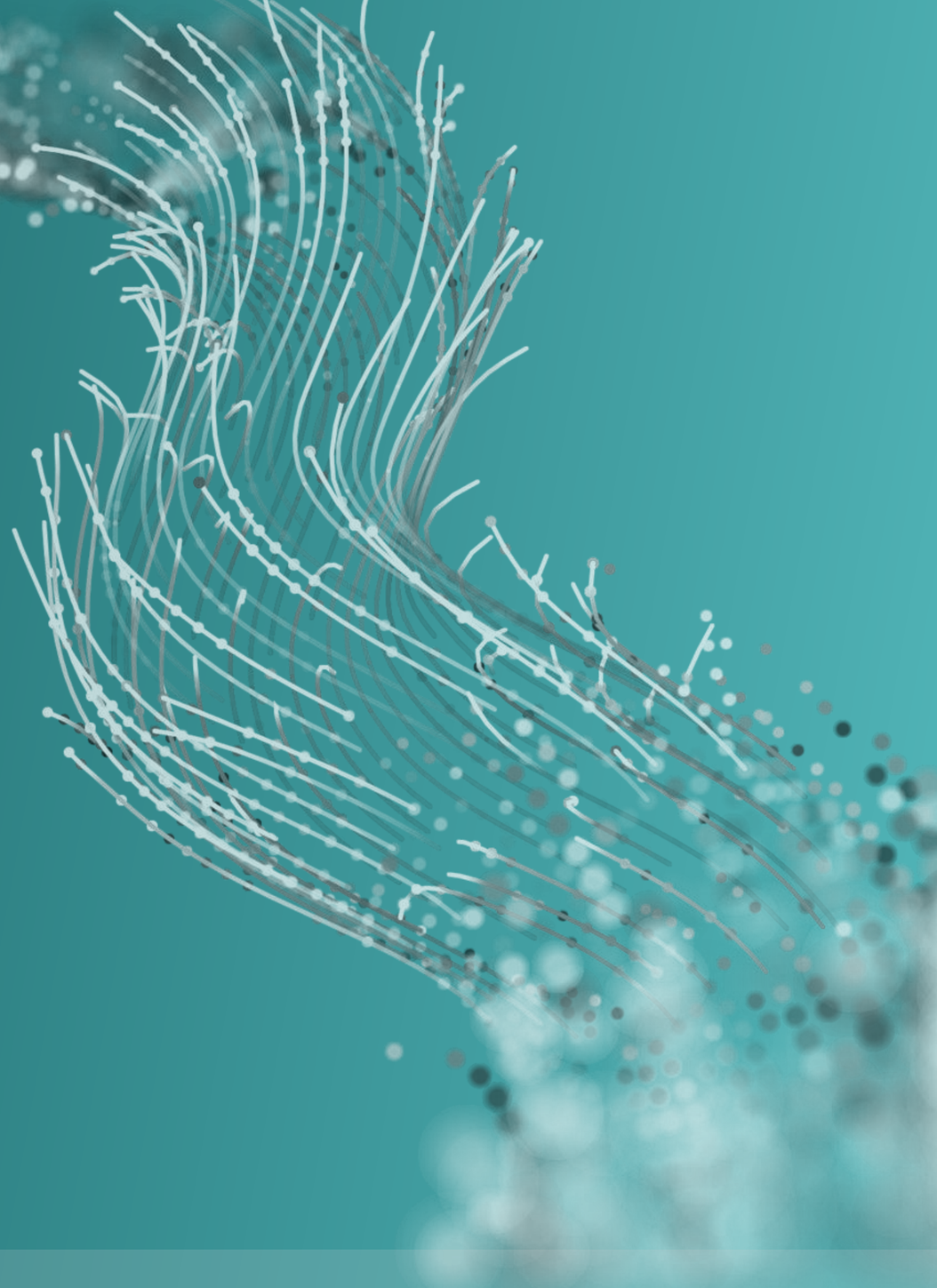
PL-1-05 : Depth Of Cover Assessment

Close out review, Nov. 14th 2022

SKIPPER NDT

Industry 4.0:
Buried infrastructure digital twin

3D pipeline mapping

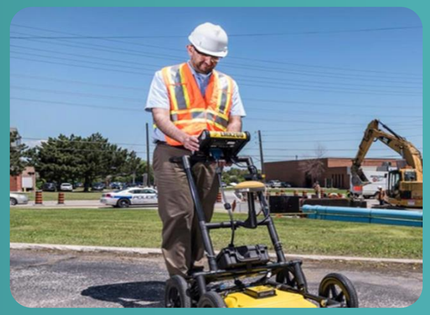


Traditional tools need to be complemented

Low density, prone to measurement biases and limited by ground conditions

- Prone to measurement biases
- Acquisition pace dependent on RoW condition
- Shallow measurement
- Low data density
- Results are dependent on soil conditions (GPR)

Electromagnetic Field (EMF)



Ground Penetrating Radar (GPR)

Unable to cover certain areas

Areas difficult to access
Safety concern for personnel

River crossing
Areas affected by geohazard events

Cultivated fields

Skipper NDT: game changer for underground pipeline mapping

Skipper NDT: purpose built tools enabling automated underground mapping

- 3/5 Fluxgate vectorial magnetometers
- 1 Centimetric-level GNSS

- 1 Inertial Measurement Unit (IMU)
- 1 Telemetric sensor

High acquisition pace
4 X compared to traditional tools

Long range measurement
3 X compared to traditional tools

Supervised process
100% automatic acquisition
90% automatic processing

High data density
100 X compared to traditional tools

Skipper NDT:
proprietary R&D developments

Performance enabled by innovations in various fields

Surface measurements

Patented Harware

Electronic card development

Component selection for minimal magnetic interference (nano tesla level)

Magnetometer compensation

25 X precision improvement compared to native performances

Location detection

Field data level control

Magnetometer movement compensation for optimal signal processing

Interference filtering

Algorithms able to clean the signal from any exterior interference (high voltage lines etc..)

Decision support

Pipeline detection algorithm

Several algorithms to detect and locate the pipeline

SaaS platform for data restitution

Output adaptable to client's Global Information System data format

Skipper NDT : field applications

Onshore pipeline mapping

Terrain with obstacles: risk of safety hazard and slow acquisition pace

Time consuming
acquisition pace is impacted by the terrain nature.

Safety concerns
several risk factors are inherent to this type of operation

Low data points density
number of data points can be impacted by the terrain nature.

