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IMAGING: A CASE STUDY IN BANGKOK, THAILAND

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ABSTRACT

This study presents the use of electrical resistivity imaging (ERI) as a tool to characterize a suburban abandoned landfill in terms of assessment of its boundary and thickness. The test site was located in a suburban area of Bangkok, Thailand, and covered around 16,000 m². An electrical resistivity method that is sensitive to the different physical properties of the subsurface was found to be necessary to confirm the presence of heterogeneities, their nature, and assess their lateral and vertical extent in the landfill. To validate the boundary and thickness of the resistivity-determined landfill, borehole information was used to correlate the ERI data with different materials. By cross-analyzing the borehole data with the ERI-derived images, it was possible to delineate the boundary of the landfill and establish the contact between the filled and natural soil materials.

KEYWORDS: Landfill, Resistivity Imaging, Geophysics



1. Introduction

Within the expansion of Bangkok city, urban development has spread out into the suburban areas of the city, some parts of which had been used previously as a waste disposal site for the community. In recent years, however, these landfill sites have been recognized as providing beneficial opportunities for suburban land redevelopment, where their remediation and reuse slows down urban sprawl and its associated impact on the environment. However, in order to reclaim the landfill site, its boundary and thickness has first to be determined. In conventional assessments, borehole drilling and trenching are commonly used but these methods only provide a localized estimation of the landfill thickness and boundary. Accordingly, in recent years geophysical methods have been used in an attempt to characterize the landfill and these methods have helped in imaging the horizontal and vertical geometry of the landfill in a three-dimensional (3D) or continuous manner.

Previous evaluation of the use of geophysical methods for the investigation of urban landfills is limited [1]. The use of geophysics for the characterization of landfills and contaminant plumes have been widely reported, where the methods that have been successfully employed are those that measure the electrical properties of the subsurface. They have notably been used to determine the boundaries and geometry of contamination in the subsurface (i.e. landfills or contaminant plumes). If there is no electrically conductive surface layer (e.g. compacted clay cap on landfills), ground-penetrating radar (GPR) has been reported to be successful in identifying buried heterogeneities, such as underground tanks or buried structures. The use of GPR has also been reported for the determination of the structural organization of heterogeneous natural soil deposits [2,3-8,9,10].

In this study, electrical resistivity imaging (ERI) was used to investigate a suburban landfill with the objective of being able to delineate the landfill boundary in 3d (both vertical and lateral dimensions). The ERI data was correlated to and checked by reference to that from boreholes. Since the thickness of the fill is a primarily concern because it will be affect the planning and designing of the foundations of any structure to be constructed in this location, then the information obtained from this site investigation was evaluated in terms of the ability of an ERI survey to improve the resolution of landfill mapping. This will be of use in helping the proper planning and development of landfill areas.

2. Materials and method

2.1 Site location

The landfill of this study was located in a suburban area of Bangkok, Thailand, and was previously operated by the local authority primarily as a garbage dump site for the local community. After the landfill was completely filled with garbage, the site was closed and abandoned without proper maintenance. However, due to a recent boom in real-estate development, the economic pressure to reuse these sites has increased. The study site has a surface area of approximately 16,000 m² and is part of a larger site undergoing redevelopment. A general view of the site is presented in Figure 1, which also shows the location of existing and demolished buildings as well as the lines of the ERI survey used in this study and two boreholes previously conducted in the study area.

Results of the preliminary assessment showed that the fill materials encountered in the area mainly consisted of a matrix of remolded natural soil material (a mixture of silt, sand and gravel) mixed with various debris (e.g. concrete, brick, metal, wood, glass, porcelain and paper), as well as industrial and domestic wastes (e.g. ash, slag, clinker, coal and shells). These debris and wastes were found in proportions of up to 100% of the volume of the fill (Figure 2).

