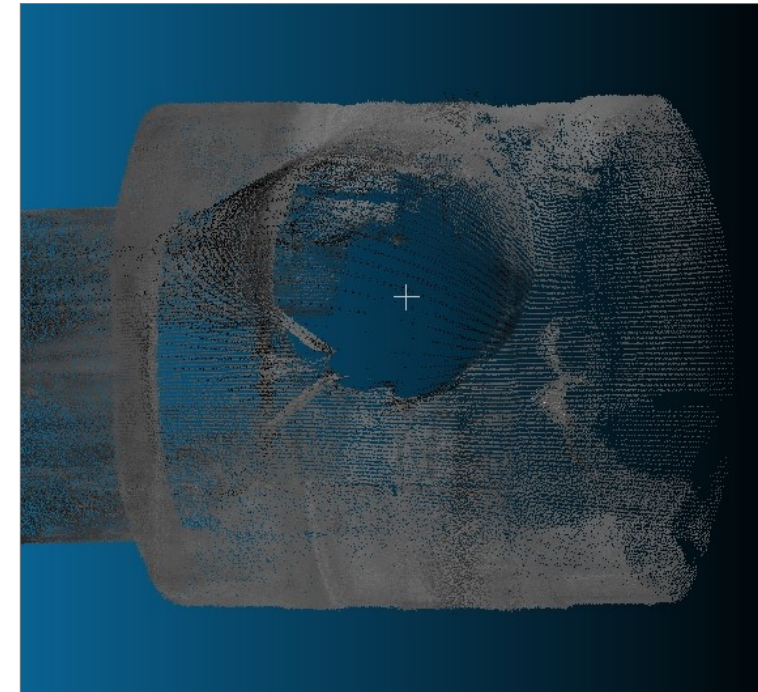
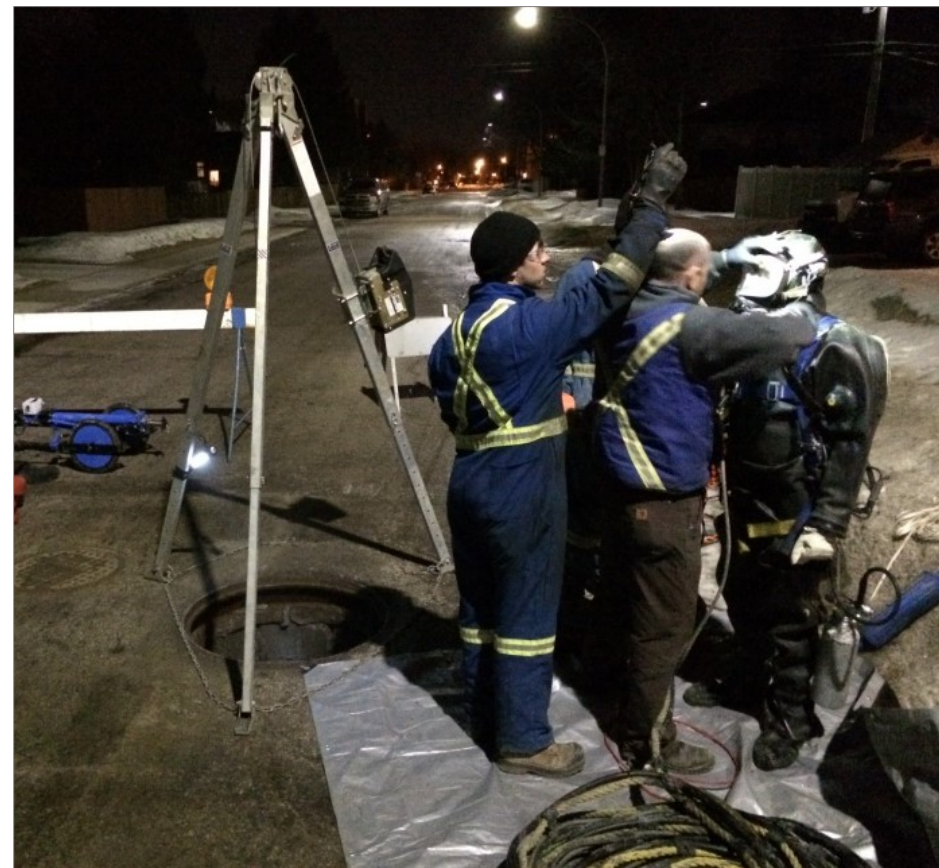
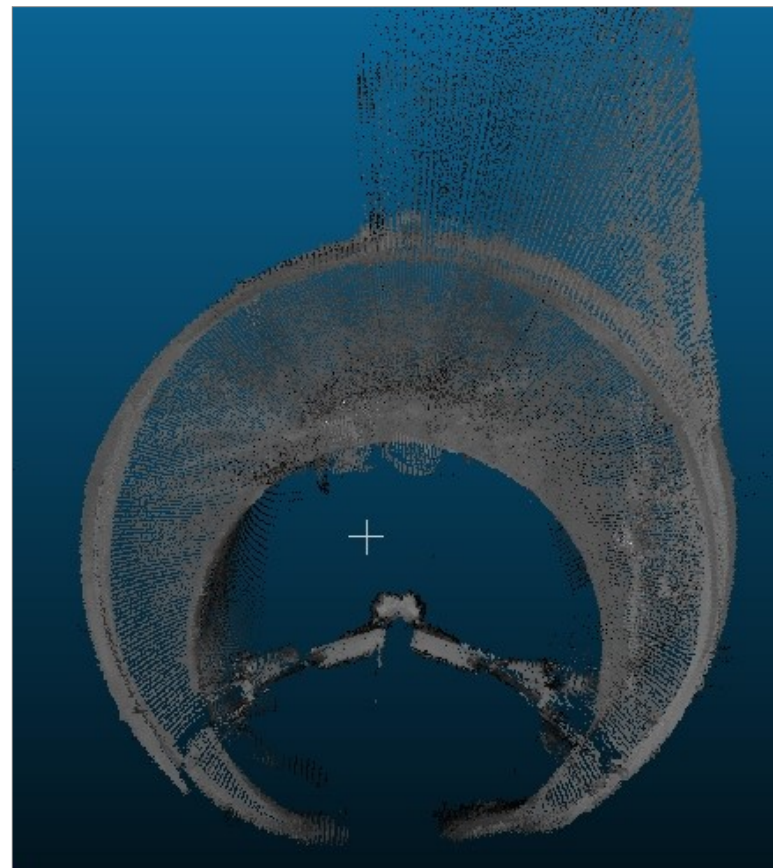
DWG NO: _____ REV: R1

