Geohazard and Infrastructure Modeling and Monitoring in 3D with the Mapped Underworld Dimension (MUD™) System:

# Auracle Geospatial

## CASE STUDY: RIPLEY SLIDE

2022

AURACLE GEOSPATIAL

# OVERVIEW

Auracle is a remote sensing and geospatial technology company specializing in airborne and satellite applications that serve global clients in mineral exploration, oil and gas, engineering, natural resource management, waste management, railways and defense.

Auracle's technology maps and models the Earth's surface down to bedrock—hundreds of meters underground and through water. The 3D **M**apped **U**nderworld **D**imension (MUD™) Model, the foundation of our technology, makes it possible to "see through" water, vegetation, ice, trees, rocks and soil to identify structures and lithologies. This technology makes it possible to explore and map, from space, with millimeter-level accuracy, day or night, through all weather, and in remote or inaccessible areas. With the MUD™ system, we can measure as little as 2mm of movement in any location, in 3D. Auracle's systems require no permits, are cost effective, are completely discrete, and provide actionable information to key decision-makers.

Auracle also generates highly accurate Continuous Surface Elevation Models© (CSEMs), specializing in shallow lake and river bottoms. These elevation models replace manual surveys of shallow lakes and rivers in geophysics, particularly gravity surveys and provide valuable terrain information needed in exploration.

Using high-definition satellite video and imagery, we construct Hyperspatial Digital Elevation Models© (HDEMs) as a monitoring system that identifies subtle movements and changes in infrastructure such as pipelines, dams, ports, landfills, roads, and bridges. This early warning system supplies our clients with a cost-effective way to monitor and manage potential environmental damage caused by geo-hazards, industrial activities, and natural disasters.

Imbedded in each project is our commitment to environmental responsibility, efficiency, and economic success. Our methods create no unnecessary human footprint, require no social license, and do not cause cultural interference.

# TECHNICAL ADVANCEMENTS

## MAPPED UNDERWORLD DIMENSION (MUD™)

Over the last 20 years, Auracle has developed a unique method of using satellites and other airborne systems, to monitor, detect and map the impact of structural movement on surface and subsurface assets such as pipelines, railroads, bridge abutments, slopes, mines, and other critical infrastructure and assets. Auracle's pioneering work began in satellite hyperspectral and synthetic aperture radar. Further advancements in satellite radar tasking and analytic systems paved the way to look through vegetation, land cover and water providing the ability to define subsurface geological structures, features and units. With exposing the non-outcropping near surface, Auracle corrected and improved geological maps and models with structural features including non-apparent strike and dip.

In 2012, Auracle began experimentation to identify and analyze features and combinations of variables that could be used as surface and subsurface 'training sites', from which signals data would be developed as search parameters for geohazards. By combining proprietary acquisition and processing algorithms, Auracle developed a robust automated tool for identifying and monitoring geohazards. This system works at, near and under the earth's surface to "see" through deep vegetation, ice, snow, water, and overburden. The MUD™ system was born.

Our positionally accurate fused radar technology uses subsequent satellite images collected over time to provide a reliable "state of change" analysis. This allows Auracle to alert and define existing and potential hazards for operators. The MUD™ system replaces point or grid-based surveys to precisely detect movement or deformation under the Earth's surface, resulting in actual not derived ground information.

## KEY FEATURES

- Monitors surface and subsurface movement well in advance of events that threaten infrastructure
- Operates day and night, through all weather
- Measures as little as 2 mm of change in 3D
- Creates no human footprint and requires no permit

MUD™, the foundation of this monitoring technology "sees" structure to monitor geohazards through:

- 100 meters of water
- 100 meters of sand and tills
- dense valley vegetation
- 30 meters of glacial ice and deep glacial tills

| Satellite Borne C Band Synthetic Aperture Radar Monitoring Types | | | | | |
|---|---|---|---|---|---|
| | Conventional Change Detection | | | | **Auracle** |
| | CCD | InSAR | DiffinSAR | PSinSAR | **3D MUD™** |
| Monitoring Frequency | >20 Days | >20 Days | >20 Days | >20 Days | **<40 Hours** |
| 2.5mm Displacement Minima Detectable | x | ✓ | ✓ | ✓ | ✓ |
| Complete Area | x | x | x | x | ✓ |
| Eliminates Layover | x | x | x | x | ✓ |
| Eliminates Distortion | x | x | x | x | ✓ |
| Uniform Spatial Accuracy | x | x | x | x | ✓ |
| Models and Monitors on Surface | ✓ | ✓ | ✓ | ✓ | ✓ |
| Models and Monitors Under Land Surfaces | x | x | x | x | ✓ |
| Models and Monitors Under Water | x | x | x | x | ✓ |

*Table 1 – SAR Monitoring Types Comparison to MUD™*

## POINT CLOUDS AND SECTION VIEWS

Point clouds are produced, in cases of land use, from the stereo radar pair using Auracle's proprietary algorithm. The clouds are then fused and further analyzed in 3D for density using a search radius of 5 meters and are not vertically exaggerated. In addition, these 3D Point Clouds represent competent reflectors at and under the earth surface which can be analyzed for their variability and used to correct and aid 3D seismic and other geophysical inversions. Auracle's 3D Point Clouds represent the subsurface and like LiDAR can be viewed using common XYZ or LAZ format software.

The following figures illustrate the ability to identify the differentiation, showing the 4 variables previously discussed:

- Difference in densities
- Difference in textures
- Differences in resistivities
- Structural bounds

In addition, signals representing these variables form the signature of:

- Underlying Bedrock
- Various composition alluvial facies
- Saturated material

# CASE STUDY: RIPLEY SLIDE

Ripley Slide case study proves the Auracle 3D MUD™ system adds informational context and understanding of potential risk from land and slope instability, erosion and subsidence in the subsurface and underwater within the entire study area.

# CASE STUDY:  Ripley Slide

The study site is the Ripley Slide (*Image 1*) within the Thompson River Valley, 7 kilometers south of Ashcroft, British Columbia, Canada.  Ripley is one of 9 landslides that have occurred within an 8-kilometer section of the Thompson River Valley.

