HOW TO MAP WASTE DEPOSITS USING RESISTIVITY AND IP

With the knowledge we have today we are aware that there are a number of actions that has to be taken when a landfill is to be closed and filled over, but this has not always been the case. Many closed landfills were just filled and covered with soil and then left as they were. As cities grow old landfills that used to be far from urban areas may now be close to cities, or even within them. On the surface of the old landfill everything appears to be fine, but beneath it lies buried waste that might be causing serious environmental problems.

PROBLEM

Old landfills often have high concentrations of heavy metals, nutrients and organic substances in the ground and as they seldom were constructed with containment as an objective they risk polluting both surrounding groundwater and downstream surface water. For environmental protection and land re-use purposes there are therefore a number of issues that needs to be investigated and considered, e.g. how much waste is buried, at which depth is it located and the status of soil covers.

SOLUTION

Resistivity imaging is a method which is great for mapping the geological and hydrogeological properties of the ground, but as waste may have a high variation of resistivity it can be difficult differentiating waste from the surrounding soil by only doing resistivity measurements. Buried waste and leakage from it often have a high concentration of ions resulting in high chargeability.

Chargeability can be measured by doing Time-Domain Induced Polarisation (IP) measurements and can easily be combined with resistivity measurements. The method to combine resistivity and IP has proven to be successful for getting the most information about both the soil and the waste. As landfills often cover big areas and the content of the waste never is evenly spread out, only doing one 2D measurement will not give complete information of the landfill. It is therefore strongly recommended performing measurements in such a way that a 3D dataset is achieved. With a 3D dataset even small variations in geology and waste composition may be seen and will give much more information on the status of the old landfill.

USING THE ABEM TERRAMETER LS COMPARED TO A DIFFERENT SYSTEM FOR A COMBINED RESISTIVITY AND IP MEASUREMENT WILL NOT ONLY SAVE YOU MONEY, IT WILL BE EASIER TO USE AND INCREASE FIELD EFFICIENCY.

Field procedure

A 2D or 3D resistivity measurement is performed by having a high number of steel electrodes inserted in the ground. The electrodes are connected to multi conductor cables that have one connection point for every electrode. The cables are then connected to the resistivity meter. The number of electrodes and cables can vary depending on how the resistivity system is configured. As the system consists of a built-in automatic electrode selector no additional movement of electrodes is required once the field setup is finished and data collection is started.

For IP measurements the field setup looks very similar, but traditionally steel electrodes cannot be used as Spontaneous Potential (SP) effects caused by steel electrodes may cause data quality to be bad. Instead a special type of electrode called non polarizable electrodes has to be used. Non polarizable electrodes cannot be used for current transmission, so this means that to do IP measurements traditionally an extra set of electrodes are needed. As most non polarizable electrodes are filled with a special fluid that regularly needs to be changed, not only does the initial investment increase but also the maintenance costs. The field procedure also becomes more difficult and time consuming as two types of electrodes must be used.

IP WITH STEEL ELECTRODES

The ABEM Terrameter LS has a unique design of its measurement channels which makes it possible to do IP measurements with steel electrodes and still achieve great data quality. So using the ABEM Terrameter LS compared to a different system for a combined resistivity and IP measurement will not only save you money needed for accessories and maintenance, it will be easier to use and increase field efficiency.

A HIGHER SIGNAL TO NOISE RATIO

The ABEM Terrameter LS can also use an array called Multiple Gradient array. Just as the Schlumberger and Wenner array the Multiple Gradient is a nested array, which means that the potential electrodes are always positioned within the current electrodes. Because of that the signal to noise ratio is much higher compared to other arrays such as Dipole-Dipole or Pole-Dipole. A higher signal to noise ratio gives much better chances of achieving data with good quality when measuring small input signals. As the input signals for IP measurements typically are very, very small this is a great advantage for getting good data quality for IP measurements. Using the Multiple Gradient array the ABEM Terrameter LS can take up to 12 measurements for every current injection, making it a very quick array and a good way of keeping expensive field time to a minimum.

