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CASE STUDY ON ELECTRICAL LEAK LOCATION USING BOTH WATER PUDDLE AND DIPOLE METHODS ON A MINING WASTE CAP TOTALLING 255,000 M2

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ABSTRACT

This paper will focus on the leak location aspect of a mining waste capping in Quebec, Canada. Water puddle and dipole surveys were conducted on 100% of the 255,000 m² HDPE geomembrane, installed in Barraute, in the summer of 2014. A few adjustments were made to the design to facilitate both of the ELL surveys and to improve their precision. As leak location was planned from the beginning of the project, the ELL company was involved early on, and provided planning recommendations that were implemented onsite, to accommodate the surveys, without hindering the contractors. Only a few minor parameters had to be modified onsite, mostly due to weather hazards and synchronous work, with all of the contractors working in the same area. Overall, no extras were charged for the leak location surveys, they caused no delays, and the methods worked very well. Twenty-three defects were located with the water puddle method, and twenty-six were identified with the dipole method. This leak density is very low when compared to similar sites. With regards to the dipole method, Forget et al. (2005) found an average of 24.7 leaks/hectare on a 1.5 mm thick geomembrane without CQA (Lessons learned from 10 years of leak detection surveys on geomembranes), whereas 1.04 leaks/hectare were found at the Barraute site. The main factors that contributed to the low defect count were the simplicity of the lining installation, good design, and the skill of the geomembrane installation crew and the general contractor when placing the cover material. One important aspect to consider for this type of project is the ability of the leak location specialists to adapt their survey speed to the installer and the general contractor, in order to blend in the workflow. The ELL company was present onsite throughout the entire project to validate final surfaces as they became available, and was able to deliver them for the next step in the design, in a timely matter.

1. INTRODUCTION

Electrical leak location on geomembranes has seen constant growth over the years. In most circles, as it has become increasingly better known, it has also become increasingly required. However, in one sector—mining—it is still not widely used mainly due to erroneous ideas that circulate and persist. These ideas include its high overall cost, the additional delays it causes and its pertinence (or efficacy). The main objective of this article is to clarify some of the misconceptions surrounding leak location using concrete evidence from a large-scale mining project (255,000 m^2) completed in 2014 in Quebec, Canada.

2. PROJECT DESCRIPTION

The Barvue mine site is located roughly 50 km north of Val d'Or and approximately 10 km northwest of the municipality of Barraute in Abitibi-Témiscamingue, Quebec. Discovered in 1950, this retired zinc and silver mine was mainly operational from 1952 to 1957. Over 5 million tonnes of ore were extracted and treated onsite. The Barvue site consists of a 32-hectare (ha) tailings facility, as well as a tailings spillway that borders the Marcotte creek until it reaches its confluence with the Laflamme River. The spillway is roughly 28 ha in size.

The wastes at the Barvue site are acid waste generators, which have the potential to release dissolved metals in the receiving environment. The Barvue mining site is classified as an abandoned site. The Ministry of Energy and Natural Resources of Quebec (*Ministère de l'Énergie et des Ressources naturelles du Québec*, also known as MERN) decided to restore the site with efficiency and sustainable development in mind. After having a tailings characterization and spillage zone study conducted in 2009, a mine closure plan was developed in 2011. The concept retained is essentially based on multi-layer imperviousness, which includes a textured HDPE geomembrane, in order to limit the process of oxidation of the mining wastes, thus slowing the production of acid drainage.

The remediation work was divided in four (4) phases:

- Phase 1: during the winter of 2012, deforestation of the project area and installation of a proper access road.
- Phase 2: during the spring and summer of 2012, reinforcement and stabilization of the mining wastes dikes. The north face of the mining waste pile required the construction of an additional dike that was more than 500 m long and the re-routing of the Marcotte creek.
- Phase 3: during 2013, transportation of all waste located in the spillage zone to the deposit area (about 400,000 m³), and stabilization and revegetation of the banks of Marcotte creek.
- Phase 4: the final phase of the Barvue restoration project started in March 2014 was completely finished in autumn 2015. It consisted of the installation of the multi-layer leak proofing system, including the geomembrane (all installed in 2014), the vegetation of the mine capping, and the installation of specialized instruments to monitor environmental parameters.

3. DESCRIPTION OF THE ELECTRICAL LEAK LOCATION MANDATE

The technical specifications required the following:

> "(…) control tests of the integrity of the geomembrane following installation and after covering (electrical leak location by <u>water puddle method</u> on exposed geomembrane and electrical leak location using <u>dipole</u> method on covered geomembrane)."

