Trial of a Process for the Identification of Reduced Depth of Cover on Buried Pipelines

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Abstract

Third-party interference is widely documented as being a major cause of damage to buried pipelines. In addition to routine surveillance, maintaining a minimum depth of cover is recognized as a key means of mitigation against third-party interference. We know that the depth of cover over pipelines can change with time. Current techniques available for measuring depth of cover on buried pipes require significant effort to produce a high-resolution survey for an entire pipeline.

A UK Innovation project completed for National Grid Gas Transmission has successfully demonstrated a methodology to identify reduced depth of cover over an entire pipeline. This methodology combines ground elevation data with high-resolution inertial measurement unit (IMU) data collected during inline inspection to calculate the pipeline depth of cover.

GPS and pipe depth measurements have been used to verify the accuracy of this method. Using the pipe centerline derived from the IMU data, and ground elevation data collected using light detection and ranging (LiDAR) techniques, depth of cover has been calculated to an accuracy of ±0.149 m root mean square error.

This paper describes the key project steps associated with planning, data collection, data processing, and the validation of results to demonstrate that pipeline depth of cover over an entire pipeline can be accurately determined.

INTRODUCTION

Maintaining a minimum depth of cover is recognized as a key means of mitigation against third-party interference. The United Kingdom Onshore Pipeline Operators' Association (UKOPA) good practice guide for managing pipelines with reduced depth of cover [1] states that the best way of determining pipeline depth of cover is to take measurements as part of an over-line survey. The guide recommends measurements should be taken at 50 m intervals but this should be modified depending on topography of the land and any known local issues such as ground erosion.

ROSEN Group (ROSEN) and National Grid Gas Transmission (NGGT) have trialed a new methodology to identify reduced depth of cover over an entire pipeline. Knowledge of the locations of reduced depth of cover can help NGGT reduce the likelihood of third party interference events occurring.

METHODOLOGY

Ground Elevation Data

Ground elevation data can be collected using several methods. Accurate data for small areas can be collected using differential global positioning system (DGPS) survey equipment. To capture ground elevation data on a larger scale, a LiDAR sensor can be attached to aircraft. LiDAR is a remote sensing method which uses laser light to measure distance to a target and is commonly used to map terrain and surface objects. The advantage of this method is that a large amount of highly accurate data can be collected allowing large areas to be surveyed efficiently.

Internal Inspection

Standards for operating high pressure pipelines require that the condition of a pipeline is established periodically. The condition is established by the use of internal inspection tool on those pipelines which can be monitored using such devices. The inspection device typically includes systems to detect corrosion and geometric anomalies such as dents. In addition, inspection devices often include an inertial measurement unit (IMU), these units contain gyroscopes and accelerometers and are used to calculate position of the inspection device. The IMU data can be linked to known reference locations along a pipeline route to provide an accurate pipe centerline as a series of X, Y, and Z coordinates.

Depth of Cover Estimation

The methodology trialed to estimate depth of cover combines ground elevation data with an accurate pipe centerline derived from internal inspection.

DEPTH OF COVER REQUIREMENTS

In the United Kingdom (UK) guidance on minimum depth of cover for onshore high pressure pipelines is provided in IGEM/TD/1 [2] and PD 8010 [3]. NGGT operate their high pressure pipelines in accordance with IGEM/TD/1 Edition 5.

Table 1 provides a summary of the minimum depth of cover requirements of IGEM/TD/1 (all editions), PD 8010 and other relevant international standards.