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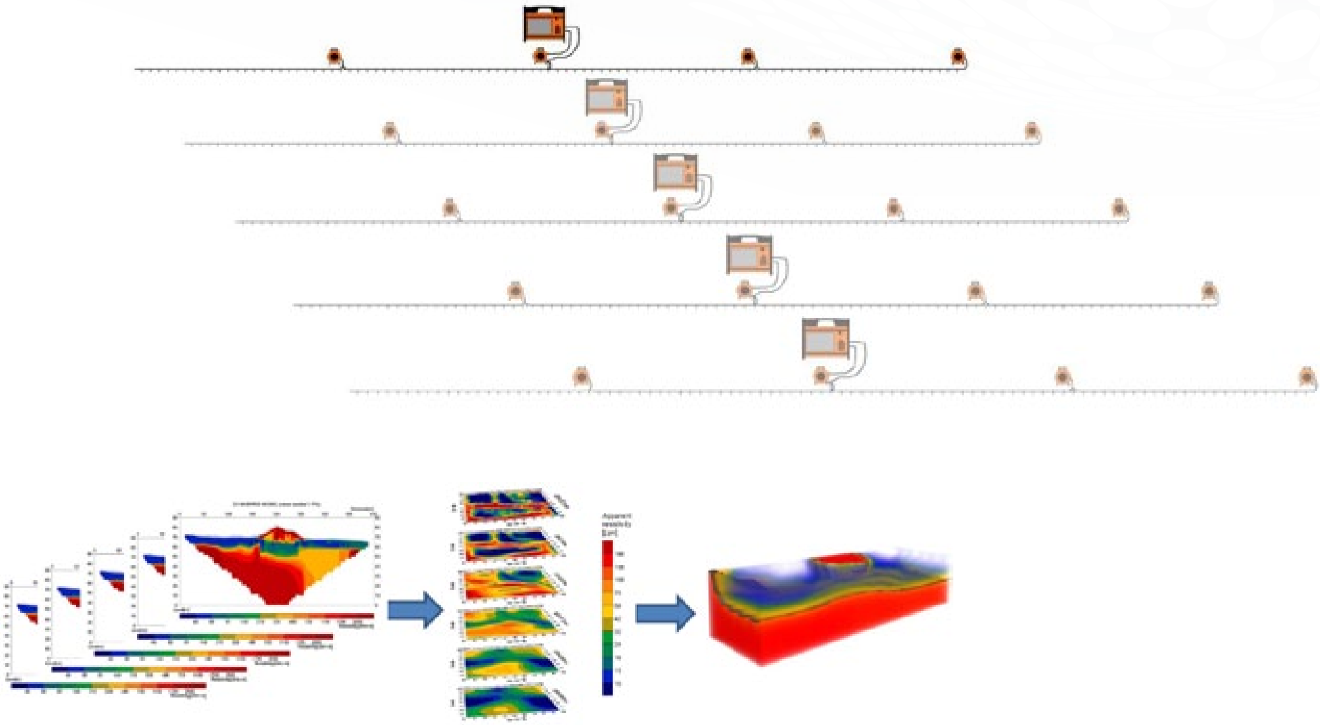
The advantage of 3D



THE PROCESS FOR 2.5D MEASUREMENTS :
PARALLEL 2D MEASURE LINES ARE COLLECTED, AS MANY AS NEEDED TO COVER THE SURVEY AREA WITH CHOSEN RESOLUTION. THE 2D PROFILES CAN THEN BE MERGED AND INVERSED AS A 3D DATASET USING SOFTWARES SUCH AS RES3DINV. THE INVERSED 3D DATASET MAY BE PRESENTED AS A 3D MODEL USING VISUALIZATION TOOLS SUCH AS VOXLER

2D VS 3D MEASUREMENTS

The difference between a 2D and a 3D measurement is that for a 2D measurement the cables are put on the ground in one straight line, resulting in a 2D dataset with information only straight beneath the measure line. For a 3D measurement a number of parallel cables are put on the ground, resulting in a 3D dataset with information covering the volume beneath all of the cables. The advantage of a 3D dataset is that there is much more information available, making it possible to interpret and map the waste with much higher detail. The disadvantage is that it requires a lot of equipment and therefore will be very expensive. But there is a way, sometimes called 2.5D, to achieve the same result as from a 3D measurement using only a 2D resistivity/IP system.

HOW TO CONDUCT A 2,5D MEASUREMENT

A 2.5D measurement starts with doing a regular 2D measurement, but once that measure line is finished the cable spread is moved so that it is placed in parallel with the original position. A second 2D measurement is done with the new position for the cable spread. When the second measure line is finished the cable spread is then moved again, so that it is being positioned parallel to the second measure line. A third 2D measurement can then be performed. The process of moving the cable spread and collecting additional 2D measurements can be continued as long as needed, there is no upper limit for how many measure lines can be taken. The 2D datasets can then be merged and interpreted as one 3D dataset. The 2.5D measurement is a simple way to keep investments to a minimum but still be able to collect big 3D datasets. In addition to costing less, it is also much more convenient to handle and operate when in the field.

The ABEM Terrameter LS's user interface makes it very easy managing a measurement project, even when including a high number of measurement lines. Each 2D dataset can be viewed separately, as a slice of the total volume, or exported and merged to be interpreted as a 3D dataset.