3.1 Description of the Water Puddle Method (Leak Detection Survey on Exposed Geomembrane)

The water puddle geoelectrical method (ASTM D7002) relies on the intrinsic insulation properties of geomembranes for the detection of small perforations (<1 mm^2) in the geomembrane, generally produced at the time of installation (see Figure 1).

A continuous DC voltage is applied into the metallic water puddle structure, and a grounding electrode is placed outside of the limits of the geomembrane. In the presence of a leak, the current will pass from the metallic structure, through the defect, into the subgrade and to the grounding electrode. A visual and auditory signal will be produced, indicating the presence of a leak to the technician. This technique requires only a thin film of water on the surface of the geomembrane, and provides a validation of the entire exposed surface surveyed.

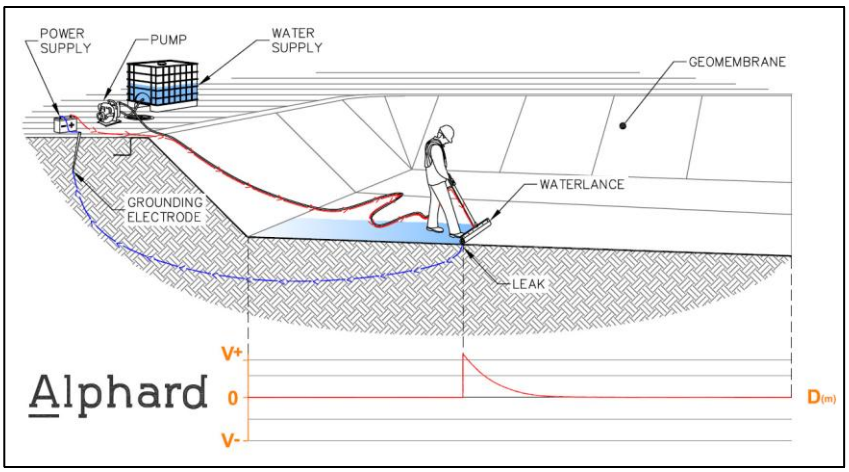

Figure 1. Typical water puddle schematic

3.2 Description of the Dipole Method (Leak Detection Survey on Covered Geomembrane)

The dipole geoelectrical method (ASTM D7007) relies on the intrinsic insulation properties of geomembranes for the detection of perforations that were created during the installation of the cover material (see Figure 2).

A current of up to 550 V is injected into the cover material, and a grounding electrode is placed outside the limits of the geomembrane. If a defect is present, the current will pass through the hole to reach the ground (electrode), which then generates a distinct electrical signature that can be identified and located by a specialized technician.

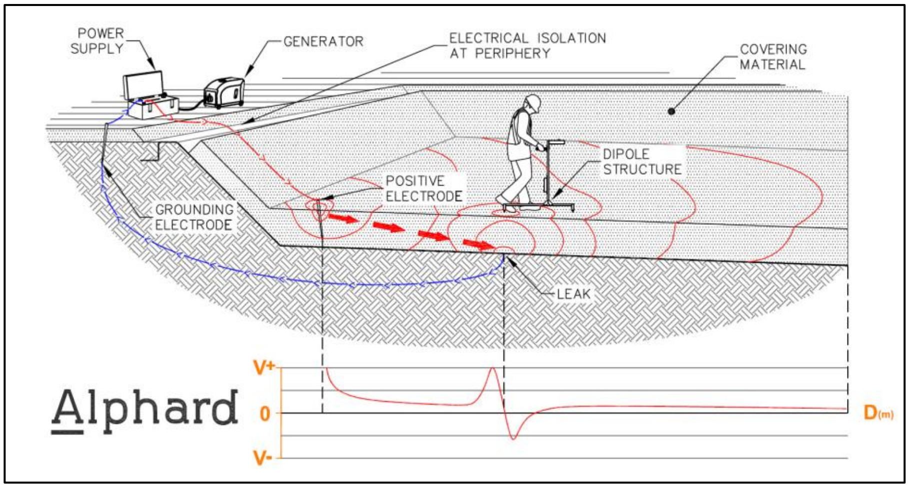

Figure 2. Typical dipole schematic

The entire surface of the installed geomembrane (255,000 m²) had to be checked for leaks, first using the water puddle method, and then again following the installation of the protective cover material (sand) using the dipole method. Texel-Géosol (hereafter “the installer”) was mandated to install the geomembrane. The leak location mandate, including daily reports for the water puddle and dipole surveys, geo-referenced maps showing the progress of the leak location surveys, and a final report (certification) was the installer’s responsibility. The installer retained the services of Groupe Alphard (hereafter “the ELL company”) to fulfill this mandate.

