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Aqueos Subsea Pipe 3D Scan

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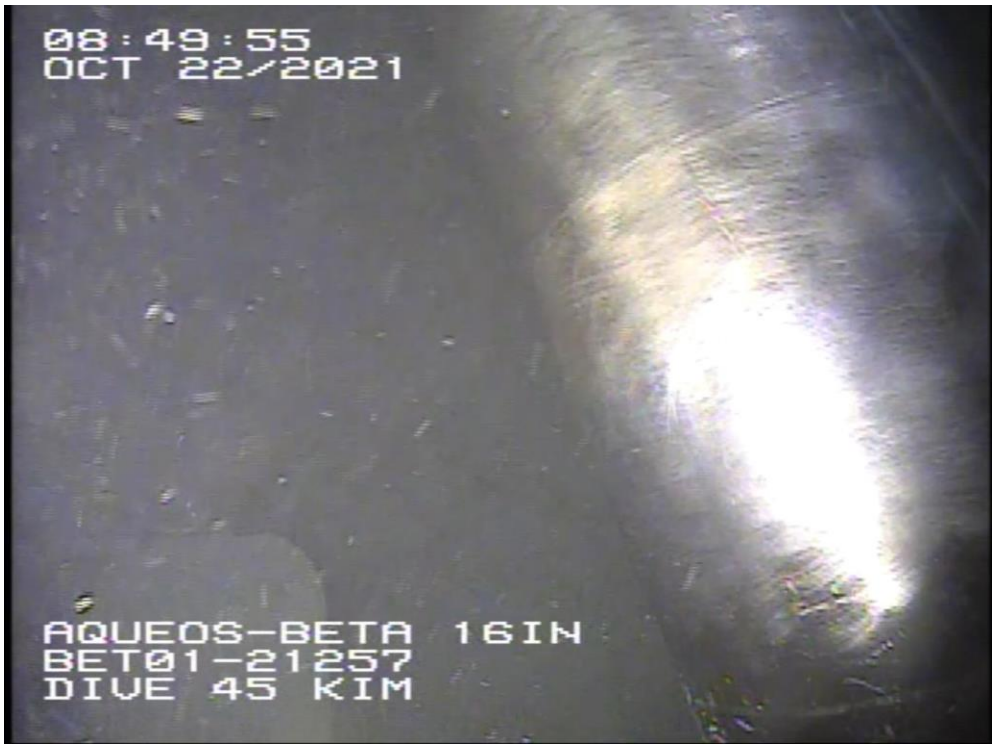


REV	DATE	AUTHOR	CHECK	APPROVE
0	10/28/2021	REDACTED PII	REDACTED PII	REDACTED PII

REVISION RECORD

Revision Date	Revision Number	Amender Initials	Summary of Changes
10/28/2021	0	REDAC	Issued for Client review

EXECUTIVE SUMMARY

- The Scope of Work was the 3D Scan of a subsea damaged pipe.
- Data Collection was carried out successfully with Aqueos divers following DimEye Instructions and Measurement Procedure.
- Multiple images were extracted from HD video files and were processed via DimEye Advanced Photogrammetry Software.
- The 3D Model of the pipe is provided with an accuracy of +/- 2 mm @2sigma (0.08 inches)
- Damages have been found and measured.

SURVEY SUMMARY

INSPECTION DATE	10/22/2021	
DATA ACQUISITION	DimEye	REDACTED PII & REDACTED PII
DATA PROCESSING	REDACTED PII / REDACTED PII	Check: REDACTED PII
CAMERA	DimEye VLS and Divers Camera	
SOFTWARE	DimEye VLS™	
UNITS	mm	
SURVEY DETAILS	563 images extracted from video files	

REFERENCE DOCUMENTS

Document	Title
Scope of Work	
DimEye Quotation Q-21032 Rev 0	Q-21032 AQUEOS 3D Pipe Inspection, October 12th, 2021 Rev0
Aqueos Purchase Order	PO# 49243 (BET01-21-257)

CONTENTS

1 Introduction

Aqueos have contracted DimEye Corp. to provide the 3D As-built CAD model and the 3D high accuracy Mapping of all damages of the Beta Pipe located in California (east of Long Beach). The Inspection took place on October 19th and 22nd, 2021, from the "Cronos" barge.

2 Scope of Work

The Scope of Work was to generate the 3D As-Built CAD Model of the Beta pipe and measure all damages in the prevision of repair.

