TAILINGS MANAGEMENT AT THE IRON MINE OF MOUNT WRIGHT

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ABSTRACT
The tailings storage facility (TSF) of the Mount Wright mine, a property of ArcelorMittal Mining Canada, has been active since 1976. It is located in the Fermont area and spreads across 15 km² which makes it one of the largest impoundments in North America. Tailings are more than 100 m thick in some areas. The tailings deposition rate has been greater than 30 Mm³ per year since 2014. Different methods are used to raise the eight kilometers of dams that confine the tailings.
This paper discusses the choice of the appropriate raising method depending on the site conditions, the environmental constraints and the borrow materials available. It also introduces the systems implemented to monitor the structures. Indeed for some of them have been monitored for 25 years.

RÉSUMÉ
Le parc à résidus de la mine du Mt-Wright, actif depuis 1976, est opéré par ArcelorMittal Exploitation Minière. Situé dans la région de Fermont sa superficie de 15 km² en fait l'un des plus grands en Amérique du Nord. L'accumulation de résidus atteint par endroit plus de 100 m d'épaisseur. Depuis 2014, le parc accueille près de 30 Mm³ de résidus par an.
Plusieurs méthodes de construction de digues et de barrages de parc à résidus sont utilisées pour ériger les huit kilomètres d'ouvrages de retenu qui ceinturent le parc. L'article présente le choix des différentes méthodes de construction ou de rehaussement des digues et barrages en fonction des conditions du terrain, des contraintes environnementales et de la disponibilité des matériaux de construction. Il introduit les différents systèmes de suivi des ouvrages. En effet, certains la banque de données pour certains d'entre eux couvre plus de 25 ans.

1 SITE PRESENTATION

The tailings storage facility of the Mt-Wright mine, a property of ArcelorMittal Mining Canada, has been active since 1976. The Mt-Wright mine site is located in the area of Fermont, north of the 53rd parallel within 50 km of the border with the Province of Newfoundland and Labrador. The climate is subarctic, with an average snow fall equivalent to 344 mm of water per year and an average rainfall of 586 mm per year. The mine produces about 24 Mt of iron concentrate per year and generates 44 Mt of tailings per year.

The following paragraph describes the main features of the TSF. The circled number written after the name refers to Figure 1.

The tailings are slurried and pumped from the mills (1) to the south-east corner of the TSF (2). Sediments settle as the slurry progresses westward. At the west end of the TSF lies a sedimentation pond named Hesse Nord (3), with an average capacity of 12 Mm³. The pond is delineated by two dams named Dam A (4) and dam Hesse 4 (5). A control structure has been built in the dam Hesse 4 (5). It allows the TSF operator to control the water level of the pond.

Waters passes through Hesse 4 decant structure (5) and is brought into the process water pond named Hesse Centre (6) through the process water channel (7). From Hesse Centre (6), water is pumped back to the plant (1). As required by law, more than 90% of the water is recycled. Over a year, the water balance is in excess and a treatment plant (8) is required to keep the water level within the safety range. The treated water goes into the polishing pond named Hesse South (9) before being released into the local watershed through the final effluent (10).