Safety first
minimum resources deployed in the field

Time & Cost efficient
cost saving compared to traditional tool

Digital twin
one data point each 10cm can be provided

Under water pipeline mapping

River Crossing: challenging environment for traditional methods

Video Link

Resource intensive
diver and support team of 3 is required

Safety concerns
several risk factors are inherent to this type of operation

Time consuming
Several week are necessary for preparation and data acquisition

Safety first
no resources deployed under water

Cost efficient
cost saving compared to traditional tool

Time efficient
3X quicker

Pipeline mapping in case of geohazard

Costly and cumbersome tools are currently used for bending strain assessment

Cost
ILI are traditionally used for bend strain assessment

Time consuming
Several weeks are necessary for preparation and data acquisition

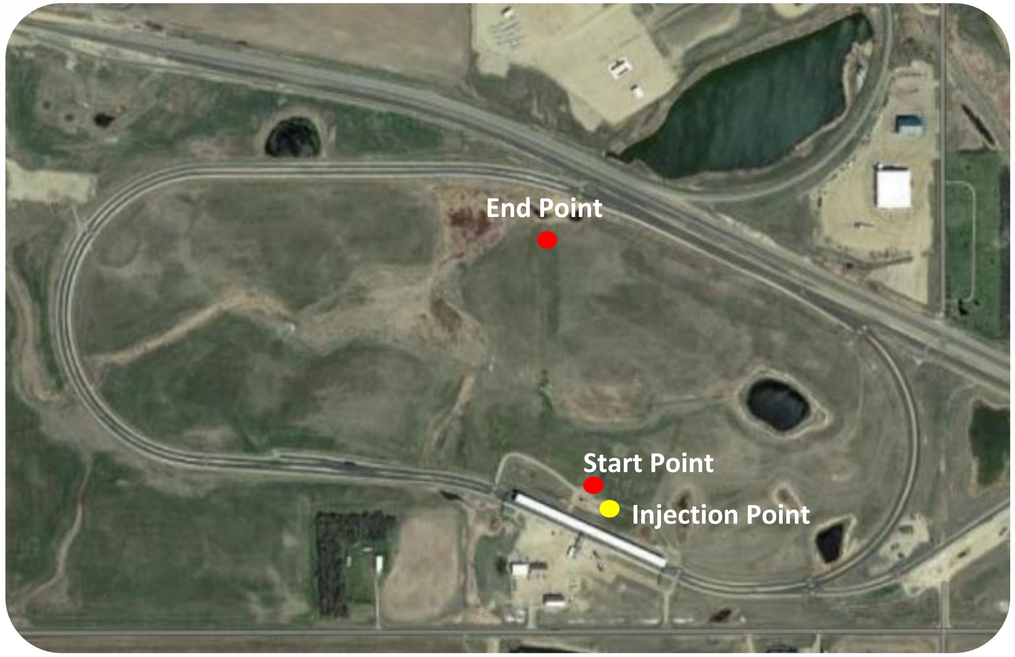
Cost efficient
50% cost saving

Time efficient
3X quicker

Skipper NDT proposes a swift method to complement In Line Inspections (ILI) and add valuable data for geohazard mitigation.

Skipper NDT: operational protocol

PL-1-05 : Scope of Work validated by SWRI



The mission's scope was defined in the *'SRWI Scope_Of_Work* sent on September 22, 2022:

- Induce a current on the 24" diameter line at the injection point.
- Perform a magnetic survey using the field and UAV-based equipment inside the rail loop, over 500 meters (1600 ft).
- Infer precise position XYZ and depth of cover from this survey in GIS-compatible format.
- Build a 3D model of the area coupled with a precise photogrammetry survey.

Magnetic mapping protocol

1600ft long inspection area

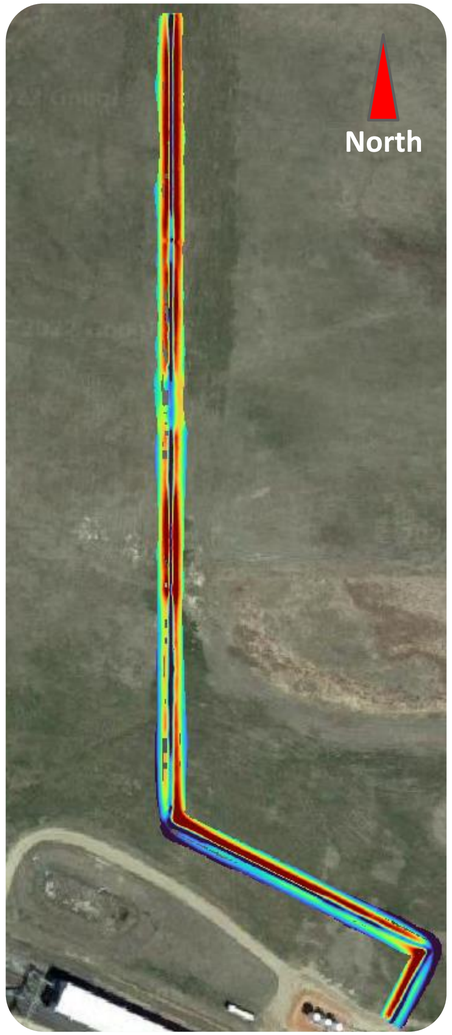
Skipper NDT's proprietary data analysis process

Filtering of potential perturbation / interferences

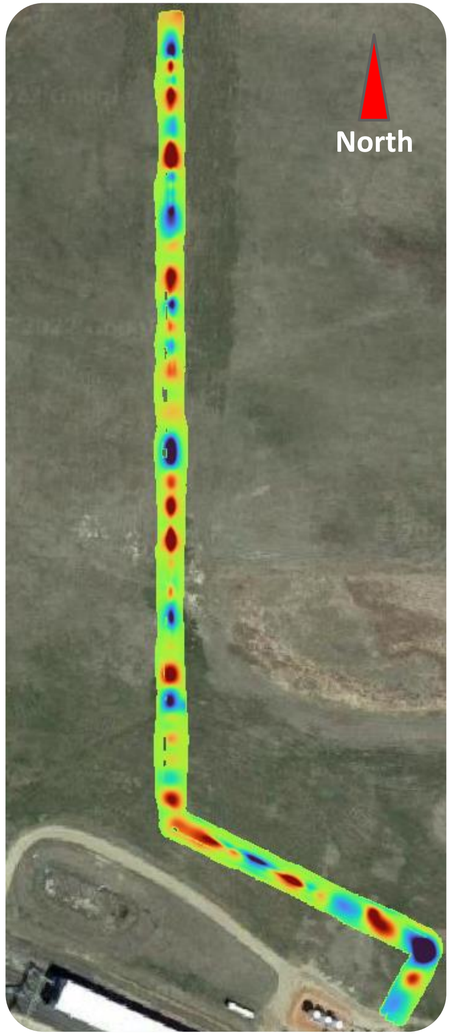
Magnetometer compensation / calibration

Pipeline detection algorithms

- Inspection performed with both Field and UAV-based equipment
- Georeferenced magnetic mapping of the buried pipeline environment
- Shapefile format adapted to customer's requirements and adapted to his GIS
- Information on the magnetic environment (parallel pipeline, nearby metallic objects, third-party work, etc.) is provided as well.



Injected frequency magnetic map

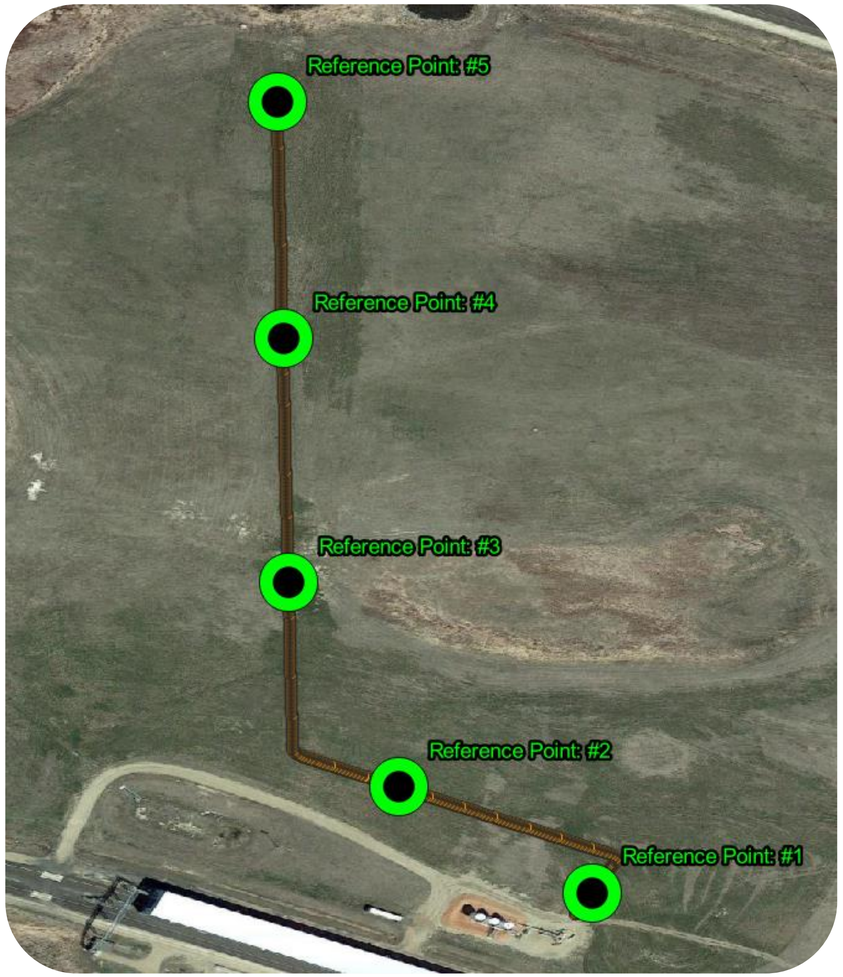


Low frequency magnetic map

Skipper NDT: performance evaluation protocol

Evaluation of positioning performance

XY and DOC comparison with 5 reference potholes



The objective is to evaluate the performance of the technology:

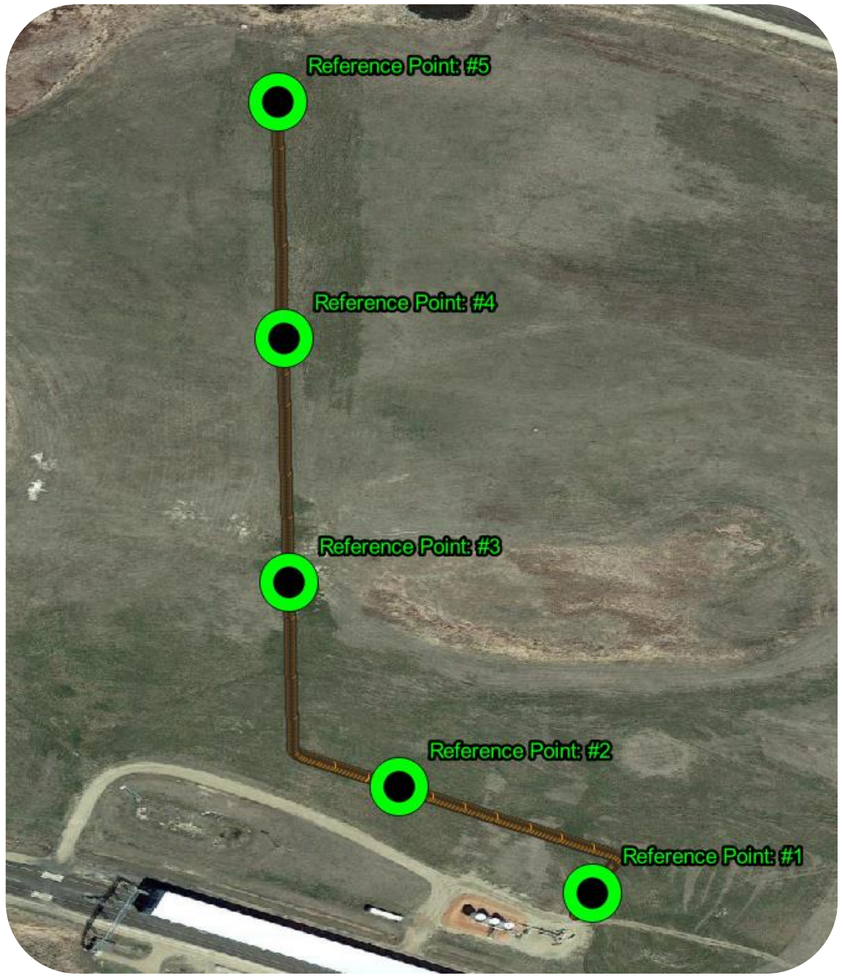
The average **accuracy** of the positioning in XY and DOC.

The **repeatability** (precision) of the measurement.

The **reproducibility** of the measurement.

Evaluation of positioning accuracy

XY and DOC comparison with 5 reference potholes



The average **accuracy** of the positioning in XY and DOC.

To evaluate the accuracy, we compare the positioning over 5 regularly spaced potholes on the line:

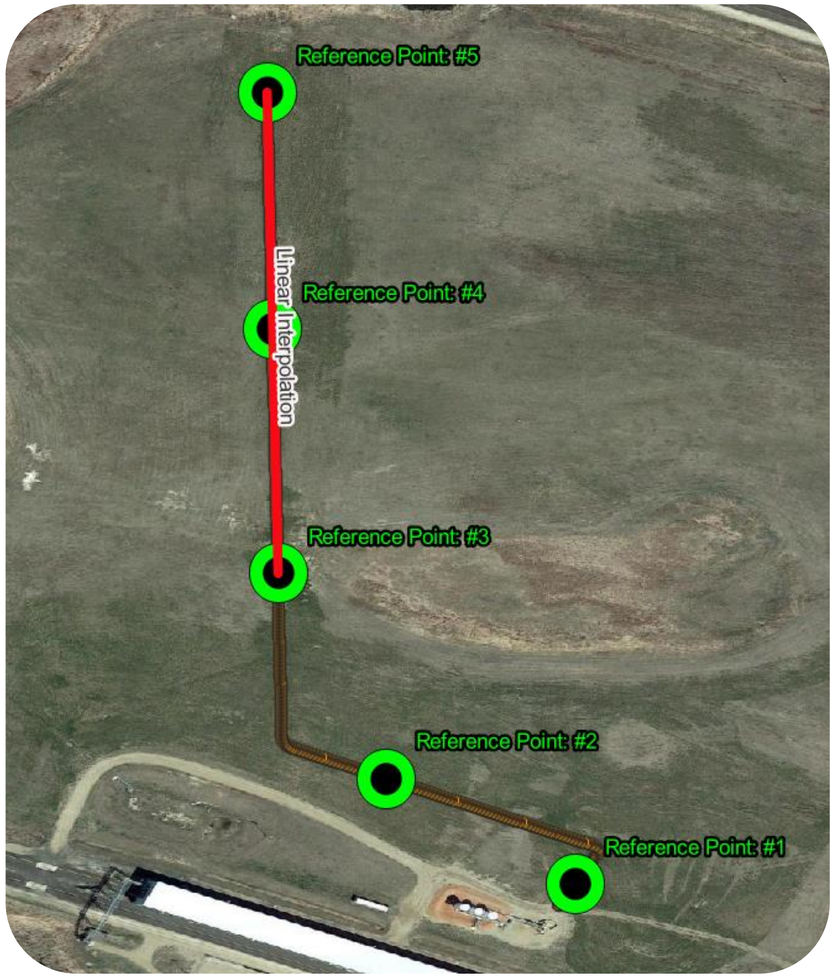
- 5 XY references
- 3 DOC references (#3, #4 and #5)

The accuracy is evaluated for both:

- UAV-based inspection
- Field-based inspection

Evaluation of positioning repeatability

XY comparison with interpolated reference line



The **repeatability** (precision) of the measurement.