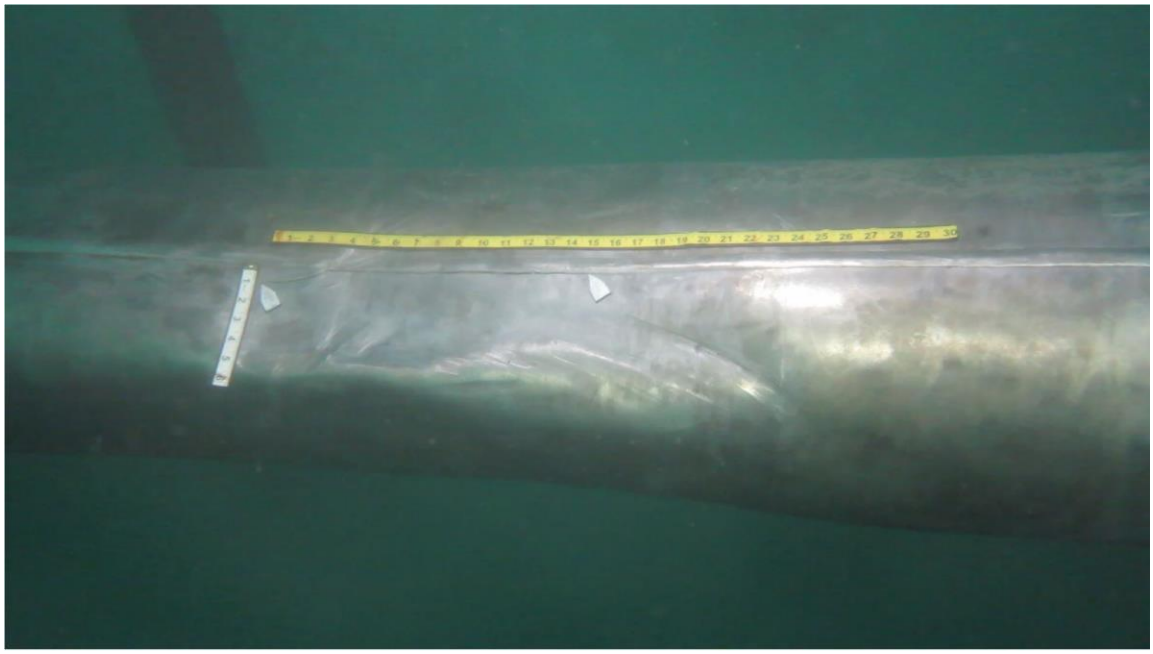


Figure 1: View of the pipe

The accuracy goal was +/- 2 mm (@2sigma) for the global CAD Model and +/- 0.5 mm @2sigma for all damages.

3 Survey description

3.1 Method

DimEye has developed a technology called VLS™ for **V**ideo **L**aser **S**can, combining innovative photogrammetry (see Figure 2) and laser measurement techniques (see Figure 3).
A single HD camera allows high accuracy 3D Measurement and as-built 3D CAD Modeling of subsea installations. In addition, for the Inspection of anomalies (such as cracks, bulges, or dents), a laser line projector device is added and generates high density and high accuracy local point clouds.

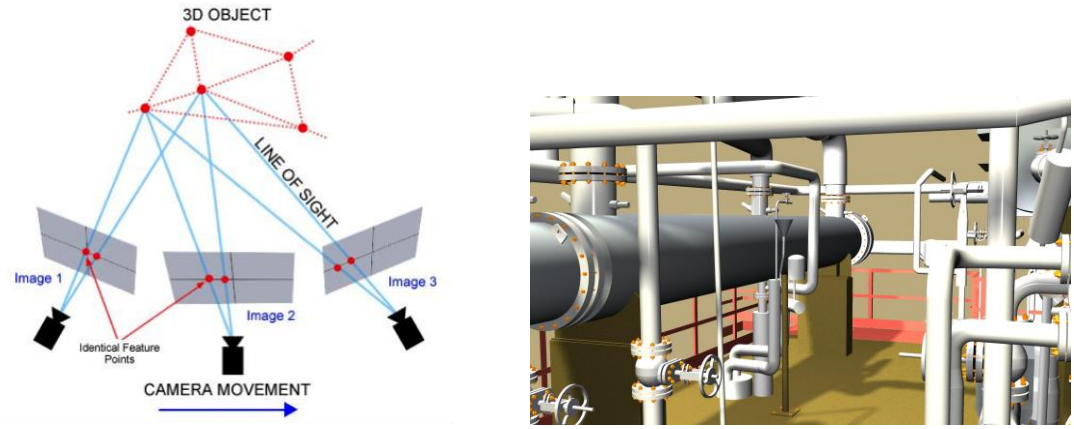


Figure 2: Photogrammetry Principle & typical output (3D CAD Model)

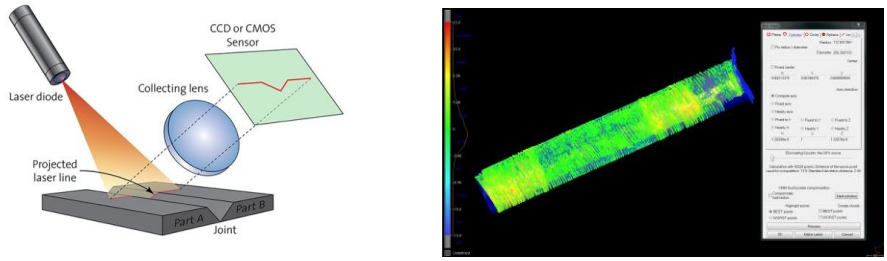


Figure 3: Laser triangulation Principle & typical output (Point Cloud)

For the Beta pipe, a first attempt to capture video files with a VLS™ device provided limited coverage due to multiple reasons:

- the light was not homogeneous (on and off) and made some areas almost invisible
- after one or two runs, particles from the seabed started floating, making visibility a challenge
- the laser failed, but the pipe was too shiny for the use of the laser anyway (the laser projection has been initially developed for textured or mat surfaces such as the black rubber of Flex Joints)

We decided to capture more data with a classic HD diver camera and associated lights and process the video with our advanced photogrammetry software, generating a high-density Point Cloud from Photogrammetry.

Data Processing was divided into three steps:

1. Image Selection: 563 still images were extracted from the video and processed.
2. Photogrammetry Computation: A free network bundle adjustment with camera self-calibration was performed within the Video Laser Scan (VLS^{TM}) software.
3. Characteristic Points and Geometrical Features are included in the bundle and directly transferred to the CAD Software (Microstation – Bentley) for further CAD Modeling.
4. Local high-resolution Point Clouds are compared to the CAD, and deviations are shown with a color code, thus indicating dimensions of damages (next step).