SCALE: 1:3 WEIGHT: _____ SHEET 1 OF 22

Edmonton Alberta, CA (cont.)

Drill and Rehab Project

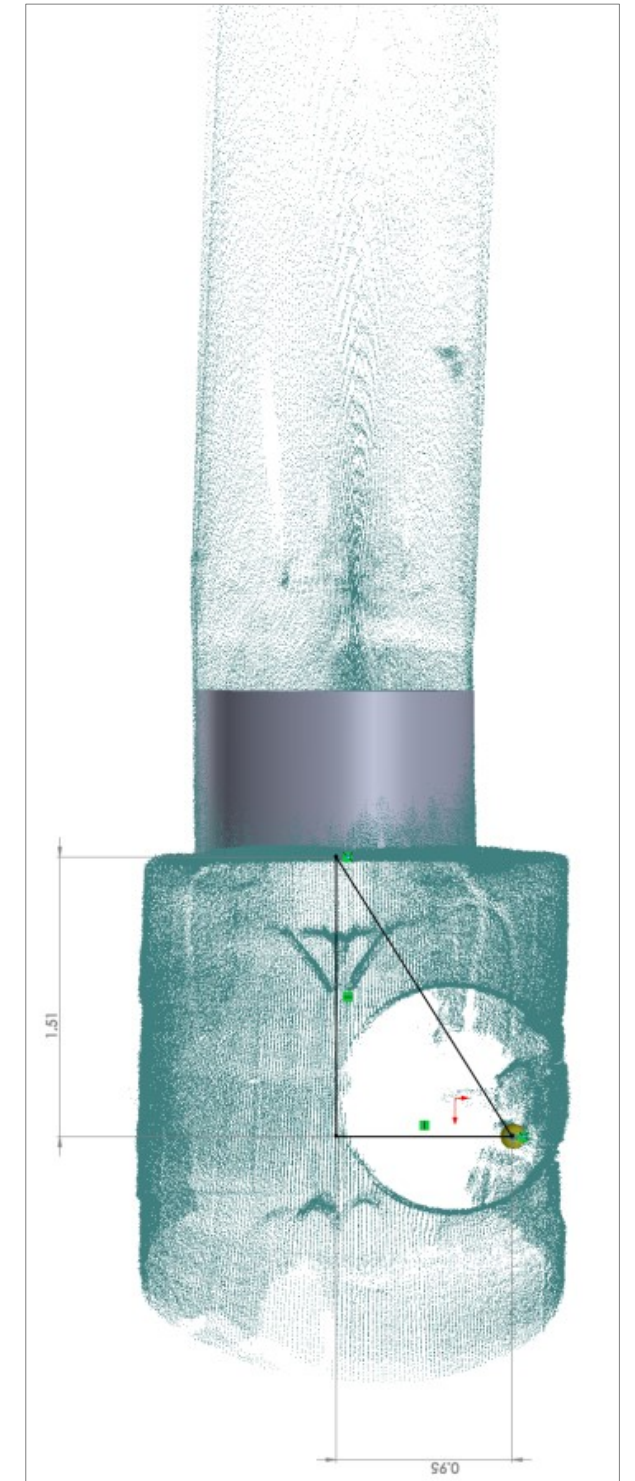
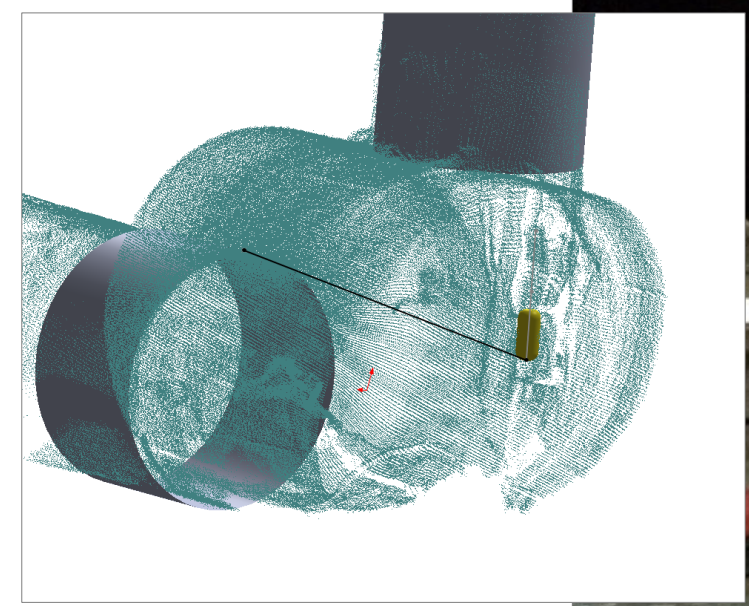
Deployment Into N-S Bypass Pipe
Scans At Bottom of 100' Deep MH