To evaluate the repeatability, we linearly interpolate between points #3, #4 and #5:

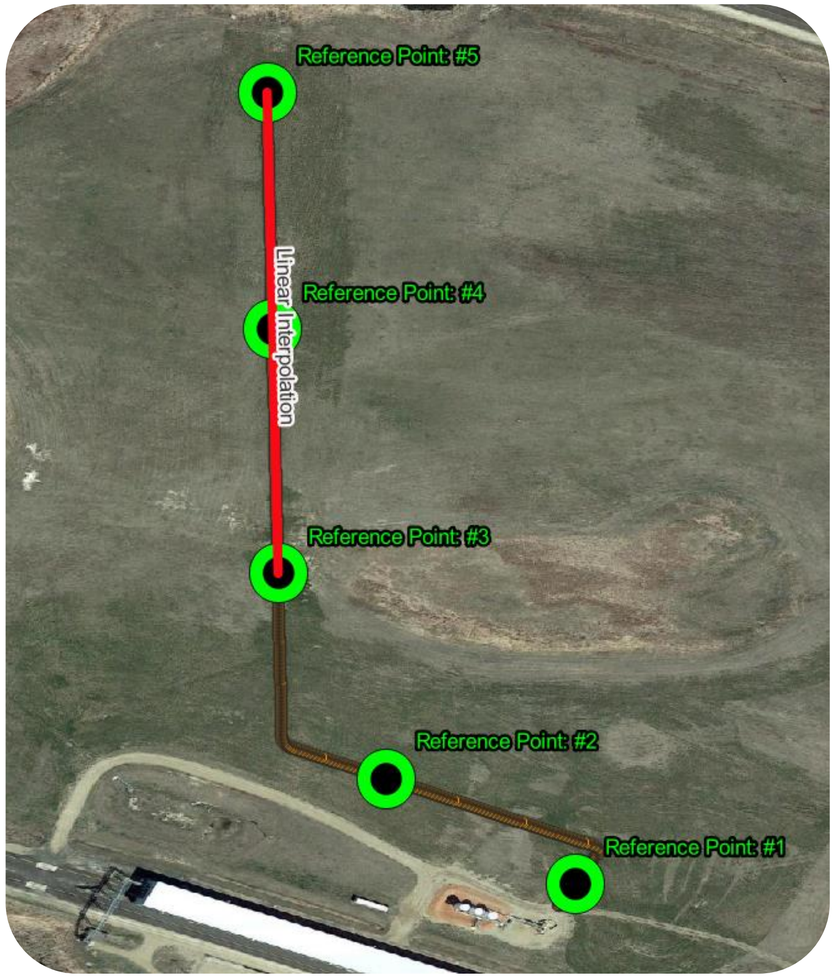
- We assume that the pipeline is XY-straight between the points.
- We create a continuous XY reference to allow repeatability evaluation.
- We cannot make this assumption for DOC.

The repeatability is evaluated for both:

- UAV-based inspection
- Field-based inspection

Evaluation of positioning reproducibility

XY comparison between UAV and Field machine results



The **reproducibility** of the measurement.

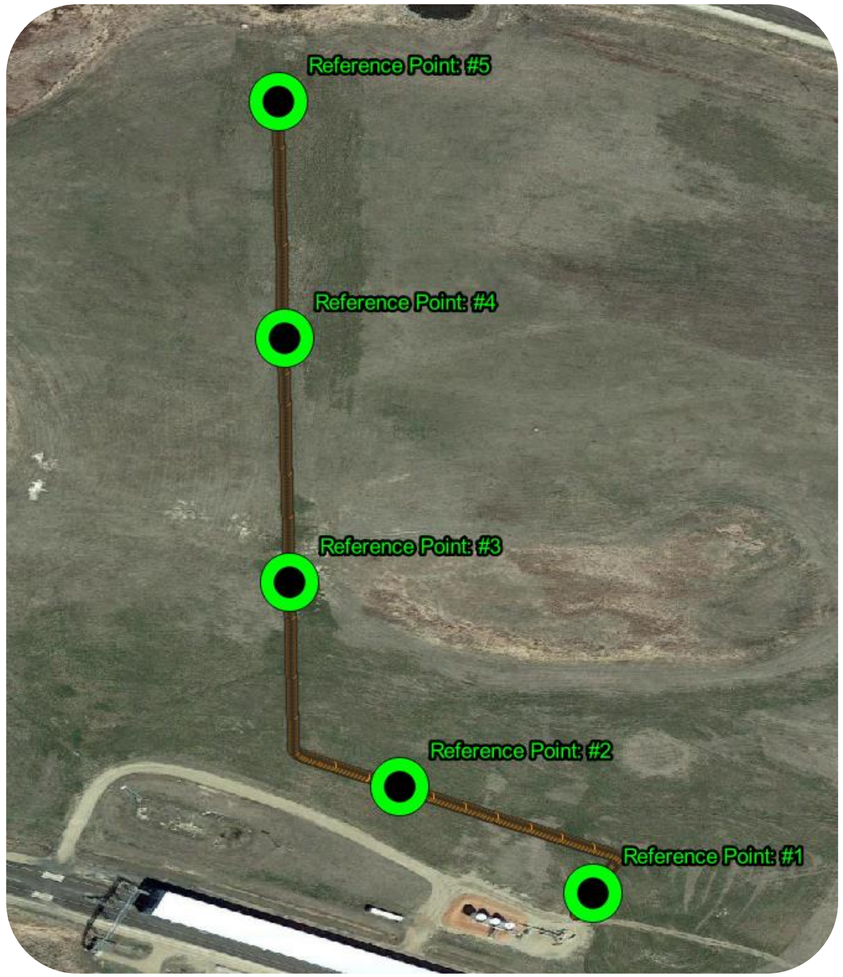
To evaluate the reproducibility, we compare UAV and field machine results over the same area:

- We interpolate the lines to the same spatial density to allow reproducibility evaluation.

Skipper NDT: XY positioning performance

Positioning performance: average XY accuracy 5”- 6”

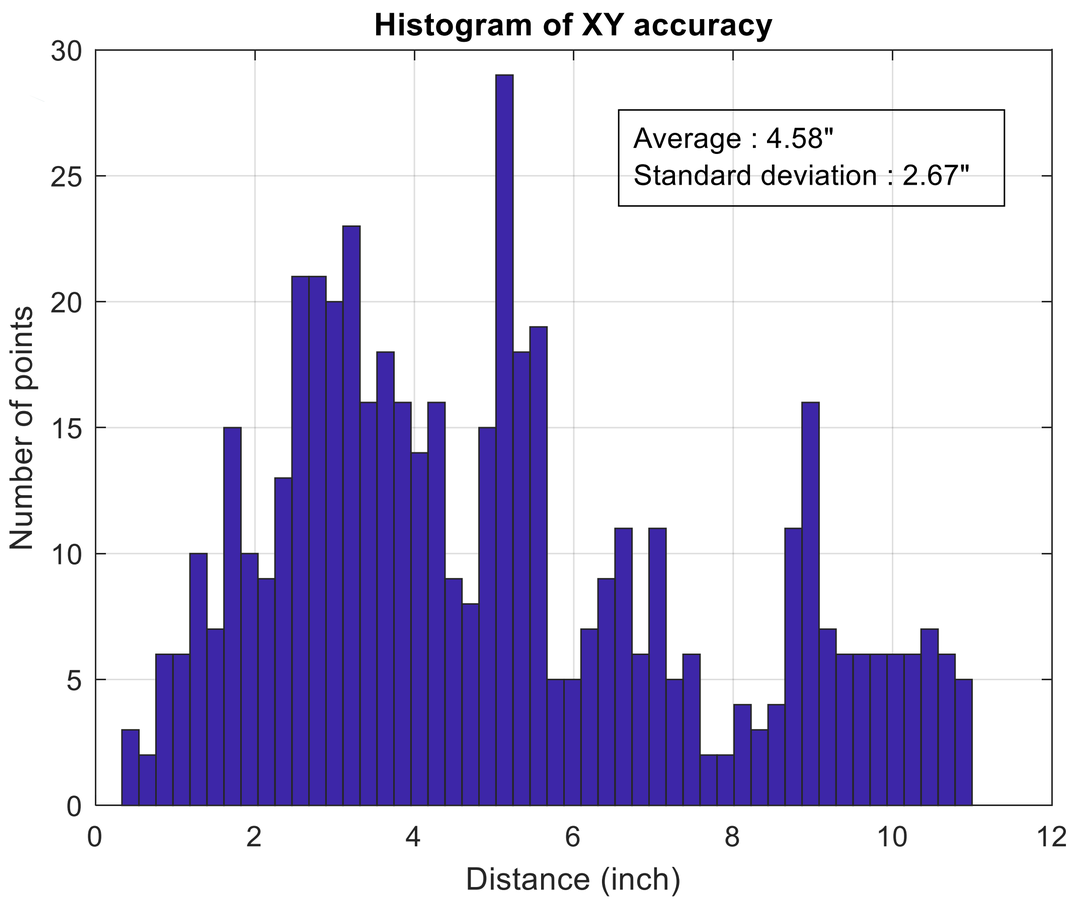
Both methods yield comparable precisions with respect to reference pothole positions.