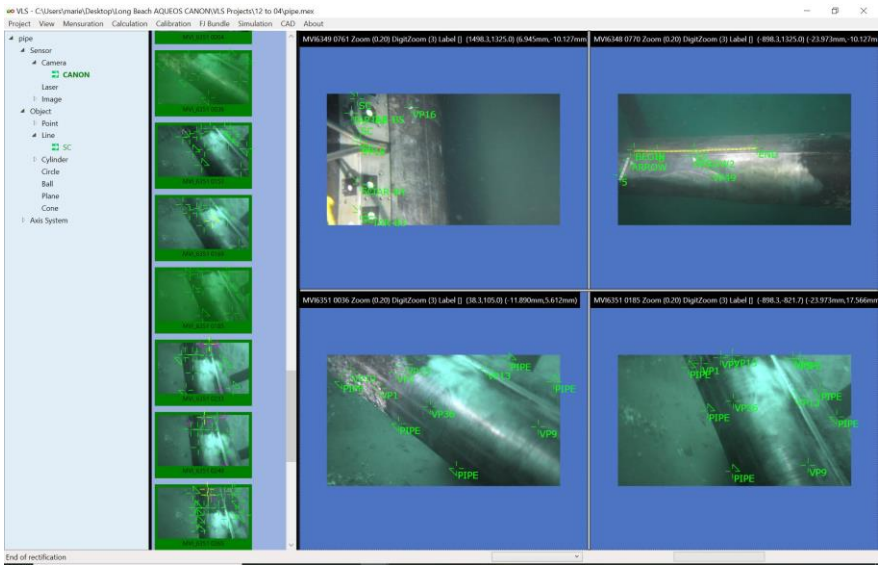


Figure 4: Typical Data Processing showing the image processing

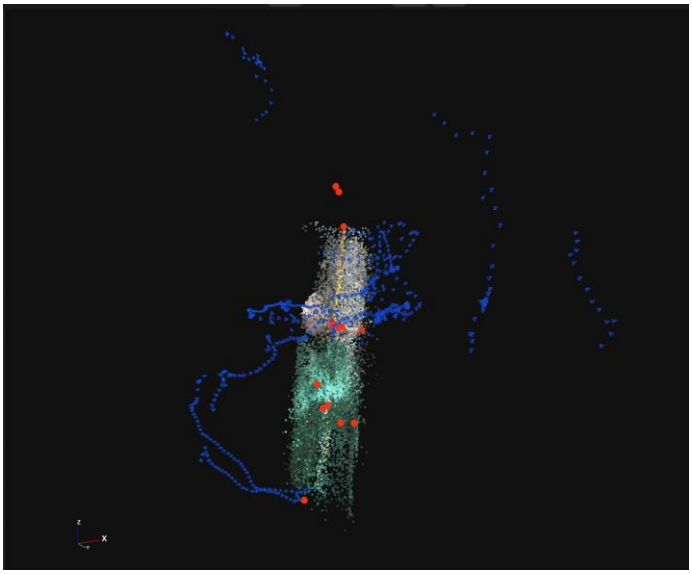


Figure 5: Typical 3D View of Photogrammetry Computation showing characteristic points, geometrical features, and camera locations as computed (blue dots)