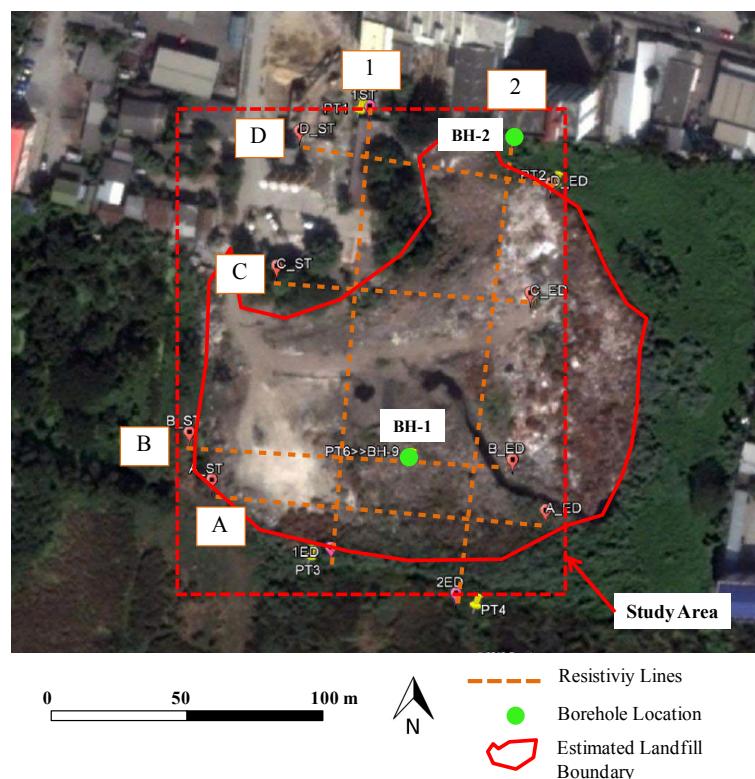


Figure 1 Map of the study site showing the estimated landfill boundary, the ERI survey lines (A–D and 1 and 2 in the West–East and North–South direction, respectively) and the borehole locations (BH-1 and BH-2).



Figure 2 Picture of the filling material generally found in the landfill area.



2.2 Methods

The geophysical technique selected to characterize this landfill site was ERI, because of the high variation in the electrical resistivity of the filling materials and the natural soil underneath that should allow for sufficient contrast between the two for their clear segregation. Also this method is rapid and cost effective compared to other direct methods, such as drilling and trenching. Six lines of ERI data were acquired throughout the study area, comprised of two survey lines (1 and 2) in the North-South direction and four survey lines (A-D) in the West-East direction. The location of these profiles was selected according to the history of the site and to ensure a uniform coverage of the site, and in each line the ERI data were acquired with dipole-dipole array using an Iris Syscal R1Plus system with a 48 electrode configuration. The electrode spacing of each line, assigned according to the space available, is shown in Table 1.

In order to validate the obtained ERI results, borehole information was used to help interpret the results. There are two boreholes available at the site (BH-1 and BH-2; Figure 1). The soil profiles at these two boreholes are described in Figure 3. BH-1 was drilled inside the landfill and encountered garbage to the maximum borehole depth of 14 m. However, this borehole was terminated before reaching the natural soil and so the actual depth of the garbage fill and natural soil underlayer at this site is unknown. BH-2, at the edge of the landfill site, was drilled to ~30 m depth and encountered garbage to 2.5 m depth, followed by soft clay and then stiff clay down to a depth of 19 m, the contact zone between the clay and the first sand layer that is the major layer of pile tip for convention building in the Bangkok area.

Table 1 The line parameters used in the ERI survey

Line	Line length (m)	Electrode spacing (m)
1	164.5	3.5
2	164.5	3.5
A	117.5	2.5
B	117.5	2.5
C	94	2
D	94	2

3. Results

The six ERI profiles obtained are summarized in Figure 4 for the West-East profile (lines A-D) and in Figure 5 for the North-South profile (lines 1 and 2), where the thickness of the landfill is represented by a dashed line. It is possible to distinguish two zones in the West-East profile (Figure 4), with a more resistive ($> 7 \text{ ohm-m}$ on average) 2–10 m deep zone and a second, less resistive ($< 6 \text{ ohm-m}$) zone underneath. This contrast in the electric resistivity corresponded roughly to the filling materials and the underneath clay layer, respectively. Variation in the resistivity values could be observed in the fill layer, which is probably due the heterogeneity of the diverse array of different fill materials that consisted of mainly concrete rubble, plastic, and so on.