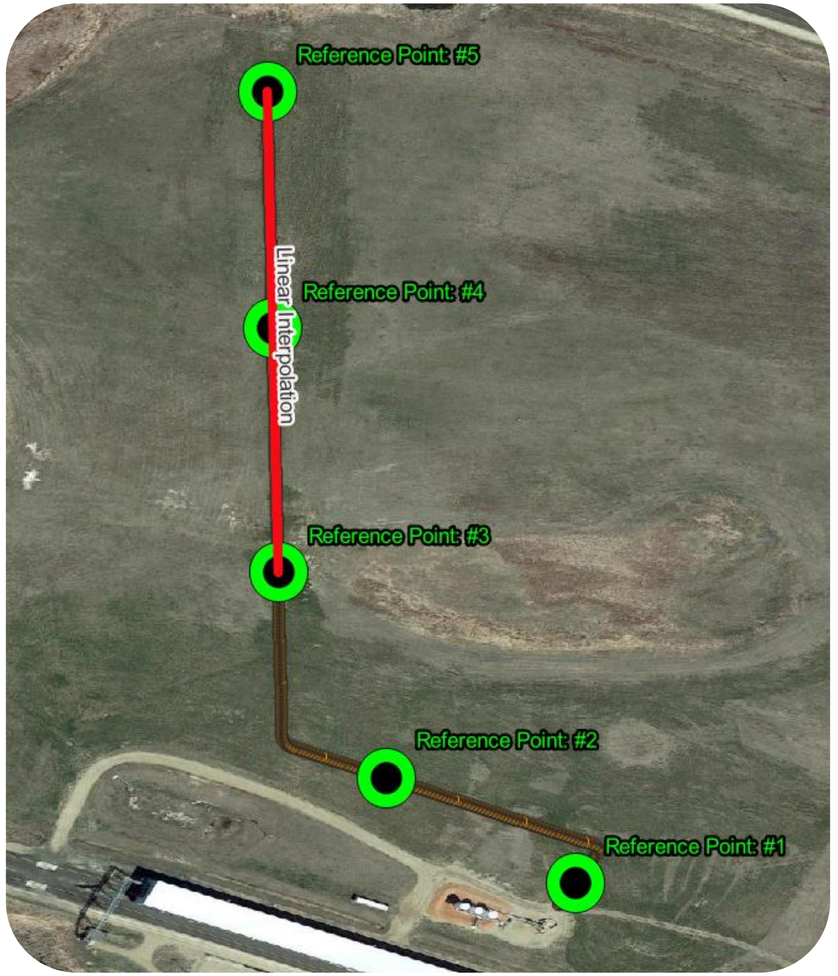


Reference point #	Field Machine delta (inch)	UAV delta (inch)
1	5.70	7.48
2	0.39	1.97
3	6.69	5.43
4	9.84	5.86
5	6.81	5.23

Field machine Repeatability: average precision 4.6” and 2.7” STD

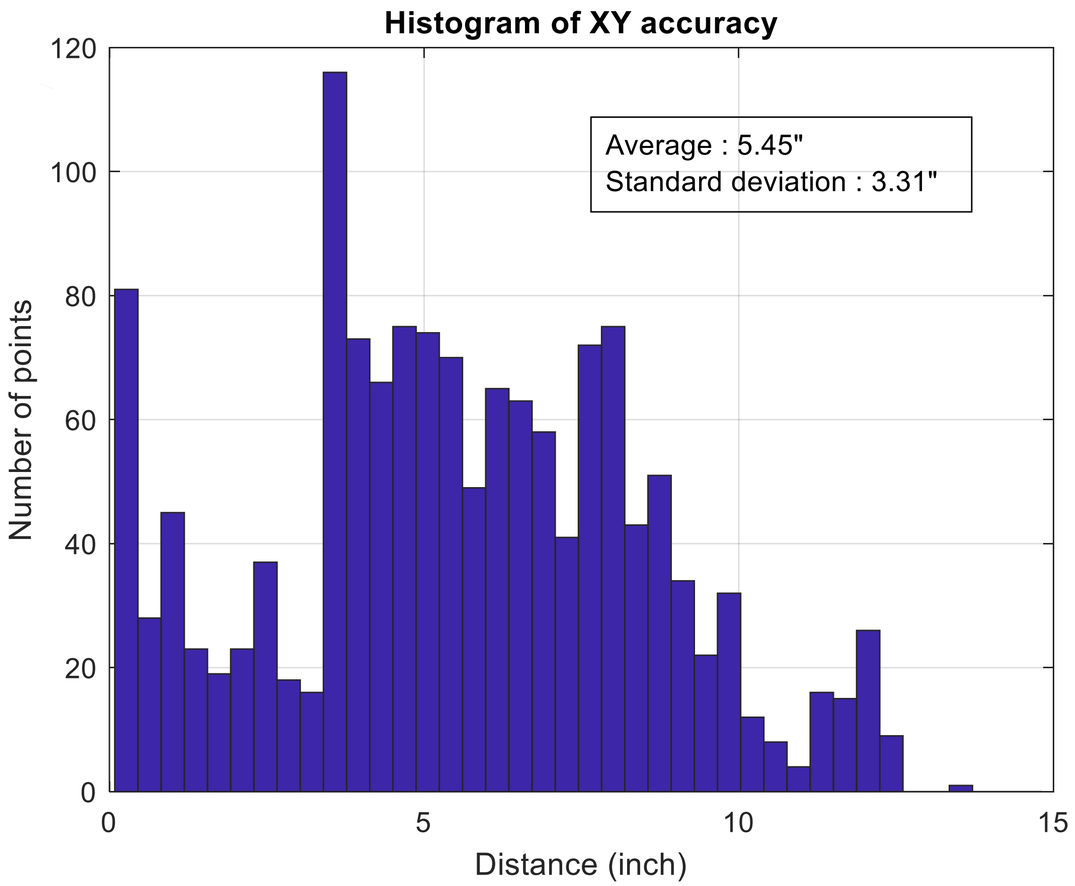
Comparison with interpolated reference : high repeatability over 530 points