Edmonton Alberta, CA (cont.)

Drill and Rehab Project Offset MH

- Drop plumb line
- GPS coordinate transfer

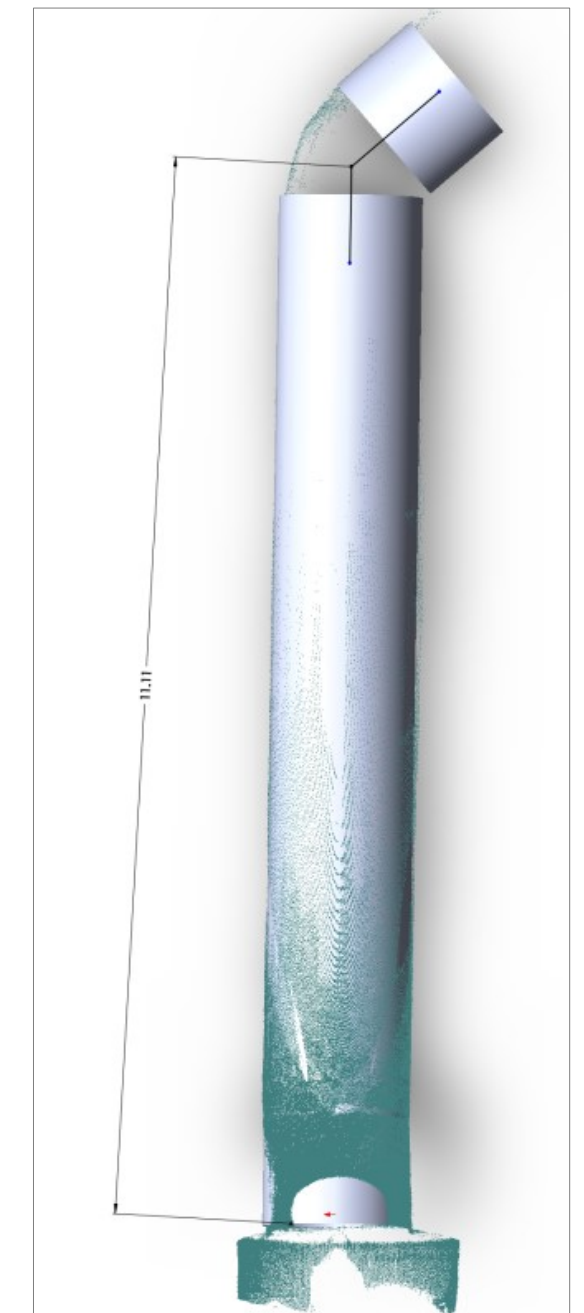