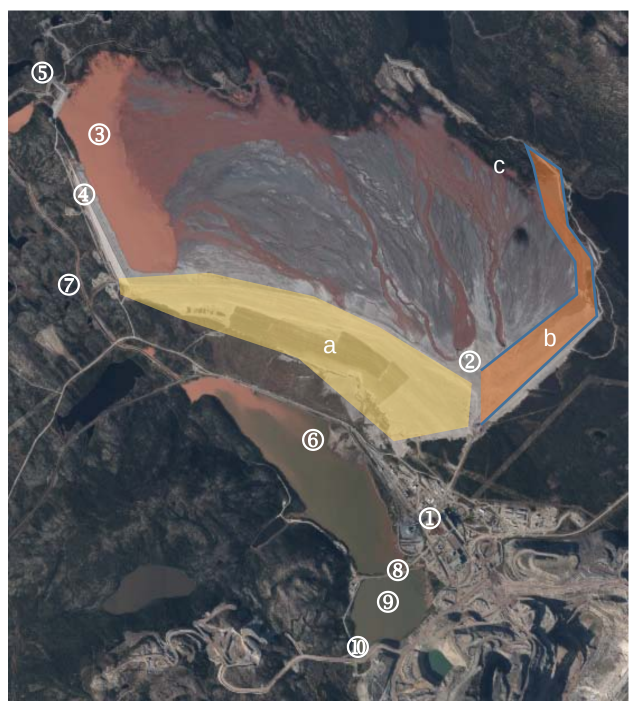

Figure 1: Overall presentation of the TSF features

There are two main types of dams at the Mt-Wright TSF. The dams that confine the sedimentation pond, Dam A and Hesse 4, are made with a till core. The dykes that confine any smaller body of water where the fine tailings settle are either made of till or lined with clay geomembranes, depending on the availability of borrow material.

The dykes that confine mixed tailings are made of coarse tailings and are built using the upstream method.

All of these structures are raised or built during the summer in preparation for the winter operation.

2 TAILINGS CARACTERISTICS

Since 2014, 44 Mt of tailings are impounded every year in the TSF. The tailings are made of a non-acid generating silty sand.

Eighty percent (80%) of the tailings produced by the mills are medium sand with less than 4% passing the 80 µm sieve. The remaining 20% of the tailings are made of silt from the thickener underflow. The typical grain size distribution of the tailings is shown on Figure 7.

The dry density of the deposited tailings is re-evaluated every year by comparing the topographic surfaces of two successive years and knowing the mass of tailings produced during the time interval. The average density is 1.41 t/m³. Figure 2 shows the evolution of the dry density of deposited tailings over the years.

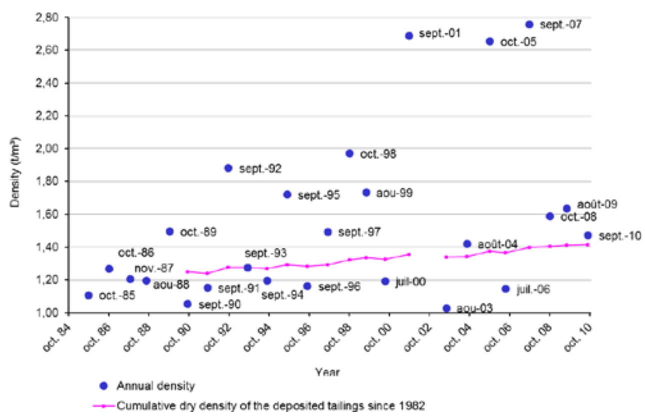

Figure 2: Evolution of the dry density of the deposited tailings since 1982

The wet density ρ_h of the deposited tailings is obtained by in situ measurements taken with a moisture density gauge: ρ_h =1,79 t/m³.

The solid density is ρ_s = 2,70 t/m³

The void index can then be evaluated: e=0,929

Finally the Figure 3 shows the composition of tailings once impounded in the TSF.

V_A = 0,0885 m³	Air	
V_W = 0,3920 m³	Water	M_W = 0,393 t
V_S = 0,5185 m³	Solid	M_S = 1,400 t
V_T=1,0000 m³		M_T = 1,792 t
V_P=0,4805 m³		

Figure 3: Tailings composition (from Amec Earth & Environmental, 2010)

According to these values, the amount of slurry water trapped in the tailings voids is 0.39 m³ per cubic meter of tailings impounded. This water is considered a loss in the water balance of the site.

3 RAISING CRITERIA

3.1 Raising criteria for the pervious dykes

The pervious dykes around the TSF are meant to impound the accumulation of tailings over two years and the potential accumulation of ice coming from the slurry.

The ice accumulation can reach 5 m of thickness in some locations. These locations vary slightly over the years depending on the geometry of the flow, the distances with the deposition point and the average winter temperatures.

3.2 Raising criteria for the impervious dykes

Hesse Nord and Hesse Centre are required to manage the project flood. The project flood is determined assuming the occurrence of the following events at the TSF watershed:

- 1:100 occurrence snow accumulation, melting over 30 days (633 mm of water over 30 days)
- 1:1000 occurrence rain fall over 24 h (98.2 mm)

These criteria correspond to the requirements of Directive 019 for low risk tailings.

