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Maximizing productivity in heap leach pads through dipole electrical leak location

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Abstract

Mining companies invest many thousands of dollars on construction quality assurance (CQA) during heap leach pad construction and expansion in order to install a high-quality geomembrane liner free of defects or leaks. The geomembrane is then covered with overliner material using large construction equipment, when significant damage can occur to the installed geomembrane. An electrical leak location (ELL) technique called the dipole method is available for locating leaks through the installed earthen cover material (ASTM D 7007-09). The dipole method has been proven to be a reliable and cost-effective tool to check 100% of the covered geomembrane for leaks through the cover material, which can then be repaired before operations begin. However, the dipole method is not typically used as part of heap leach pad construction and CQA. The general practice is for a CQA tech to "observe" overliner placement activities. Subsequently, random test pits are excavated in order to inspect the condition of the liner. It is difficult to impossible for a CQA tech to detect damage to the geomembrane during placement of the cover materials, since it is placed quickly and is immediately covered up. Cover material is also commonly placed at night, when visibility is severely limited. Statistically, the procedure described above is not representative of the geomembrane installation quality. The significant damage locations caused during overliner placement are not only a source of potential environmental and legal problems, but also cause a loss of revenue by the leakage of the pregnant solution into the subsurface.

In this paper, current CQA practices during and subsequent to overliner placement are compared to the alternative of performing a dipole-method ELL survey. The dipole-method experience detailed comes from high altitude heap leach pads in the Andes, where the technology successfully detected damage locations of various sizes, several of them extremely significant. From both a financial and technological point of view, incorporating the dipole ELL method is a far more effective CQA tool than what is currently used in preventing future environmental impacts, potential legal claims and certain loss of revenue through leaks that could have been easily detected by ELL during the heap leach pad construction phase.

Introduction

Every year, mining companies in South America build new heap leach pads and upgrade existing ones, which corresponds to about 300 to 400 ha[1] of new geomembrane liner installed per year. Most of them already include traditional CQA as part of their standard construction procedure, investing significant resources and thousands of dollars to install high-quality geomembrane-liner systems. However, traditional CQA does not focus on the activities where the significant damage to geomembrane occurs. The most significant damage to installed geomembrane occurs during cover material placement (Scheirs, 2009). In the authors' experience, this damage largely consists of punctures from cover material, track marks from equipment tread getting too close to the geomembrane, and direct rips from equipment blades and buckets. From statistics gathered from over 300 sites comprising over 3,250,000 m^2, 24% of geomembrane damage occurs during liner installation, 73% occurs during geomembrane cover material placement, and 3% occurs in the postconstruction phase (Nosko, 1996). The same statistical study showed that the damage incurred during cover material placement had the following distribution of leak types: 68% stone punctures, 16% heavy equipment directly, and 16% grade stakes.

The ELL method for locating leaks through the installed earthen cover material is the dipole method (ASTM D7007-09). The dipole method has been proven to be a reliable and cost-effective tool to directly locate the most significant damage locations in the geomembrane after cover material placement, giving an early opportunity to detect and fix the damage before the site begins operation. However, performing an ELL survey as part of heap leach pad construction after the placement of the overliner material is not common practice in South America (Beck, 2014). This is despite the fact that previous analyses have shown that the cost of an ELL survey can be recovered over the life of a site simply through the retention of precious metals that otherwise would leak through the lining system, had the survey not been performed (Thiel, 2005).

This paper presents two case studies of two high altitude heap leach pads where traditional CQA measures were taken, followed by a dipole-method ELL survey. The efficacy of both procedures is thus evaluated based on their ability to control the significant damage caused to the geomembrane during cover material placement.

Case study # 1 site description

This heap leach pad was located in the Andes Mountains, at 4,400 m above sea level (masl). Figure 1 shows the area general overview. Weather at this site is generally dry, with a rainy season from December through February. The pad area to be surveyed was 110,000 m^2, with a schedule restriction of ten days to finalize

[1] Authors' estimate based on local market knowledge.

the project. Maximum slope was 2.5H: 1V, overliner material was high-grade ore with a minimum thickness of 0.6 m and a maximum thickness of 1 m.

2.0 mm LLDPE geomembrane single liner was used, placed on top of 30 cm soil liner (1.3 E-07 cm/s) layer.