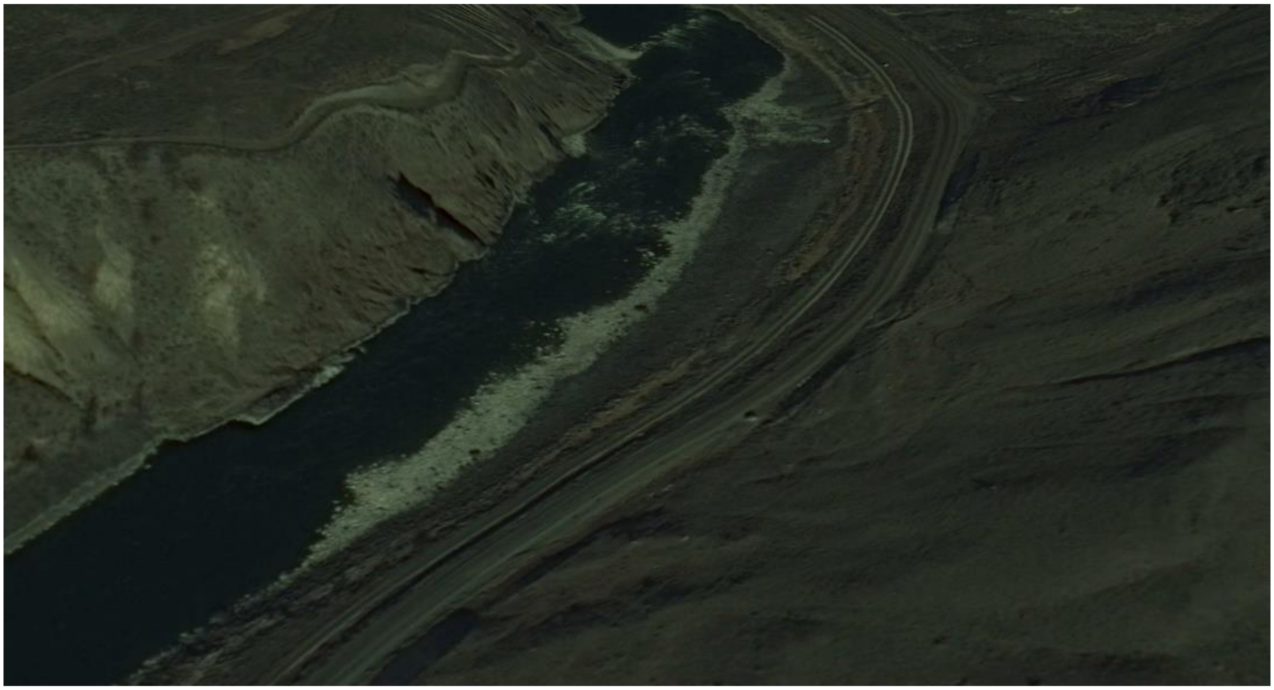

*Image 1 - Ripley Slide in Thompson River Valley*

This slide has been characterized as a postglacial slow-moving slide within a narrowly constrained transportation and infrastructure corridor.  A major river, a national highway, an interprovincial pipeline, a high-tension electrical powerline and two national railroads all lie within the slide zone.  These railroads provide the vital rail link for Canada to the Port of Vancouver.

Government agencies, universities, engineering firms and the rail industry have extensively researched and analyzed this critical transportation and infrastructure corridor.   In this study, Auracle used three types of archived data:

- Ground Penetrating Radar (GPR)
- Drill log results
- Corner reflector placements

This study duplicated the specific geographic locations and depths of sections collected by the Geological Survey of Canada (Open File 8062 survey, 2017.)

The purpose of this study was to correlate the 3D MUD™ system with established findings and to demonstrate how the 3D MUD™ system adds critical layers of information from the surface, subsurface and underwater to identify and monitor geohazards.

**Image 2**: Shows the Auracle CSEM or surface elevation model containing both the land elevation and the river-bottom elevation or bathymetry.