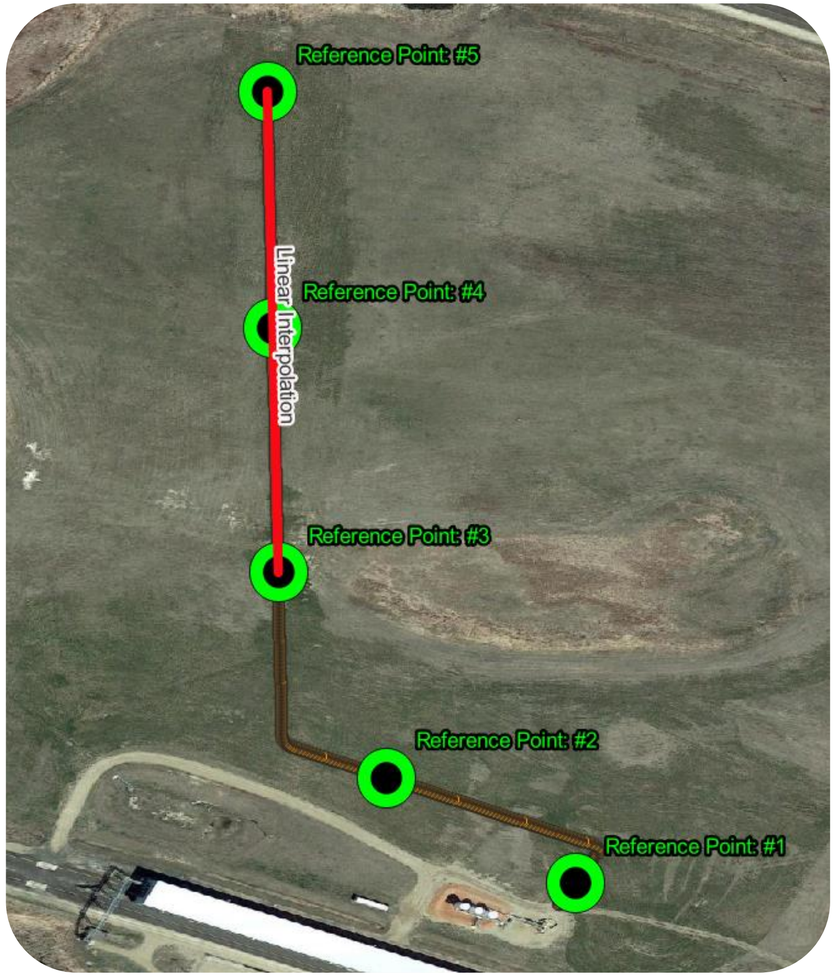




UAV Repeatability: average precision 5.5” and 3.3” STD

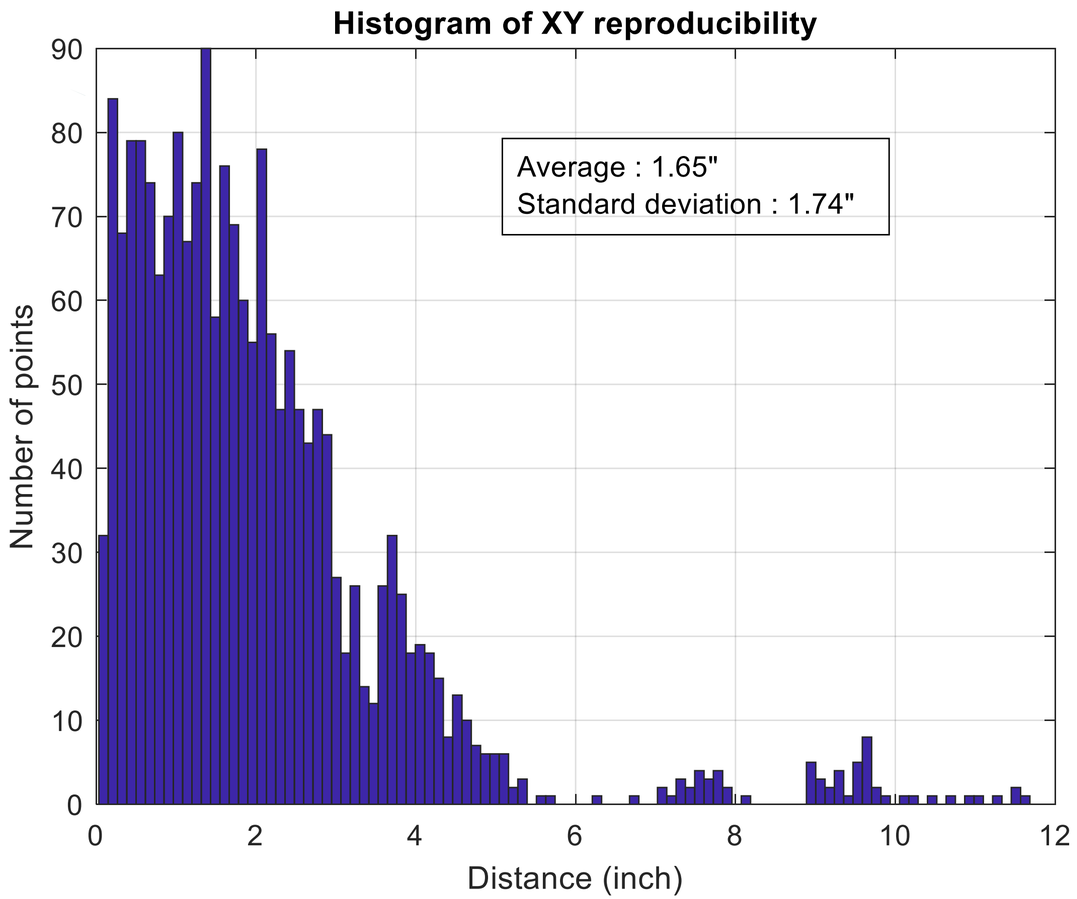
Comparison with interpolated reference : high repeatability over 1,480 points