Example of a combined resistivity and IP survey

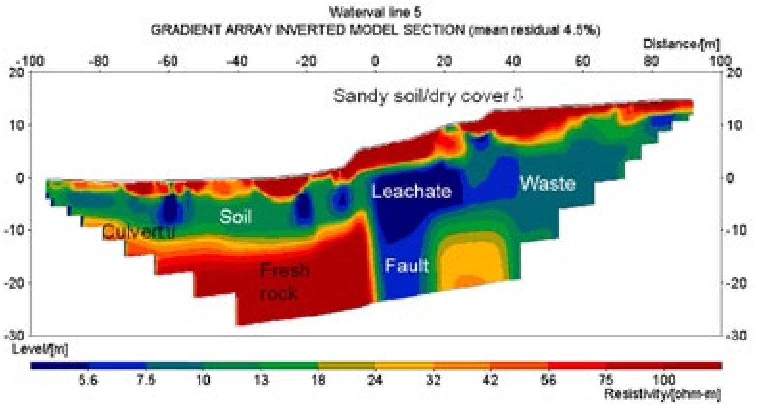
A combined resistivity and IP survey was done on an old landfill in Johannesburg, South Africa by Lund University, the Swedish Geotechnical Institute and the University of the Witwatersrand. It had been concluded by groundwater sampling that the groundwater outside of the old landfill was contaminated. The objective with the survey was to develop a method that could be used for detection of leachate contamination of the geohydrological system close to a landfill.

To get as much information as possible a 2.5D survey consisting of eleven parallel 2D measure lines was done. As depth requirements was only about 30 meters a cable spread with 2 meter electrode spacing was used to obtain highest possible data resolution. The Multiple Gradient array was chosen to get as good data quality as possible and to make measurements quicker.

The results from the resistivity and IP survey was compared to results of groundwater sampling and to results from previous investigations, and showed that the method of combining resistivity and IP measurements could successfully be used for detecting contamination of groundwater and to locate buried waste. The results also showed that the method could be used for mapping leachate plume migration.

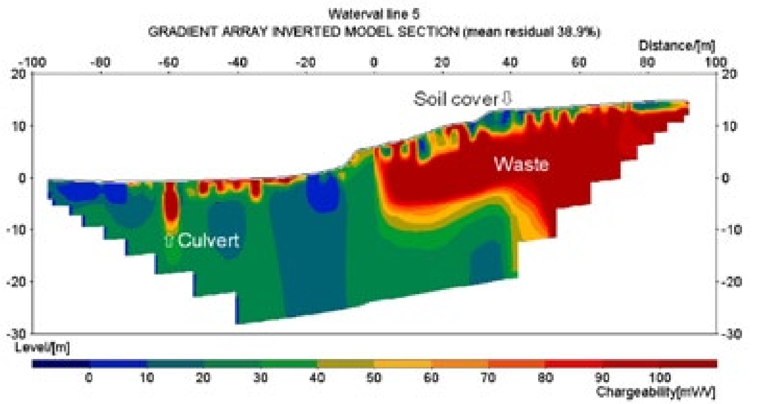
MODEL SECTIONS WITH RESISTIVITY AND IP FROM ONE OF THE ELEVEN 2D MEASUREMENT LINES.

RESISTIVITY



THE UPPER MODEL SECTION SHOWS THE RESISTIVITY RESULTS AND IT CAN CLEARLY BE SEEN THAT BY USING RESISTIVITY ALONE IT IS NOT POSSIBLE TO DETECT WHERE THE WASTE IS LOCATED AS THE WASTE LOCATED IN THE RIGHT PART OF THE SECTION HAS APPROXIMATELY THE SAME RESISTIVITY AS THE SOIL IN THE LEFT PART OF THE SECTION.

INDUCED POLARISATION



THE LOWER MODEL SHOWS THE IP RESULTS AND WITH THIS ADDITIONAL INFORMATION THE WASTE CAN EASILY BE IDENTIFIED AS ITS CHARGEABILITY IS SIGNIFICANTLY HIGHER THAT THE SURROUNDING SOIL.

THE LOW RESISTIVITY IN THE LOWER RIGHT PART OF THE UPPER MODEL COULD INDICATE THAT THERE IS A FAULT, POSSIBLY LEAKING LEACHATE WATER INTO THE GROUND WATER.

REFERENCES • Rosqvist, H., Dahlin, T., Fourie, A., Röhrs, L., Bengtsson, A. and Larsson, M. 2003. *Mapping of leachate plumes at two landfill sites in South Africa using geoelectrical imaging techniques*, Procs. Ninth International Waste Management and Landfill Symposium, S. Margherita di Pula (Cagliari), Sardinia, Italy, 6-10 October 2003, 10p • Dahlin, T. And Zhou, B.. *A numerical comparison of 2D resistivity imaging with 10 electrode arrays*. Geophysical Prospecting, 2004, 52, 379-398. • Dahlin, T., Johansson, S., Rosqvist, H. and Svensson, M.. *Resistivity-IP characterisation and short term monitoring at Filborna waste deposit*. 14032. EAGE, SPE EUROPEC 2012