College of Engineering, Mathematics & Physical Sciences

Camborne School of Mines

CSMM143: Poldice Assignment

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Contents

Part A

1.1. Overview

Two investigations have been undertaken on different sites in the UK.

Site one is located S of Manaccan, on the Lizard Peninsular, Cornwall [50.0764, -5.1206]. A magnetic survey has been undertaken on the S section of the field and subsequent data can be seen projected in ***Part 2.1***. Magnetic surveys measure the interaction between the ground and the Earth's magnetic field. Ferrous material reacts with the magnetic field along with voids, which create anomalous readings (dipoles). Cultural noise also influences these surveys.

Site two is located is located N of Sedlescombe, near Hastings, Sussex. There are two data surveys; set one [581115, 121105], in the E field, and set two [581022, 121065], in the W field. An Electromagnetic pulse (EMP) survey has been undertaken in both sites respectively and subsequent data can be seen projected in ***Part 3.1***. EMP surveys measure the propagation of incident electromagnetic waves caused by the properties within the underlying material. An electromagnetic field is created by passing alternating electrical current through a coil. Conductors in the ground cause secondary fields and the receiver in the machine records the phase and amplitude difference between primary and secondary fields; the better the conductor, the greater the phase lag value.

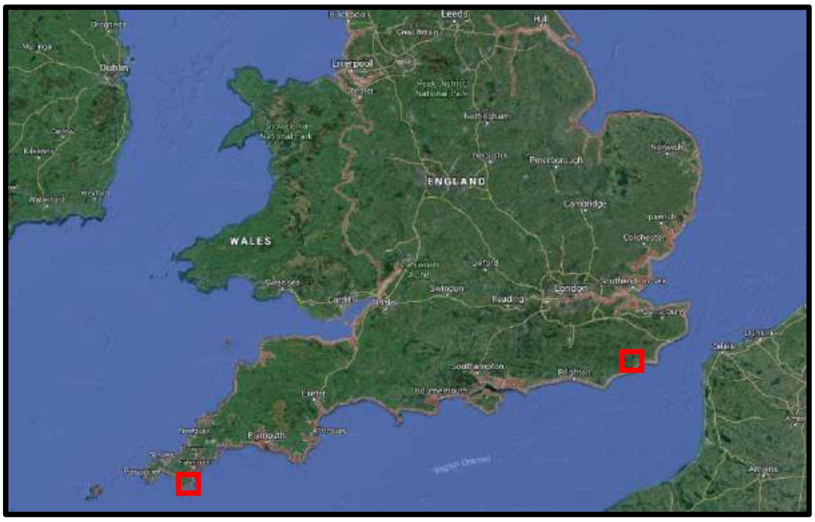


Figure 1: *Map to show locations of investigation Sites. Site one is located in the SW of the UK and site two in the SE. Displayed in Google Maps.*

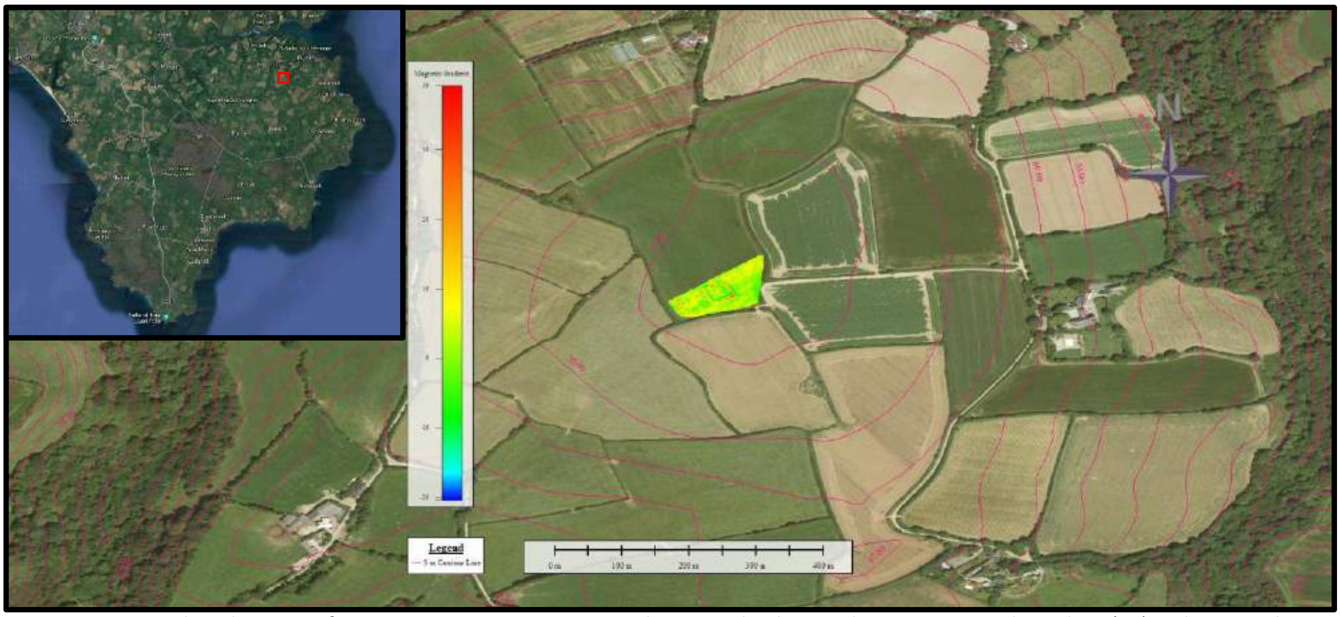


Figure 2: *Map to show location of investigation Site 1 on an aerial imagery background. Magnetic gradient data (nT) is shown in the data set and OS Terrain 5 m Contouring. Magnetic data displayed in Global Mapper.*

2.1. Site One Data

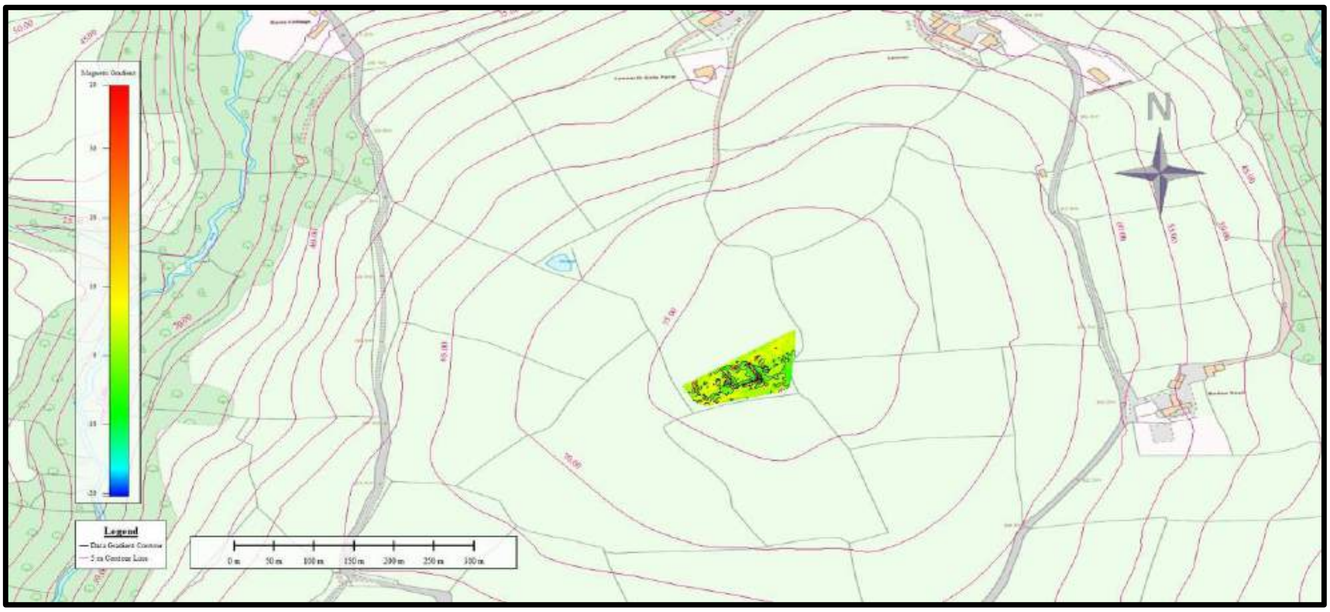


Figure 3: *Magnetic gradient data (nT) displayed in Global Mapper. Contouring within the data set is shown to highlight gradient spikes. Magnetic gradient data is shown in the data set and OS Terrain 5 m Contouring. Magnetic data displayed in Global Mapper.*

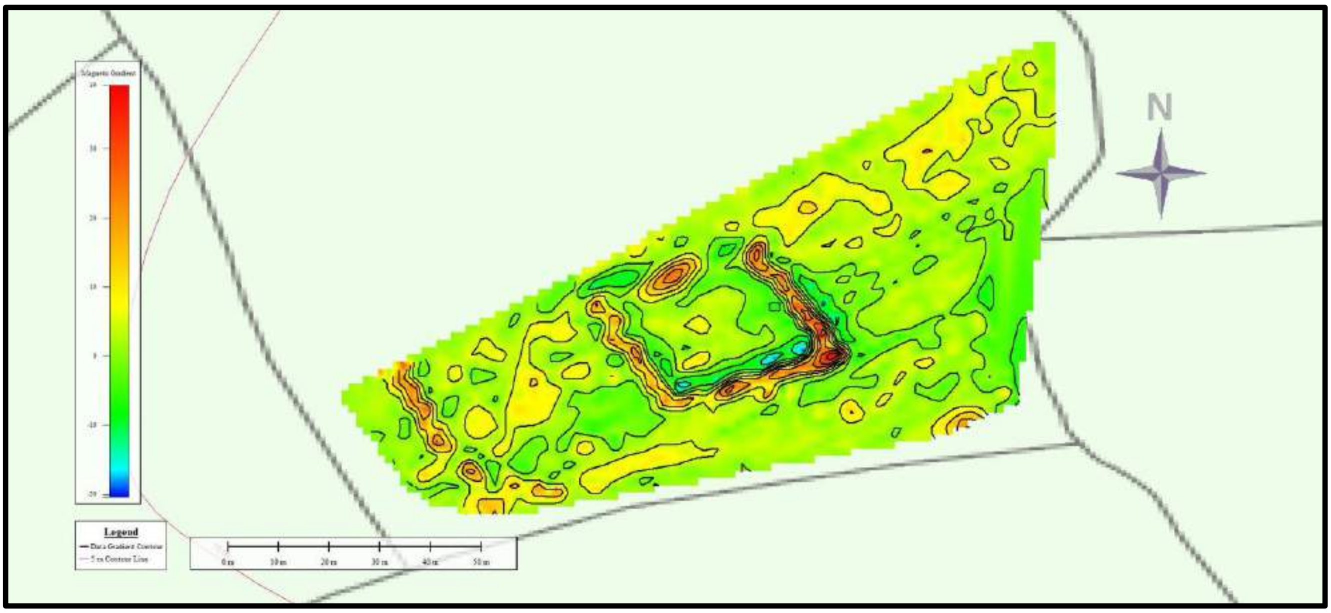


Figure 4: *Contouring highlighting the magnetic gradient (nT) changes within the data. The central region shows the spike in gradient correlating with the colour shading. Magnetic data displayed in Global Mapper.*

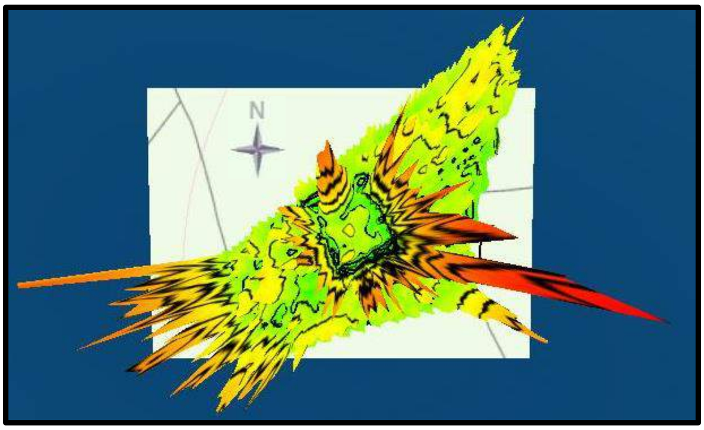


Figure 5: *3D model of magnetic data (nT) showing the raised gradient values. The raised spikes clearly show the structure of the gradient change; square shaped in the central region and a further structure to the W of the data set. Magnetic data displayed in Global Mapper.*

