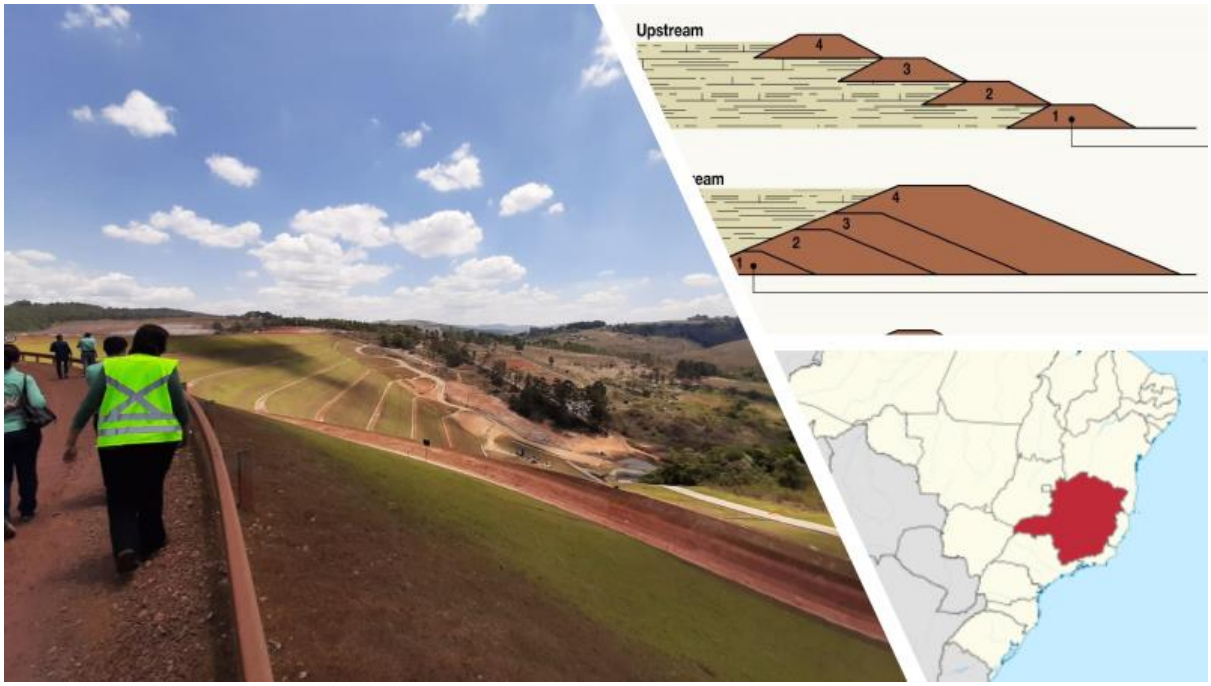
Kingdom of the Netherlands




Dutch Risk Reduction Team: Reducing the Risk of Water Related Disasters

# DRR Team mission report Minas Gerais state, Brazil

Mission dates: 13-19 October & 25-29 November, 2019

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|---|---|
| **Document title** | DRR Team Mission Report<br>Minas Gerais state, Brazil |
| **Status** | |
| **Date** | December 2019 |
| **Project name** | |
| **Reference** | DRR219BR01/06 |

| | |
|---|---|
| **Drafted by** | DRR Team |
| **Checked by** | DRR Team leader |
| **Date/initials check** | 11 December 2019 |
| **Approved by** | |

# Contents

# Summary


**Introduction**

On January 15, 2019 in Brumadinho in the state of Minas Gerais, a mine tailing dam or Tailing Storage Facility (TSF) from the Vale mining company failed. This resulted in the loss of 256 lives, with 14 people still missing, and immeasurable damage to people's well being, to the environment and to the economy of the area.

In 1953 in the Netherlands a key flood defence dyke broke, leading to the loss of life of 1853 people. This disaster, which was preceded by other severe but less deathly events, led to a decision in Dutch society and politics that such a disaster should never happen again. Legislation and financial means, as well as the strengthening of sector organizations in the Netherlands were key measures taken. This has resulted in a system of dykes and flood defences that is nowadays providing approximately 8 million Dutch citizens with unparalleled security against flooding, even though they live in highly flood prone areas or even below sea level.