4. PLANNING THE LEAK LOCATION WORK IN ADVANCE

The ELL company clearly stated months in advance the services that the installer would need to provide. For the water puddle survey, this included an on-site water source located near the areas to be surveyed (capable of supplying roughly 5 m^3 per day for a team of one to two technicians), and a pump able to provide sufficient flow at the end of the 125 m hose used by the leak location technicians.

A protocol for repairing the defects was implemented to ensure due diligence: detected perforations were to be repaired as quickly as possible, and the repairs then re-verified using the water puddle method. In the planning, it was also specified that the site had to be well isolated electrically. No contact could be made between the water used in the water puddle method and the subgrade, particularly along the periphery during the construction and impermeabilization of the trenches. The last specification given by the ELL company was that the geomembrane had to be exempt of pebbles, debris, and large puddles of water.

For the dipole survey, it was foreseen that a system for watering the cover material (sand) superficially would need to be on-hand. The cover material could be wetted, as necessary, to provide a good electrical contact between the leak location apparatuses and the sand. The removal of the sand, in the event of a detected signal, was the contractor's responsibility. In the event that multiple leaks were located, the survey speed would be impacted greatly, especially if the material were thick and wet. For a repair to be conducted on the geomembrane, the installer required an 80-cm wide base diameter to be cleared around the repair, which corresponds to roughly 0.5 cubic meters of sand needing to be removed for the average-sized hole.

The ELL company foresaw the need for nine grounding plates—all were indicated on a georeferenced map provided to the client—to provide sufficient contact to the subbase in all areas. Directions were given to all of the contractors regarding repairing those areas after the plates had been removed at the end of the project, and to stockpile the required amount of sand beside the holes to backfill using light machinery (mini-hoe with rubber treads or a bobcat). As such, all was planned and budgeted for, in order to minimize surprises and budgetary excesses in this regard.

Regarding the schedule, it was decided that the water puddle survey would commence one week after the geomembrane installation had started in order to minimize costs and downtime. The leak location team would have enough space in which to work, and could advance at full speed until either they had caught up with the installer or the installation had been completed. This decision did not impact the overall schedule, as the general contractor had other work to perform onsite, and so did not need to wait on the leak location team to finish their survey before placing the cover material. The dipole survey kept pace with the installation of the cover soil.

5. EXECUTION OF THE LEAK LOCATION SURVEYS

5.1 Surprises, Adjustments

The ELL company's first realization upon arriving on-site was that strips of sand (roughly 1 m wide and 30 cm high, shown in Figure 3) had been deposited directly on the geomembrane, along the full length of a roll, at the end of each day (roughly 6 widths of geomembrane). As this was a mining waste cap, the subgrade was raised, and therefore more exposed to wind. Sand bags had not been sufficient to keep the structure safely in place, the longest slopes being roughly 90 meters long. It was therefore decided that a width of sand would be placed on the geomembrane at the end of each day of installation. As such, those sections could not be surveyed using the water puddle method, and were only surveyed using the dipole method.

The capping is designed to be drained by a trench that runs along its periphery and gently slopes to a low point. During the water puddle survey, the site received consistent rainfall that filled the trench, sometimes above the height of the geomembrane (see Figure 4). This electrical contact between the water within the trench and the soil outside cancelled the electrical isolation, giving a constant false positive signal (the water collected from the huge slope flowed down into the trench, which was in contact with the exterior). The water level in the trench therefore had to be brought down below the level of the geomembrane. The subsequent trenches were covered by geomembrane up to the top, to avoid this for the rest of the mandate.

Figure 3. Ballast sand strips on the geomembrane

Figure 4. Loss of electrical isolation in the trench

5.2 Tally and Types of Leaks Detected, Statistics

A total of 23 leaks were detected during the water puddle survey. These leaks were recorded, repaired, and retested. A greater number of leaks (26) were detected using dipole method. Table 1 summarizes the types and sizes of the leaks detected. Although this may seem like a lot of defects, over an area of 255,000 m² this averages to 0.90 leaks per hectare and 1.02 leaks per hectare respectively. According to the article "*Lessons learned from 10 years of leak detection surveys on geomembranes"* (Forget & al. 2005), an average of 24.7 leaks per hectare were detected using the dipole method on a 1.5 mm HDPE geomembrane, on a site without construction quality assurance on the geomembrane (same parameters as this site).