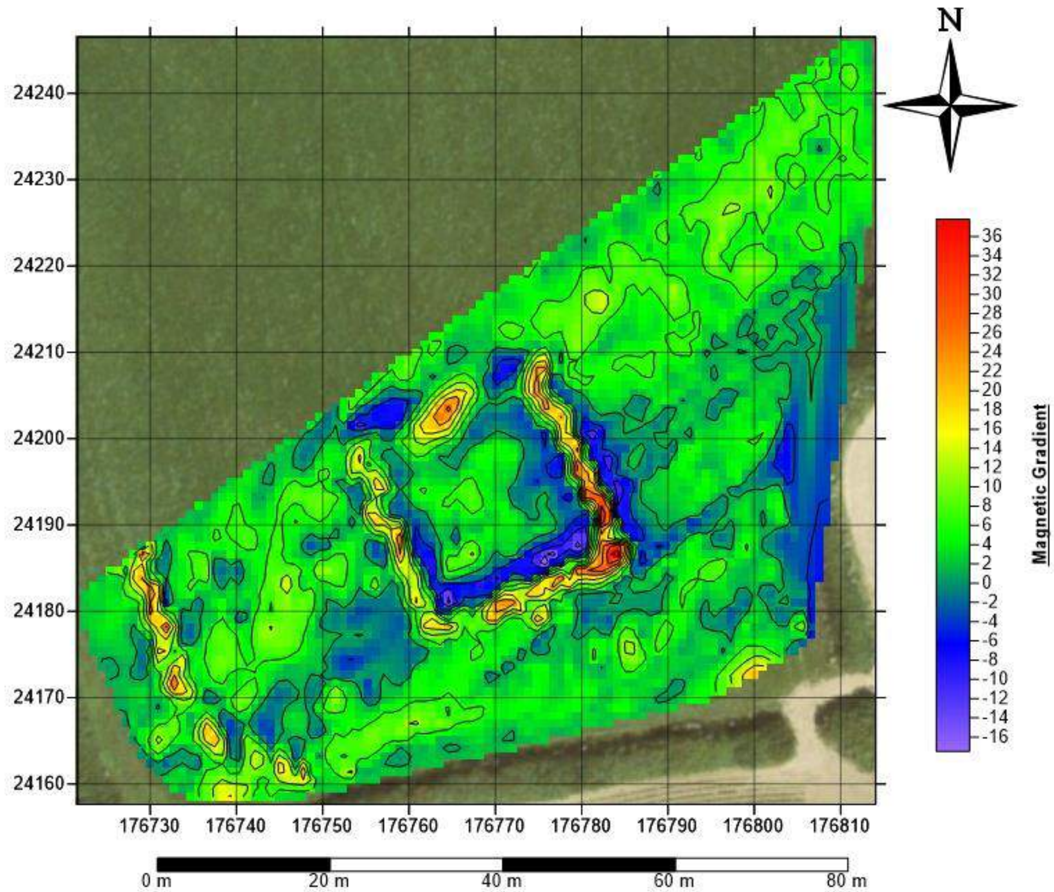


Figure 6: *The magnetic anomalous data (nT) spikes can be seen in the central region and the W region of the area. Magnetic data displayed in Surfer.*

2.2. Interpretation

There is a clear positive magnetic gradient (nT) anomaly shown in the data. The structure is located on a hilltop; within the 75 m contour (***see figure 3***). This anomalous data gradient is > 12 nT, with anomalous low values surrounding it; not in keeping with the background readings of ~ 6 nT and suggesting a possible void.

The main structure in the central region of the data set shows a horseshoe shaped continuous structure (***see figure 6 in Surfer***). This has a length of 26.64 m (Y axis) and a width of 25.83 m (X axis), the width of the sections is on average 2.78 m. The overall area enclosed by the structure is 688.11 m². There is a further spike in gradient on the upper limb of the structure; but only 10.48 m in length, 2.84 m in width and in the centre of the two side limbs. This is made especially clear when imposed in 3D (***see figure 5 in Global Mapper***).

There is what appears to be a similar structure to the W extent of the data, however, the data does not extend further so interpretation of the structure cannot continue (***see figure 4 in Global Mapper***).

From the data displayed, a shape can be determined within the structure. There are 4 structural limbs and run at a 90° to one another. The physical structure looks to be man-made.

2.3. Spatial Resolution

Spatial resolution can be described as the maximum viable rasta dimensions; the optimum definition that can be achieved with the data points. The quality of the data set is primarily determined by this, as the collection techniques of the data is unknown. The higher number of observations per unit of area, the higher the viable spatial resolution becomes. Point density further affects the spatial resolution. This is calculated by taking the area of the data set and dividing this figure by the number of data points taken.

4,402 m²/ 3366
= 0.765 points/ m²

This point density has been produced by the data collection method. This is the use of equally spaced parallel lines, with equal spacing between each data point; creating a grid.

2.4. Recommendations

Further investigation is recommended in order to determine the extent of the structure. This would be in the form of more magnetic gradient analysis to the SW of the area to see if there is another continuous limb. This will trace the boundaries of the structure. It is also recommended; dependant on the scope of work, for further analysis in the surrounding area as there may be further structures; as seen in fogou sites where there can be multiple structures in the immediate area.

Excavating shallow trial pits (< 3 m) is also recommended to investigate the magnetic gradient anomalies. This would unveil the type of structure and allow for further research. The materials used in construction of the potential structure will give insight into the specific historical time period.

3.1. Site Two Data

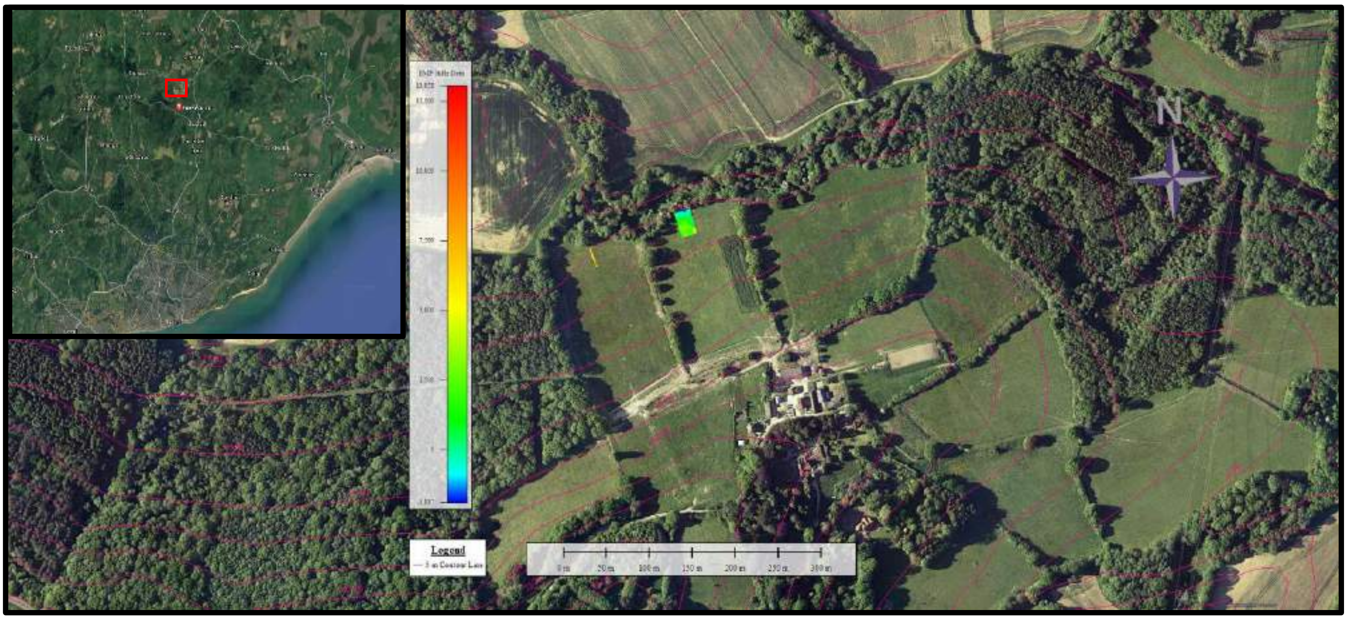


Figure 7: *Map to show location of investigation Site 2 on an aerial imagery background. EMP400-78 is the data set to the E and EMP400-79 is in the W field. EMP 3 kHz (PPM) is shown in the data set and OS Terrain 5 m Contouring. Magnetic data displayed in Global Mapper.*

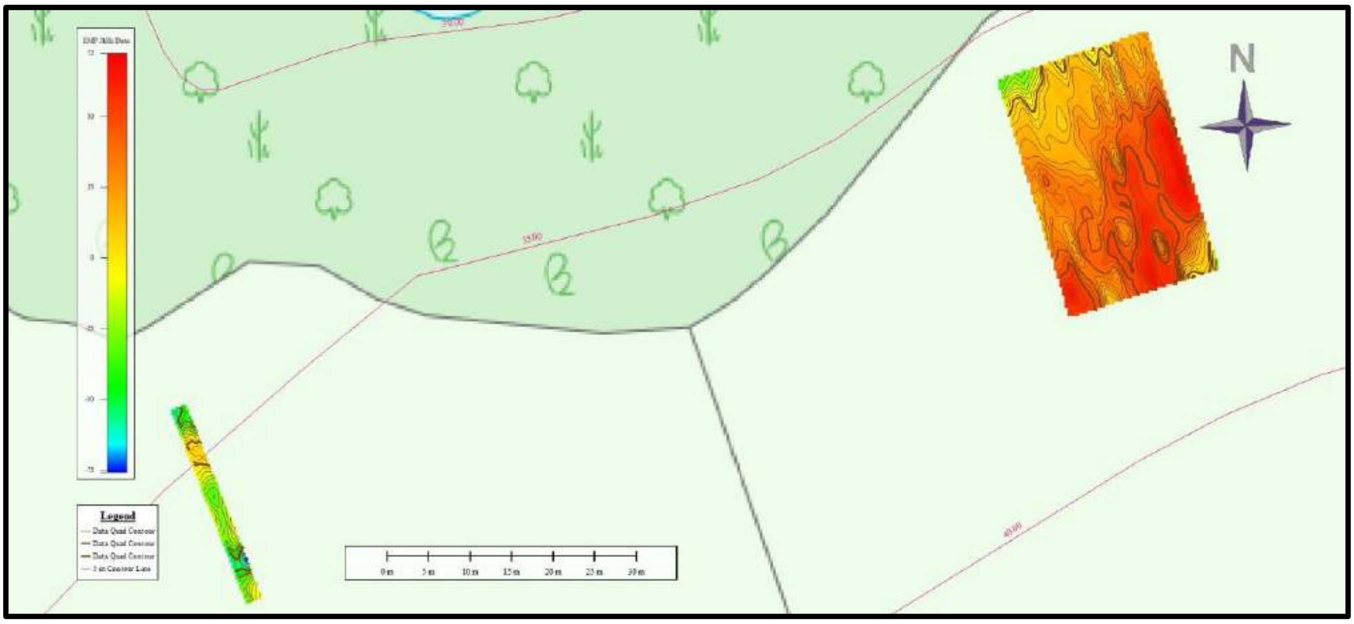


Figure 8: *Contouring highlighting the 3kHz Quad (PPM) variation within the data. There is a data reading spike in the E of EMP400-78 (> 30) and 5 m to the N of the central region of EMP400-79 (> 5). Magnetic data displayed in Global Mapper.*