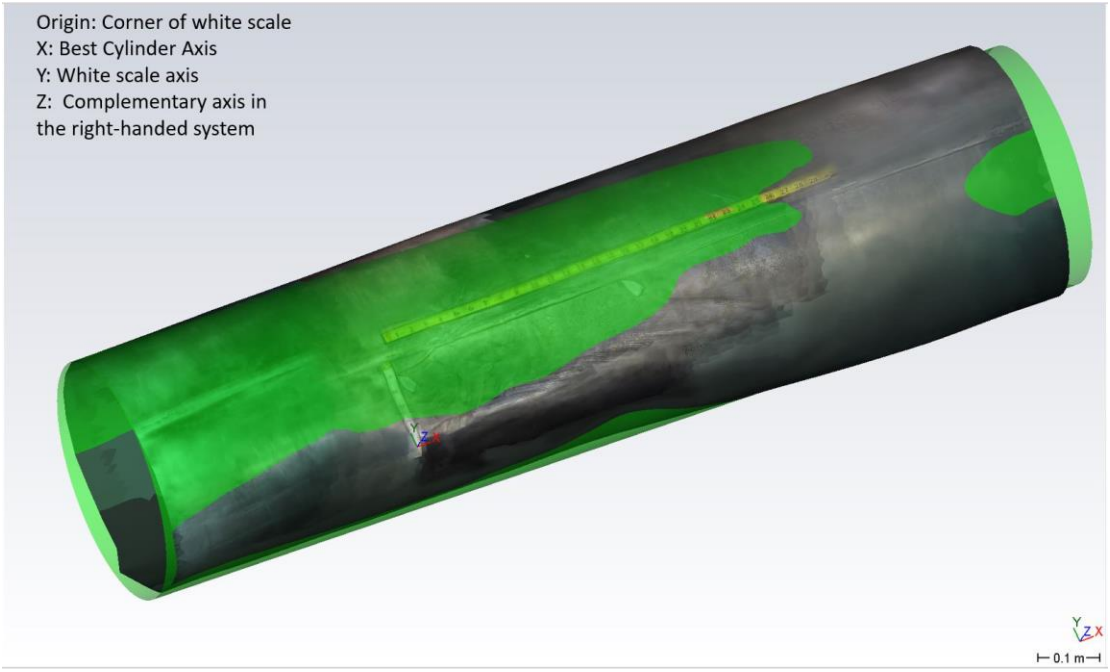


Figure 6: Final 3D Mesh and System Axis

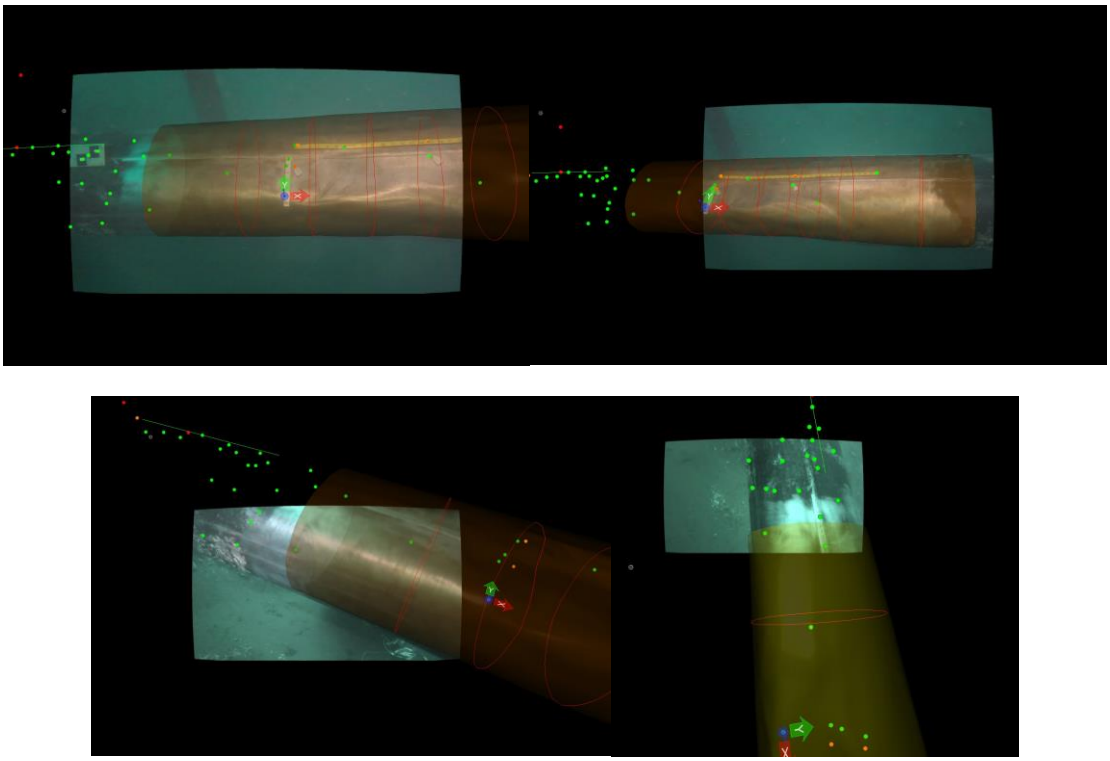


Figure 7: Superimposition of pictures and 3D As-Built CAD Model for Quality Check.

Scaling:

The scale is provided by the length of the scale bar measured with high accuracy on the barge before installation providing known dimensions in the scene. The scale bar placement is shown in Figure 8.

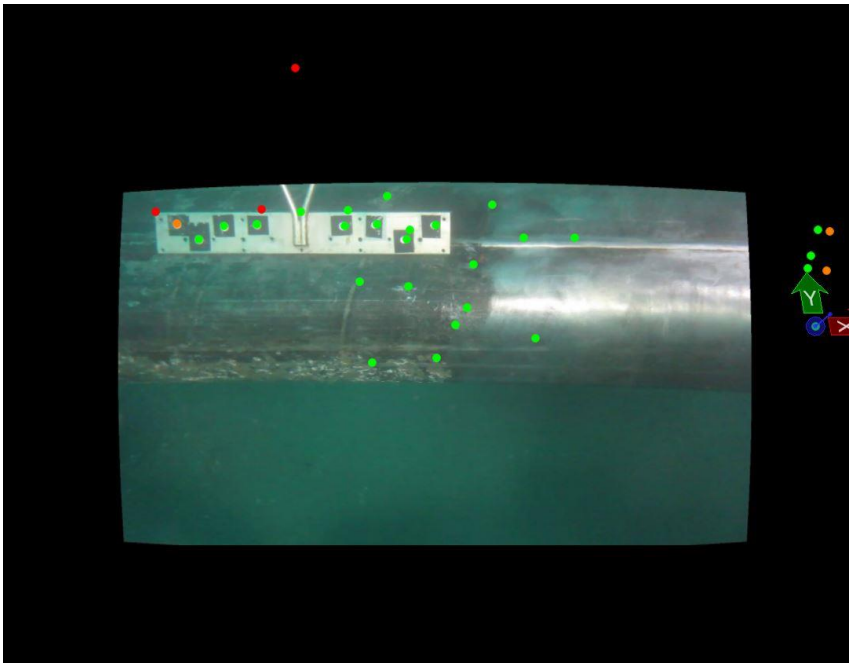


Figure 8: View showing the scale bar location

3.1 Means

The following Personnel and Equipment were used to carry out the Measurement Tasks.

Preparation:

- DimEye Project Manager

Data Capture:

- DimEye Project Manager
- Aqueos Offshore Team
- DimEye Divers HD Camera and lights
- Scale Bars

Figure 9: Divers Camera & Lights

Figure 10: Scale Bars

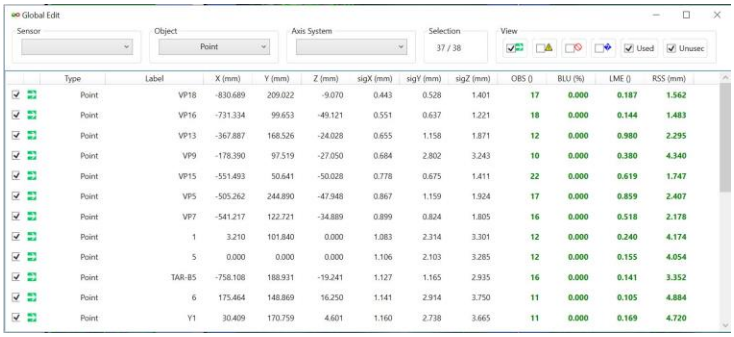
Data Processing:

- DimEye Project Manager
- Computer with DimEye VLS™ Advanced Photogrammetry Software interactive with Microstation CADCAM Software (Bentley)

4 Results

4.1 3D As-Built CAD Model

The measurement accuracy of the 3D As-Built CAD Model is estimated at +/- 2 mm @2sigma (+/- 0.08 inch). The following table (Figure 11)