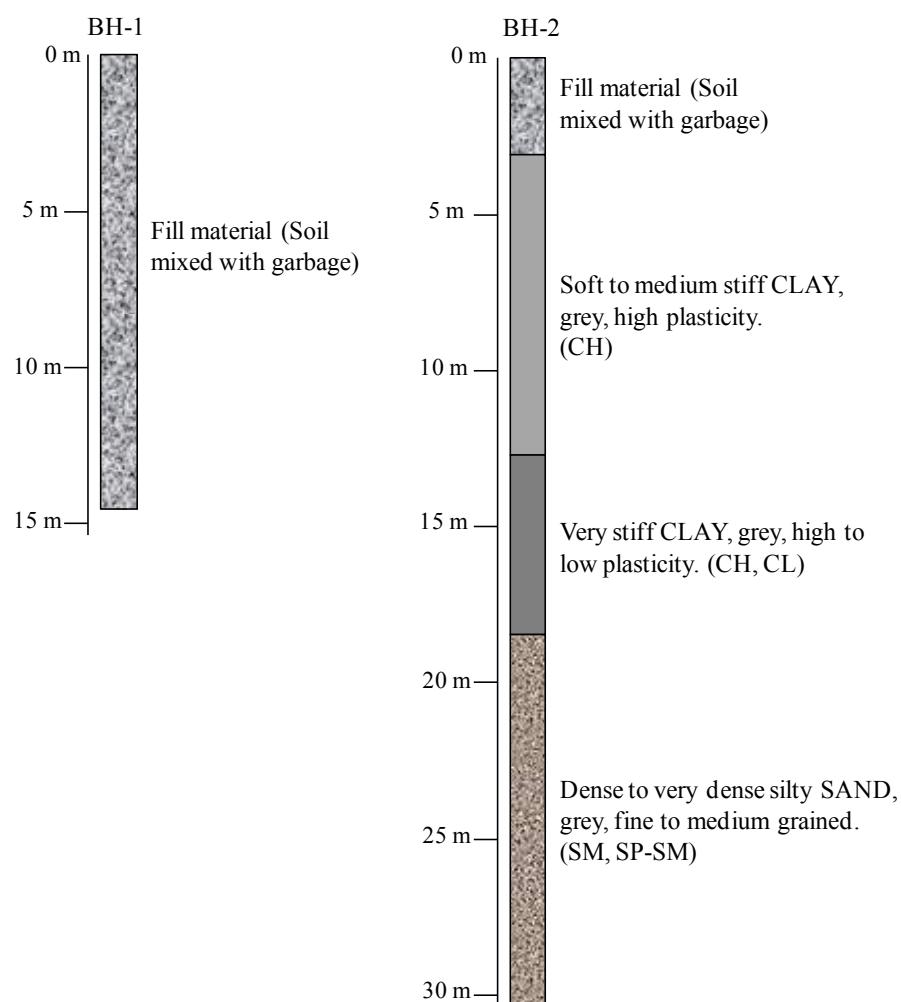


Figure 3 Soil profiles from the two available boreholes (BH-1 and BH-2) in the study area.

The second layer in the ERI profiles was interpreted as the clay layer based on the information from BH-2. The thickness of the garbage layer tended to increase towards the eastern side of the area, and the maximum garbage layer thickness was observed between lines B and C. The data was supported from the BH-1 profile, where the garbage fill was encountered throughout the entire borehole (< 15 m depth). The obtained ERI model of Lines 1 and 2, located in a north–south direction, gave a garbage depth that correlated well with the lines in West–East direction, and had a deepest garbage layer depth (~15 m) in line 2 at distance of 80–120 m along the transect.

As already mentioned, within the garbage fill layer the resistivity values varied considerably from a low to high resistivity, which was probably due to the mixture of different fill materials in the landfill. According to borehole data, the more resistive zones (> 20 ohm·m) in the fill were related to the presence of a significant proportion of different types of demolition waste, such as bricks and concrete rubble. This is congruent with the known resistivity of the materials, where, for example, concrete can have a resistivity between 10 and 2000 ohm·m. The debris was very coarse and had a very small water retention capacity, and in general remained largely unsaturated. The medium resistive zone, which is the dry



soil mixed with garbage, had an apparent resistivity of between 7 to 20 ohm-m. These resistivity anomalies have a large lateral continuity (Figure 5). After each resistivity section was interpreted and the garbage-clay interface was drawn, the thickness of the garbage layer was contoured (Figure 6).