Figure 1: Survey area general overview

Figure 2: Overliner material

Figure 3: Dipole survey

Case study # 2 site description

This heap leach pad was located in the Andes Mountains at 4,200 masl. During the survey time, weather at this site was generally rainy with showers, heavy rain, and thunderstorms generating significant delays to the project schedule. Due to this and other nonoperational contingencies, the schedule was extended from fifteen days to almost twenty-seven days of field work for a 170,000 m^2 pad area. Maximum slope was up to 2H:1V, overliner material was mineral ore with a minimum thickness of 0.25 m and a maximum thickness of 1.5 m. At this site, 2.0 mm LLDPE geomembrane liner was placed on top of 30 cm low-permeability soil liner on lower-slope areas and on top of GCL on higher-slope areas.

Typical CQA effort to control damage during overliner placement

In the two case studies evaluated by the authors, CQA technicians observed the placement of the overliner material to monitor for any damage created by equipment. Test pits were selected following traditional CQA criteria, which means that the test pits were executed in areas where the CQA inspector or the engineers considered that there were higher chances for geomembrane-liner damage, like steeper zones, areas where the overliner thickness was suspected to be thinner, or areas where for some reason (e.g., testimony of third parties present during construction) the geomembrane liner was suspected to be damaged.

Table 1: Test pit execution and efficiency

Project	Case study #1	Case study #2
Total pad area (m^2)	100,600 m^2	155,000 m^2
Number of blindly selected executed test pits (estimate)	166	192
Number of leaks / problems found by blindly selected pits (estimate)	0	10
Blindly selected test pits efficiency (%)	0	5
Test pit dimensions	1 m by 1 m	1 m by 1 m
Exposed geomembrane Inspected Area (m^2)	160	190
Inspected area using blindly selected test pits (%)	0.167	0.125

The test pit "Efficiency" was calculated to be the percentage of leaks / problems located in the test pits divided by the total number of test pits executed.

Dipole-method execution

For Case Study 1, a dipole-method ELL survey was requested by the client to provide an additional level of confidence in the quality of the installed geomembrane. At the Case Study 2 site, damage was encountered in the test pits, which suggested that further damage had been incurred throughout the remainder of the pad. Therefore, the client requested a dipole-method ELL survey to make a more thorough check of damage incurred to the geomembrane during cover material placement.

When performing the dipole method on single-lined heap leach pads, the power source positive electrode (current injector) is inserted into the overliner above the geomembrane. The earth ground is wired to the soil outside the pad. The dipole is used to measure the voltage throughout the survey area, using geophysical probes in direct contact with the earth (overliner). The voltage potential across the geophysical probes is measured and recorded.

Dipole equipment has significantly evolved since its inception in the 1980s, from a garage-made-two-volt-meters manual recording device, into a fully integrated electronic device with high precision GPS capabilities, automatic data recording, higher sensitivity, and approximately ten times faster survey speed.

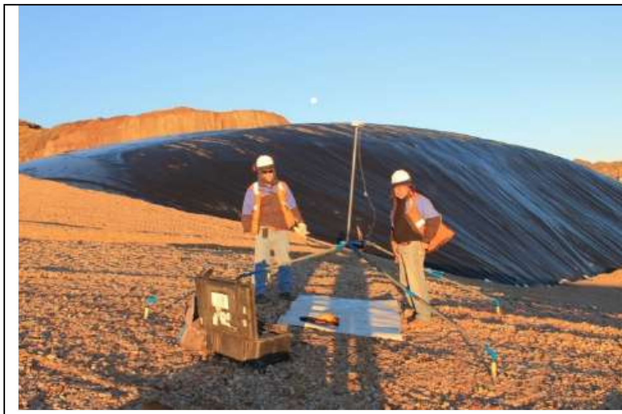

Figure 4: Dipole meter

Figure 5: Dipole base station

Based on the authors' field experience at these two case study sites, state-of-the-art dipole equipment is capable of surveying up to 50,000 m^2 in a single day, with an average of 20,000 m every ten hours of field work, including survey and preparation tasks, which is far superior to the capabilities of former technology equipment. Therefore, a typical heap leach pad ranging from 10 to 20 ha may be adequately surveyed in 1 to 2 weeks, under reasonable fieldworking conditions.