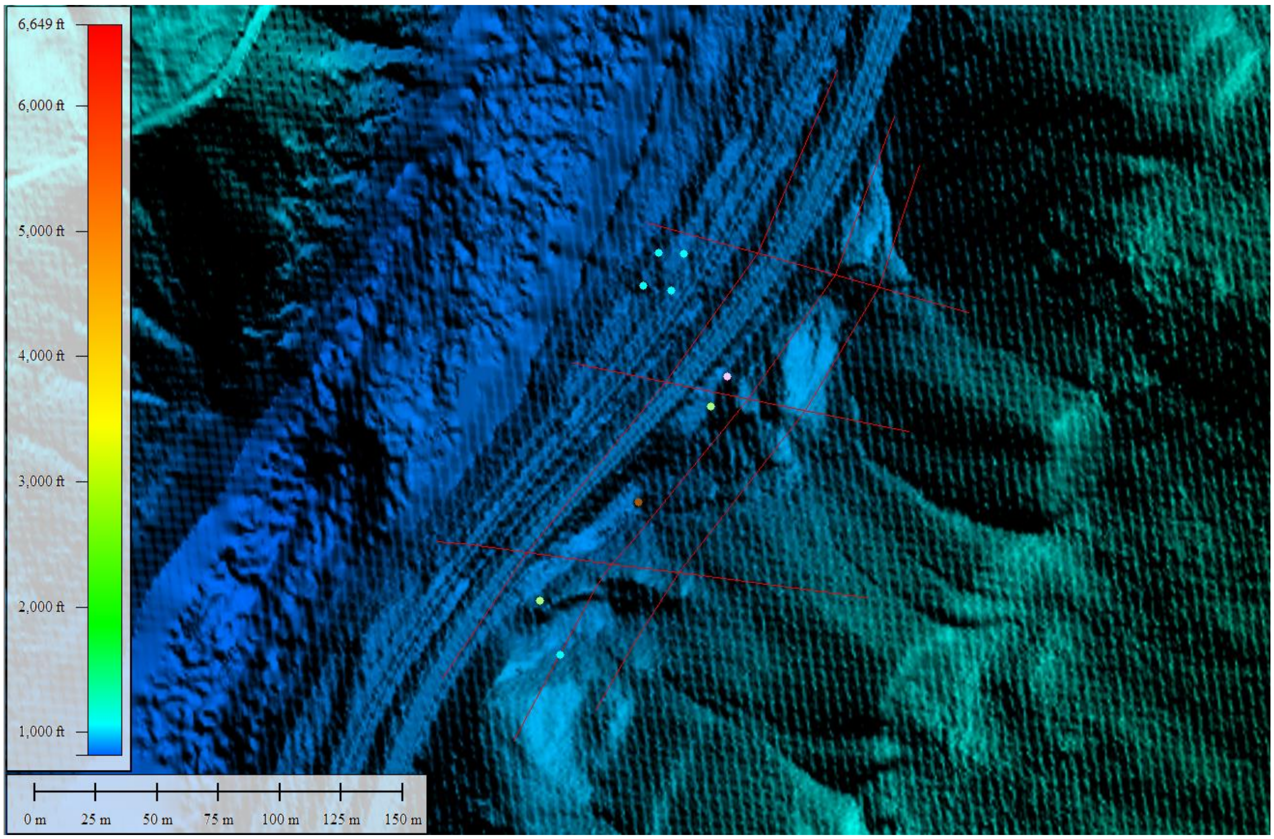


*Image 2 - CSEM with Drill Holes as colored dots and GRP lines shown in red.*

**Image 3**: Shows the CSEM and outlines the specific drill holes compared in the MUD™ system point cloud volume slice and the centerline of the volume slice or section.