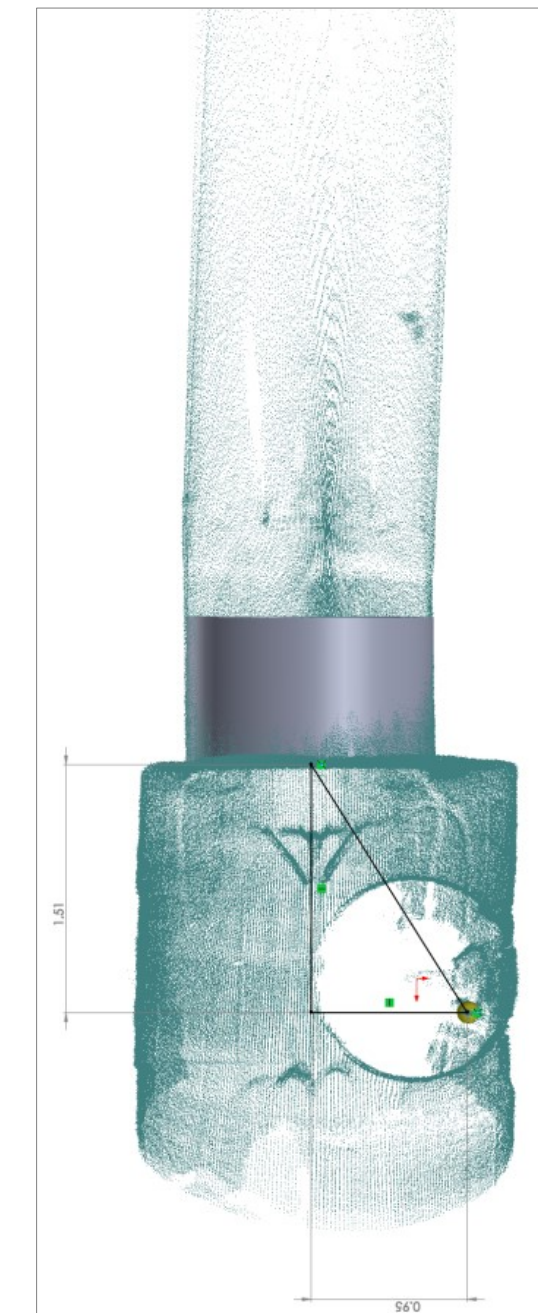
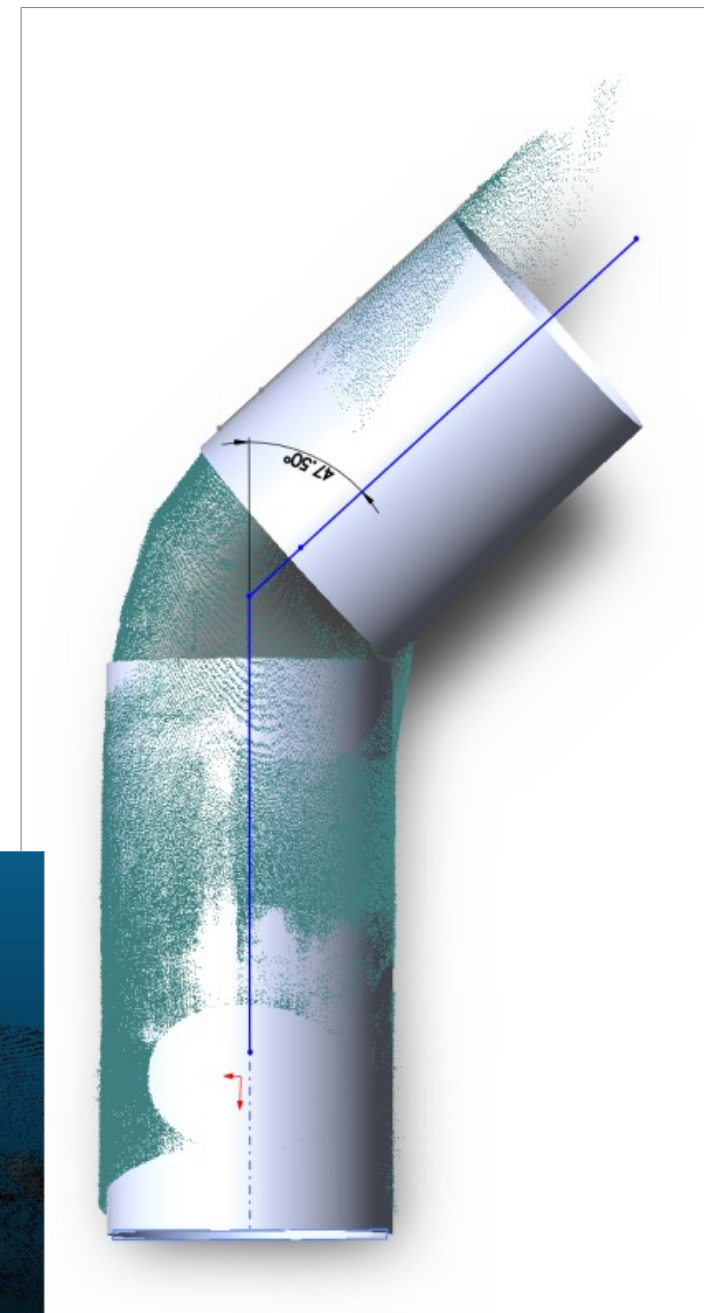
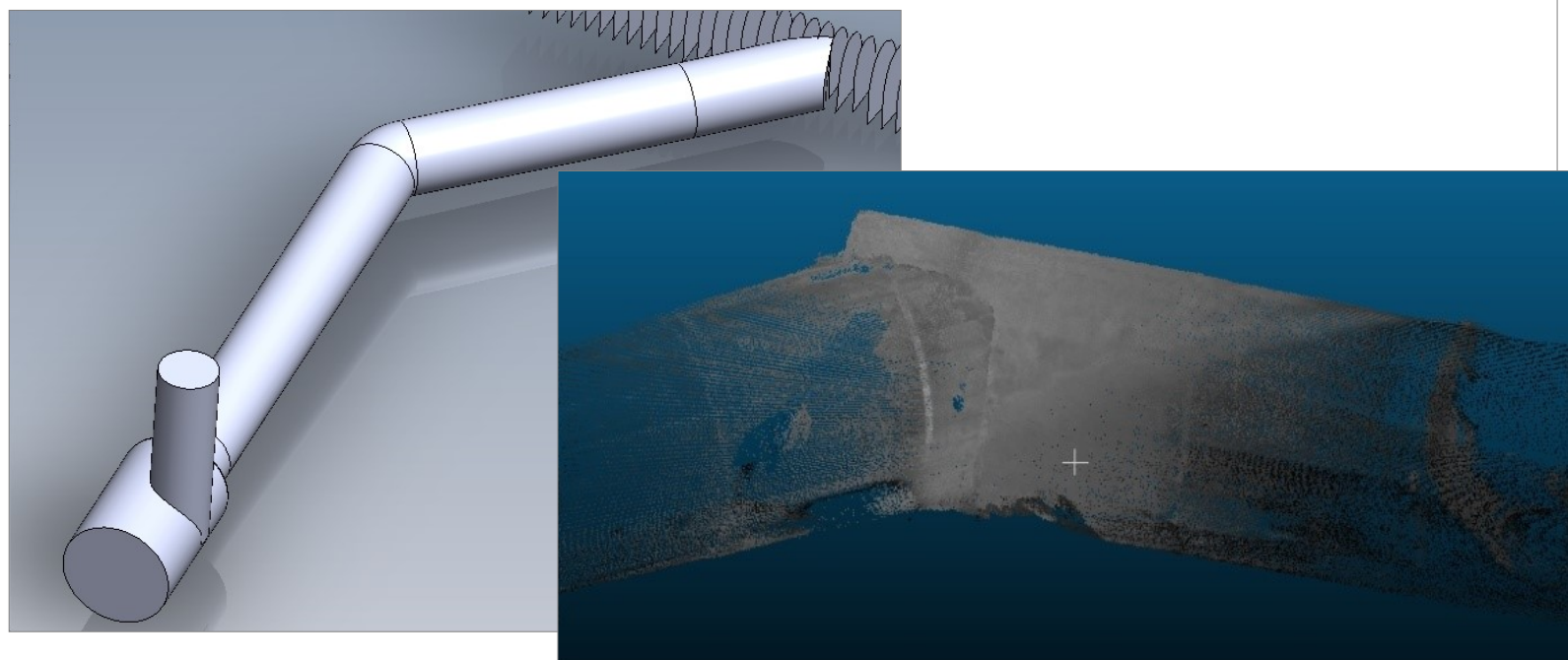