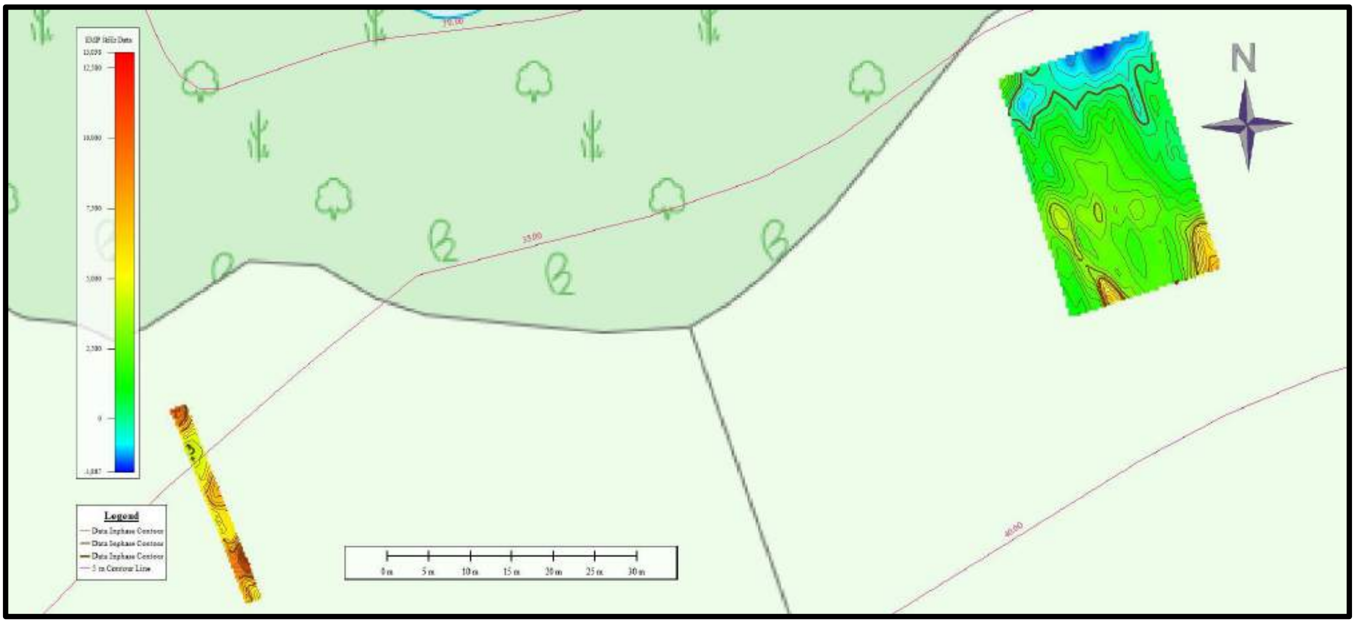
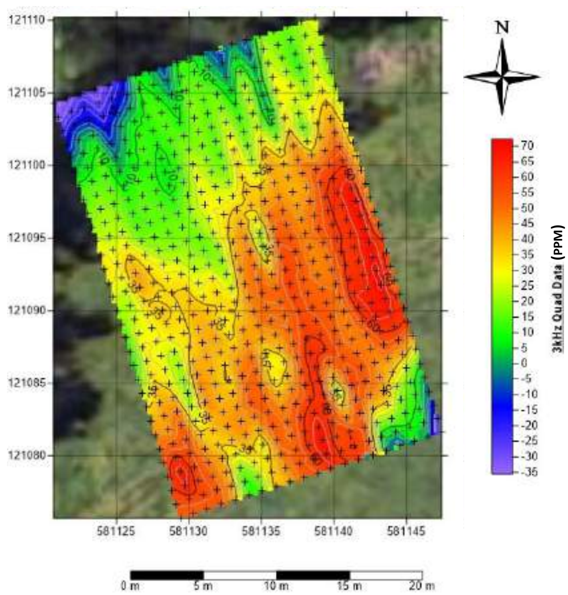
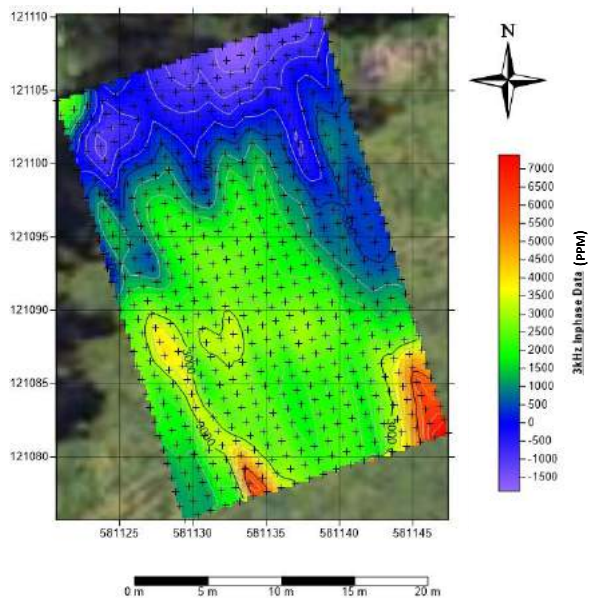
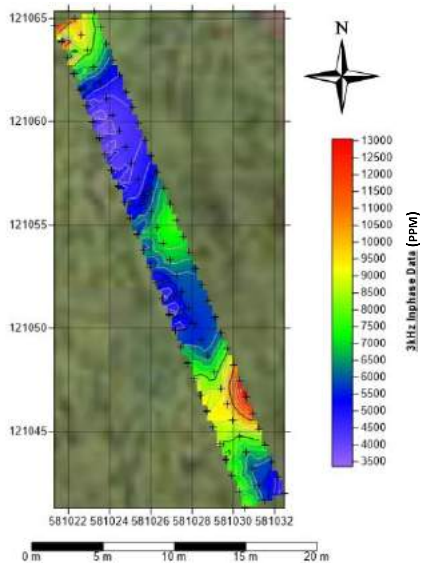


Figure 9: *Contouring highlighting the 3kHz Inphase (PPM) variation within the data. Magnetic data displayed in Global Mapper.*







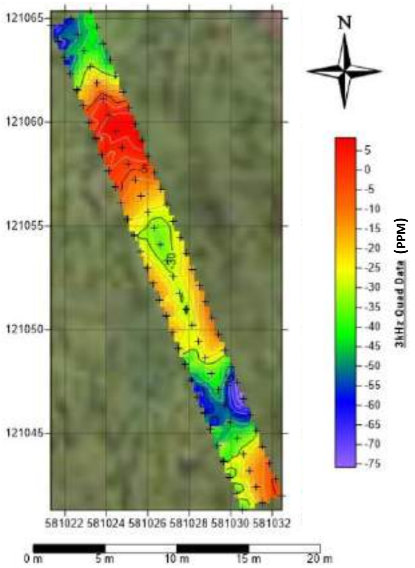
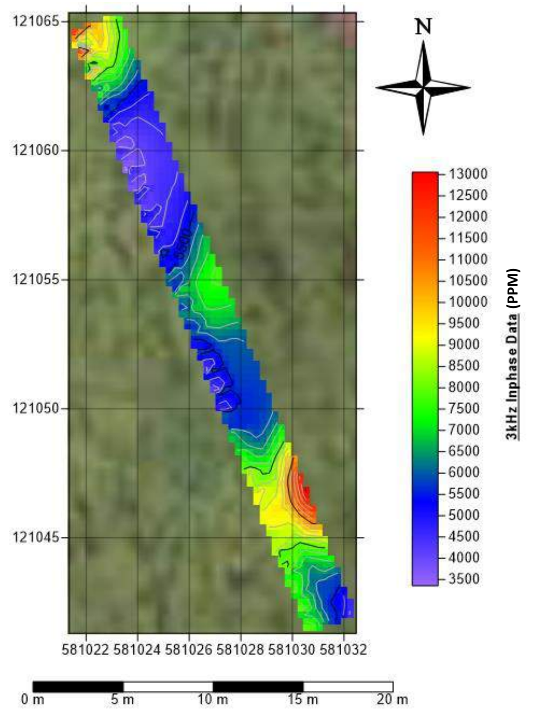


Figure 10a (top left):
Figure 10b (top right):
*Post maps highlighting the spatial resolution and point density of the data. Showing EMP400-78 Inphase (**Figure 10a**) and Quad (**Figure 10b**) data (PPM).*

Figure 10c (bottom left):
Figure 10d (bottom right):
*Post maps highlighting the spatial resolution and point density of the data. Showing EMP400-79 Inphase (**Figure 10c**) and Quad (**Figure 10d**) data (PPM).*

Magnetic data displayed in Surfer.



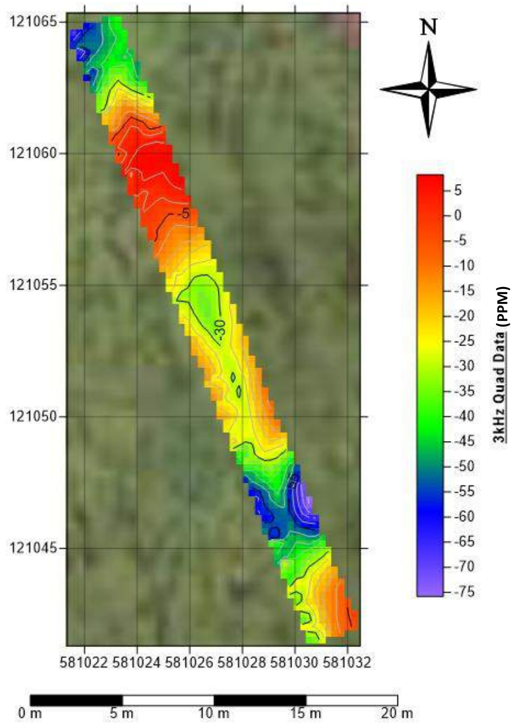


Figure 11a (left): *Map showing the 3kHz Inphase (PPM) variation within the data of EMP400-79. Magnetic data displayed in Surfer.*

Figure 11a (left): *Map showing the 3kHz Inphase (PPM) variation within the data of EMP400-79. Magnetic data displayed in Surfer.*

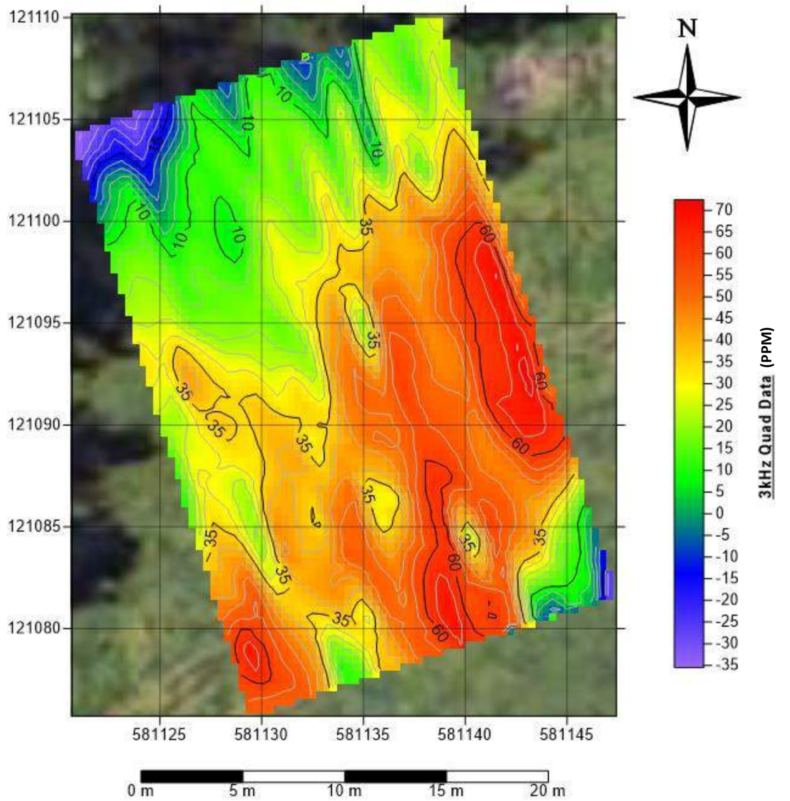


Figure 12: *Map showing the 3kHz Quad variation (PPM) within the data of EMP400-78. Magnetic data displayed in Surfer.*

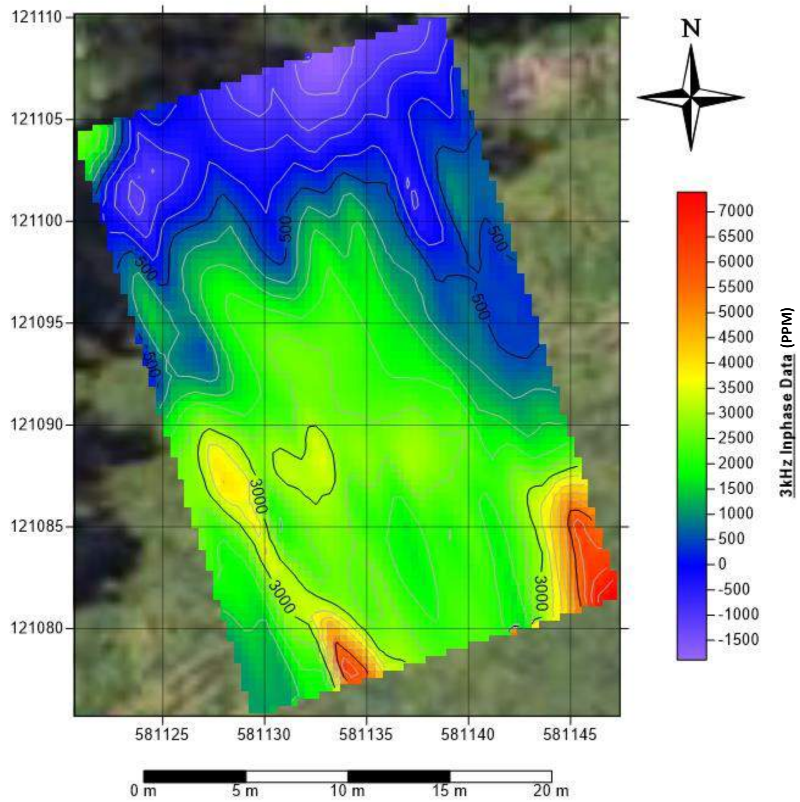


Figure 13: *Map showing the 3kHz Inphase (PPM) variation within the data of EMP400-78. Magnetic data displayed in Surfer.*

Part B

Aim

"A report is to be produced giving an overview/ investigation into housing development within Poldice, Cornwall, UK. Non-intrusive methods are to be used, including; geochemical analysis, 2D mapping using tapes and GPS, a topographic survey, a magnetic survey using a gradiometer and electromagnetic survey using an EMP (*order undertaken for Group 1*)."