However, sediments accumulate progressively in the sedimentation pond (Hesse Nord), resulting in a reduction of its capacity. Therefore, the dams A and Hesse 4 that confine the Hesse Nord pond must be raised periodically to ensure sufficient capacity.

In order to forecast the loss of capacity, Amec Foster Wheeler has developed a tool based on the empirical data obtained from bathymetry surveys performed every year. If the elevation/capacity curves of Hesse Nord are represented over time, those curves shift year after year. The translation is proportional to the production of solids.

Every year, the curve obtained with the topographic data is compared to the one estimated the year before. The difference in terms of volume for a designated elevation is around 3%.

The equation of the curve obtained from the topographic data is updated and the equations of the future curves are also updated.

Figure 5 shows the capacity curves of Hesse Nord over the years. As shown on the graph, the capacity decreases progressively. To prevent the capacity of Hesse Nord from dropping below the minimum limit needed to manage the project flood as determined by Directive 019 [6], the dams are raised periodically. In order to spread the investment, their rise is progressive over 2 to 3 years. In the graphical representation of Figure 4, the impervious dams are raised over three (3) years by four (4) meters. While the dams are raised, the emergency spillway of Hesse Nord, designed to evacuate the probable maximum precipitation over 24 h, is maintained below the level of the lowest crest elevation.

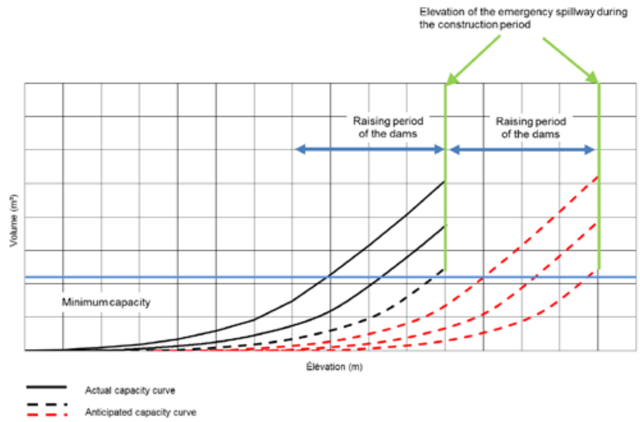

Figure 4: Evolution of the capacity curves of Hesse Nord

4 WINTER OPERATION

In winter, both coarse and fine tailings are mixed up in the plant and pumped to a single deposition point located in the South-West portion of the TSF ((5) on Figure 1). During this period, the freeboard along the dykes is regularly checked by visual inspections. If a portion of the TSF is filled up, either the pipes are moved or the slurry is pumped to a secondary deposition point (backup). Generally little maintenance is required during the winter.

Figure 5 illustrates the winter ramps from which the tailings are deposited into the TSF. The deposition cone formed by the tailings is clearly visible on the picture. Figure 6 illustrates the installation of the pipe on the top of the ramp.

At the end of each summer, the winter ramps are extended by several hundred meters towards the middle of the TSF. The aim of the extension is to maintain a freeboard of 6 m below the ramp to be able to deposit tailings during winter without moving the pipes.

Figure 5: Winter ramp after several months of operations

Figure 6: Deposition ramp seen from the top

5 RAISING STRATEGIES

5.1 Context

The grain size distribution of the mixed tailings is illustrated on Figure 7. The mix of fine and coarse tailings gives the composite overall slope of the TSF. The average slope of the TSF, based on the topographic data, is 2%. The upper portion of the TSF is steeper (3%) while the lower part, containing finer grains, is smoother (0.4%).

The fine tailings tend to erode any deposited tailings and bring them to a gentler slope, close to 0.4%. On the other hand the coarse tailings deposit with a steeper slope than the average (7% to 8%).

In order to raise the dams with tailings, fine and coarse tailings must be segregated. The fine tailings are dumped on the north edge of the TSF, close to point (c) on Figure 1.

Meanwhile, the coarse tailings are slurried and pumped along the pervious dykes to be used as backfill material.