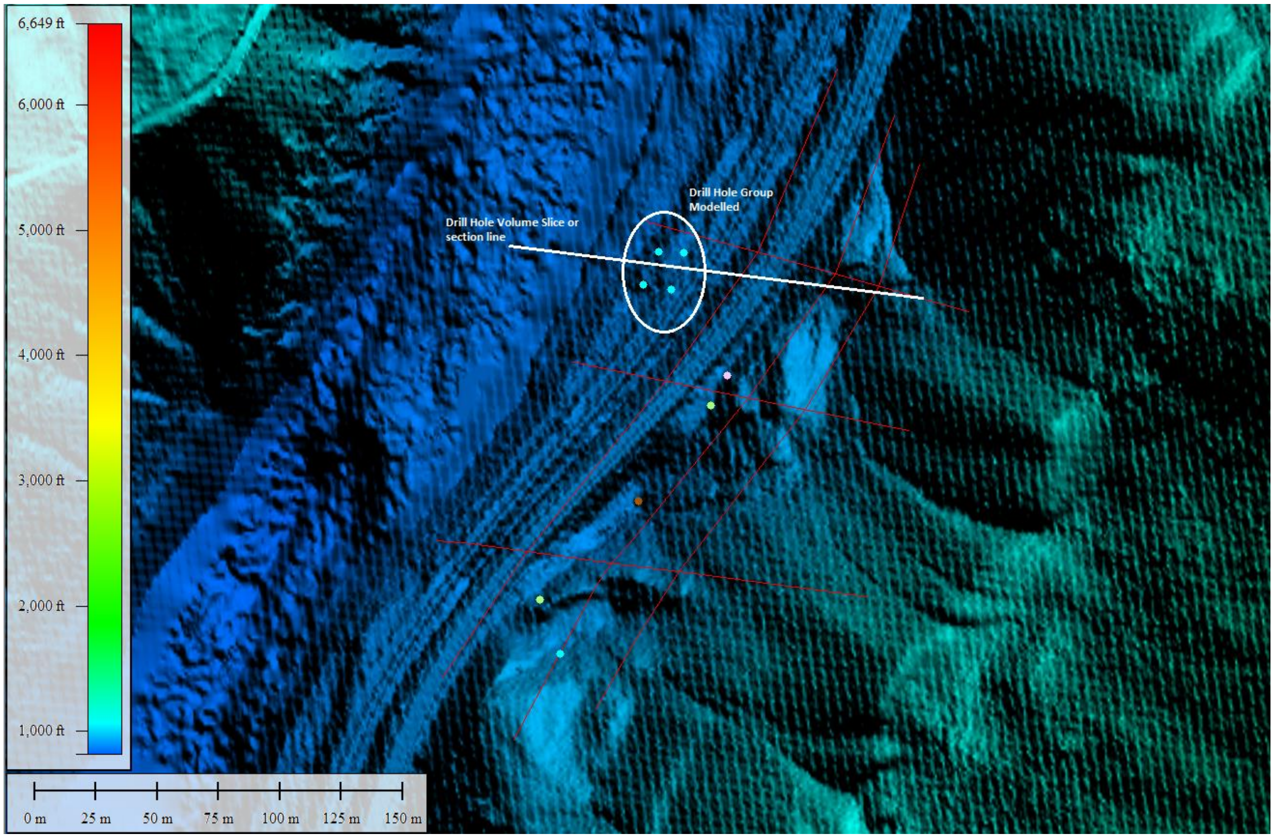


*Image 3 - Specific drill hole and volume slice location.*

**Image 4**: Shows the drill hole intersections as color symbols within the 3D point cloud volume slice.

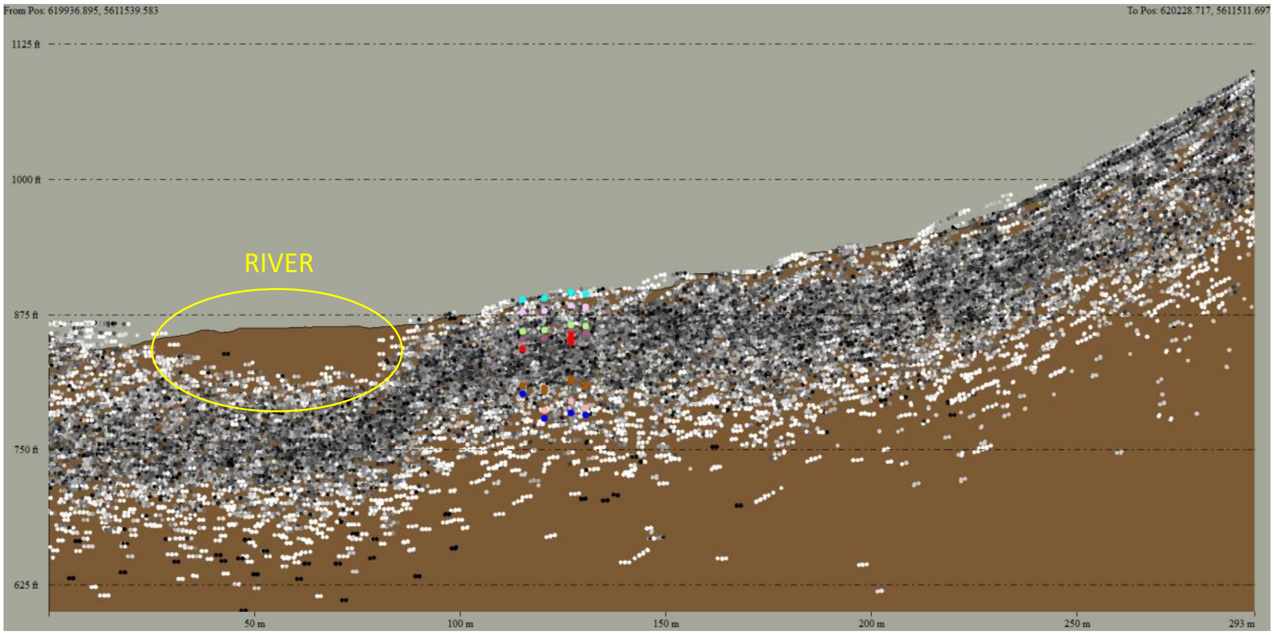


*Image 4 - Drill hole intersections of differing strata shown as different colored dots in the 3D MUD™ system subsurface point cloud volume slice.*

**Image 5**: Same volume section and drill holes as Image 4 but with the 3D MUD™ system classifications of composition displayed as separate colors.

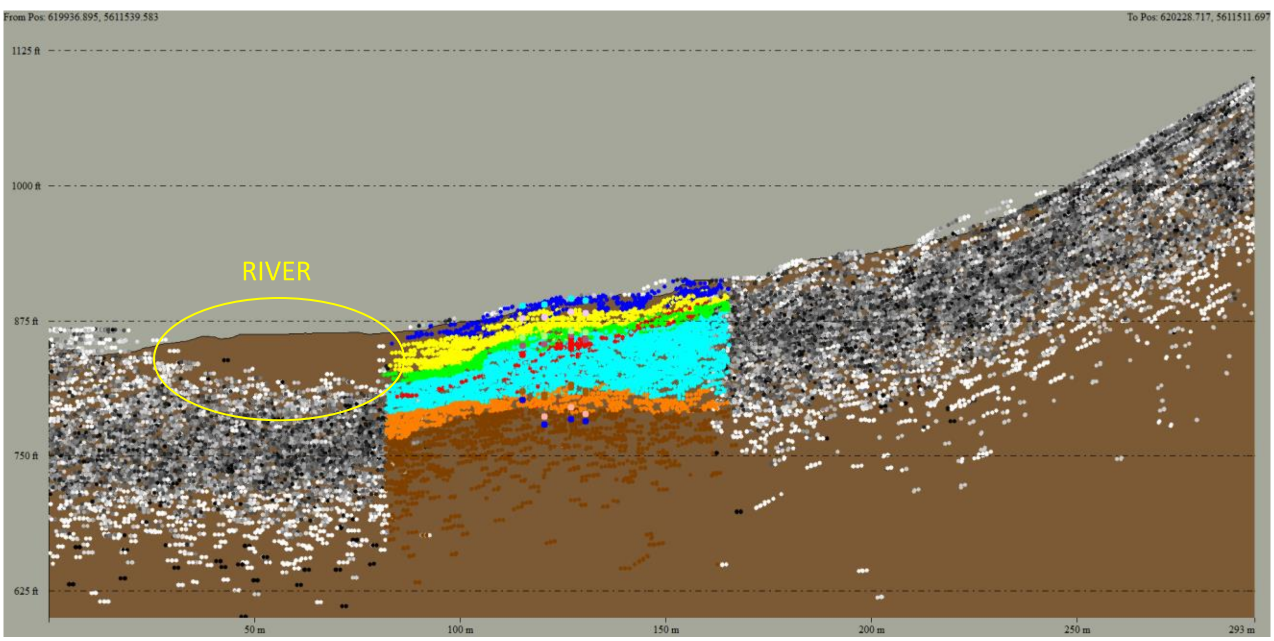


*Image 5 - Drill Holes classifications of the 3D MUD™ system point cloud volume slice.*

**Image 6**:  This 3D MUD™ point cloud volume section shows tracings of classification divisions and their alignment with drill intersections.