This report aims to provide a brief overview of the results obtained from the variety of investigations. These were undertaken over October and November. Interpretation of data has been carried out to enable the construction of conclusions and recommendations for further study.

Site Overview

Poldice is located in the SW of England, Cornwall [50.236, -5.173]; at the heart of Cornish mining heritage. It is based in the Mylor Slate Formation, with a boundary to the Porthtowan Formation. Hosting a bypass of the Portreath Tramway (extended to Crofthandy in 1814), copper ore was exported out, and coal imported in for use in the Poldice, Wheal Unity and Wheal Gorland engines. Poldice was the most profitable mine on the tramway; owned by the Williams family, however due to competition from the Hayle Railway, was derelict by 1870. Poldice mine was in full tin extracting operations in 1748, however, copper extraction exceeded tin by 1790. The mine merged with Wheal Unity in the early 19th century to optimise the Carnon Valley lodes and adits for drainage. After a wet winter in 1873, the engine could not viably pump water and the mine ceased metalliferous production. Poldice mine continued with Arsenic production until 1930, before closing for the final time. Over the life span of the mine, over 150,000 tonnes of copper ore, 1,500 tonnes of tin and 2,500 tonnes of arsenic were extracted (*Poldice Information Board, 2018*).

Figure 1: Figure to show location of area. Shown in Global Mapper and Google Maps.

Methodology/ Planning

Due to methods of data collection, the site visits were weather dependant; rain limits accuracy of GNSS receivers/ GPS and the accuracy of total stations. A walk over was undertaken prior to data collection to familiarise with the extent of the site. This also allowed for the identification of any prominent features; shafts, spoil heaps, buildings. Following data collection, the data was uploaded and brought into GIS to show the days findings. This allowed for the identification of potential areas of interest to follow up with different survey methods.

2D mapping involves the usage of a 50 m tape and a GPS to collect hard features. These include paths, buildings and fences. GPS accuracy varies, but, generally was only 3 m (3D). To limit potential error only one coordinate point was taken and the remainder of the feature was mapped using the tape and a bearing. *Equipment: 50 m tape, handheld GPS (Garmin)*

The topographic survey was positioned around Tom2 [174091.589 E, 42987.232 N, 64.875 m height] and Jerry2 [174107.995 E, 42964.362 N, 66.343m height]. Resections were used and secondary set ups to move around the site. A Trimble M3 total station was used, along with a mini red circular prism (constant of -18 mm). The known coordinates were obtained using a Trimble R2 GNSS receiver. As time was limited and no robotic lock slowed total station point collection, the R2 was used to further increase the spot height data density of the area.
Equipment: M3 total station, 3 tripods, 2 prism set ups, 1 mini prism on a pole, wooden pegs, hammer

The magnetic survey involved walking around the site with the Gem GSM 19-GW. This recorded a data point every ½ second, resulting in a large data density. 55,488 data points were collected. Magnetic surveys measure the interaction between the ground and the Earth's magnetic field. Ferrous material reacts with the magnetic field along with voids, which create anomalous readings (*dipoles*). Cultural noise influences these surveys. Gridding was used to ensure maximum coverage over the site. The Gem had to be held at a consistent height and the user switched after 40 minutes. If data spikes were observed, the area was walked over in more detail. Magnetic hygiene was observed. *Equipment: Gem GSM19-GW*

6 grids were used for the electromagnetic pulse survey. An EMP400 was used and the locations were where magnetic spikes had been identified whilst undertaking the magnetic survey. Electromagnetic pulse surveys measure the propagation of incident electromagnetic waves caused by the properties within the underlying material. An electromagnetic field is created by passing alternating electrical current through a coil. Conductors in the ground cause secondary fields and the receiver in the machine records the phase and amplitude difference between primary and secondary fields. Data was recorded at 1 m intervals within the grids. Calibration was undertaken at a relatively neutral area with limited footfall. Magnetic hygiene was observed.
Equipment: EMP400, control unit, calibration stand, pegs plus optical square and tape, Trimble R2 plus pole, rope

Table 1: Table to show coordinates for location of A0 on each grid.

Grid	Coordinates for A0
Grid 1	174090, 43010
Grid 2	174080, 42895
Grid 3	174044, 42852
Grid 4	174259, 42801
Grid 5	174310, 42890
Grid 6	174024, 42994

A Niton pXRF was used to undertake the geochemical analysis of site. Samples were taken using a hand auger and bagged. 62 samples were taken. The machine tests each sample and gives a read out of elements in the soile (ppm). The location was recorded using a handheld GPS. Strict safety was adhered to due to the radioactive hazard potential of the machine (*see* ***Risk Assessment***). Areas were chosen based on variation; such as lack of vegetation, differing flora.
Equipment: Niton pXRF, sample bags, auger, handheld GPS (Garmin)

Risk Assessment
A risk assessment has been undertaken to ensure the limitation of potential hazards and risk whilst undertaking the investigation. This includes health/ safety, and risks to data collection. A "Go-no-go analysis" was undertaken whilst in the field to further assess variable factors.

Table 2: Display of risk matrices and subsequent scoring

Risk Level	Likelihood Score				
	Rare – 1	Unlikely – 2	Possible – 3	Likely – 4	Almost Certain – 5
Catastrophic – 5	5	10	15	20	25
Major – 4	4	8	12	16	20
Moderate – 3	3	6	9	12	15
Minor – 2	2	4	6	8	10
Negligible – 1	1	2	3	4	5

Acceptable	Further Review	Unacceptable

Table 3: Risk assessment for the investigation undertaken; showing both personal safety and risks to data collection/ other.

Potential Hazard	**Risk**	**Control measures**	**Likelihood**	**Severity**	**Initial Risk Rating**	**Responsibilities**
Slips, trips, falls	Small cuts, possible strains, bone fractures	Sturdy footwear worn, colleagues spotting when using Gem GSM 19-GW.	1 ②3 4 5	1 ②3 4 5	4	To wear sturdy footwear with adequate ankle support.
Manual handling of kit	Strains, muscle tears, back problems	Safe manual handing techniques; bend with knees not back. Use 2 people to carry large Gem GSM 19-GW box.	1 ②3 4 5	① 2 3 4 5	2	Adhere to safe manual handing techniques.
Sampling using Niton pXRF	Exposure to radiation	Adhere to safety recommendations. Use in controlled area; against walls, do not point/ stand 1 m away. Training provided.	① 2 3 4 5	1 2 ③ 4 5	3	Follow training provided.
Exposure to heavy metals (Cd, As)	Poisoning	Wash hands thoroughly, wrap food and do not touch with hands. Avoid getting soil in mouth.	1 ②3 4 5	1 2 3 ④ 5	4	Wash hands thoroughly.
Dogs, other animals on site	Bites, allergic reactions	Stay away from animals and do not antagonize. Carry allergy medication if allergic.	1 ②3 4 5	1 ②3 4 5	4	If known to have allergies notify Neill Wood. Stay clear of animals/ respect them.
Exposure	Hypothermia, hyperthermia, exhaustion	Drink water, inform Neill Woof of any medical history. "Take5" if feeling unwell. Dress appropriately.	1 ②3 4 5	1 ②3 4 5	4	Dress appropriately. Bring adequate water supplies.
Use of Niton pXRF; GEM GSM 19-GW; Trimble R3 and R2; EMP400	Damage to equipment from misuse/ poor set up	Use equipment as how trained to. Ensure tripod legs are dug in. Keep equipment close. If unsure, ask for help	1 ②3 4 5	1 2 3 ④ 5	8	If unsure then ask. Treat equipment with care and keep in sight at all times.
Cross contamination of environment	Spread of Japanese knot weed	Do not disturb any vegetation, check for any possible contamination of clothes.	① 2 3 4 5	1 2 ③ 4 5	3	Do not disturb any vegetation. If discovered move away and notify colleagues.
Passers by	Disturbance to equipment set up	Ensure grids are not obstructing paths. Talk to people and ask them to avoid equipment. Hi vis worn.	1 ②3 4 5	1 ②3 4 5	4	Be friendly to people and explain the reasons for investigation.
Metallic objects on person	Magnetic data affected	Ensure no magnetic objects are on person; no steel toe caps, phones	1 ②3 4 5	1 ②3 4 5	4	Ensure steel toe caps are not worn and all metal is removed

2D Mapping Survey Data

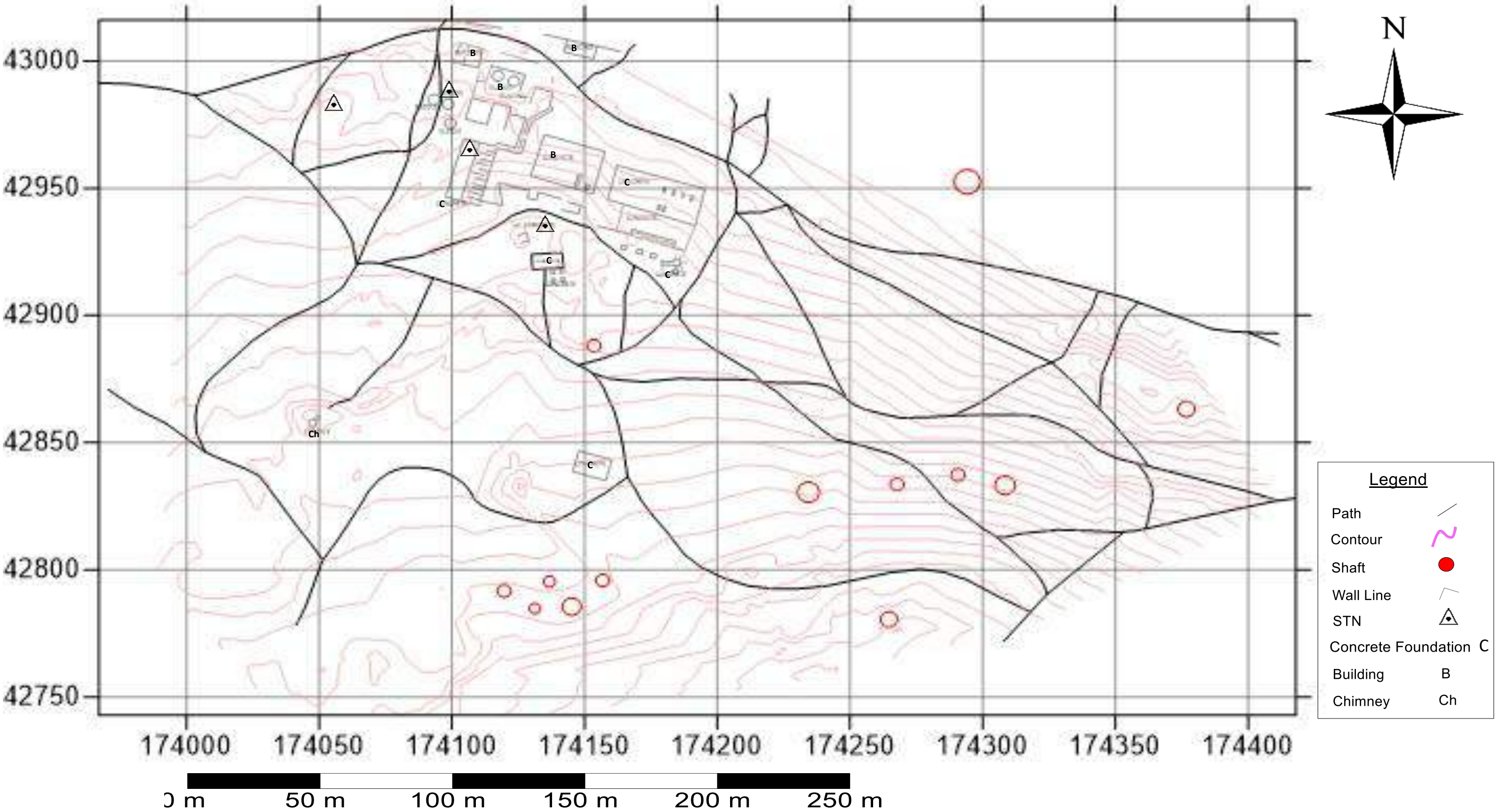


Figure 2: Figure to show 2D mapping data collected of site. Contour data overlain. 2D Data presented in Surfer.