Location / Spec.	IGE/TD/1 Edition 1	IGE/TD/1 (Ed. 2, 3 & 4)	IGEM/TD/1 Edition 5	PD 8010-1:2015	ASME B31.8 [4]	AS 2885.1[5]
All (m)	0.91 (3 ft)	1.1				
Rural (m)			1.1	0.9	0.61 (Class 1) 0.76 (Class 2)	0.75
Suburban (m)			1.1	1.2	0.76 (Class 3 & 4)	0.9
Roads (m)			1.2	1.2	0.91	-
Watercourses, canals, rivers (m)			1.2	1.2		1.2
Railways (m)			1.4	1.4 - 1.8	0.91	-
Rocky Ground (m)				0.5		0.9 (W) 0.6 (T1, T2) 0.45 (R1, R2)

Table 1: Standards Requirements for Minimum Depth of Cover

Key:

R1 – Rural	W - Submerged
R2 – Rural Residential	Class 1 – Rural
T1 – Residential	Class 2 – Rural residential
T2 – High Density	Classes 3 & 4 - High density

DEPTH OF COVER ASSESSMENT

The methodology was trialed on a 36" diameter, 45 km pipeline in the UK.

Pipe Centerline

Following completion of the internal inspection the IMU data was processed to produce an accurate pipe centerline. The output from the processing is a spreadsheet containing a series of X, Y and Z coordinates, Figure 1. Points can subsequently be imported into a geographic information system (GIS) and used to create a pipe centerline polyline feature.

Ground Elevation Data

There were two sources of ground elevation data used within this trial, the Environment Agency (EA) LiDAR and Ordnance Survey Terrain 5 data.

The EA [6] offer LiDAR data with a spatial resolution of between 25 cm and 2 m. It is currently stated by the EA that accurate elevation data is available for over 75% of England. The absolute height error is quoted to be less than ±15 cm. This is the root mean square (RMS) error.

The Ordnance Survey (OS) Terrain 5 data [7] has a quoted height error of ±1.5 m. This is the RMS error for urban and major communication routes. For rural and mountain and moorland areas the error is higher at ±2.5 m. The spatial resolution for all OS Terrain 5 data is 5 m.

log dist. [m]	latitude [deg]	longitude [deg]	height Z [m]	MARK_PNT
0.002	52.54601140	-1.17715253	85.938	T
2.646	52.54600745	-1.17711417	85.934	F
3.443	52.54600619	-1.17710264	85.93	F
6.419	52.54600176	-1.17705946	85.92	F
7.551	52.54600011	-1.17704303	85.911	F
7.875	52.54599963	-1.17703834	85.896	F
8.14	52.54599924	-1.17703451	85.868	F
8.386	52.54599887	-1.17703100	85.826	F
8.632	52.54599851	-1.17702753	85.766	F
8.919	52.54599809	-1.17702358	85.678	F
9.304	52.54599754	-1.17701838	85.541	F
16.037	52.54598812	-1.17692823	82.959	F
17.946	52.54598541	-1.17690261	82.237	F
18.277	52.54598493	-1.17689809	82.125	F
18.546	52.54598453	-1.17689436	82.049	F
18.795	52.54598417	-1.17689083	81.996	F
19.038	52.54598382	-1.17688734	81.96	F
19.[illegible]	[illegible]8344	[illegible]337	81.938	F

Figure 1: Example of points provided from post inspection data processing

Figure 2: Example Depth of Cover Report
(Aerial imagery source: Esri, DigitalGlobe, GeoEye, Earthstar Geographisc, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community)

Given the better spatial resolution and greater accuracy of the EA LiDAR data, this was the preferred dataset for use in this trial. However, examination of the available EA LiDAR data identified that there was not full data coverage of the trial pipeline. A 6 km missing section of EA LiDAR data was supplemented with OS Terrain 5 data for the trial.

Reporting

A key requirement is providing a depth of cover report for the pipeline. Figure 2, shows an example report using color bands to represent the estimated depth of cover along the pipeline. Table 2 shows the classification that has been used for the field trial.

Figure 3 shows an example of ground and pipe elevation plotted according to distance along the pipeline. At this location the pipeline crosses a series of embankments and ditches. The bottom image is a hillshade rendering of ground elevation data to aid visualization. The example demonstrates how the inspection tool has measured the change in pipe elevation as the pipe passes beneath the ditch crossing. The increase in depth of cover associated with the two embankments is also evident.