Type	Label	X (mm)	Y (mm)	Z (mm)	sigX (mm)	sigY (mm)	sigZ (mm)	OBS ()	BLU (%)	LME ()	RSS (mm)
Point	VP18	-830.689	209.022	-9.070	0.443	0.528	1.401	17	0.000	0.187	1.562
Point	VP16	-731.334	99.653	-49.121	0.551	0.637	1.221	18	0.000	0.144	1.483
Point	VP13	-367.887	168.526	-24.028	0.655	1.158	1.871	12	0.000	0.980	2.295
Point	VP9	-178.390	97.519	-27.050	0.684	2.802	3.243	10	0.000	0.380	4.340
Point	VP15	-551.493	50.641	-50.028	0.778	0.675	1.411	22	0.000	0.619	1.747
Point	VP5	-505.262	244.890	-47.948	0.867	1.159	1.924	17	0.000	0.859	2.407
Point	VP7	-541.217	122.721	-34.889	0.899	0.824	1.805	16	0.000	0.518	2.178
Point	1	3.210	101.840	0.000	1.083	2.314	3.301	12	0.000	0.240	4.174
Point	5	0.000	0.000	0.000	1.106	2.103	3.285	12	0.000	0.155	4.054
Point	TAR-B5	-758.108	188.931	-19.241	1.127	1.165	2.935	16	0.000	0.141	3.352
Point	6	175.464	148.869	16.250	1.141	2.914	3.750	11	0.000	0.105	4.884
Point	Y1	30.409	170.759	4.601	1.160	2.738	3.665	11	0.000	0.169	4.720

Figure 11: Accuracy Estimates (SigX, SigY & SigZ) @2sigma

The following final 3D As-Built CAD Models have been delivered as .stl and dwg file: "Aqueos Beta Pipe." In addition, a 3D pdf file has also been generated.

All 3D analyses are provided in Appendix 1.

4.2 3D Mapping of Damages

The following damages areas have been measured:

- Crack

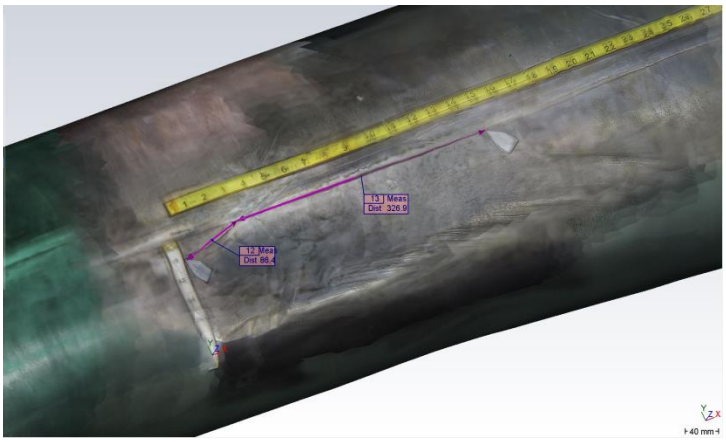


Figure 12: Crack dimensions

5 Conclusion-Limitations-Lessons Learned

The scope for the survey has been completed successfully, and a high accuracy 3D model of the pipe has been provided in the preparation of further repair.

The main items have been measured with an accuracy of +/- 2mm @2sigma (+/- 0.08 inch).

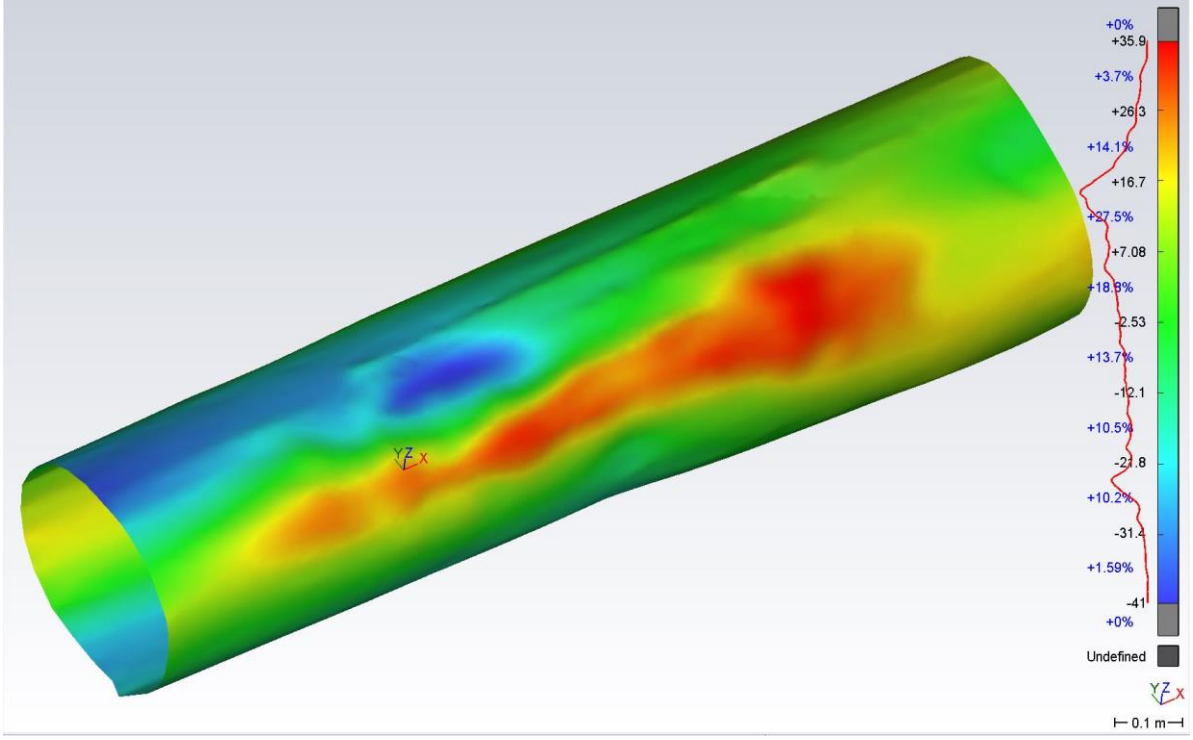
Some areas have not been measured due to access difficulties, especially under the pipe in the central part. However, areas under the pipe at both extremities have been measured.