Topographical Survey Data

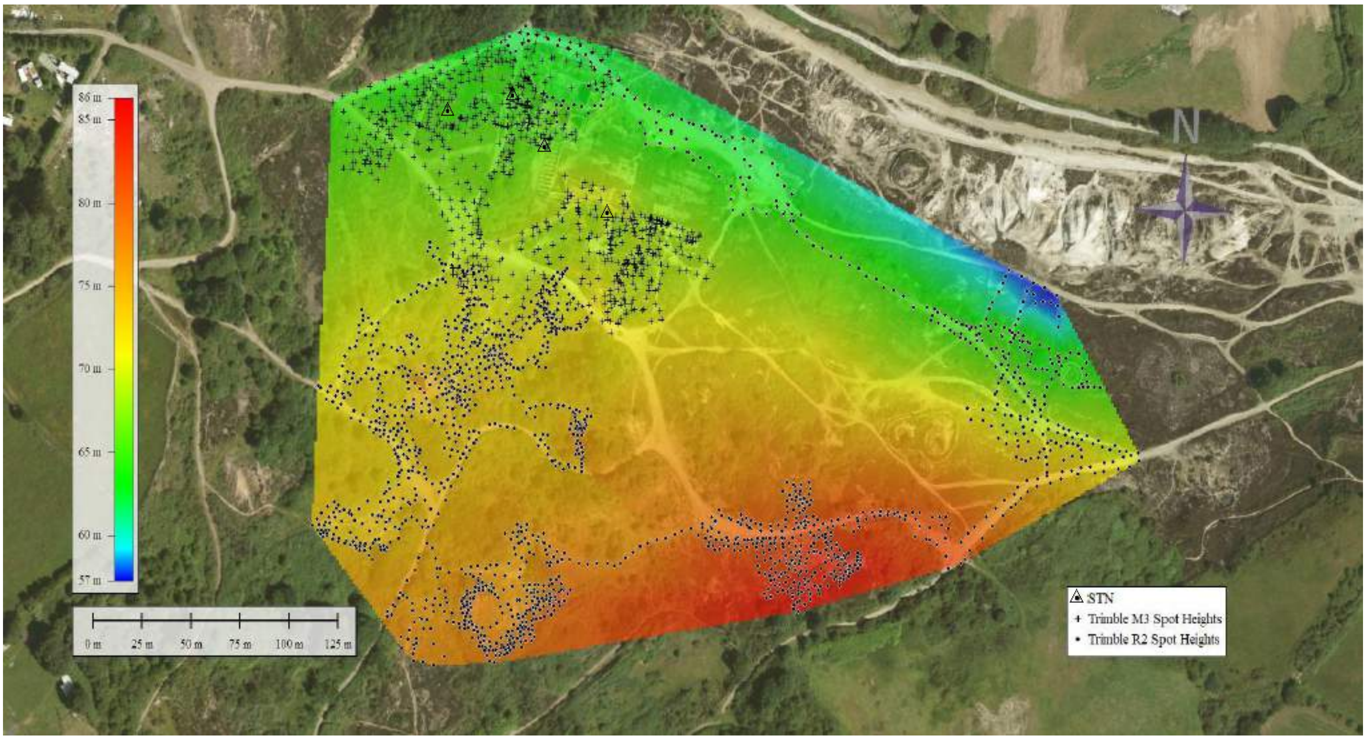


Figure 3: Figure to show topographical spot height data points collected at site. An elevation raster has been created to show elevation change. Topographical data shown in Global Mapper.

Topographical spot height data points were collected using the Trimble M3 Total Station and Trimble R2 GNSS receiver. 2523 spot height points were collected. The corresponding points can be seen highlighted in ***Figure 3***. Station set ups can also be seen in ***Figure 3***. The data collected shows an overall decline in a SE – NW trend, which represents the South valley decline. This is within the Poldice Valley, which trends SE – NW towards Porthtowan. If data collection was to extend past the area, it would be expected to see an increase in spot heights; showing the opposite valley side. The NE low point [57 m] characterises the waste dump, with the highest point [86 m] in the SE, along the footpath.

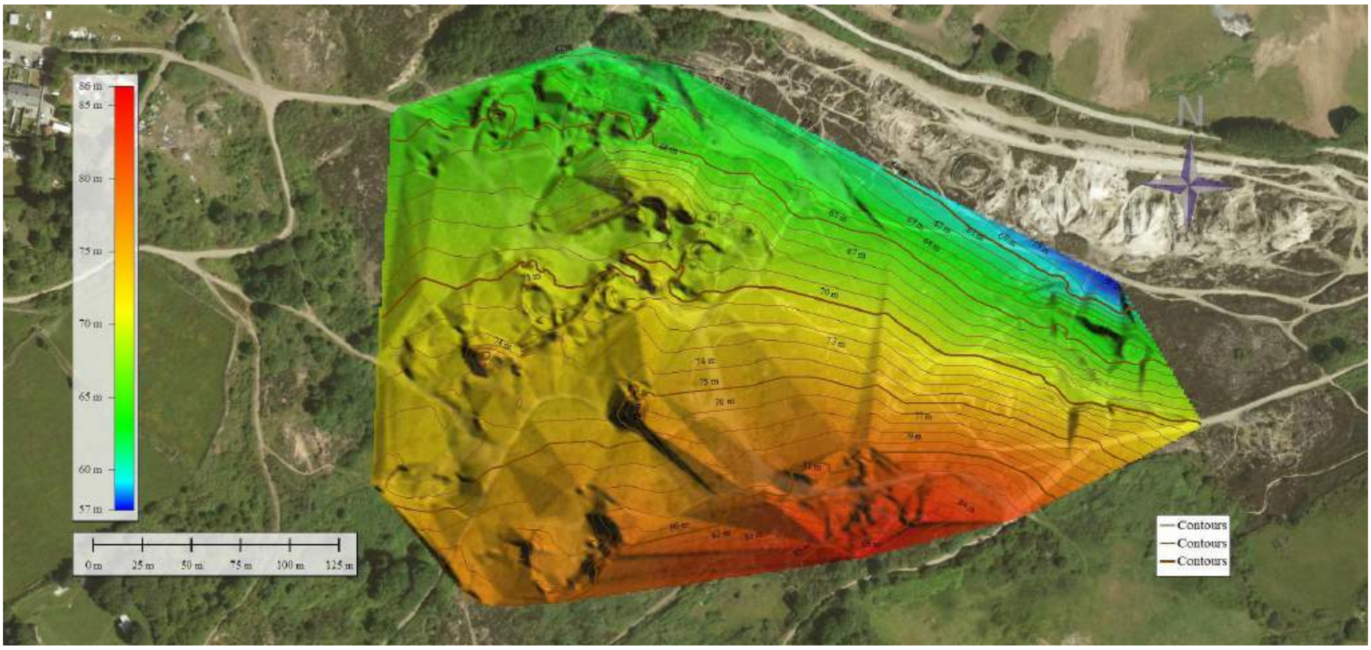


Figure 4: Figure to show topographical contouring produced from the terrain file. Topographical data shown in Global Mapper.

EMP Survey Data

Figure 5: Figure to show locations of grids and subsequent post map data points collected at each grid. EMP data displayed in Global Mapper.

Grid 1

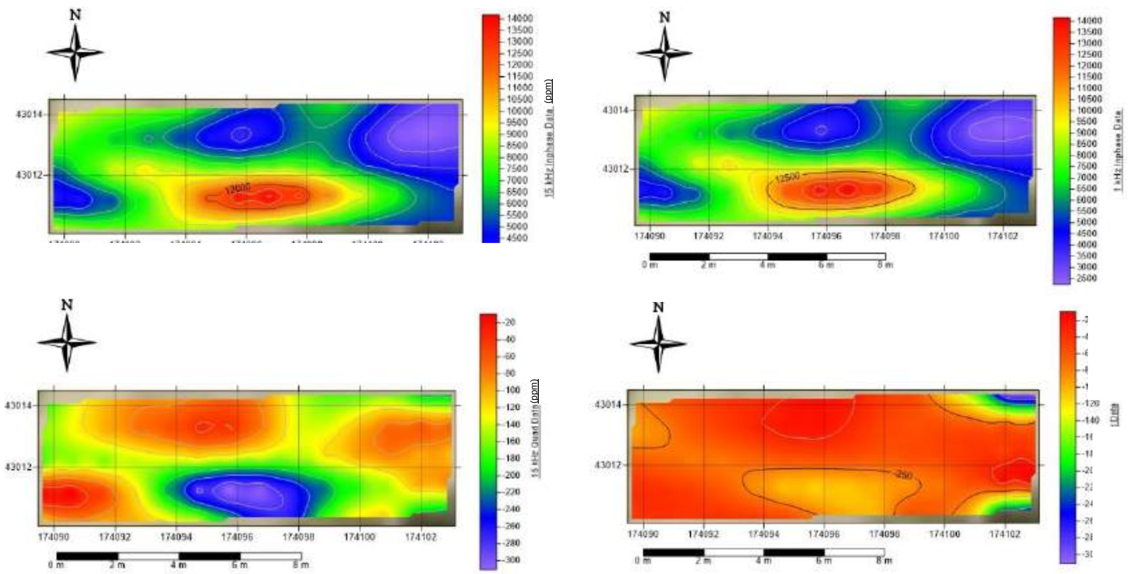


Figure 6: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid One. EMP data displayed in Surf

Grid 2

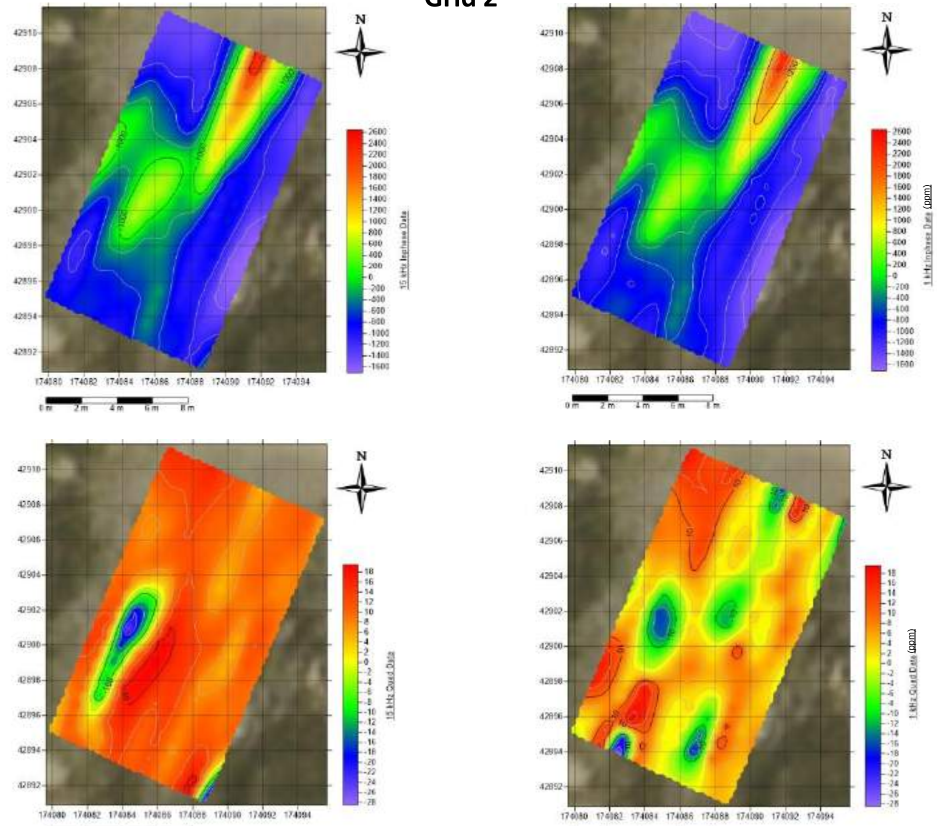


Figure 7: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid Two. EMP data displayed in Surfer.