Table 2: Dipole survey speed

Project	Case study #1	Case study #2
Surveyed area (m^2)	100,600	155,000
Surveying time (hours)	38	78
Average surveying speed (m^2/ ten survey hours)	27,894	19,834
Inspected area using dipole data (%)	100	100

The ASTM standard (D7007-09) establishes calibration and sensitivity tests to be conducted at the beginning and end of each survey, on a daily basis. Sensitivity depends on multiple site-specific factors including number of leaks, overliner thickness, overliner material composition, overliner conductivity, moisture content, soil liner conductivity, site perimeter electric isolation, and daily weather conditions, among others. In addition, sensitivity is also subject to equipment technology factors, and operator proper setup. Therefore, for the same site and under the same conditions, depending on the equipment, the operator and other field conditions, different sensitivities may be achieved. The dipole method should be able to reliably detect holes as small as 6.4 mm under 0.6 m of covering material, and often locates much smaller leaks. Even with reduced sensitivity caused by thicker cover material, it retains adequate sensitivity to detect the larger damage caused by trucks and dozers through up to 3 m of cover thickness.

Based on ASTM 7007-09 the "R" value ("signal + noise" to "noise" ratio), must be equal to or greater than 3.0. (ASTM Subcommittee: D35.10, 2009).

Table 3: Dipole detection sensitivity

	Case I	Case II
R value (S+N / N) for a 6.4 mm artificial leak	4.8	3.0 – 26.6
Smallest detected leak (cm^2)	6	0.25
Biggest detected leak (cm^2)	14,000	4,800

Data is recorded and correlated to a local coordinate system, which is established through the high-precision GPS rover and base station. The data is then downloaded and analyzed for voltage anomalies, which could be indicative of leak locations. Data is mapped using specific software and converted into a fast detection tool looking for electrical anomalies. The map is colored based on the actual dipole rover voltage reading (crosses). Readings are collected on a 3 m by 3 m grid, in lanes executed parallel to the "y" axis, going back and forth. Areas where the color changes quickly from positive (green – yellow) to negative (red – blue) are considered anomalies which correspond to a significant change in the electrical field distribution. In the map in Figure 6, two anomalies can be observed:

- The first anomaly is generated by the current injector located at (880;410). Since the voltage increases approaching the current injector from the bottom and decreases moving away from it on the upper portion, all the readings below the current injector should have a positive (green – yellow) value, and all the readings above the current injector should have a negative (red – blue) reading.

- The second anomaly, located at (850;550) is an area of potential concern (point for field verification and leak location) to be identified and rechecked by the dipole team. In fact, the anomaly turned out to be a large hole at this site.