Lesson 1: for this level of cleanliness, the laser can't be used. There are two options: either cleaning a little less (leaving some marine growth or paint in some spots) or using advanced photogrammetry techniques (like we did in this case)

Lesson 2: divers should always stop for a while after two runs to avoid too many particles flying in the water

APPENDIX 1:

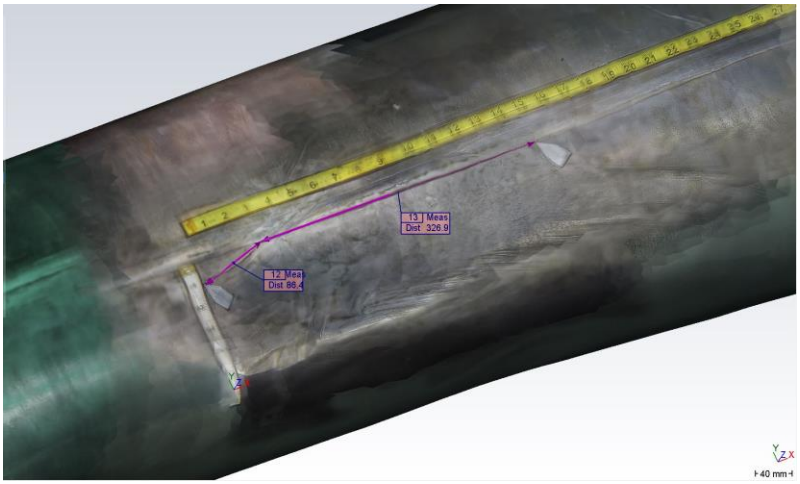
3D Analysis & Measurements



Global Comparison with Nominal Pipe

The percentages on the right correspond to the number of points with a deviation to nominal between the two values. For example, there are 3.7% points (on the top of the color bar) with a deviation between +26.3 mm and + 35.9 mm.

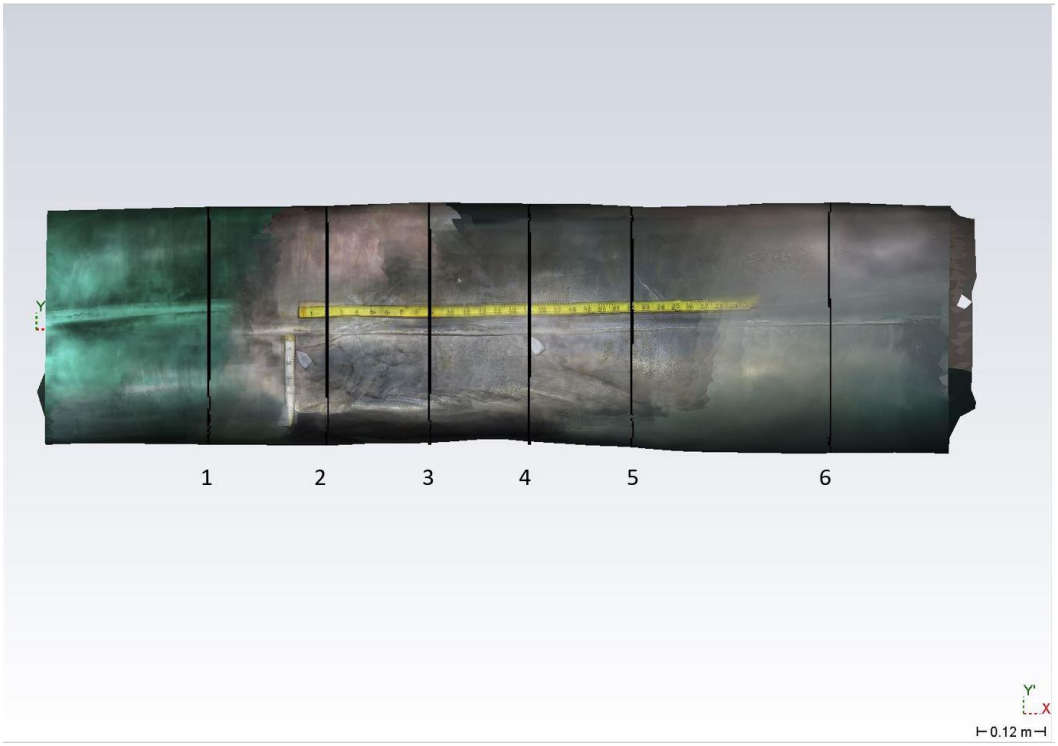
Dents are in blue, bumps in red.

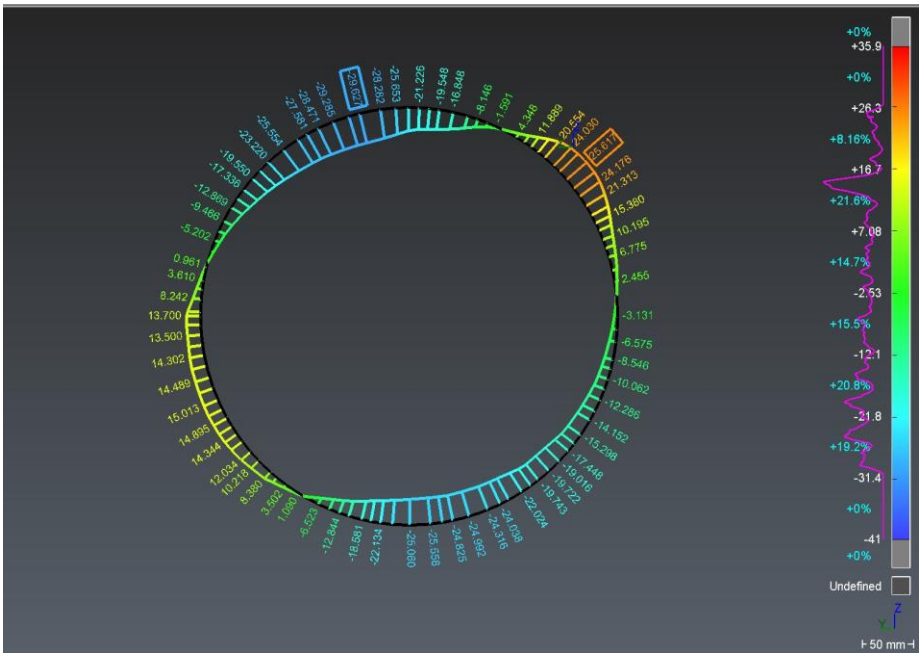


Dimensions of the crack

The length of the crack is 86 mm + 327 mm.