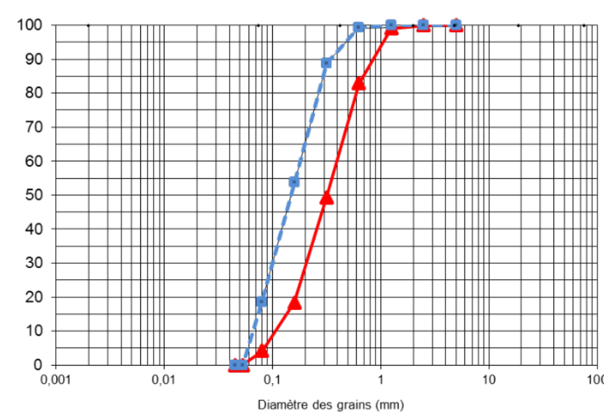

Figure 7: Extreme grain size distributions of the mixed tailings inside the TSF

5.2 Raising the pervious dams

While the fine tailings are stored separately, the coarse tailings are used to create a beach on the upstream side of the existing dyke or dam. To create the beach, a specific slurry distributor has been developed as part of an R&D program (see Bedard & Lemieux, 2001). This tool is a structure (beam) made of steel plates that is fed with slurry (see Figure 8 and Figure 9).

The beam is installed parallel to the axis of the dyke that is meant to be raised (front plan on Figure 8). Inside the beam (which can be several kilometers long) a separation occurs: the sediments tend to stay lower while the water and the remaining fine particles are on the upper portion. The beam section is approximately the same as the slurry pipeline. Once the slurry is in the beam, the lower and denser portion of the slurry goes through openings on the side. It spreads out and forms a beach. The lighter and upper portion of the beam flows through to the tip and is ejected inside the TSF.

Figure 8: slurry distributor seen in elevation (from Amec Environment & Infrastructure, 2013)

The beam allows the creation of a beach segment approx. forty (40 m) meters long in twelve (12) hours. Moreover, contrary to the traditional spigot, the beam can be installed with an offset of thirty five (35 m) meters inside the impoundment and one meter and a half (1.5 m) higher than the crest of the previous and existing dam.

In order to enhance the efficiency of the operation, two beams are generally installed.

Once the beam has created a beach in front of the dams meant to be raised, a dozer uses the beach as a borrow pit and caps the deposited portion. Sixty-centimeter (60 cm) thick layers of tailings are compacted progressively, to eventually create a new eight (8 m) meter wide crest which is higher by four (4 m) meters.

The average slope of the upstream raised dams at Mt-Wright is 10%. This smooth slope allows the proper drawdown of the water table through the coarse tailings.

The use of the beam requires limited manpower. Table 1 shows the rise performed over the last few years with a team of four to five workers and a foreman. The equipment is limited to one D10 type dozer, two D8 type dozers, one compactor and one loader.

Two dykes have been raised using only coarse deposited tailings. The first one is Hesse. It is 4 km long and 110 m high at its maximum. The second one, Hesse 1, is 4 km long and 30 m high at its maximum. These two dykes are shown on Figure 1 as (a) and (b) respectively.

Figure 9: slurry distributor as seen from upstream (from Amec Environment & Infrastructure, 2013)

5.3 Raising the impervious dams

The dams that confine the sedimentation pond Hesse Nord are made with a till core.

Dam A is being raised according to the centerline method. This choice is possible because the slurry can be brought up to the dam and deposited to create a beach (see Figure 10). This beach is used as a foundation for the upstream side of the dam (see Figure 11)

The dam Hesse 4 is being raised using the downstream method. Despite the higher resulting cost in terms of backfill volumes, this is the best solution because of the control structure that is part of the dam.

These two dams are raised periodically to maintain a sufficient storage capacity in Hesse Nord. Indeed, while the project flood, determined by Directive 019, is constant over the years, the capacity of Hesse Centre is fixed and the sedimentation that occurs in Hesse Nord reduces its capacity.

Figure 10: Example of deposition in front of Dam A (from Amec Environment & Infrastructure, 2013)

Figure 11: Construction of Dam A on the upstream beach (from Amec Environment & Infrastructure, 2013)

Other smaller dams or starting dykes have been built and/or are planned around the TSF to confine the tailings. These dykes are North dyke, C1 dyke, C2 dyke, Mogridge and Hesse 3. They are shown on Fig. 1. While the first three dykes are made of till or built with a till core, the last two are made of compacted tailings, covered with a single clay liner. In the future, as the TSF fills up and the fine tailings are brought further down the slope, they will be raised on the upstream side by slurry deposition.