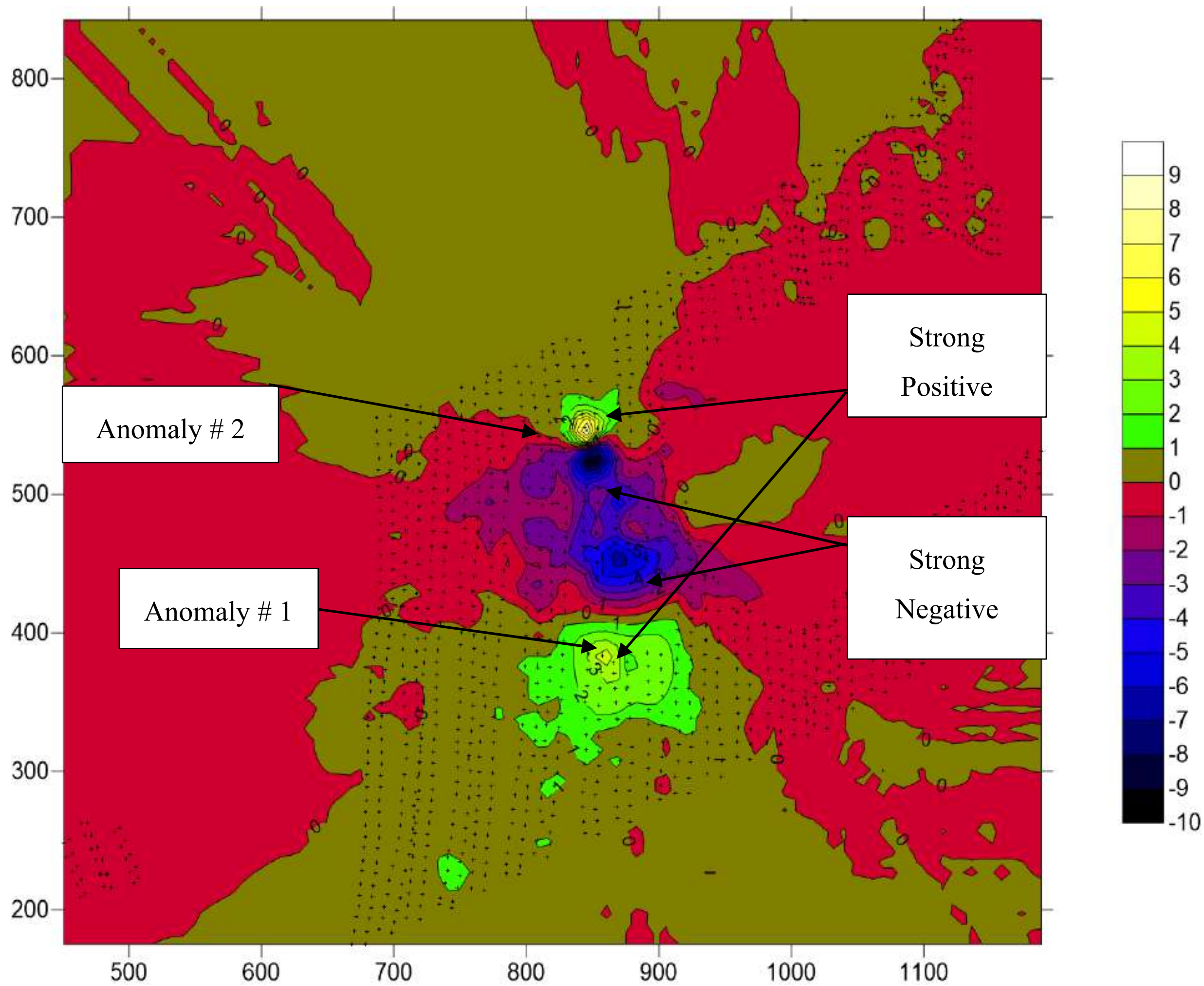

Figure: 6 Dipole data mapping

Organizing the data into the format shown in Figure 6 makes it possible for the survey results to be reviewed by supervisors or third parties. Actual leaks are located by the dipole team during the recheck process through direct measurement of the anomaly locations with higher data collection points reading density. Those anomalies identified by the dipole team to be actual leaks are then carefully exposed for visual verification. Since smaller holes may remain covered by the overliner material around the bigger holes, subsequent detailed survey around exposed areas is required by ASTM D7007-09. This iterative process allows smaller leaks to be located, exposed and repaired as well.

Figure 7: Anomaly verification (leak location)

Figure 8: Overliner excavation

Figure 9: Overliner thickness verification

Figure 10: Damage exposure

Figure 11: Perimeter verification

Figure 12: Location of smaller leaks previously masked by bigger leaks

Conclusions

The observation of cover material placement followed by random test pitting in case study #1 did not locate any actual leaks in the geomembrane. The results of the test pit analysis leave the impression that the geomembrane was generally well constructed and not likely to contain leaks. However, the dipole survey performed at the same site located significant leaks in the geomembrane totaling over 20,000 cm^2 in area. In a separate financial analysis of this case study site, the leaks encountered during the dipole survey would have resulted in approximately $US26,000 in value of solution lost every year of the heap leach pad's operation (Beck, 2014). With an assumed survey cost of $US50, 000, which is the average rate for a survey of this size, the payback period is achieved in less than two years.

In case study #2, the random test pit analysis showed that the geomembrane installation had issues due to improper cover material placement. Had a dipole-method ELL survey not been performed, it is likely that either the entire lining system would have had to be uncovered for inspection, or the significant damage would have remained in the geomembrane for the life of the site.

As these two case studies illustrate, dipole-method ELL surveying in high altitude heap leach pads can economically and efficiently detect geomembrane damage locations of various sizes—potentially extremely significant—as part of heap leach pad construction and CQA. Due to the evolution of the dipole-method equipment, which can now rapidly scan large areas of installed geomembrane, it is possible to quickly assess where the geomembrane damage locations are located. The damage can range from minor, if the overliner material was carefully placed, to major breaches that certainly compromise the design intent of the containment facility. Blindly selected test pits would typically cover less than 0.2% of the geomembrane liner, which is not acceptable from a statistical and quality control point of view. On the other hand, using dipole-orientated test pits it is possible to reliably inspect 100% of the geomembrane area.

Traditional CQA activities are no longer best practice in terms of minimizing leakage. By incorporating ELL technology, financial resources can be more effectively applied to directly locate leaks in the installed geomembrane and significantly improve the overall liner performance with a modest initial investment. It is strongly recommended that heap leach pads, tailing dams and any other sensitive geomembrane-lined containment facility, should include dipole ELL in their engineering design and CQA requirements.

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