Following are some Cross-Sections as located in the drawing below:





Cross-Section 1

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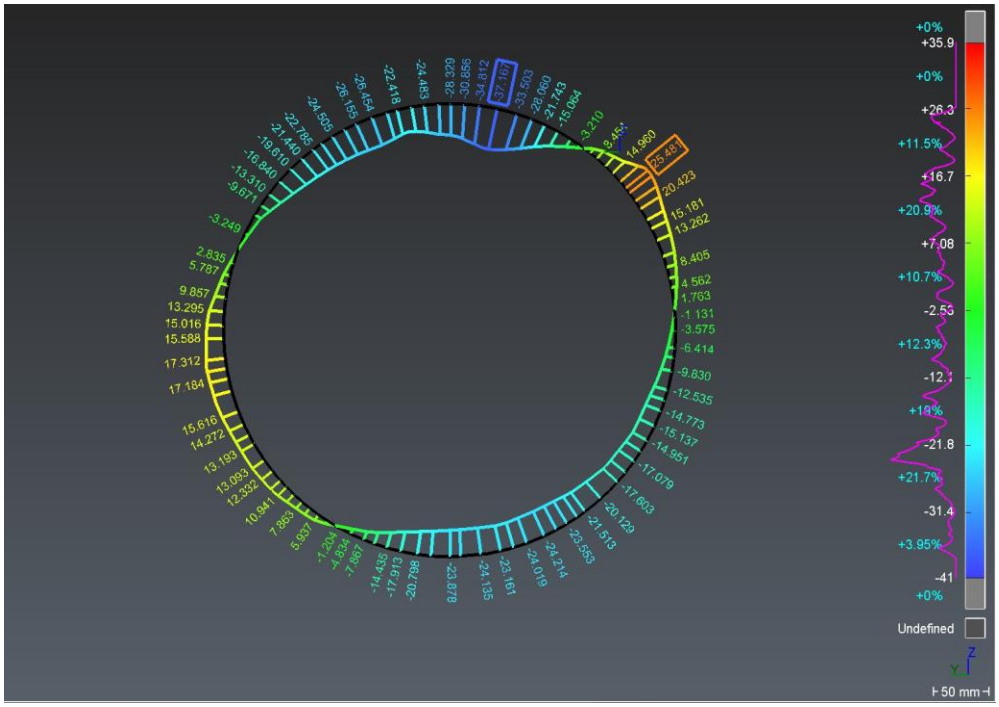

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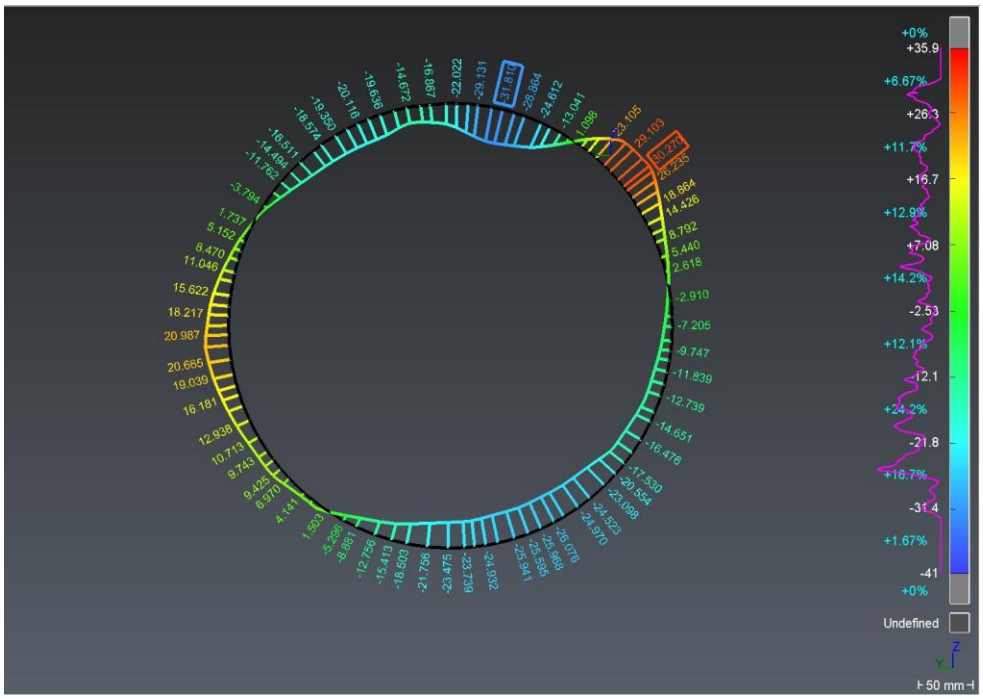