Grid 1: There is an anomalously low conductivity reading [174096, 43011] of -7 ppm in the South of the grid at 15 kHz. A high inphase reading of 14,000 ppm and low negative quad reading of -300 ppm at 15 kHz represents a localised area of high magnetic susceptibility, with low bulk apparent conductivity. This is also apparent in the 1 kHz inphase data. Quad data at 1 kHz becomes anomalously high, > -80 ppm, which, could suggest ground water influence. There are low quad readings; -200 ppm, in the NE and SW 1 kHz data.

Grid 2: There is an anomalously high spike [174092, 42908] of 2600 ppm in the 15 kHz inphase data set, which is consistent at depth in the 1 kHz data. The 15 kHz quad data has an anomalous spike [174086, 42901] further S, with a low point of 18 ppm. The 1 kHz quad data is highly anomalous with a large variation in data. There are two further spikes in the S of the grid [174082, 42894], [174087, 42894]. This could suggest bulk conductivity within material at the surface, but, at a depth a change; the possible dumping of material.

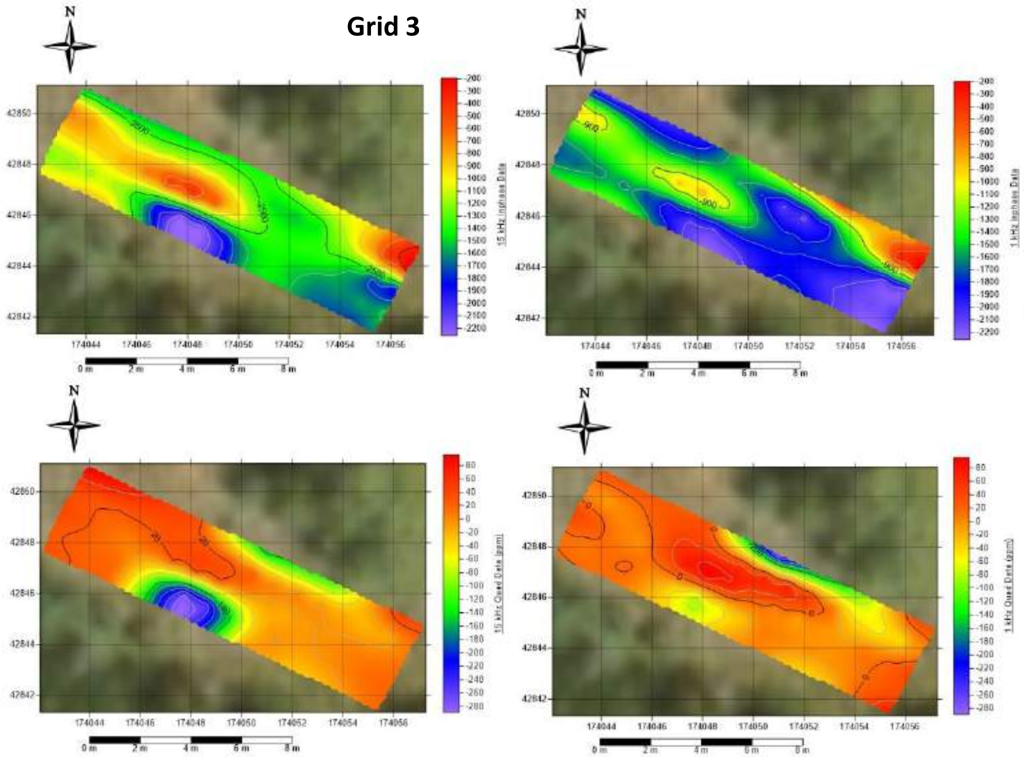


Figure 8: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid Three. EMP data displayed in Surfer.

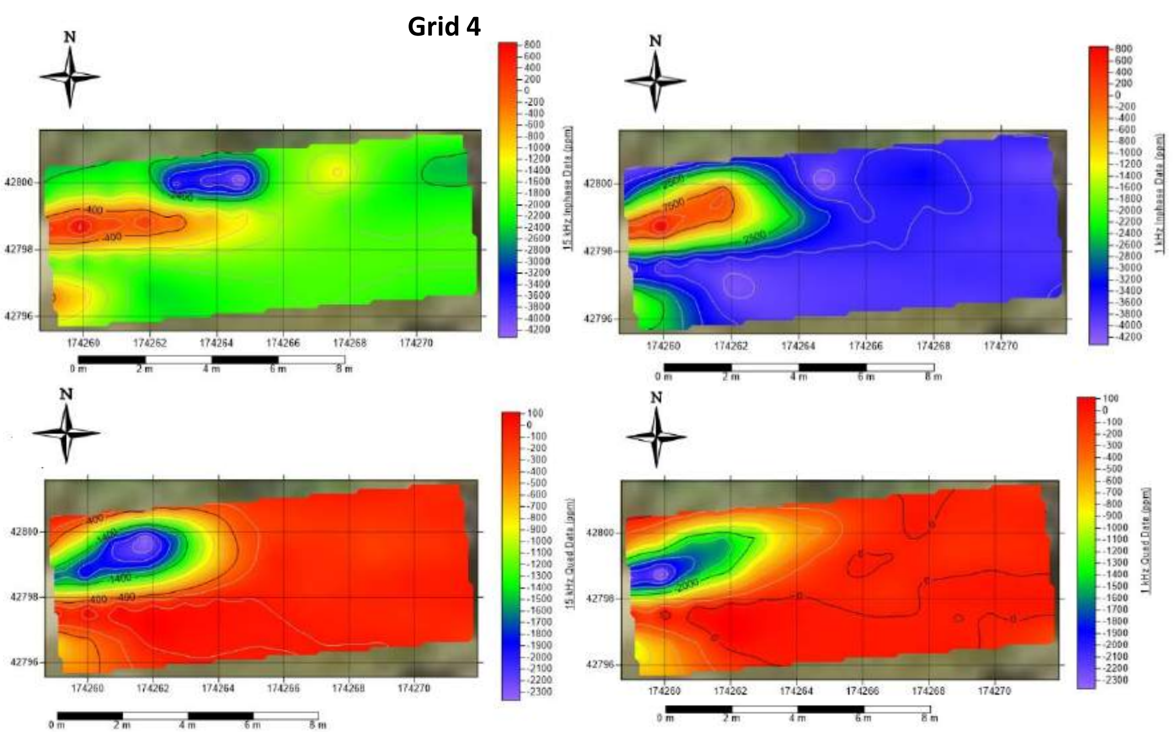


Figure 9: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid Four. EMP data displayed in Surfer.

Grid 3: Relatively low inphase values across Grid Three; -200 ppm max, and relatively high quad values; 80 ppm max, at 15 kHz, shows a large variation that is likely to suggest influence from other factors. The quad data is similar at 1 kHz, however, the anomalous spike [174048, 42845] is not as prominent; only -120 ppm. This could be indicative of groundwater variation, as a pose to a subsurface metallic material.

Grid 4: A spike in inphase values can be observed [174260, 42799] of 800 ppm at 15 kHz. A very low quad value of - 2300 ppm is also observed at 15 kHz. The remainder of the grid hosts low inphase values, at both 15 kHz and 1 kHz. Low inphase values are also observed within the 1 kHz data. The area shows low bulk conductivity.

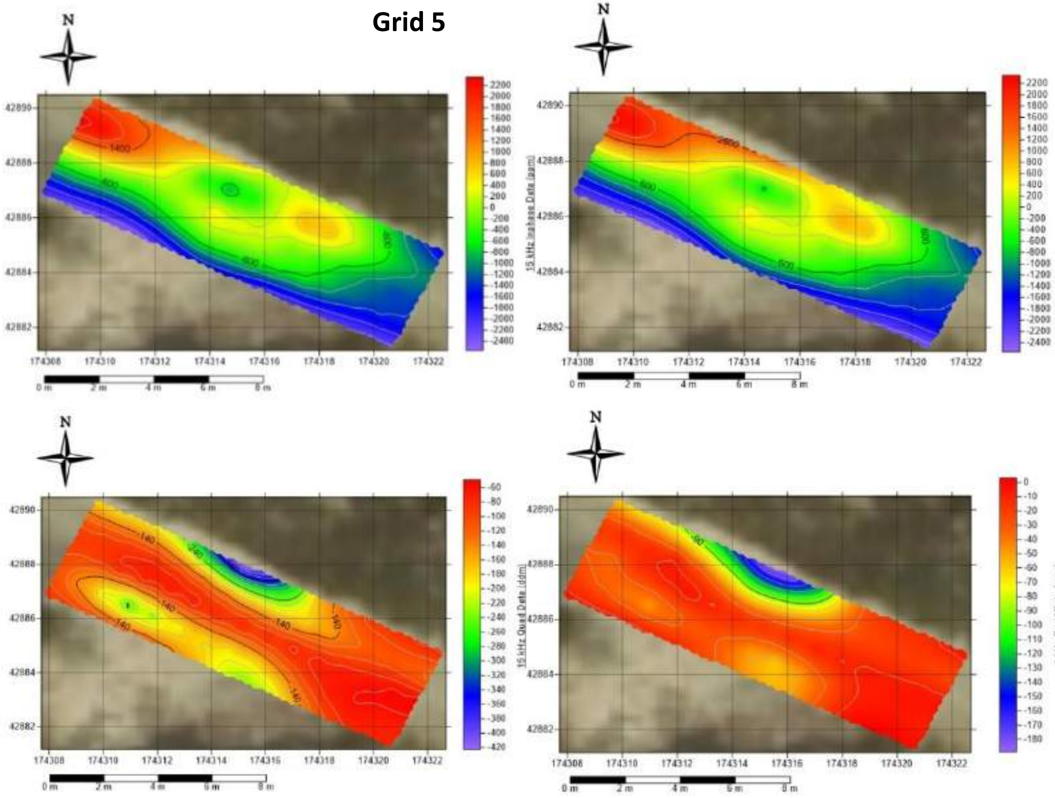


Figure 10: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid Five. EMP data displayed in Surfer.