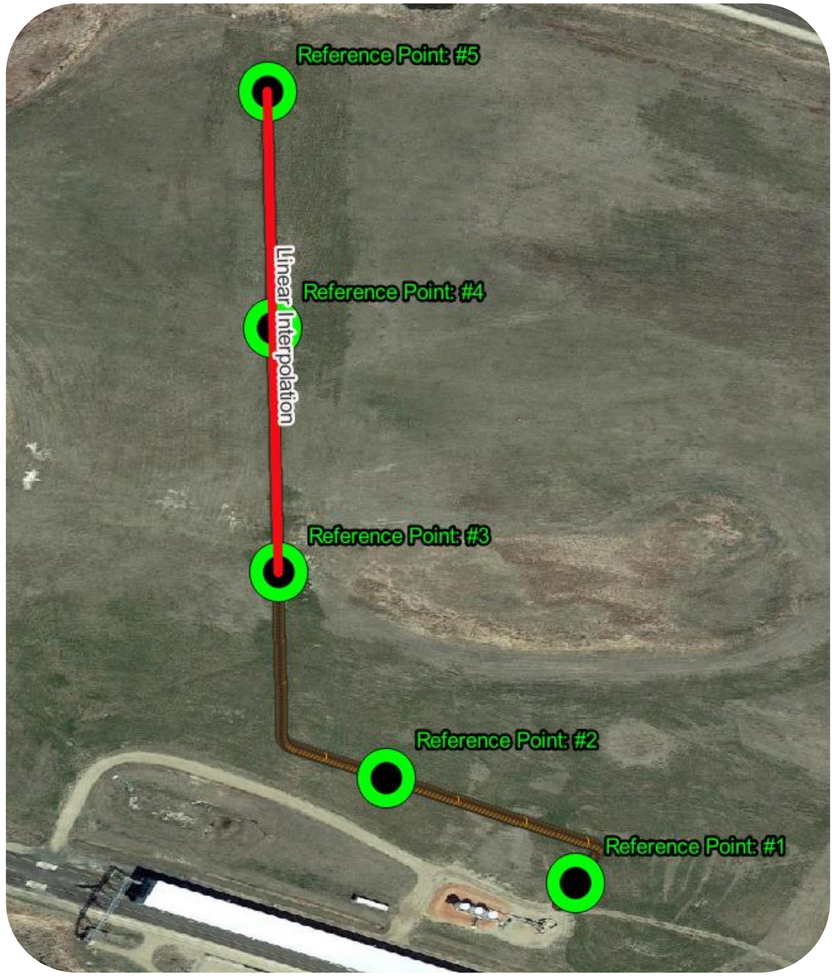




Reproducibility: average 1.7” and 1.7” STD

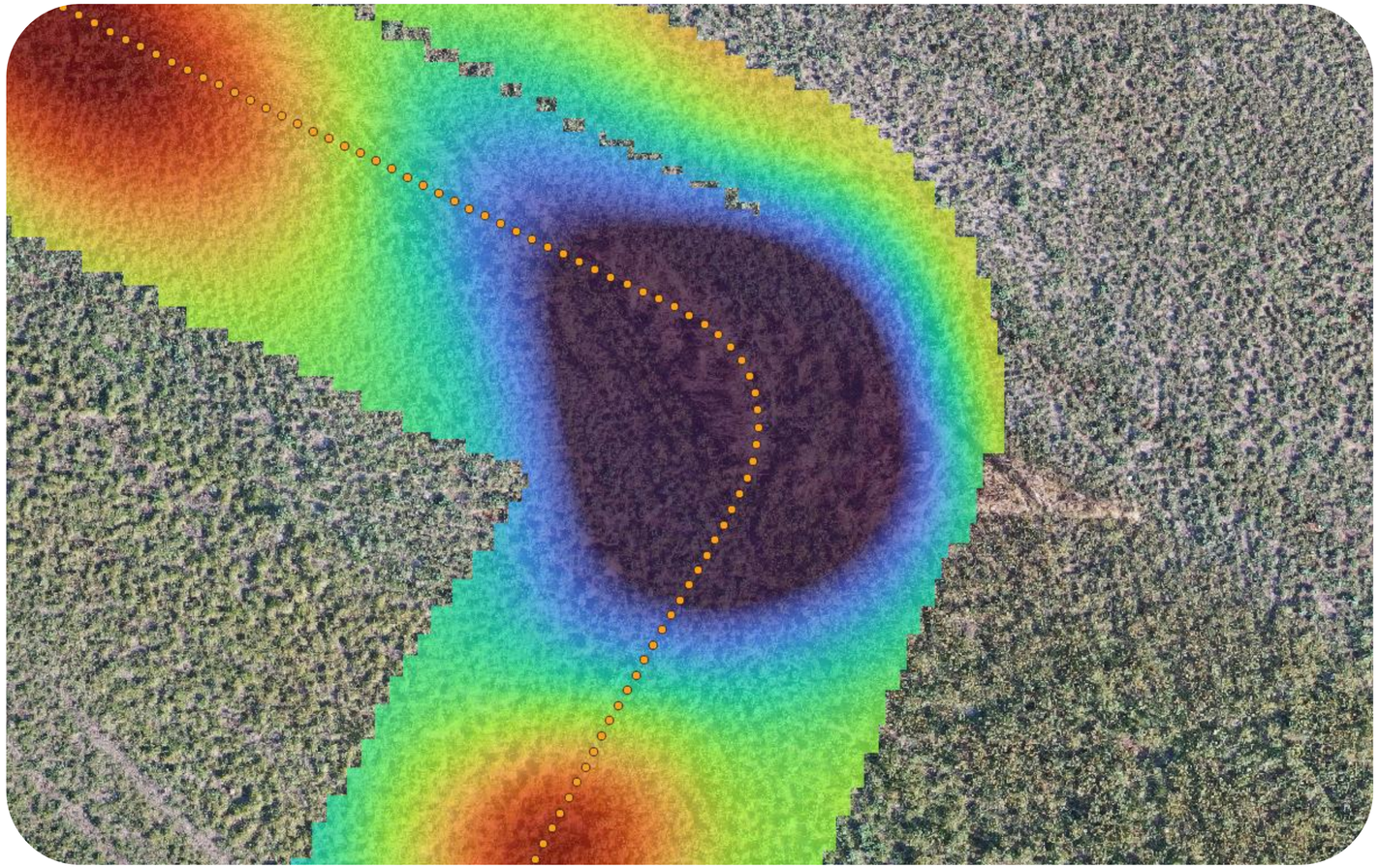
The technology is highly reproducible with < 2” difference with two different field technicians, vectors and acquisitions





Higher positioning density

Both localisation methods allow a higher measurement density to define the pipeline trajectory: useful for bend definition

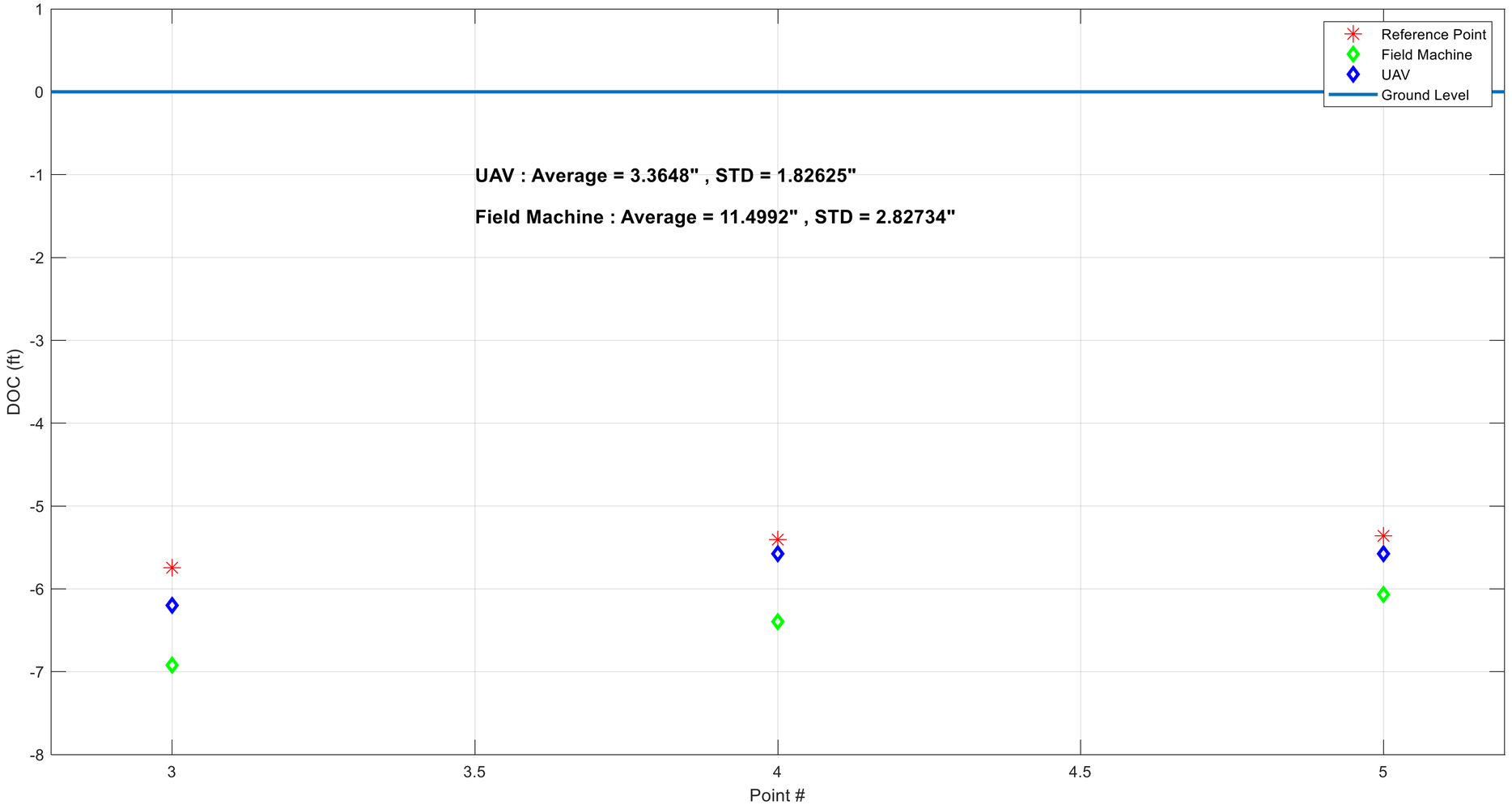


First bend localization with 1 point per 50cm (1.6ft) data density.