INFIELD VERIFICATION

To assess the accuracy of the results obtained from the depth of cover assessment, infield verification was performed along 10 sections of the pipeline route. The depth of cover and pipeline position were measured at regular intervals (approximately 2 – 3 m) using a Vivax Metrotech vLoc-5000 pipe and cable locator, the position was recorded using a Topcon Hiper SR GNSS unit and Topcon FC – 500 GPS unit.

Classification	Depth of Cover Range (m)	Colour
1	Depth < 0.6	Red
2	0.6 m ≥ Depth < 1.1 m	Orange
3	1.1 m ≥ Depth ≤ 2.5 m	Green
4	Depth > 2.5 m	Blue

Table 2: Classification for reporting depth of cover

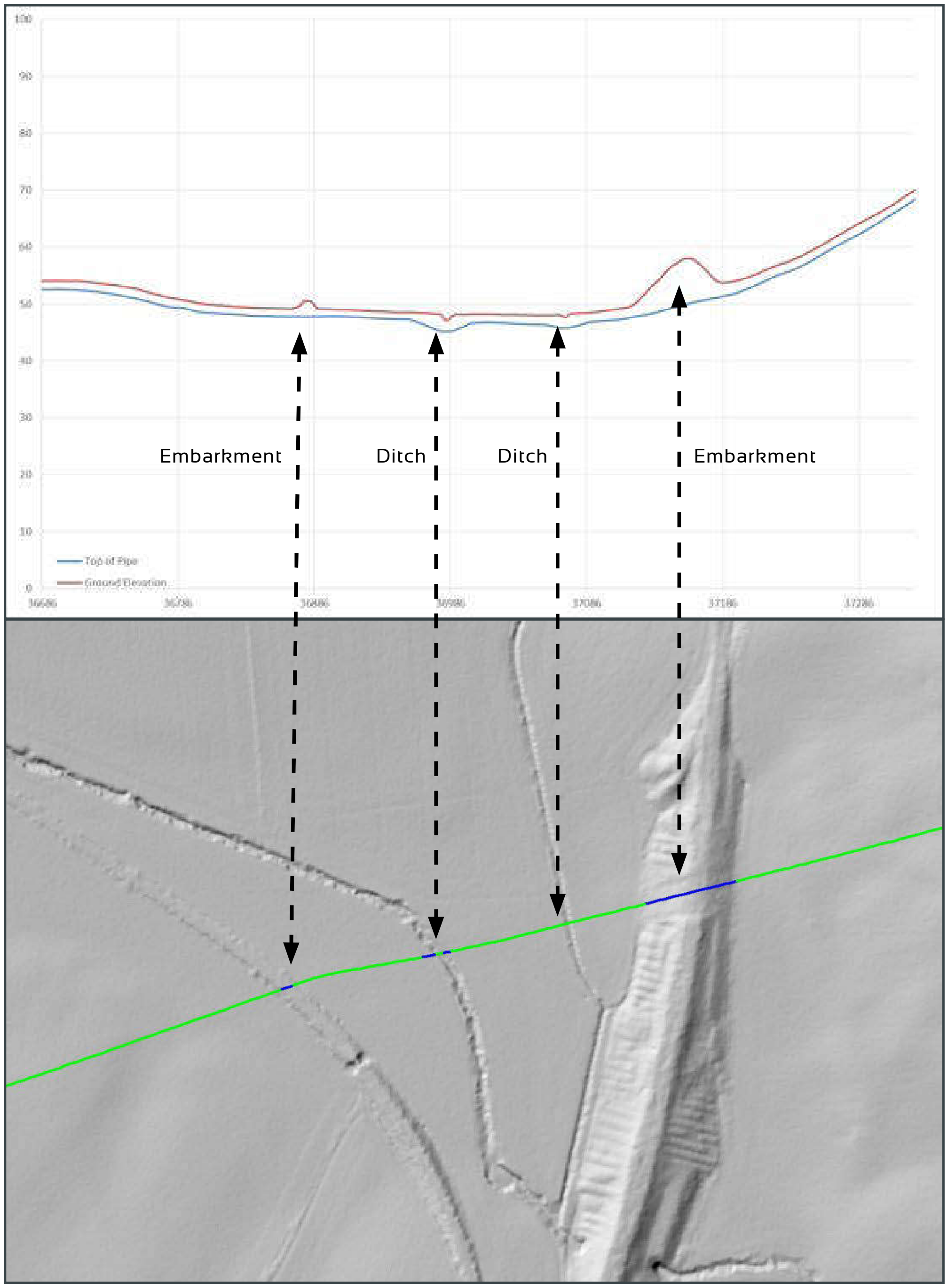

Figure 3: Example of ground and pipe elevation combined where an embankment and ditch

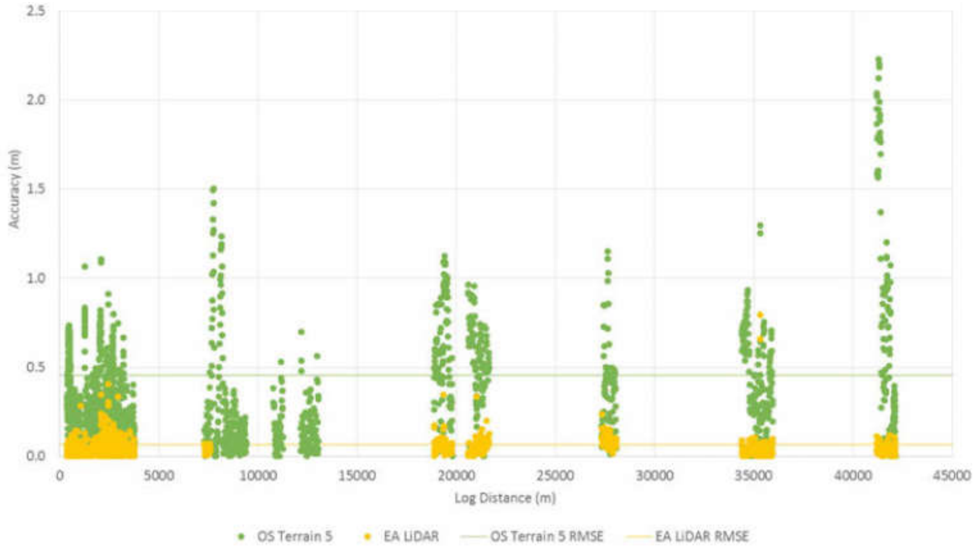

Figure 4: Accuracy Assessment of Ground Elevation Data

It can be seen that the OS Terrain data has a lower accuracy than the EA LiDAR data.

The OS Terrain data has a lower stated accuracy for the product and also has a lower resolution.

The consequence of lower resolution is that the detail of ground features is missing from the data, see Figure 5.

This can be seen at distances 2120 m and 2320 m.

Ground Elevation Data

To assess the accuracy of ground elevation data a comparison between infield measurements, EA LiDAR and OS Terrain 5 data was made. Figure 4 shows an accuracy assessment of the EA LiDAR and OS Terrain data against in field measurements. A ±0.07 m RMS error was calculated for the LiDAR data and ±0.46 m for the OS Terrain data. This is within the stated accuracy for each product.