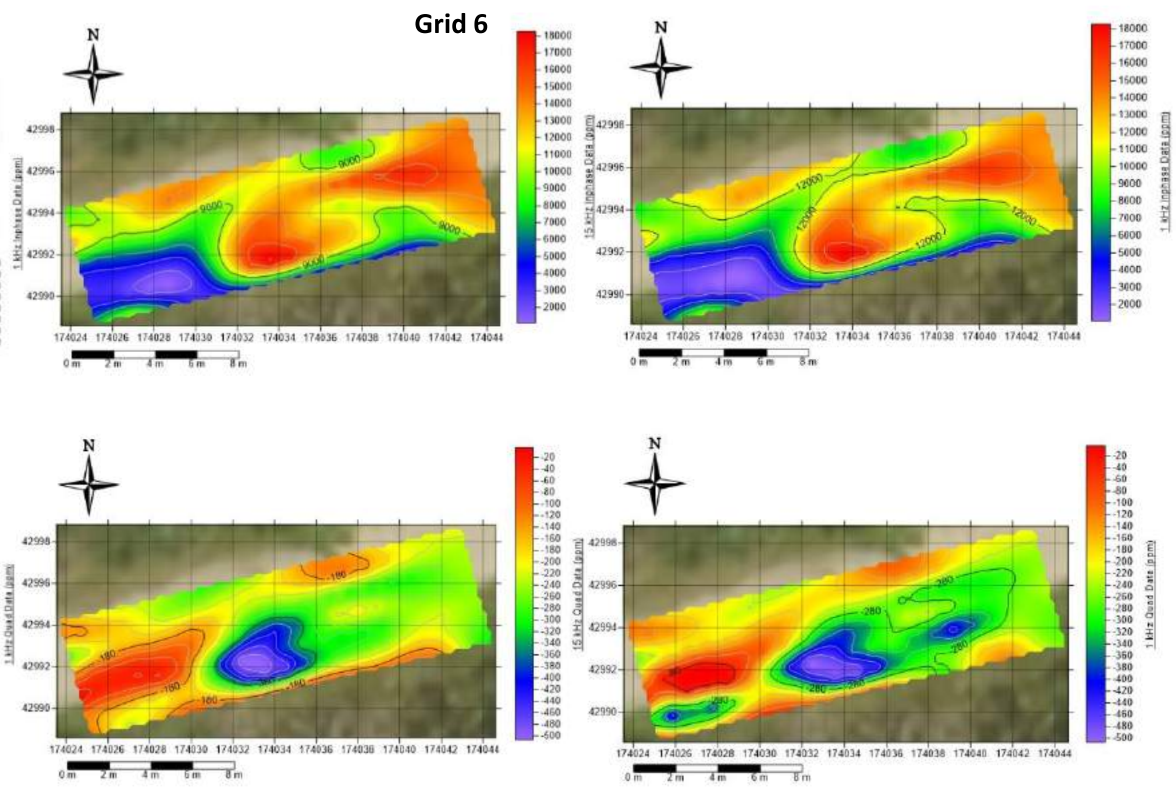


Figure 11: Figure to show 15 kHz/ 1 kHz EMP Inphase and Quad data for Grid Six. EMP data displayed in Surfer.

Grid 5: An anomalously high value of 2200 ppm can be observed in the 15 kHz inphase data [174310, 42889], as well as in 1 kHz. The depth variation is minimal in the two data sets. The 15 kHz quad data shows a low value of -420 ppm at 15 kHz [174317, 42888], which, has a value of -180 ppm at 1 kHz. This shows a decrease in frequency with depth.

Grid 6: An anomalously high spike [174034, 42992] can be observed of 18,000 ppm in the 15 kHz inphase data, which, is continuous with depth, as seen in the 1 kHz data. The Quad data set is also consistent with depth between the 15 kHz and 1 kHz data. High inphase values and low quad values is indicative of a localised area of high magnetic susceptibility, with low bulk apparent conductivity.

Magnetic Survey Data

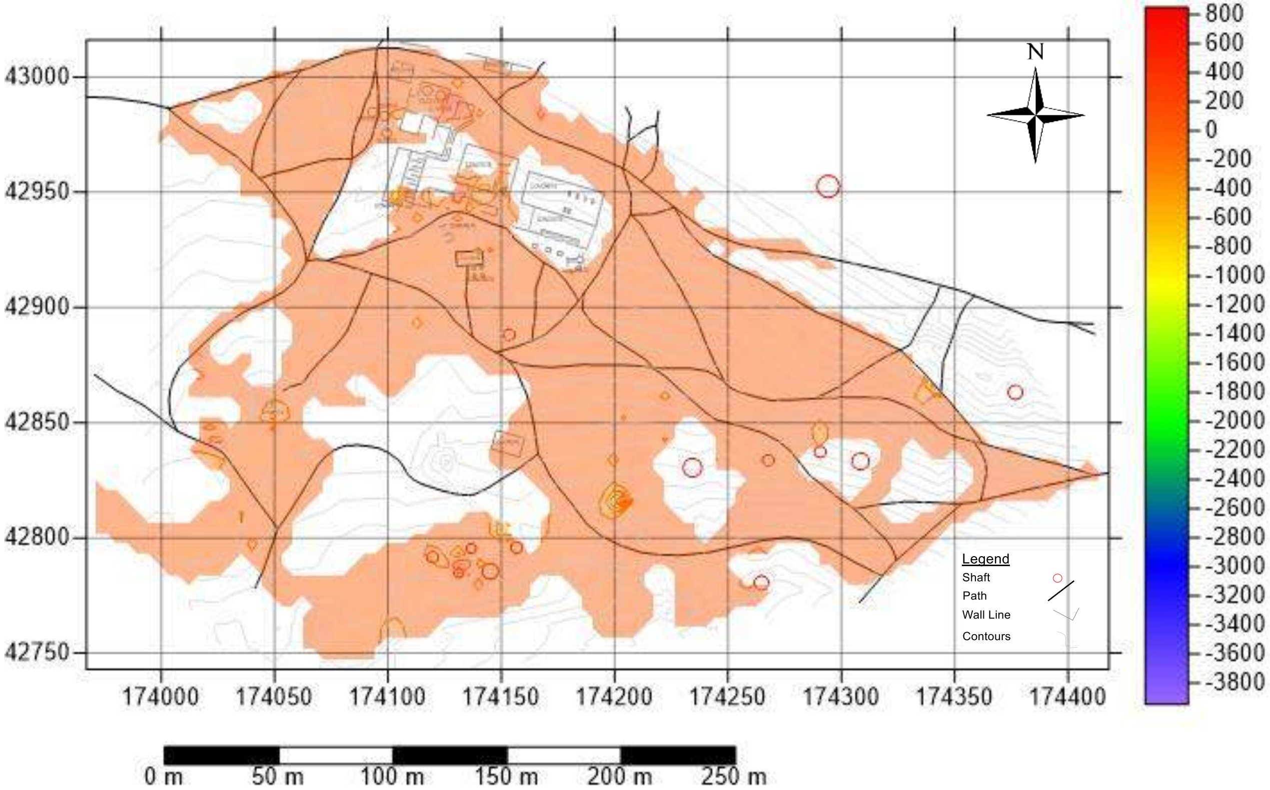


Figure 12: Figure to show Magnetic data across the site in relation to 2D mapping. Magnetic data displayed in Surfer.

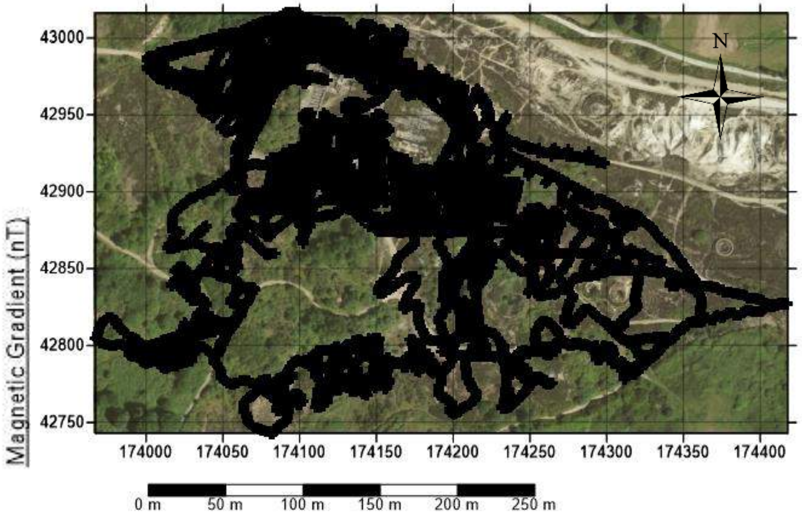


Figure 13: Figure to show Magnetic data points post map across the site. Magnetic data displayed in Surfer.

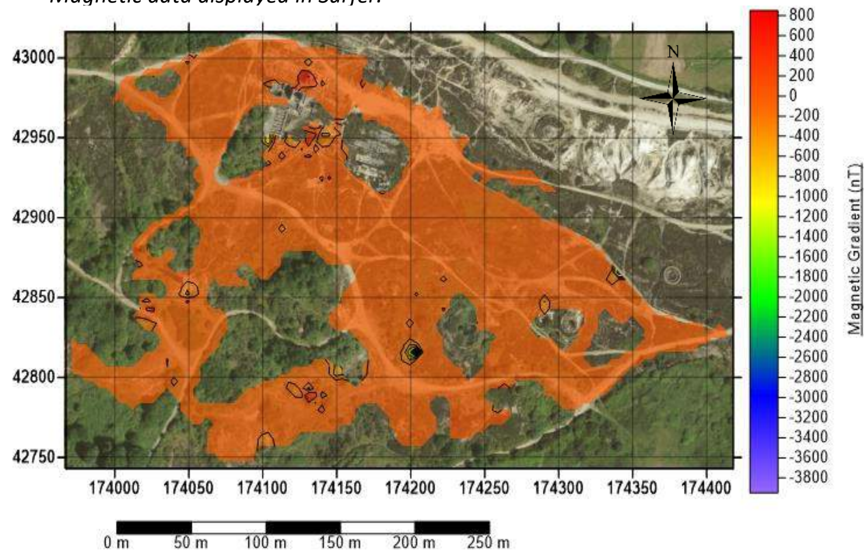


Figure 14: Figure to show Magnetic data. Magnetic data displayed in Surfer.

A magnetic gradient spike of -1800 nT can be observed at [174200, 42820]. The largest spike recorded in the area is 800 nT [174125, 42985]. Further notable spikes of 400 nT [174125, 42785] and -1400 nT [174050, 42850] have been observed. ***Figure 12*** and ***Figure 13*** show contouring around the spikes. ***Figure 13*** shows the data collection points, which were recorded every 0.5 seconds. Blanking has been used to prevent interpolation of data and restrict interpretation to the data collected. Spikes are recorded around the processing buildings, calciner and shafts. Some further surveying is required in the areas which have been blanked.

Geochemical Sampling Survey Data

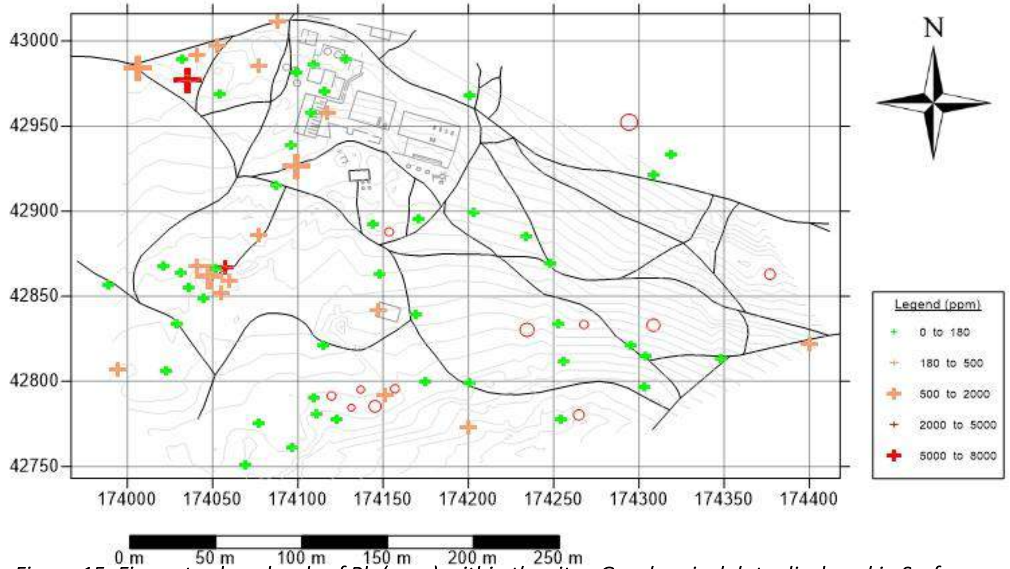


Figure 15: Figure to show levels of Pb (ppm) within the site. Geochemical data displayed in Surfer.