Skipper NDT: DOC assessment performance

DOC performance: average 3.4” and 1.8” STD

Both methods yield small dispersions, around 2”

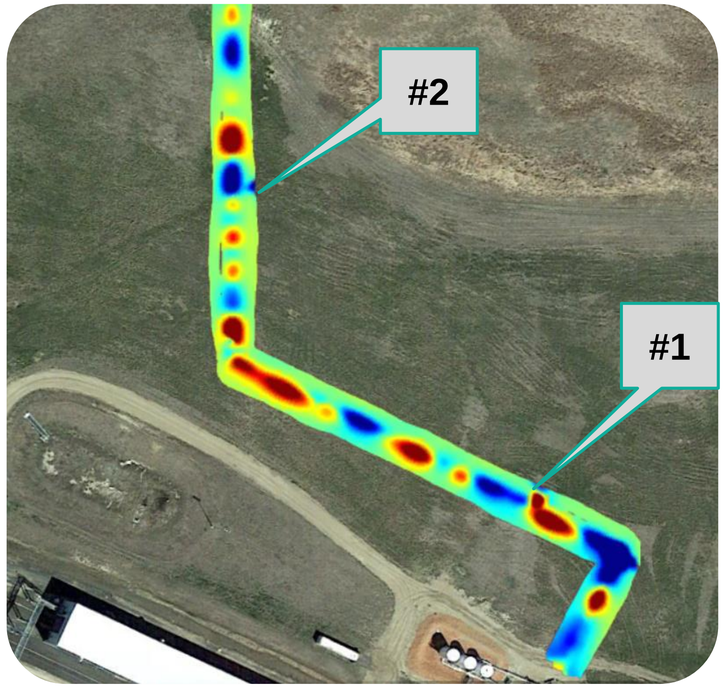


Skipper NDT: magnetic anomalies and 3D render

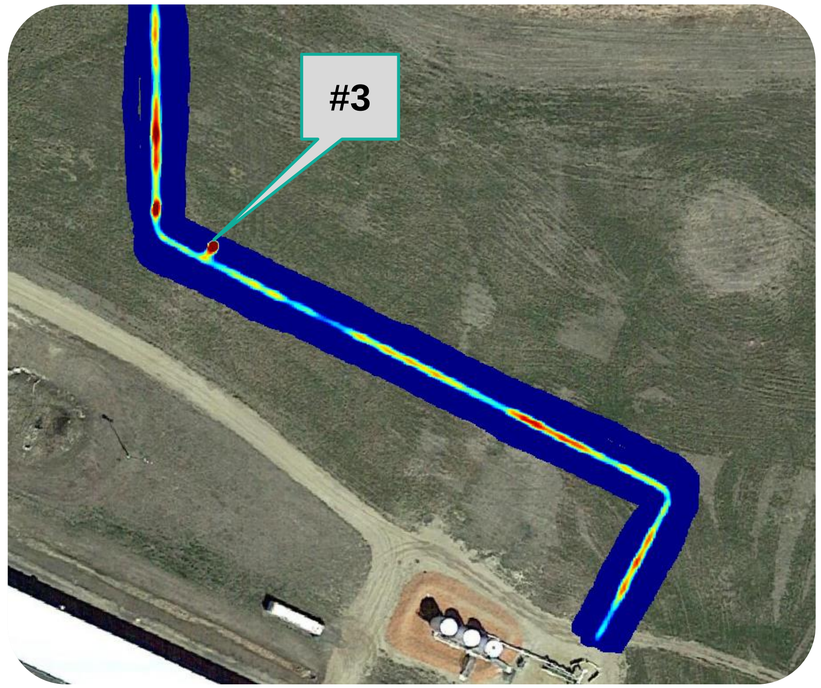
Magnetic anomalies detection

Information about the magnetic environment for integrity purposes

Anomaly #	Longitude (WGS84)	Latitude (WGS84)	Interest level	Comments
#1	-101.7577	48.31511123	Medium	Probably a metallic object buried near the pipeline around the same depth.
#2	-101.7589	48.31591277	Medium	Probably a metallic object buried near the pipeline around the same depth.
#3	-101.7588	48.31543467	Low	Current flow towards the ground or an electrically connected object.



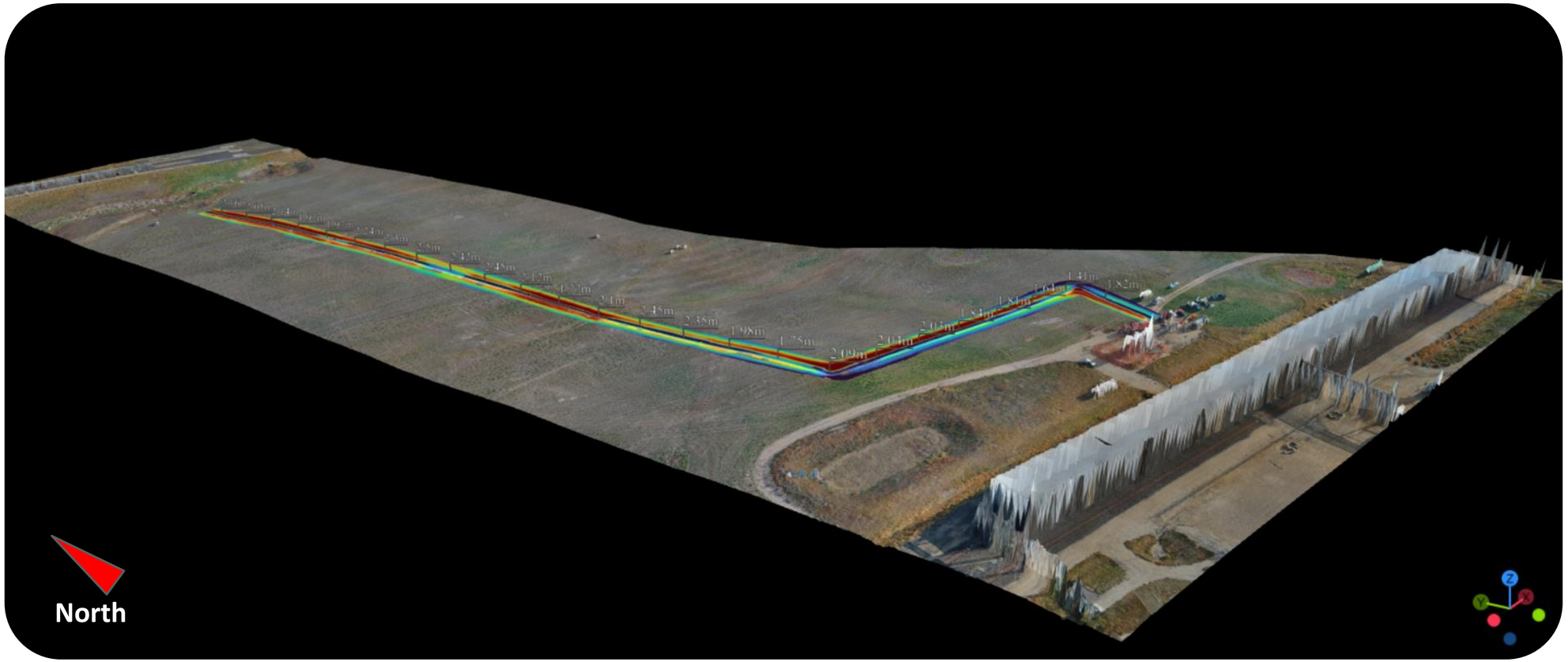
Low frequency magnetic map and its associated magnetic anomalies.



Harmonic frequency magnetic map and its associated magnetic anomaly.

Interactive 3D-render of the RoW

A better way to display data with the 3D representation of the RoW



GIS compatible layers of the Row : Photogrammetry, magnetic map and pipeline.

Conclusion

Skipper NDT technology shows precise 3D-positioning results with a high repeatability and reproducibility

Technology results for the SwRI pilot, 24” diameter pipeline over 1,600ft long inspection area:

DOC average accuracy : 3.4”

XY average accuracy : 5.5”

Repeatability (precision) : **3.3” STD**

Reproducibility : **1.7” Average and STD**

Thank you for your attention