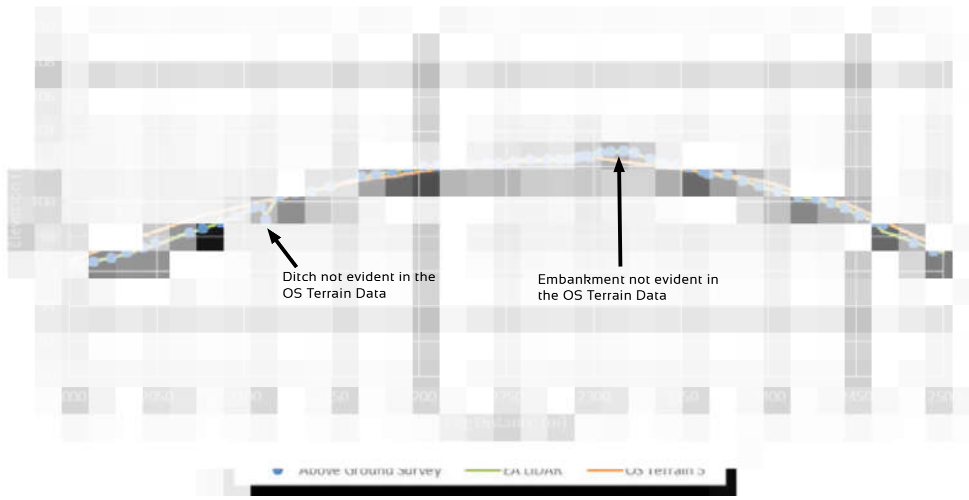

Figure 5: Comparison of Ground Elevation Data sets

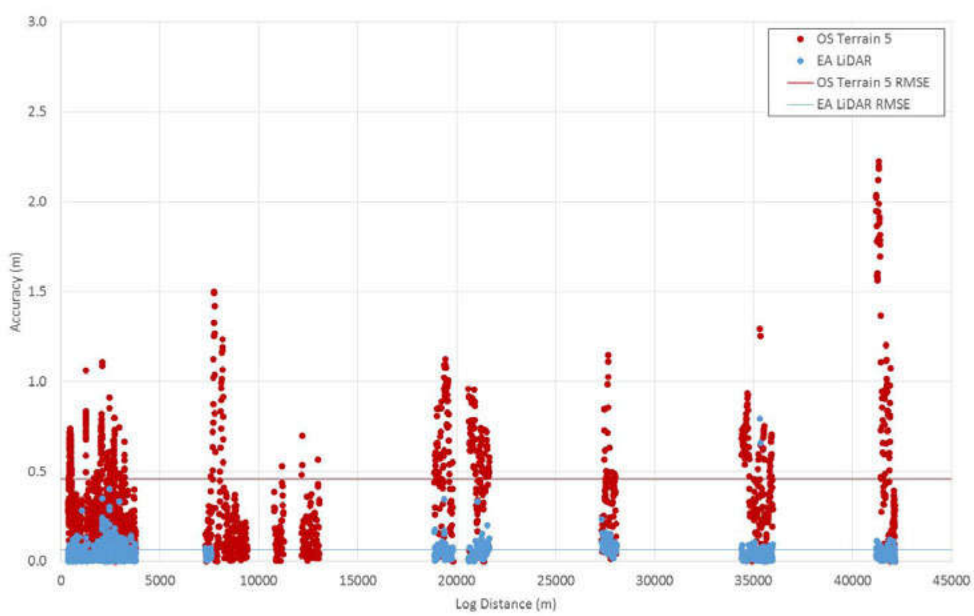

Figure 6: Accuracy Assessment at all 10 Pipe Sections

Depth of Cover

To assess the accuracy of depth of cover results, a comparison between the estimated depth of cover and infield measurements was performed.

Figure 6 shows the accuracy assessment using the pipe centerline data for all 10 pipe sections. This includes depth of cover calculated using EA LiDAR data and OS Terrain 5 data.

The RMS error for depth of cover based on EA LiDAR data is ±0.15 m and for the OS Terrain data is ±0.46 m.

CONCLUSIONS

- The trial has successfully demonstrated ROSEN's methodology to estimate the depth of cover over pipelines. This includes producing an accurate pipeline centreline from data obtained during a routine internal inspection, combined with ground elevation data available from the Environment Agency (EA) to calculate depth of cover.
- The results of the calculation have been validated against infield depth of cover measurements obtained using a pipe and cable locator. The accuracy of the depth of cover results has been calculated using a root mean square (RMS) error method. This has determined an overall accuracy of ±0.15 m using EA LiDAR data.
- Infield ground surface measurements were compared with the EA LiDAR and OS Terrain data. A RMS error of ±0.07 m was calculated for the EA LiDAR data and ±0.46 m for the OS Terrain data. These show that the accuracy of the data is within the stated product specifications.

References

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