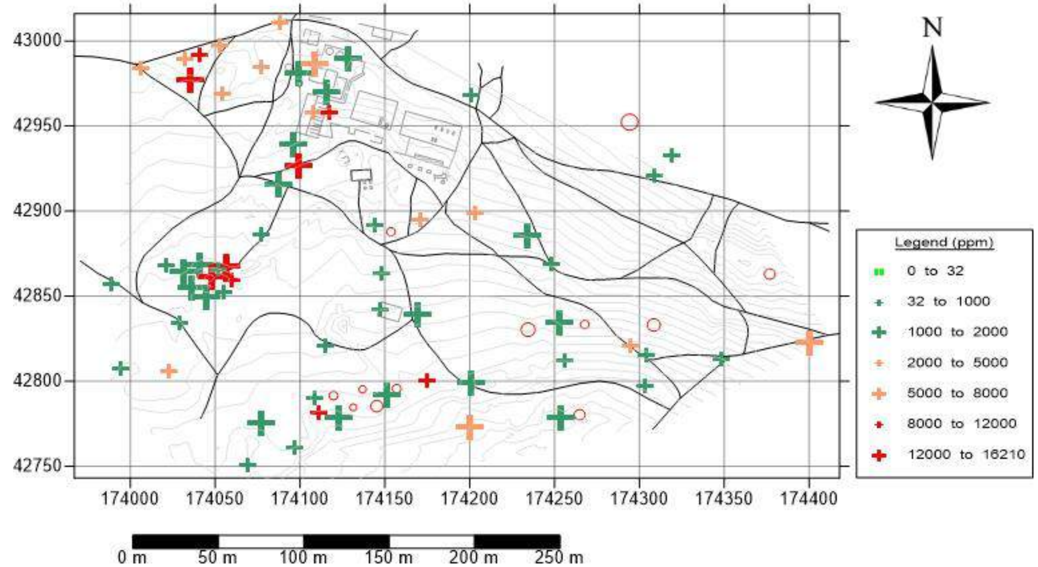


Figure 17: Figure to show levels of As (ppm) within the site. Geochemical data displayed in Surfer.

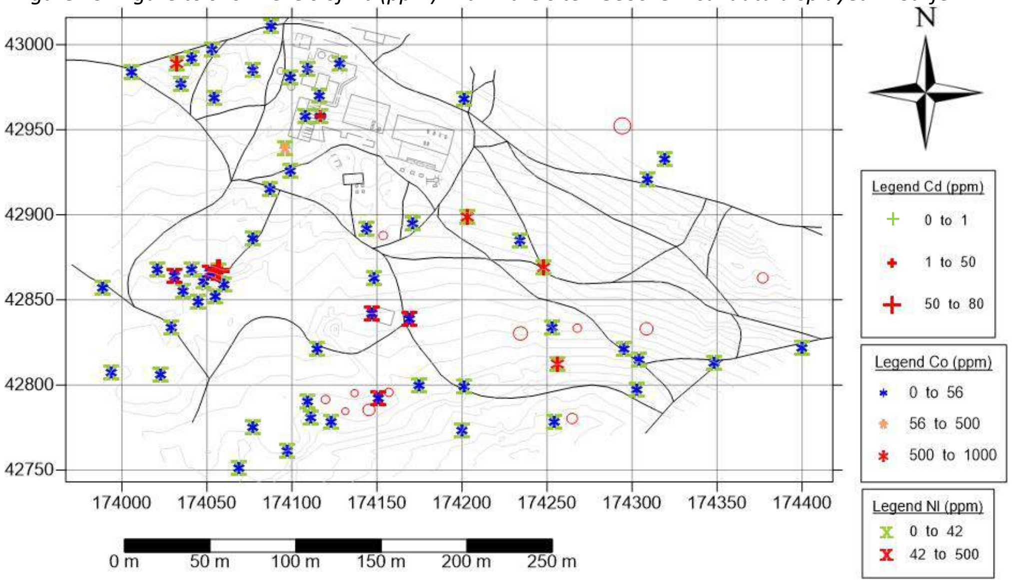


Figure 16: Figure to show levels of Cd and Co (ppm) within the site. Geochemical data displayed in Surfer.

The recorded data for 0 – XX ppm is the average background of contaminant in the UK. The values have been compared to this background value; e.g. As 32 ppm (Ander, 2013). 43 Lead samples were below the UK soil background. The highest recorded value was 7176 ppm [174035, 42977]. Pb causes increased risk of high blood pressure and kidney damage. Nickel levels were under the UK soil background levels; only 5 samples were over, the highest being 362 ppm [174151, 42792]. Ni can cause bronchitis, reduced lung function and cancers. Cobalt levels are mainly below the UK soil backgrounds. The highest value is 850 ppm [174032, 42989]. Co poisoning is caused by excessive levels, caused either by inhalation or ingestion. Arsenic levels are above the UK background levels all across the site. The largest value was 16,200 ppm [174048, 42862]. Cadmium is the most dangerous element observed on site; 2 values were observed within the site of 71 ppm [174057, 42867] and 40 ppm [174117, 42958]. Due to the high toxicity of As and Cd, along with the classification as a carcinogen, these levels are very high. Spikes of some other elements were observed; Ag, 106 ppm [174035, 42977] and Ti, 5660 ppm [174035, 42977], but these are not a risk to human health in presence.

Interpretation
The Cd observed is a primarily a by-product of the mining activities; smelting and refining copper. The largest value [174057, 42867] is located at the chimney, with the other high value [174117, 42958], located within the calciner (*see **Figure 2: 2D Map***). This is the path the ore would have taken during As production. The concentration is defined by the physical workings. As levels spike around the chimney (*see **Figure 17***), due to the pathway of production; the calciner also hosts large values. Grid Two is located along the pathway and suggests bulk conductivity within material at the surface. There is a change at depth, which suggests the pathway is at surface (*see **Figure 7***). The area surrounding the calciner and processing area hosts the highest magnetic gradients; 800 nT (*see **Figure 12***). This is further corroborated in Grid One; a high inphase reading of 14,000 ppm and low negative quad reading of -300 ppm at 15 kHz. This further represents a localised area of high magnetic susceptibility, with low bulk apparent conductivity (*see **Figure 6***). The largest spike is observed in heathland [174048, 42862], which corresponds with a Pb spike. This suggest a possible waste dump, however, due to lack of accessibility, there are no EM readings for the area (*see **Figure 13**: area of blanking*). The highest values of Ni are located at the chimney, as seen supported in the high concentration of other heavy metals. The chimney has an observed magnetic gradient of -1400 nT. Spikes in levels of As (1000 ppm – 12000 ppm), Ni (0 ppm – 500 ppm) and Pb (0 ppm – 500 ppm) are observed around the dense shafts in the S [174125, 42985]. This corresponds with an EM value of 800 nT. This spike in heavy metal concentration and EM anomaly is due to the shaft presence and the subsequent extraction that would have occurred around. A magnetic gradient spike of -1600 nt [174200, 42820] is located within a spoil heap, however, due to accessibility restraints, no geochemical sampling was done within the heap. Samples were taken directly NW and show 1000 ppm – 2000 ppm of As, 42 ppm – 500 ppm Ni and Pb was within the UK soil background levels. A further spike in magnetic gradient [174260, 42780] of 200 nT is observed, which correlates with the presence of a shafts (*see **Figure 12***) and a spike in inphase values of 800 ppm at 15 kHz and very low quad value of - 2300 ppm at 15 kHz. The geochemical analysis shows 1000 ppm – 2000 ppm of As and levels within UK background of Pb and Ni. Once again this distribution is down to the shaft presence and the extraction linked to it. Data collection was limited and blanking has been applied (*see **Figure 13***). As levels vary throughout the area, the main force on distribution appears to be footfall; spikes appear along footpaths [174290, 42825], [174400, 42825]. Grid 6 data and EM data suggest anomalous magnetic data [174310, 42889], which correspond with the old tramway, suggesting a possible buried line. The UK prevailing wind direction is predominately SW, and the highest values of As contamination are to the NE of the chimney; corresponding with the prevailing wind direction. However, the largest density of heavy metals is located to the SW of the chimney suggesting a NE wind direction. This could be due to variable wind directions during the processing. The slope gradient has controlled dispersion to an extent, as observed in the concentration of heavy metals in the NW. There is consistent dispersion throughout the site, however, which could be due to vegetation preventing the movement of heavy metals downslope via plant uptake.

Restraints/ Limitations; Data Collection and Processing
Access was limited in some areas of the site; due to vegetation and mine shafts. This limited Gem GSM 19-GW data when walking around. A gridding technique was used to prevent data density bias towards the paths. Due to public access, there were multiple dumped metallic objects in the vegetation and in the ground. These could cause spikes and anomalous data readings whilst undertaking magnetic surveys. The site was located on the S Poldice Valley slope (*see **Figure 1***). This resulted in the increased water flow in the poorly consolidated ground conditions (*Mylor Slate Fm*) after periods of rain, affecting the EMP quad and inphase data. Data collection shown in this report was from group 1 order; 2D mapping, topographical survey, magnetic survey, EMP survey, geochemical analysis. This allowed identification of areas of interest in the magnetic survey which was followed up in EMP and chemical analysis. The weather is variable in SW England over autumn. This limited R3 accuracy on some days; only 6 mm (3D) was achieved when being used. When the

handheld GPS was used; 3 m accuracy was achieved. This resulted in the 2D mapping results being vastly out. The topographic survey was undertaken first and did not represent areas sampled. Time constraints also limited the topographical detail, as the site is so large. This data was supplemented with R3 spot height data. Geochemical sampling was limited to timing restraints and only the areas of interest from previous weeks were sampled. Sampling contamination posed a risk whilst undertaking the geochemical analysis. The auger was not washed off after every sample and a pen was used to get the sample into the bags. This could alter and contaminate samples from previous samples. Iodised water should have been used to clean the auger and pen after each sample. Blanking was not chosen to be used for topographical data the overall trend can be obtained from very few data points that cover the site. It was noticeably trending SE – NW, therefore, it was deemed appropriate to not blank the data. It is harder to identify linear relationships in magnetism and therefore blanking was used on the magnetic data. This prevented interpolation from distorting the data and causing potential bias and spikes that were not present.

Recommendations

Follow up geochemical sampling is recommended to increase data density of the site. Due to time restraints only 62 samples were taken which could be greatly increased with a gridding method spanning the whole site. Vegetation limited some access so follow up studies may require vegetation clearance. A further spread of EM data is therefore recommended, in a more gridded and representative fashion (gridding shows the areas lacking in data). Further EMP grids are recommended in areas of high magnetism such as at; [174200, 42825], where a value of -1800 nT was observed and at [174125, 42775], where a value of 700 nT where observed. This is in addition to the 6 grids collected. Non-intrusive sampling was undertaken and in areas of high concentration of dangerous heavy metals, it is recommended to sample to a greater dept. Excavating shallow trial pits (< 3m) in areas such as [174290, 42825] and [174057, 42867], would show the extent of heavy metal contamination. Geotechnical assessment is further recommended to assess the stability of the ground. High magnetism and the presence of elements in sampling such as Pb, Ag, Ti, Co, Ni, shows the extent of mining and the presence of multiple waste heaps. These heaps are visibly apparent at [174300, 42950] and [174225, 42825], and if development is to be considered, geotechnical integrity needs to be considered.

Conclusions

Development is not recommended on this site. This is due to multiple shafts; both known and unknown (multiple shafts centred around [174125, 42775]). The ground is unstable and construction may destabilise these shafts and cause subsequent collapse. The extensive mining has resulted in the presence of multiple spoil heaps; [174300, 42950], [174225, 42825], which further destabilise the ground conditions. Without extensive geotechnical and further geophysical investigation, the true extent of shafts and heaps cannot be assessed. The extent of such assessment would not be financially viable. For development of site to be possible, remediation of the site is needed; due to the high levels of heavy metals within the soil. The As guidelines for residential land use are <37 ppm; <40 ppm without home grown produce/ <49 ppm with, and commercial use, <640 ppm (*Ander, 2013*); the area exceeding all these levels. Cd levels are within tolerance; commercial use, <410 ppm and residential without produce, <150 ppm (*Ander, 2013*), however, the presence of other heavy metals restricts usage. This would involve soil washing of millions of tonnes of soil (top 3 m of soil). A membrane could be used as a barrier, which would further involve the use of a soil top layer; further destabilising shafts and causing subsidence. For continued public use the area is recommended to be sampled once a year (geochemical sampling; to pick up potential mass collection of poisonous heavy metals following weather events/ erosion), and more adequate signage to be erected for personal safety and awareness at pathway entrances. Due to high levels of As and Cd surrounding the chimney, it is recommended to fence this area off.

References

(***Ander, 2013***) Ander. EL, Johnson. CC, Cave. MR, 2013, “Methodology for the determination of normal background concentrations of contaminants in English Soil”, Science of The Total Environment, Volumes 454-455, Pp 604-618

All data representation has been projected using a combination of Surfer and Global Mapper **(*see each figure for reference*)**.

Base Maps have been obtained from Digimaps and a selection of OS Ariel Imagery, OS 1:1000 Base Maps and OS Terrain 5 m Contour files have been used.