Edmonton Alberta, CA (cont.)

Drill and Rehab Project

N-S Bypass Pipe – Bend Analysis

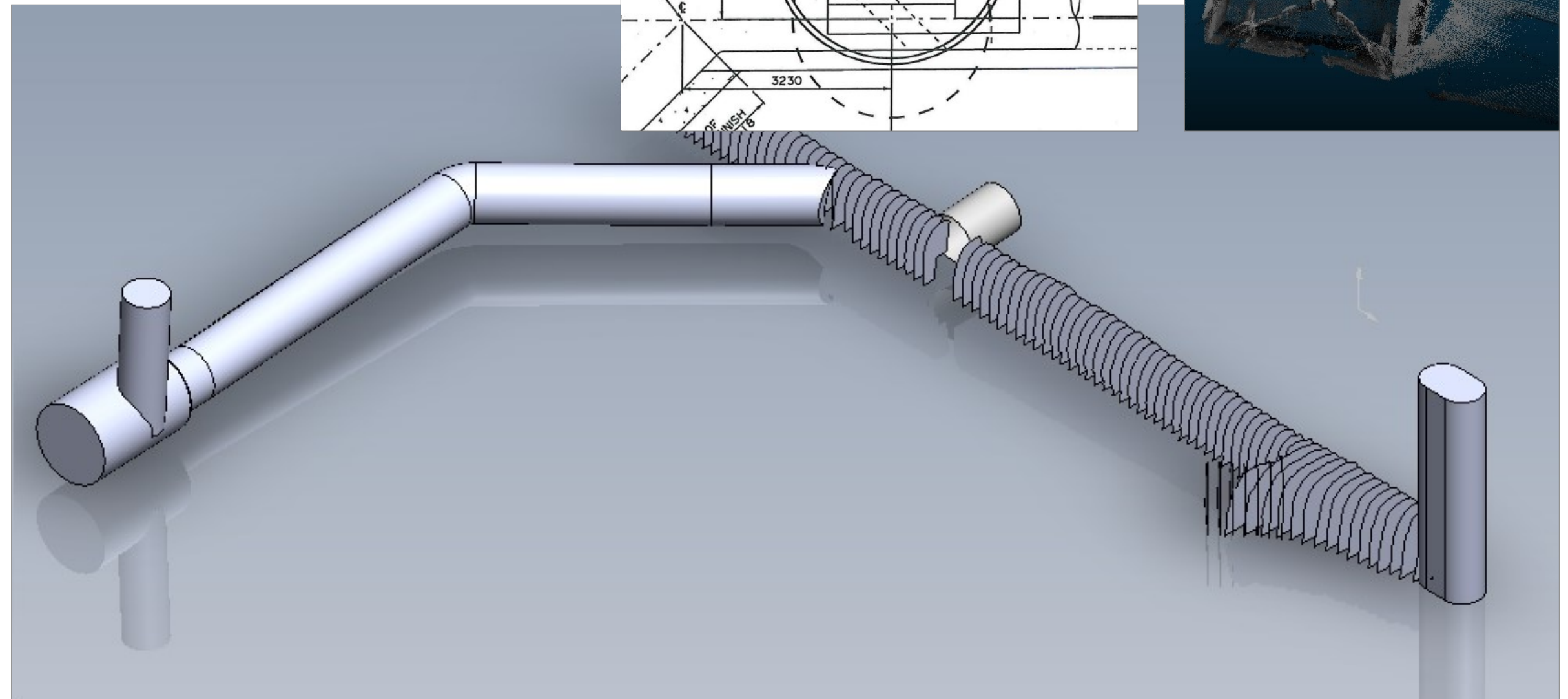
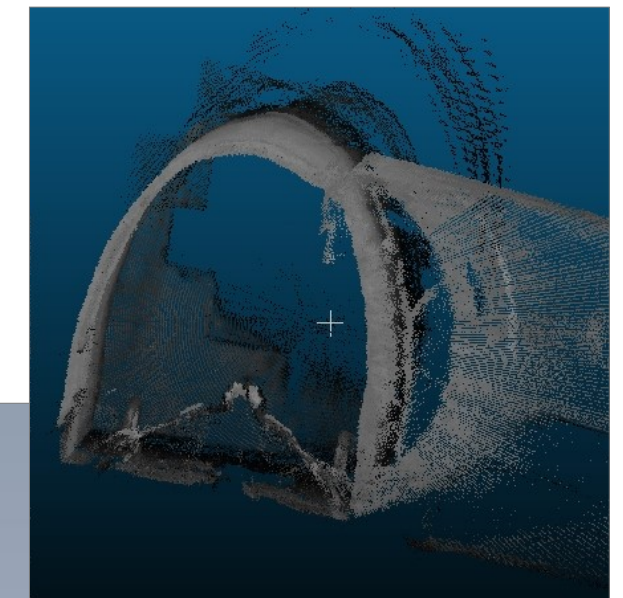