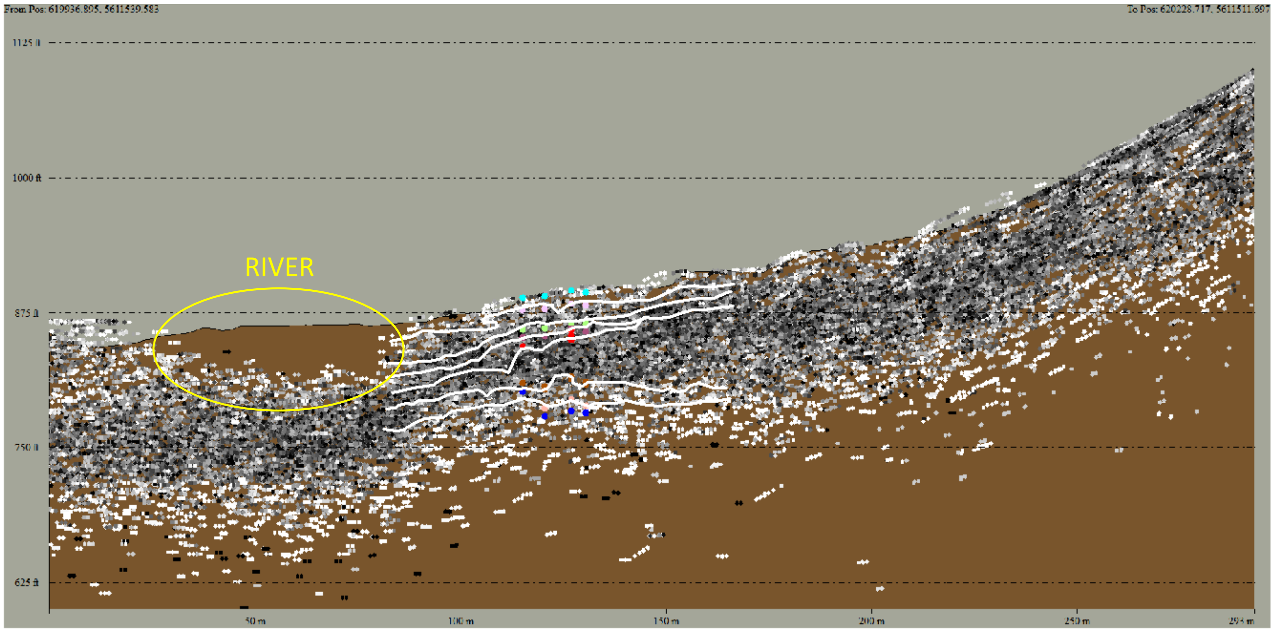


*Image 6 - Showing classification tracing lines and their alignment with drill intersections.*

**Image 7**: Shows the location of the cross section labeled T-GPR Line C of the GPR section extracted from 2017 Geological Survey of Canada Open File entitled:

*Ripley Landslide: the geophysical properties of a slow-moving landslide near Ashcroft British Columbia D. Huntley, P. Bobrowsky, N. Parry, C. Candy, and M. 8062 (page 15 Figure 3)*

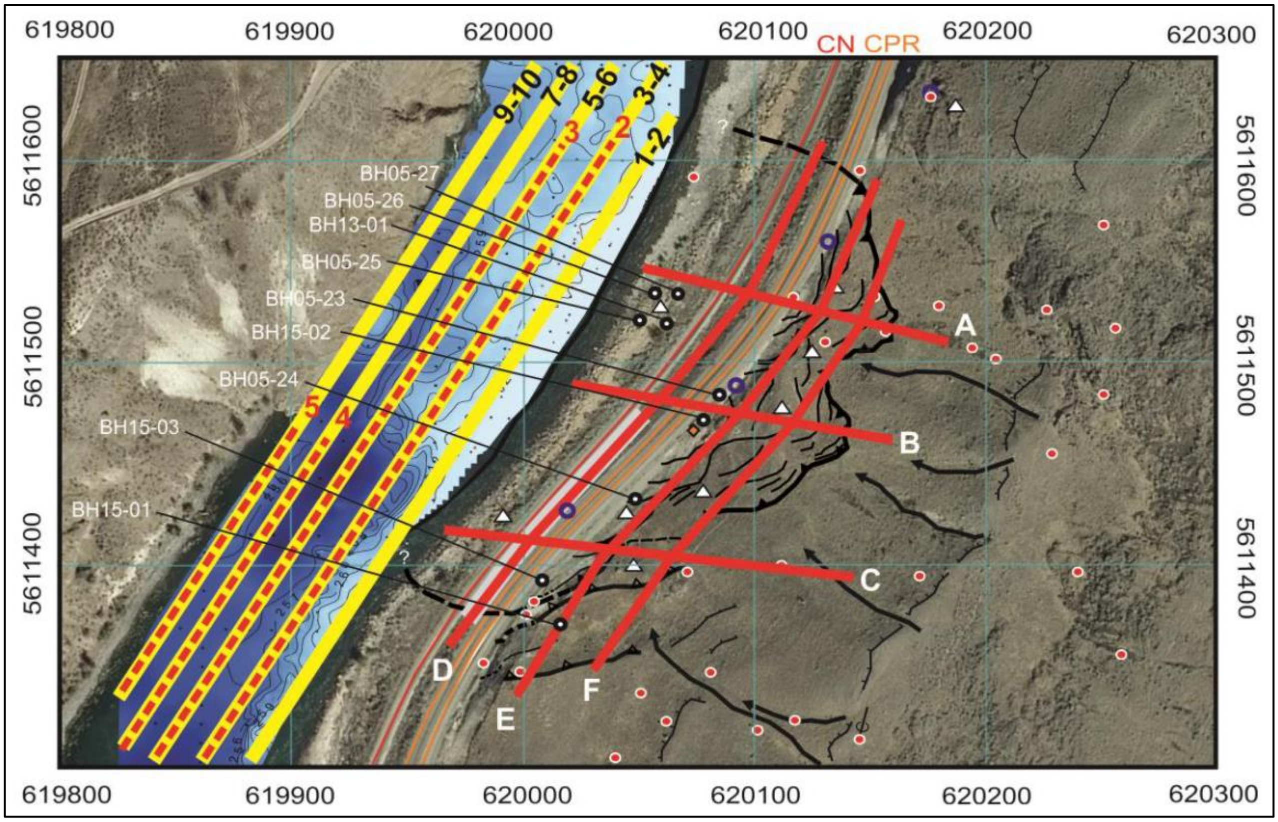


*Image 7 - Plan view map showing the line for GPR Line C which was used in this study.*