It is clear that the thickness of the garbage layer increased from the western to eastern part of the area. In the eastern and northern part the full thickness ranged from 2 m to about 6 m deep, whilst in the western part of the area the thickness of fill was greater with a range from 10 to 18 m deep, as also seen in BH-1. It has been reported that this area was previously used as a dumping pit. From a foundation design perspective, the appropriated foundation types would have to be carefully considered due to the thickness of the fills in this part.

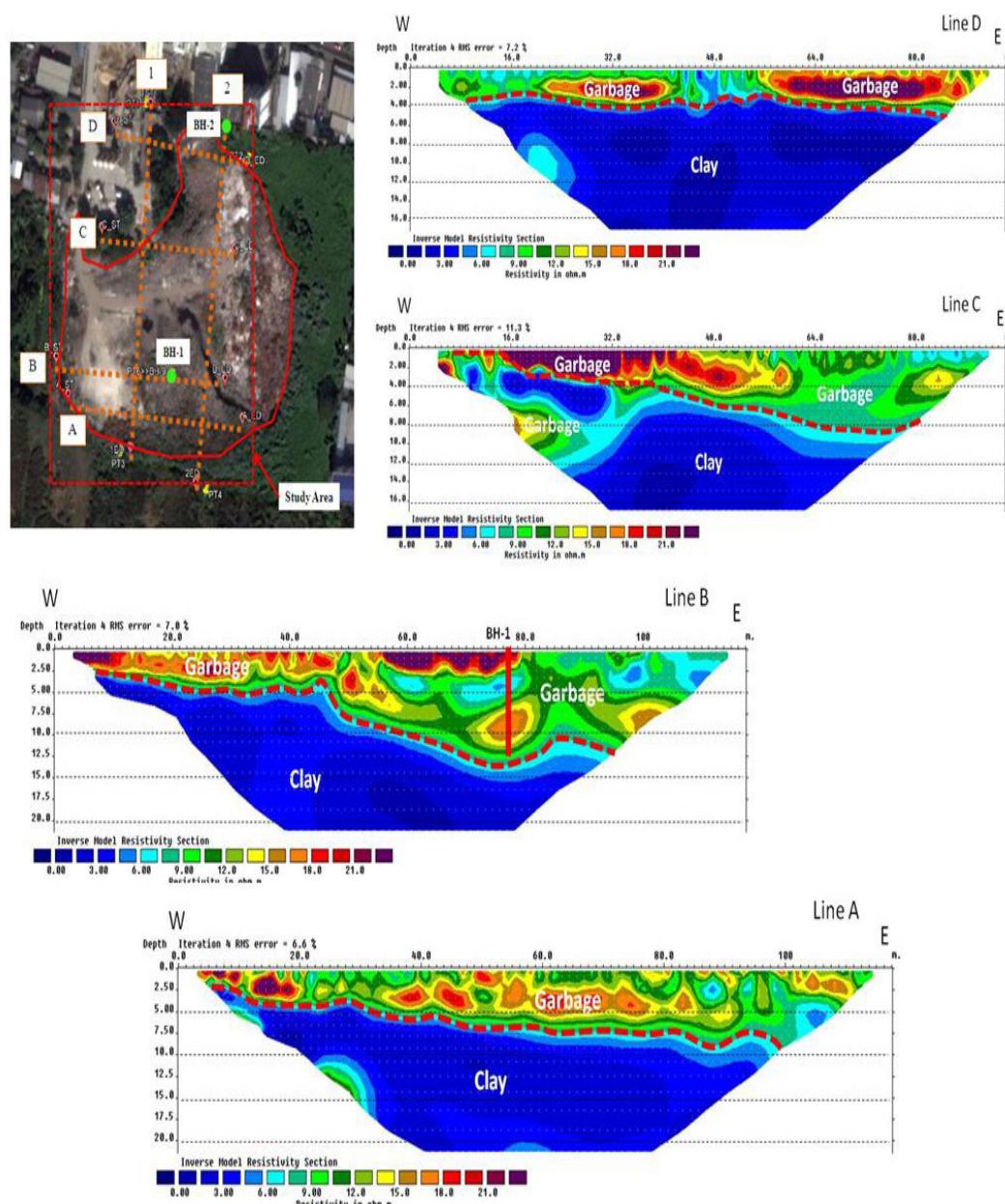


Figure 4 Resistivity image of the West–East profile (Lines A–D).