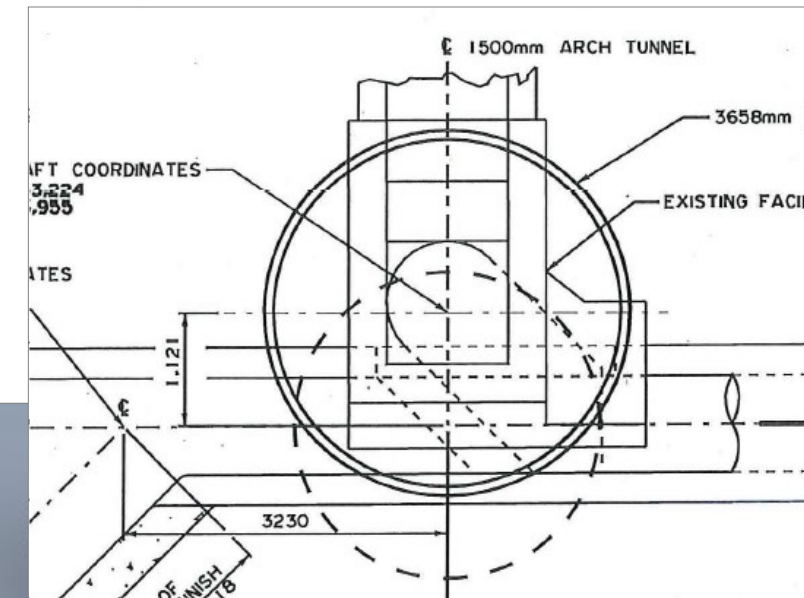
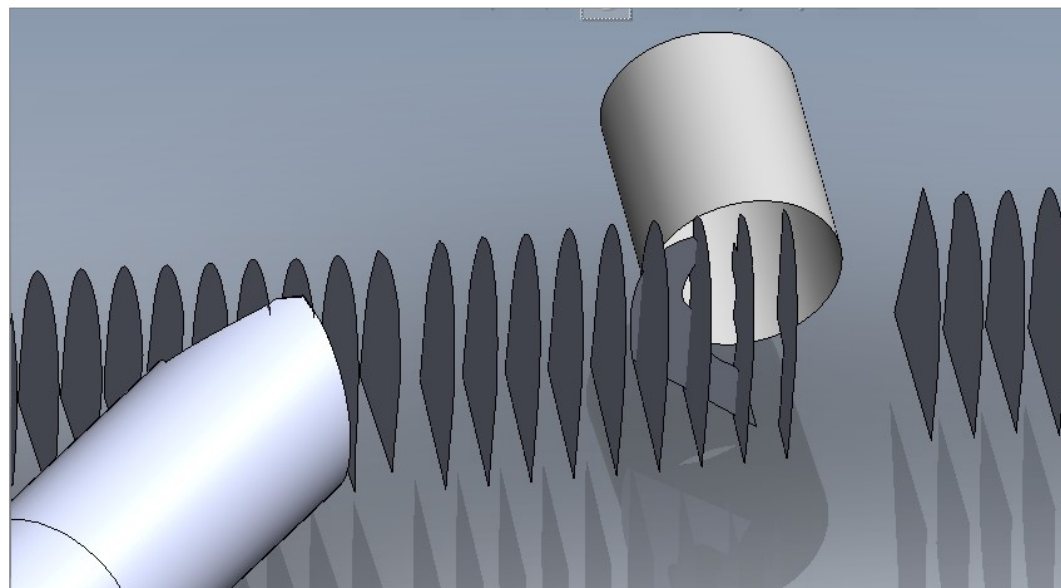
- Import point clouds into CAD
- Define pipe wall and CL
- Measure angles
- Update 3D model