**Image 8**: Shows the Auracle 3D MUD™ system point cloud volume slice or section along line C.

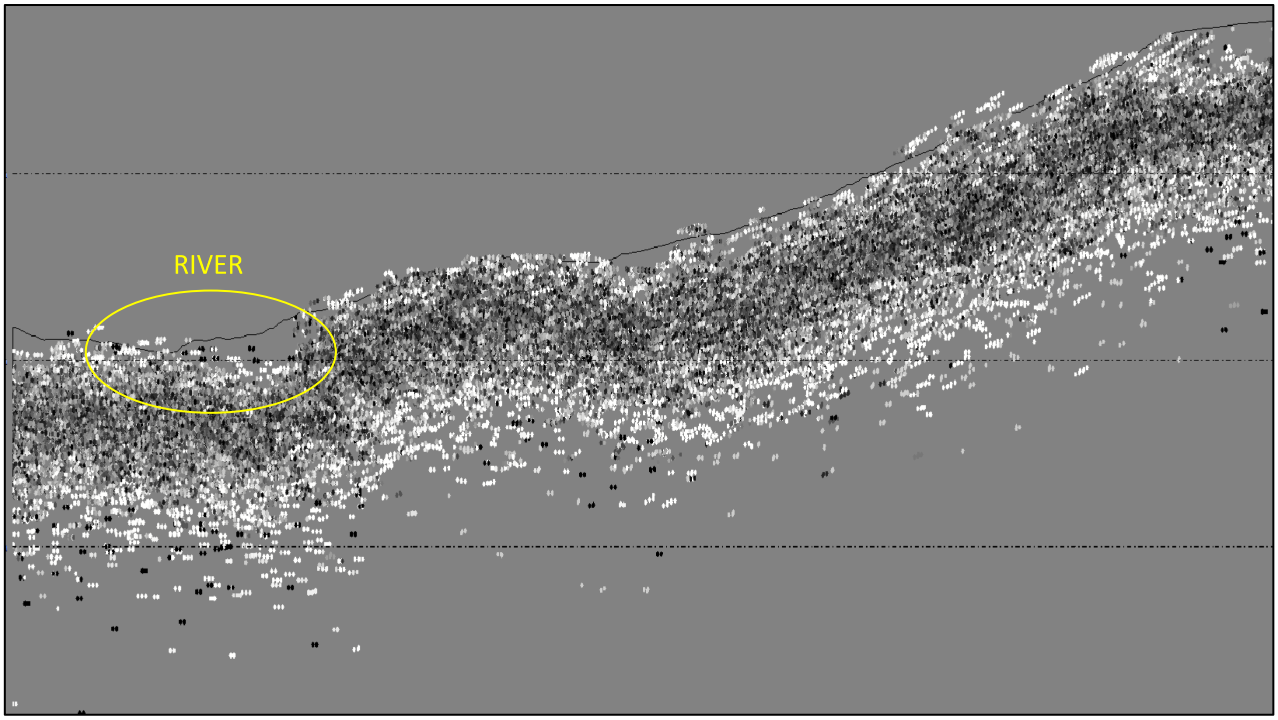


*Image 8 - Line C subsurface view using Auracle MUD™ system as a point cloud volume section of Density.*

**Image 9**: Displays the same section of the point cloud in Image 8 with a section classified according to composition using the 3D MUD™ system.

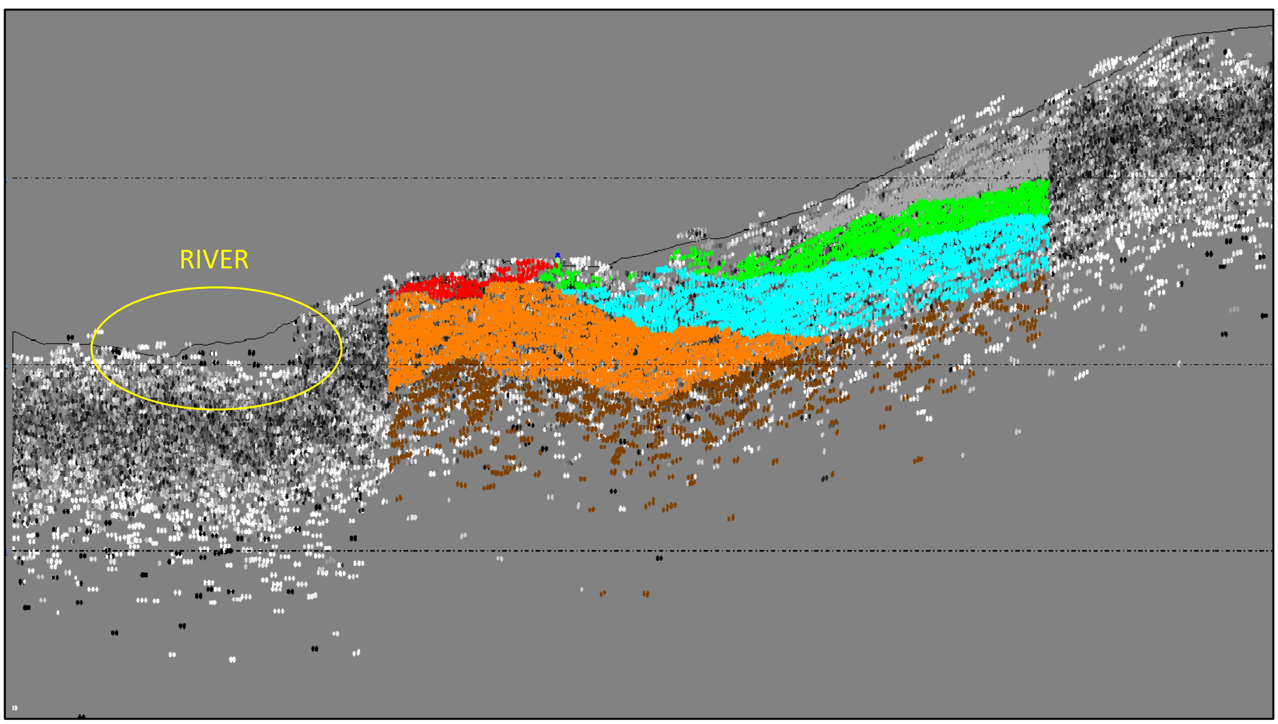


*Image 9 - 3D point cloud volume slice with a classified zone for comparison with GSC published GPR data.*