Table 1. List of detected and repaired leaks

WATER PUDDLE METHOD			DIPOLE METHOD		
Leak #	**Description**	**Size (mm²)**	**Leak #**	**Description**	**Size (mm²)**
FJ01	Puncture	6	FD01	Tear	140
FJ02	Puncture	20	FD02	Tear	18
FJ03	Puncture	10	FD03	Tear	10
FJ04	Puncture	10	FD04	Tear	40
FJ05	Puncture	7	FD05	Tear	60
FJ06	Tear	55	FD06	Tear	110
FJ07	Cut (Knife cut)	40	FD07	Tear	150
FJ08	Cut (Knife cut)	20	FD08	Tear	100
FJ09	Puncture	10	FD09	Tear	20
FJ10	Cut (Knife cut)	20	FD10	Puncture	8
FJ11	Puncture	5	FD11	Tear	55
FJ12	Puncture	10	FD12	Tear	120
FJ13	Puncture	5	FD13	Tear	60
FJ14	Tear	10	FD14	Tear	35
FJ15	Cut (Knife cut)	2	FD15	Tear	170
FJ16	Cut (Knife cut)	60	FD16	Tear	270
FJ17	Cut (Knife cut)	220	FD17	Tear	10200
FJ18	Tear	50	FD18	Tear	160
FJ19	Tear	70	FD19	Tear	3500
FJ20	Tear	120	FD20	Tear	70600
FJ21	Puncture	1	FD21	Puncture	140
FJ22	Cut (Knife cut)	100	FD22	Puncture	250
FJ23	Cut (Knife cut)	30	FD23	Tear	106000
			FD24	Tear	50
			FD25	Tear	150
			FD26	Tear	100

The overall results of the detected leaks show that on the exposed geomembrane:

- 43% of the leaks were punctures, generally caused by rocks or tools.
- 34% were cuts, generally caused by cutting patches on top of the geomembrane.
- 22% were tears, generally caused by heavy objects or people slipping on the slopes.

On the covered geomembrane, the results lean heavily towards one type of defect:

- 88% were tears, caused by the impact of heavy machinery or from moving sand with rocks.
- 12% were punctures, caused by heavy machinery passing over solid objects near the geomembrane.

It should be noted that these numbers are based on an average leak density of one leak per hectare (10,000 m²) —a very low leak density—but accidents do occur and it is impossible to detect all leaks onsite. For the water puddle survey, the average size of leak detected was roughly 40 mm² (2 mm by 20 mm), whereas with the dipole method it was roughly 8,350 mm² (4 cm by 20 cm). Since the small holes were detected using the water puddle method, when the dipole method was performed the only leaks to be detected were larger ones created during the placement of the cover material. These results therefore show the average size of leaks that are generally created during each step of the installation process (geomembrane installation and cover material placement) and do not reflect the sensitivity of the two types of leak location surveys; the smallest defect detected during the dipole survey was a 8 mm² puncture.

5.3 Survey Speed, Downtime, and Weather

Based on the installer's estimates for geomembrane installation and cover material placement, the leak location company calculated 51 days to perform the water puddle survey (at a speed of 5,000 m² per day), and 43 days for the dipole survey (at a speed of 6,000 m² per day). Added to this were contingency days in the event of rain. Sufficient area needed to be ready to be surveyed so that the technician could work consistently to maintain this speed. A surface was only considered ready to be surveyed using the water puddle method once all of the quality control tests had been performed on the geomembrane by the installer. It is not recommended to perform the water puddle survey at the same time as the quality control tests, as the hoses and electrical cords can become tangled, the presence of electrical current will induce background noise detectable to the water puddle equipment, and the water from the apparatus can gravitate towards the installer's work area, thereby forcing them to dry the area in order to weld.

In the end, 54.5 days were required to perform the water puddle survey, and 36.5 days were required for the dipole survey. The extra days required for the water puddle survey were in part due to the general contractor requiring the access ramps to be built in specific areas to bring in his sand. These areas, sometimes far away, had to be surveyed and the leak location company had to move their equipment for 20 minutes of work, only to return afterwards to their original work area. Additionally, the survey speed in the 90 m long, 4H:1V slopes was over-evaluated. Roughly 20% of the site consisted of these slopes, which translates to 11 days surveying just slopes—a taxing feat. The speed can be more varied when considering the dipole survey. Depending on the results when calibrating the equipment and the quality of the signal, it is sometime possible to enlarge the size of the grid spacing and therefore the speed.

Including downtime outside of the leak location company's control (issues with water supply or empty water tanks), the delays due to changing the zones being surveyed, and the time to set up and take down equipment, on average, the survey speed was 4,595 m² per day for the water puddle method, and 6,986 m² per day for the dipole method. There were a total of 13 rain-days, representing 12.4% of the total of number of days spent onsite – not an insignificant amount.