Edmonton Alberta, CA (cont.)

Drill and Rehab Project

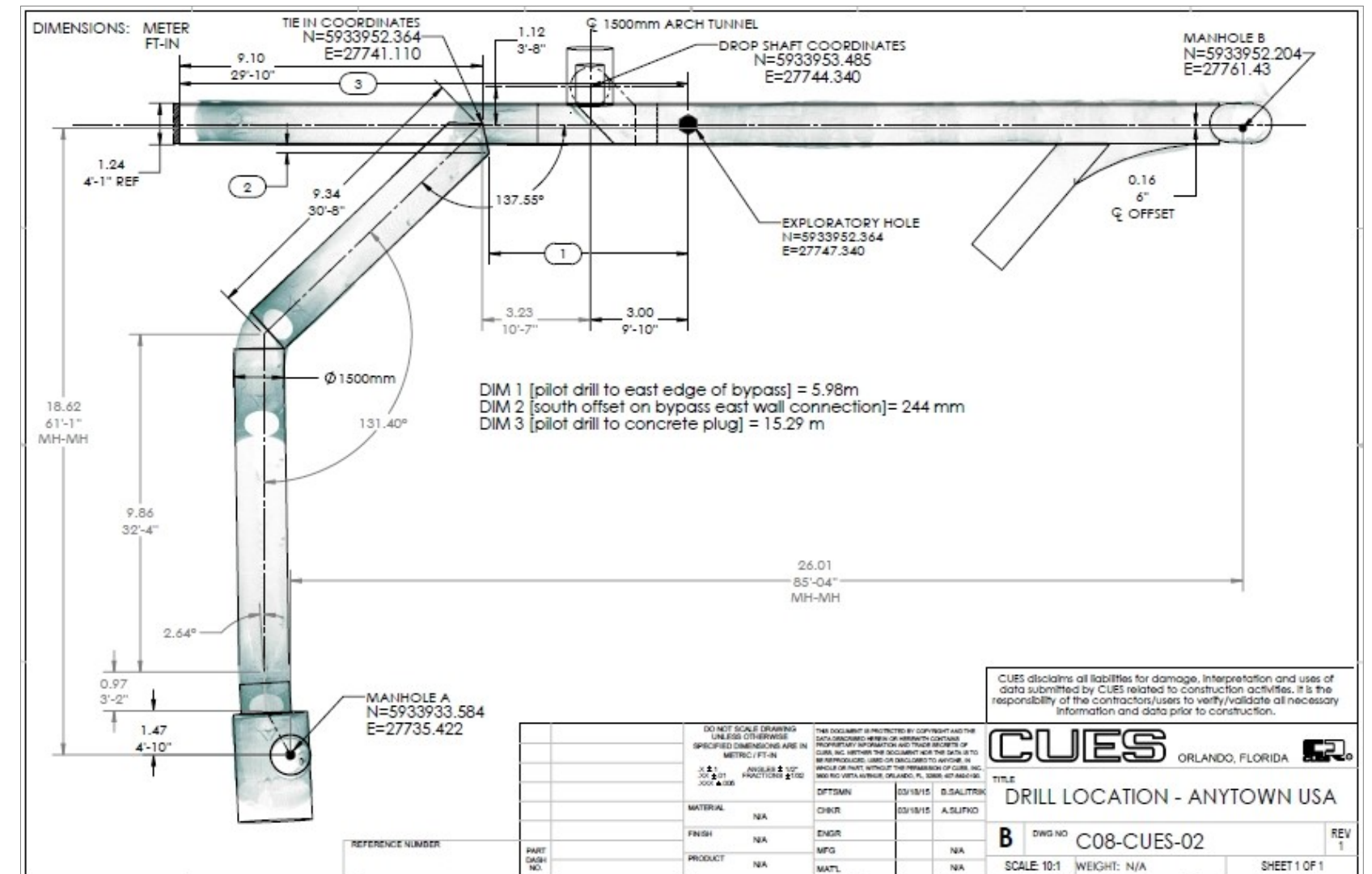
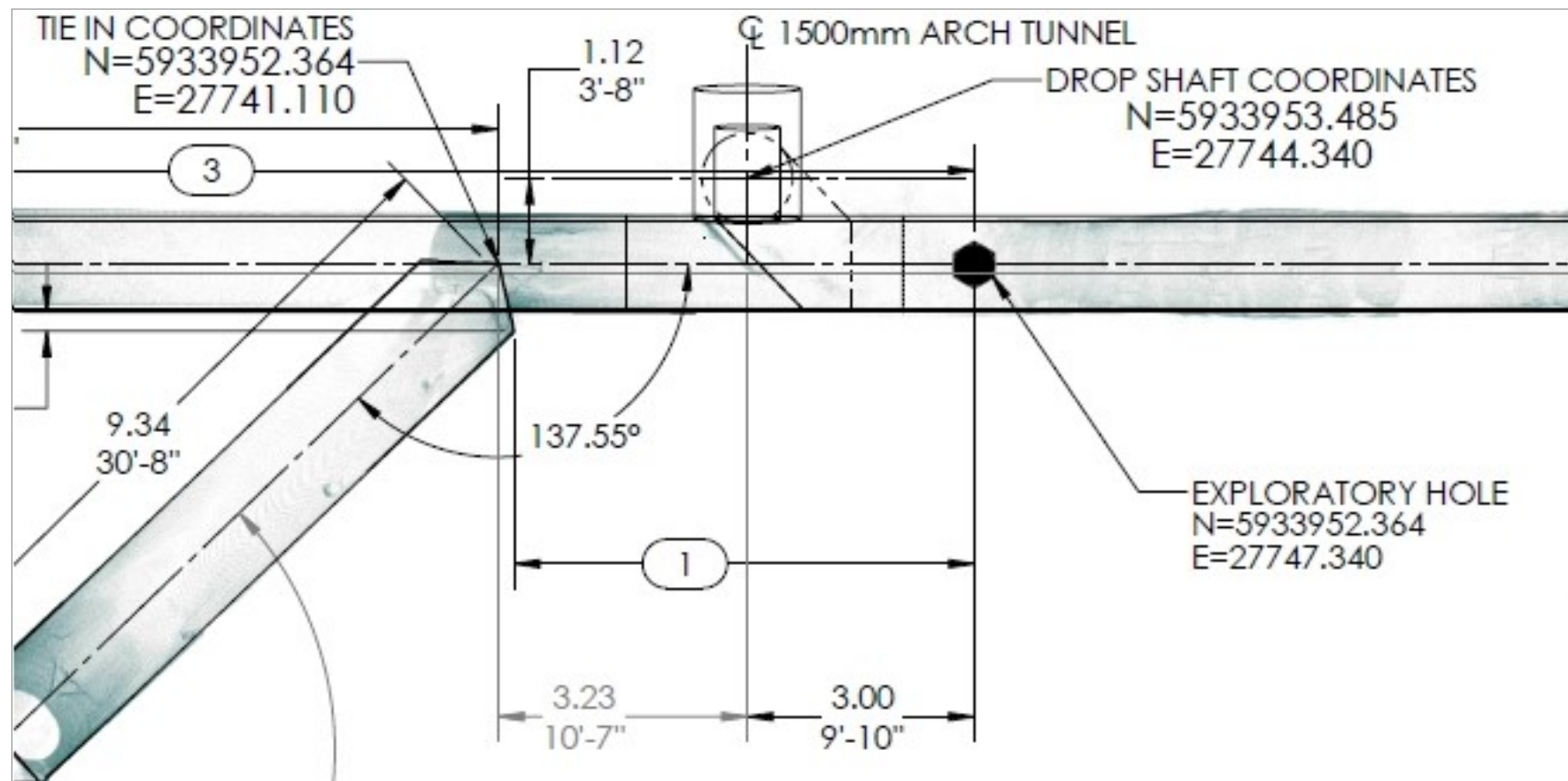
Tie The Pipe And Tunnel Together



Edmonton Alberta, CA (cont.)

Drill and Rehab Project

Deliverable – Access Shaft Dig Coordinates



Edmonton Alberta, CA (cont.)

Drill and Rehab Project

Results – Exploratory Hole For Shaft

- String line to South wall – 500mm
- String line to North wall – 490 mm