6 STRUCTURE MONITORING

Presently, 67 piezometers are installed in the pervious dams and 118 in the impervious dams of the TSF. Moreover, settlement plates and inclinometers complete the instruments panel used to monitor the dams' performance. The instruments are regularly read by the design consultant. For some of the infrastructure, the data gathered cover more than 24 years. The analysis of the data thus obtained constitutes an excellent tool to monitor the behaviour of the structures and illustrates their evolution through time.

The piezometer follow-up shows the appropriate draw down of the water table in the impervious dams. The Figure 12 shows a typical monitored water table in dam A section. The water table draws rapidly through the till core and stays near the ground surface.

The piezometer readings of Hesse dam present a slow draw down of the water table in this pervious dam, as shown in Figure 13. As the downstream slope of the pervious dam is about 10H:1V, the hydraulic gradient at the dam toe is low and does not produce serious erosion of the dam slope which affects the dam safety, only local erosion occurs and needs few maintenance work.

The inclinometers in dam A shows little displacement of the dam after several raising stages.

Nevertheless, the inclinometers and settlement plates in Hesse Dam present the movement of the dam which corresponds to the upstream hydraulic raising and the slowly thaw of ice lenses buried in the dam foundation at the early construction stages.

Each year, a document approved by the principal designer of the dams reports on the overall behaviour of the TSF and the surface water management infrastructure (diversion and collecting channels), including interpretation of instrumentation readings.

7 CONCLUSION

The tailings storage facility of the Mt-Wright mine, active since 1976, impounds more than 650 Mm³ of tailings. Since 2014, the mine operation has been producing 30 Mm³ of tailings per year.

The operation and the construction alternative are adapted to the tailings production rate, the short construction time frame available and the frigid conditions in winter.

Depending on the availability of borrow materials, the dams have been built using different methods (either upstream, centerline or downstream).

The panel of instruments installed and maintained periodically follows the expansion of the TSF. These instruments allow the designer to follow the performance of the dams and ensure the adequate behaviour of the TSF infrastructures.

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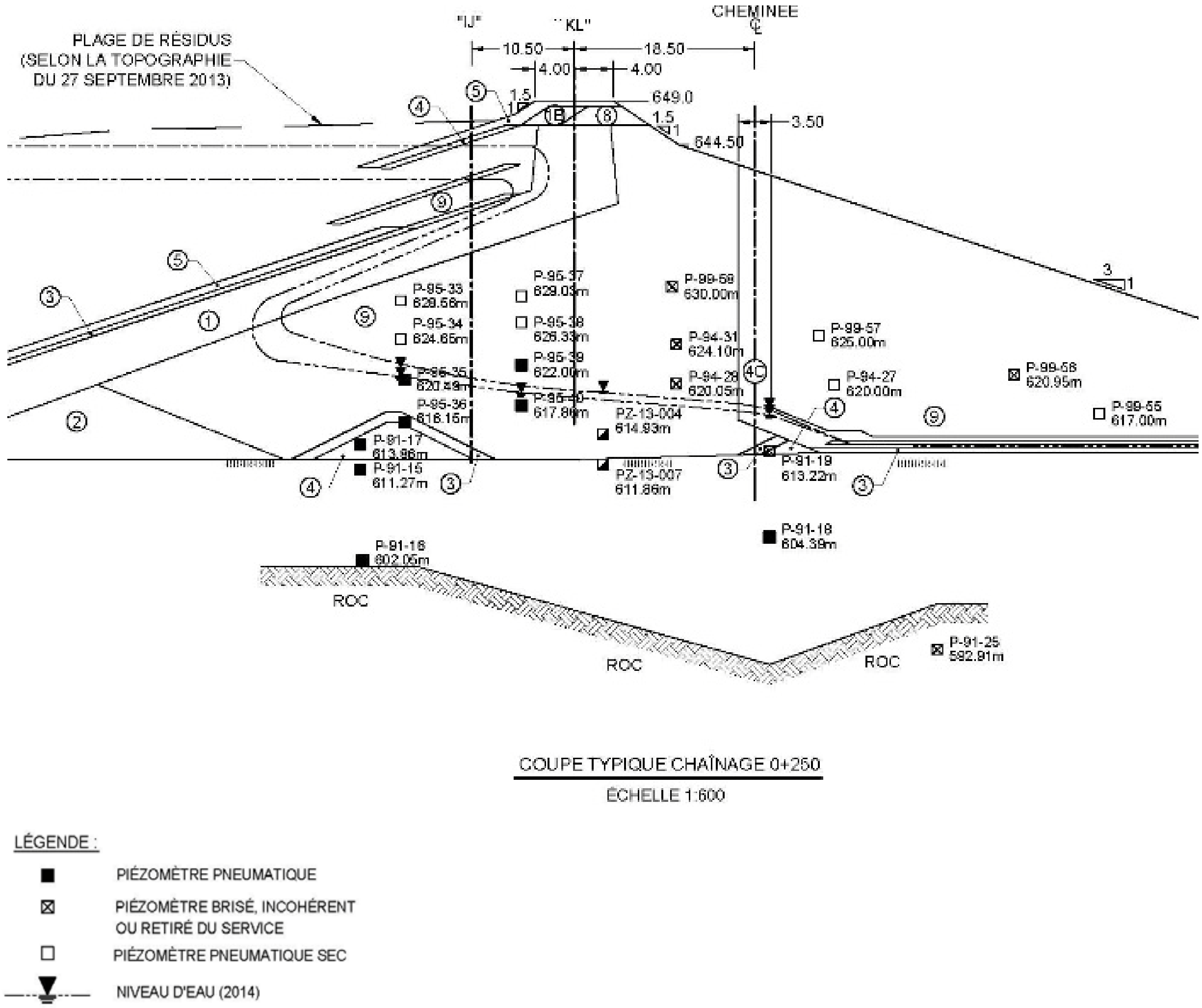