5.4 GPS Mapping of the Progress

Given the large area of the work in question, it was not possible to track rigorously the areas surveyed and the exact location of the leaks detected using the standard methods (keeping traces of areas with spray paint, measuring with a measuring wheel, or stepping off). The extents of the surveyed areas, the located defects, and other singular points were therefore treated in a geo-referenced application (see Figure 5). Color codes were used to differentiate between the completed zones and the zones that were impossible to survey due to poor electrical isolation (areas that later had to be re-worked or pumped free of water). This was done for both the water puddle and dipole survey.

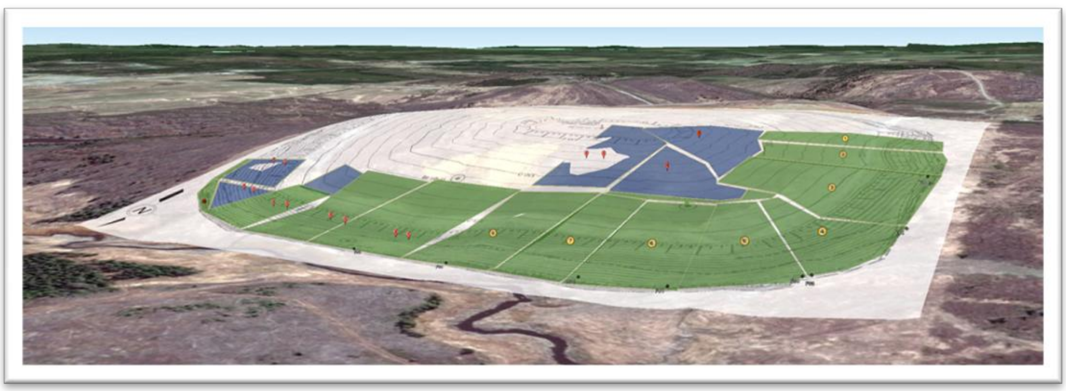

Figure 5. 3D visualization of the progress of the leak detection survey

5.5 Budget

After all of the leak location work had been completed (both the water puddle and dipole surveys, as well as the daily and final reports), the final amount invoiced respected the amounts budgeted in the proposal. For the water puddle survey, the estimated survey speed was not attained due to various singular requests from the general contractor (factors outside of the ELL company's control). The rain-days had not been budgeted in the services proposal, but clearly explained, with a special downtime rate. Additionally, the installer had foreseen a certain contingency for rain-days.

These 13 rain-days extended the duration of the mandate, and two additional mobilizations were required to switch-out the on-site personnel (the leak location crew did not extend their stay by 13 days).

In the end, the leak location surveys accounted for 0.63% of the overall construction costs (project design not included in the construction cost).

6. CONCLUSION

The remediation project for the Barvue Mining site in Barraute had been planned for some time, with the leak detection survey requirement clearly stated since the beginning of the project. Several meetings were held to validate the plans for the geomembrane installation, the leak location surveys and the placement of natural cover material. This proactive approach to working greatly limited surprises, both technical and financial.

As a result of performing the leak detection surveys, 23 of the geomembrane installation defects and 26 of the defects from the installation of the 30 cm sand cover were found and repaired. The low number of leaks when compared to the installed area (255,000 m²) can be attributed to the engineering, the choice of materials, the know-how of the contractors, and the simplicity of the design (no abrupt angles and no penetrations). The leak detection surveys were incorporated into the overall work sequence—by adapting to the geomembrane and cover material installation speeds—in order to not delay the contractors. It was therefore important to validate the surfaces at the same speed as the other parties involved, not faster, and not slower. The construction ended on schedule, and the leak detection respected the budget, which was less than 1% of the total cost of the project.

By performing the leak detection surveys, the integrity of the work was assured, and the technical performance of the capping was guaranteed. The leak detection surveys also helped to validate the design of the site, the choice of materials, and the expertise of the selected contractors in a concrete manner. Additionally, having the leak location company on-site throughout the project certainly contributed to keeping pressure on everyone involved in the project. Knowing that if anything were overlooked, and that all errors would be detected and recorded, helped to ensure high quality work from both the general contractor and the installer.

Finally, unlike the operation of a mine, the closure of a mine does not bring in any revenue. It is therefore common to be confronted by tight budgetary constraints; expenses are limited and all non-essential activities are cut or kept to a minimum. As the leak location survey cost just 0.63% of this project's overall budget, the client was able to ensure quality work despite budgetary constraints. Not only did the leak location survey provide information on the number of leaks—which was well below the average—it also gave an indication as to the performance of each of the project's stakeholders, as well as the design of remediation plan, thus helping to guarantee the integrity of the final product.

Figure 6. Aerial photo of the works

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