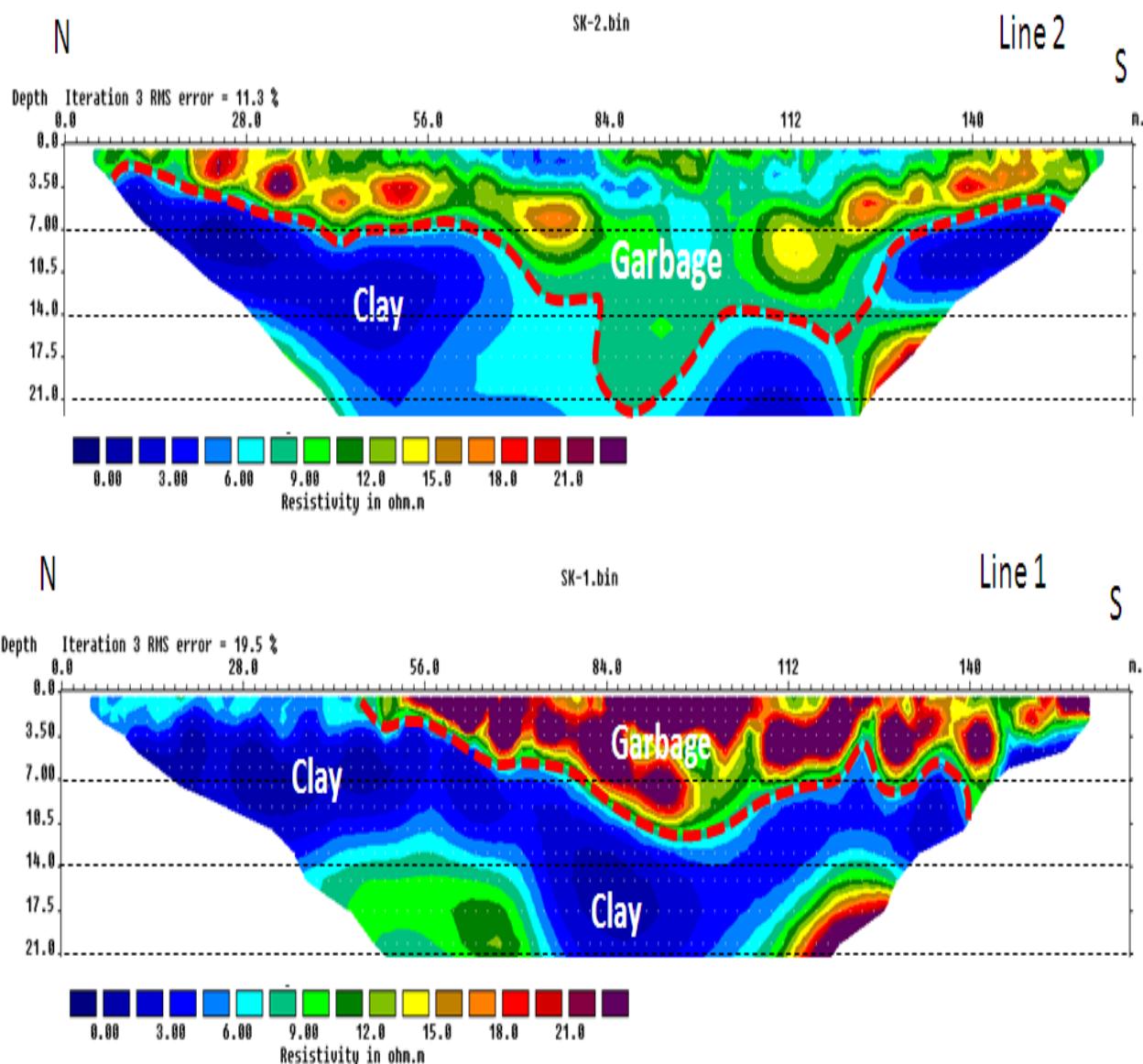


Figure 5 Resistivity image of the North–South profile (Lines 1 and 2).