**Image 10**: An extraction showing the results from the GSC Open File GPR data.

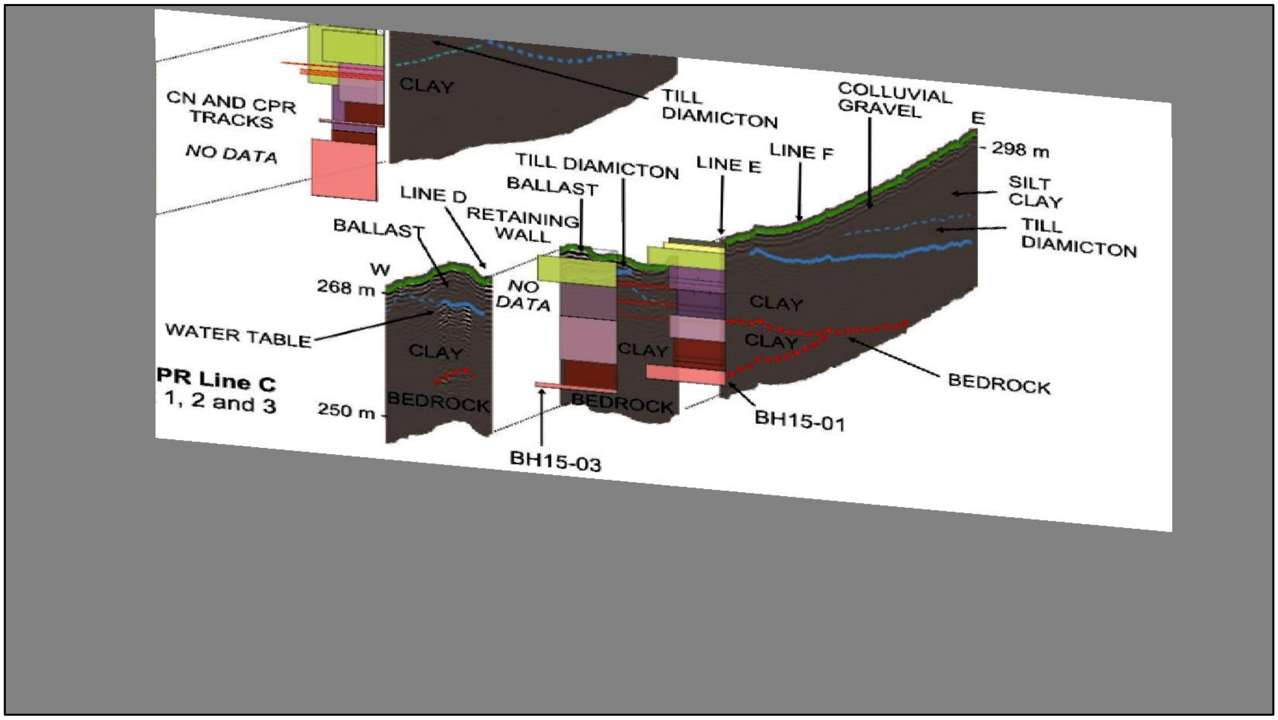


*Image 10 - GPR Line C extraction and orientation to grade as shown on Figure 7 Plan view.*

**Image 11**: An overlay comprised of Image 9 draped on Image 10 providing comparative spatial context for the following images.

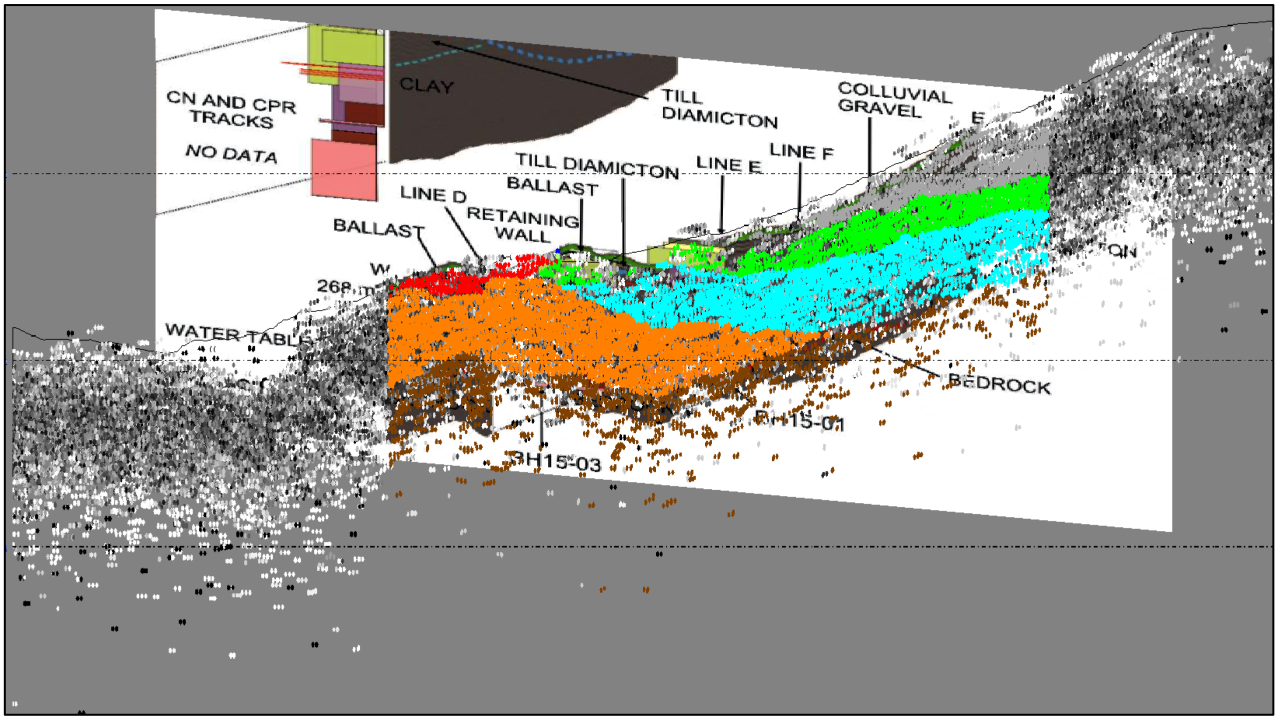


*Figure 11 - Showing the 3D MUD™ system classified sub-surface point cloud section data and the oriented GSC Open File GPR data.*

**Image 12**: Shows the line tracings from the divisions in the 3D MUD™ system classifications overlying the GSC Open File GPR data.