Figure 12: Typical water table across dam Hesse

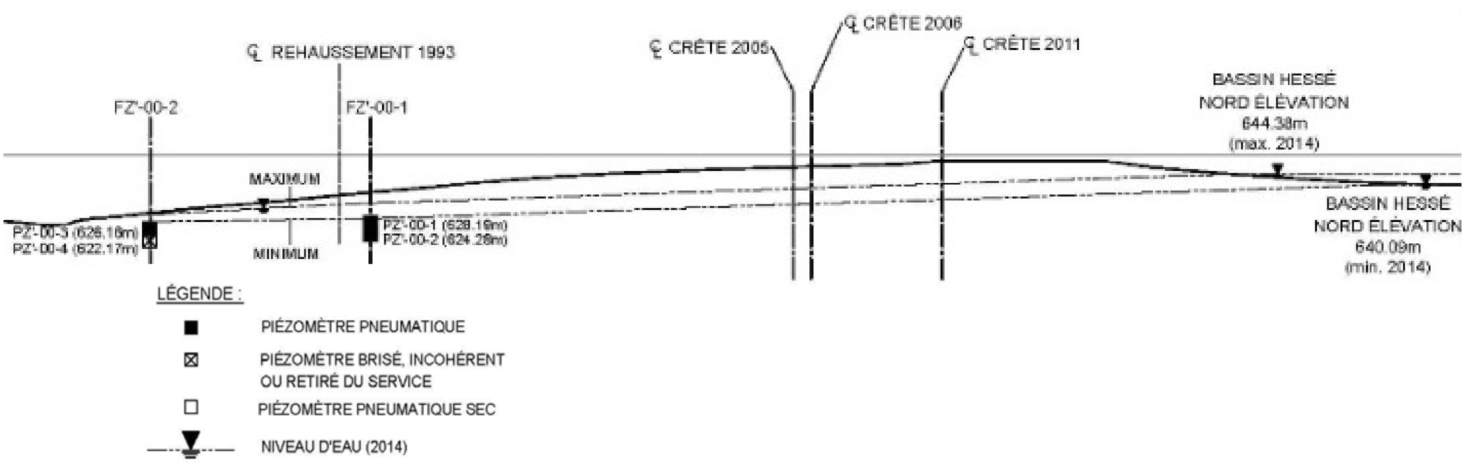

Figure 13: Typical water table across dam Hesse