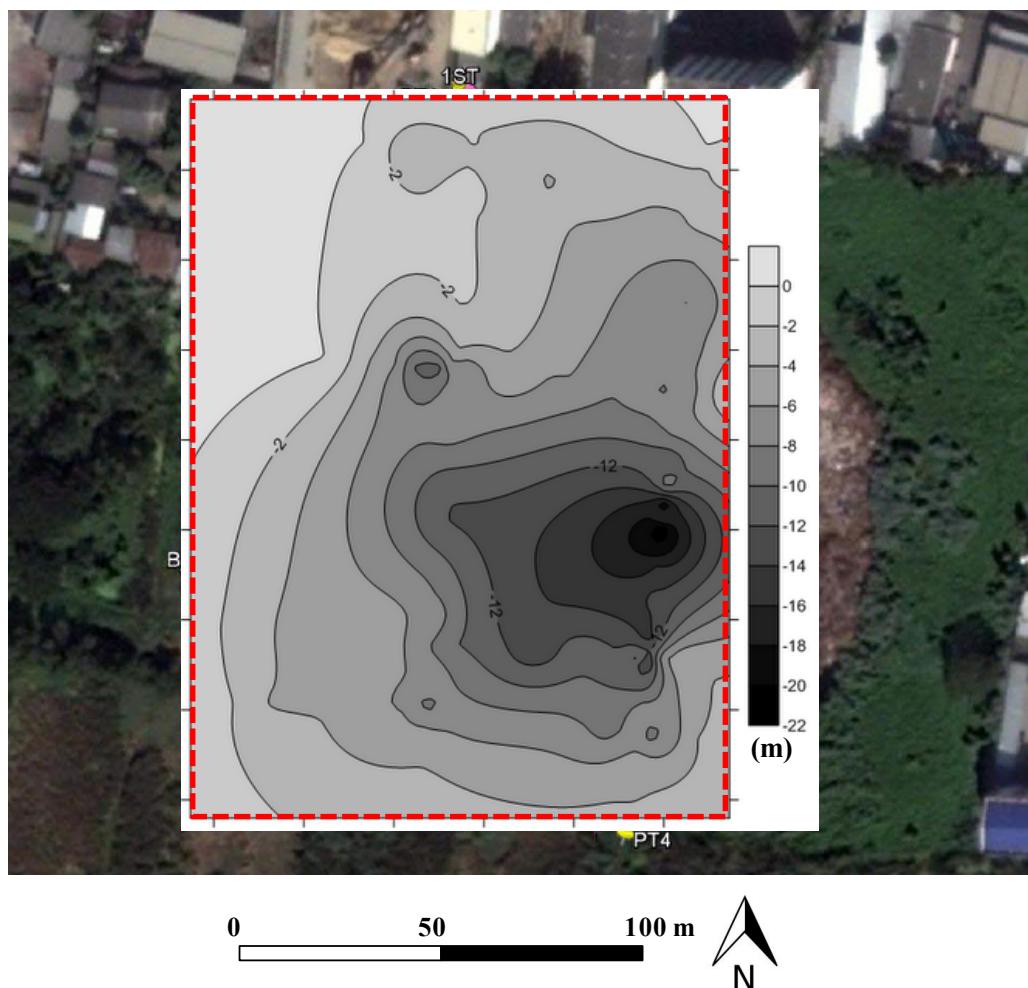


Figure 6 Estimated depth of the garbage in the landfill site, as derived from the ERI analysis

4. Conclusion

The geophysical ERI technique, a method that is sensitive to electrical contrast between the soils and fill material, was used to determine the thickness and boundary of landfill at an abandoned site. As opposed to conventional characterization techniques, which rely on trench excavation or borehole drilling and only provide a localized estimation of fill thickness, ERI analysis helped picture the geometry of the fill in a 3D (continuous) manner. The potential of ERI to improve the characterization of urban fills through a more precise determination of their geometry was clearly shown, where the external geometry of the fill was successfully described by the ERI data allowing an estimated depth of the boundary between the fill and the underlying natural soil deposits to be mapped over the area. Another approach would be to perform the ERI survey on a densely sampled grid and to invert the data for a 3D resistivity model. Volumes of landfill material could then be directly estimated from the 3D model.

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