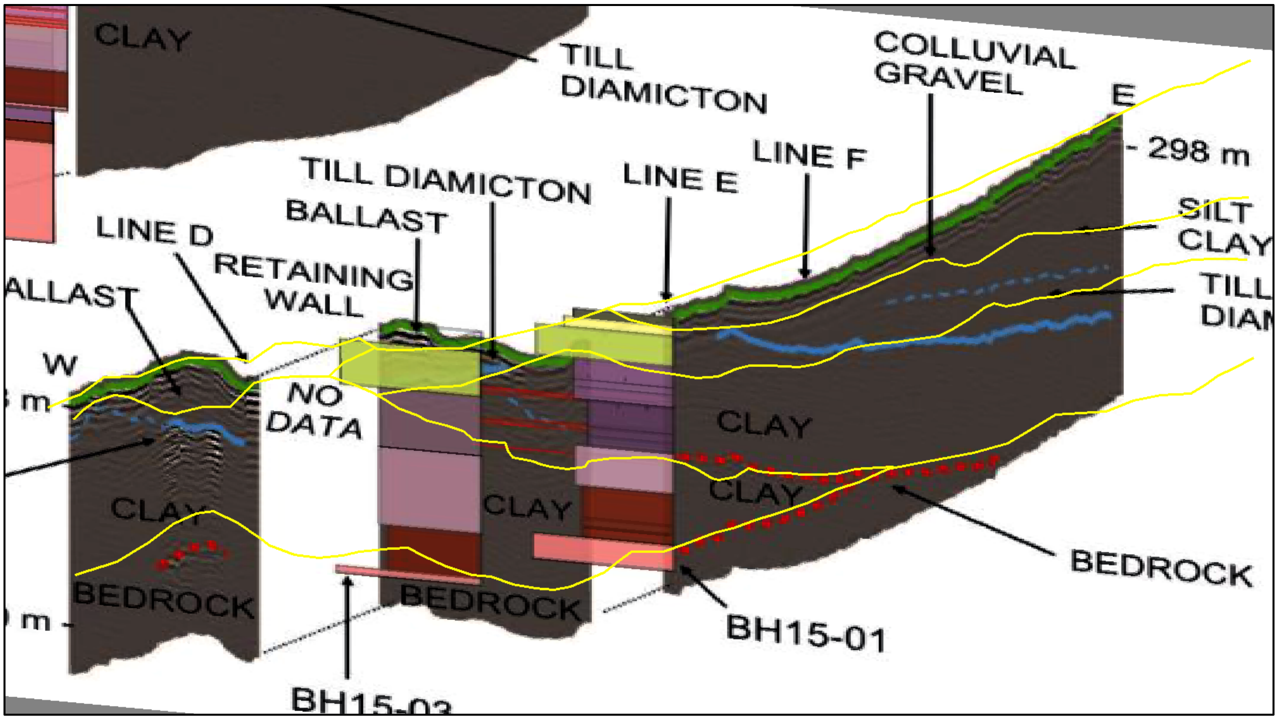


*Image 12 - showing strong depth and spatial correlation between dashed red lines and Auracle's yellow tracings of divisions as well as ballast locations and clay facies subdivisions.*

# CONCLUSION

The study proves the spatial correlation between Auracle's MUD™ system and the data collected and tested at the site. Auracle successfully illustrated the MUD™ system can be used as a tool to model subsurface composition in complex, difficult or remote areas using satellite data. This is important because the Auracle 3D MUD™ system can be further used to monitor sub-surface, sub-centimeter change in 3D.

In all the studies conducted on the Ripley Slide, there are apparent hypotheses employed, investigated and presented as the subsequent foci of drilling locations, GPR paths, inclinometer array placement and geophysical survey parameters. GPR, LiDAR and other geophysical methodologies cannot be used as bases for ongoing change modeling because their positions and altitudes, and timing cannot be precisely duplicated. In addition, areas are difficult to survey with GPR or other forms of traditional geophysical survey methods due to occupied and unoccupied buildings, roads, parking lots, infrastructure and other constructs.

Unlike these methodologies, the 3D MUD™ system is an event agnostic, wide area, holistic analysis. It can also be used to model and measure the underwater river bottom and bank changes. This means that potential chains of causation that may be quite distant from the locations of concern are surveyed from space and included in the analysis. This adds informational context and understanding of potential risk from land and slope instability, erosion and subsidence in the subsurface and underwater within the entire study area.

The MUD™ system is not impeded by the issues of land cover typically blocking other forms of underground survey. This data forms a base model for 3D monitoring which can be used to determine changes to subsurface and underwater composition and threats that may arise from geohazards

Through the Ripley Slide study, graphic interrogatable models, cross sections and volume slices were produced which spatially correlated with 3rd party established results data. These results provided apparent evidence of MUD™ verity. It follows that if the model is proven, then the measurement of change in 3D of the model are also correct.

# REFERENCES

Huntley, D., Bobrowsky, P., Parry, N., Bauman, P., Candy, C., and Best, M., 2017. Ripley Landslide: the geophysical properties of a slow-moving landslide near Ashcroft, British Columbia; Geological Survey of Canada, Open File 8062, 66 p. doi:10.4095/300563

Ripley Landslide: the geophysical properties of a slow-moving landslide near Ashcroft British Columbia D. Huntley, P. Bobrowsky, N. Parry, C. Candy, and M. 8062 (page 15 Figure 3)

Parry, N., Caston, M., Budd, C. and Brasnett, G. (2014) Geophysical data collection: Electrical Resistivity Tomography, Fixed Frequency Electromagnetic Induction, Ground Penetrating Radar and Seismic Refraction; Ripley Slide, near Ashcroft, BC., TetraTech EBA, Unpublished Report for the Geological Survey of Canada, File: 704-E11103058

# THIRD PARTY OBSERVATIONS
## by Paul Metcalfe Ph.D. P.Geol. FGS

My training is predominantly in the fields of volcanology, igneous petrology and mineral exploration. I have also assisted in a Ground Penetrating Radar survey and understand the principles. I have experience in remote sensing, particularly the interpretation of processed satellite-based synthetic aperture radar (SAR) data. I have neither direct experience of the study area nor expertise in surficial geology.

For clarity, I participated neither in development nor application of the Mapped Underworld Dimension (MUD™) System, nor am I an interested party. Furthermore, I will receive neither direct nor indirect consideration from this review, excepting only remuneration for my time.

I have examined the publication and the three-dimensional videos which demonstrate the model generated by the MUD™ System. In both sections examined using SAR, there is credible spatial correlation between the geological and geophysical properties measured by the 2017 study and the 3D model of geophysical properties assembled from the SAR data. Moreover, there are credible discontinuities within the SAR data, not observed by the earlier study, which may provide new insight as to the structure of the Ripley Slide.

It follows then that, given there is reasonable agreement between the multidisciplinary study documented by Huntley et al. (2017) and Auracle's MUD™ System, it follows that interferometric observation of these properties in the subsurface is also possible, providing a viable, inexpensive tool for monitoring of a geological hazard.