Cross-Section 3

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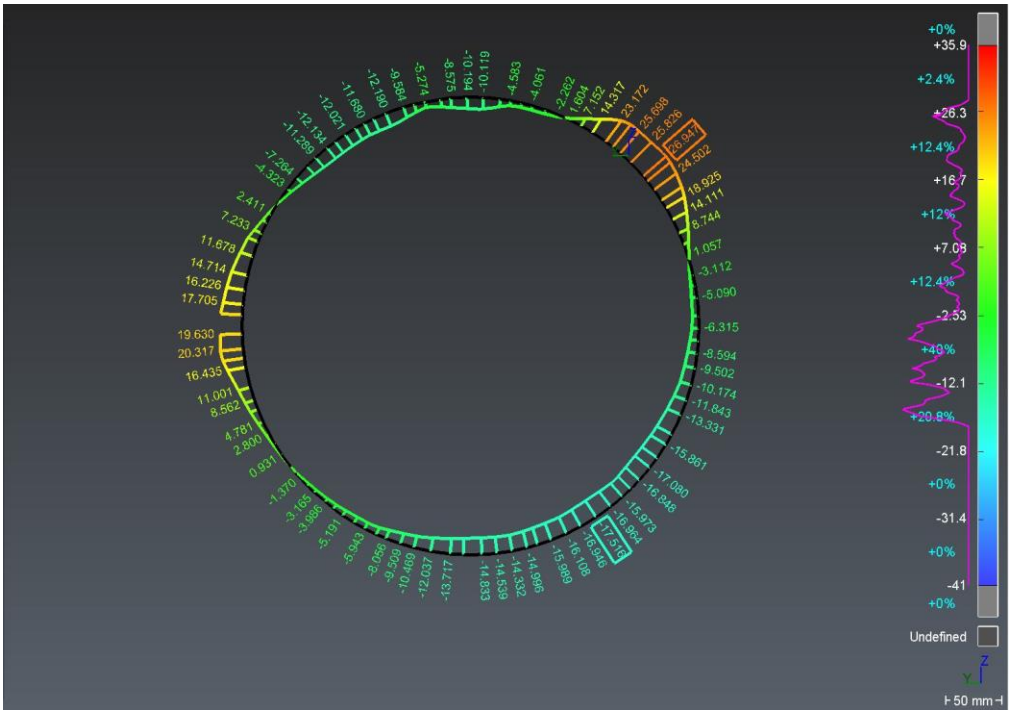

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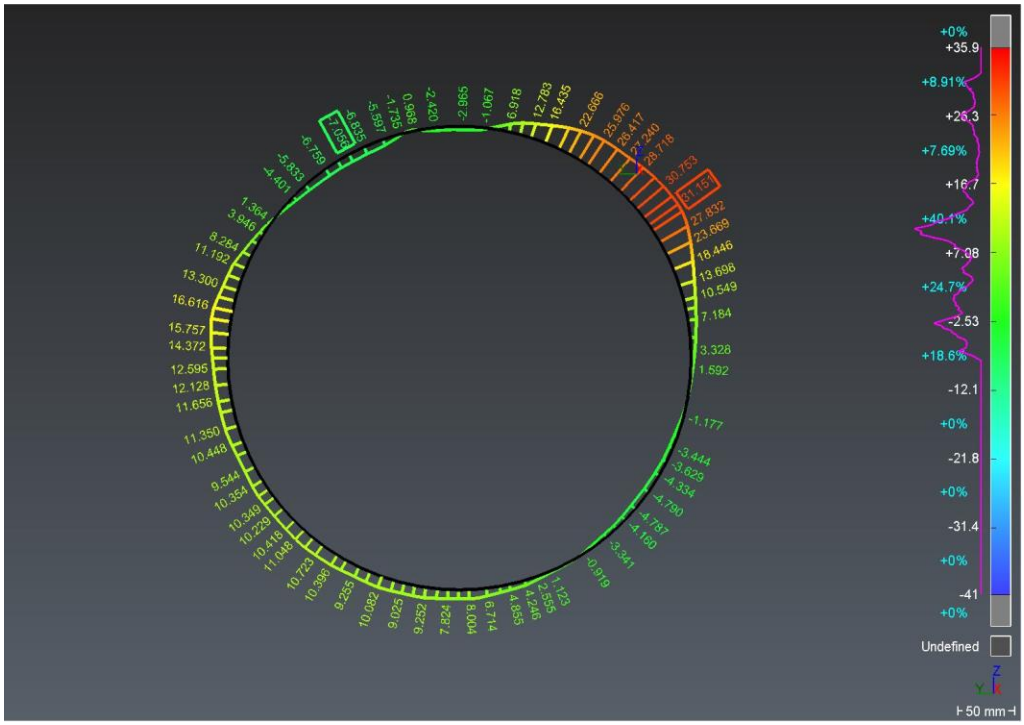

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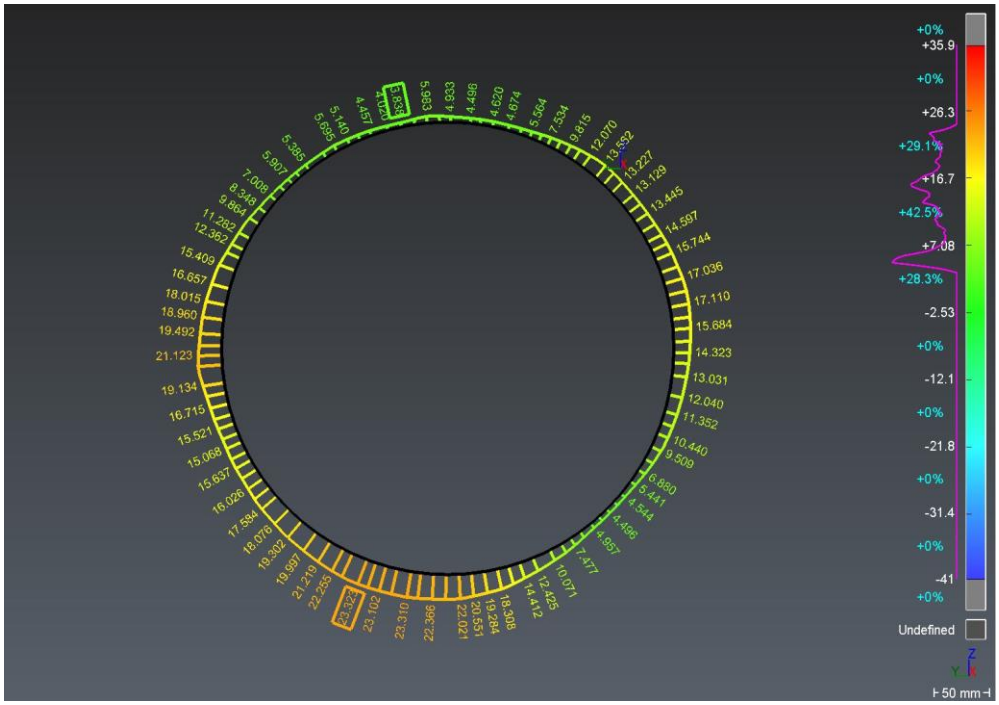

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