In Brazil, the Mariana dam disaster of 2015 and the Brumadinho disaster of 2019 have the potential to become the same turning point in society that the 1953 disaster was for the Netherlands. Society can no longer carry the burden of the insecurity that results from too weak mining dams and dykes.

In July of 2019 a request from ANM – the National Mining Agency of Brazil was received by the Netherlands Embassy in Brasília, prompting two missions from the Dutch Risk Reduction Team to Minas Gerais and Brasilia in October and November of 2019, to work with ANM and various stakeholders, in particular to share knowledge from the Dutch experience with dykes and levees. This report presents the findings and outcomes of the missions.

The team had intensive discussions with ANM, and with SEMAD and FEAM in Minas Gerais, visited three dams of the Vale mining company, met with community leaders and a school teacher in one affected community, spoke with representatives of the Public Ministry, visited the Vale head quarters where information was received on the monitoring system and on the compensation, resettlement and social programs for the affected peoples, and the DRR-team held workshops on the findings in Belo Horizonte and in Brasilia. Chapter 2 presents the itinerary of the two missions. Chapter 3 presents the key information about the visited dams.

**Key findings** of the missions can be found in chapter 4, and include:

1. The overall impression is that important and significant steps have been taken by all parties involved since the disaster happened, and that these are mostly motivated by emergency legislation adopted directly after the disaster and the raised public awareness. Section 4.1

2. Tailing dams are often raised to a level that they are of enormous proportions. With crest levels rising to 100 m and tailing volumes exceeding 100 million $m^3$ of tailing materials, they should be considered as high-risk structures of which there is always a chance of failure. Section 4.1

3. There are no inherently safe dykes and dams. In the current legislation there is a predominant focus on the risk of upstream raised tailing dams, while downstream raised tailing dams are generally perceived to have a much lower risk. The two dams that failed recently in Brazil were upstream dams and inherently the construction of upstream dams is less safe than downstream or centre-line dams. But this does not mean that all downstream dams are safe, and all upstream dams are unsafe. The risk for every tailing storage facility (TSF) is different and unique. The latter perception is shared by ANM. Section 4.2

4. What became also apparent during the fact-finding mission is that the slope angles of the tailing dams are often very steep, which increases the risk. Slopes of 1:2 appear to be common design practise, irrespective of the slope material, foundation characteristics or

location. In the Dutch experience, dealing with soft soil and saturated soils, embankments this steep are rarely used. The design practise of using steep slope might be perceived economical by the industry, but on the other hand it becomes very difficult to reach a stable geotechnical situation, even under optimal conditions, which could become a potential economic risk for the sector as well. Section 4.3

5. It also appears that geotechnical site investigations (using for instance CPTu or sampling by drilling or SPT) to analyse the stability of the TSF is generally limited in numbers in comparison to the Netherlands. It appears also that most of the design parameters are derived from CPT data. This is not necessarily a bad approach. In Dutch design practise this is common too. However, it is also common practice to still obtain samples to verify the derived characteristics with laboratory tests. Also, the investigations of the geological foundation and shoulders of the tailing dams appear to be sometimes overlooked, while this can have an important impact on the stability and development of seepage and piping issues. The incorporation of drainage (blankets) appears to be limited and not sufficiently anticipated to future raises. Section 4.3

6. One of the main issues with the currently considered critical upstream dams is that it is not always clear how they were designed, constructed and operated. Sometimes, the dam raises were executed differently or to larger heights than originally planned. Often, they are legacy dams and proper documentation on design, construction methods and operations are lacking. This means that the structure of the TSF and geotechnical characteristics of the materials are largely unknown. Section 4.3

7. In the Netherlands most effort is put in the first stages of the safety chain. The Dutch like to have an elaborate soil investigation plan and a lot of field data to assess the current situation, because they perceive a large variability in soil structure and materials. Based on this site investigation, the design is conducted, and construction works are carried out according to the design. Safety checks are conducted in line with the expected loading cases. In order to make monitoring successful, it is critical to have a very detailed and elaborate site-investigation program and large detail of the design and subsequent operation steps in order to know what to look for during monitoring. Section 4.4

8. It should always be kept in mind that monitoring is a measure at the end of the safety chain. It is a welcome addition to the safety chain. The success of monitoring as an early warning system relies heavily on the feedback loop with the design. Based on the assumptions and input used in the safety calculations of the dam monitoring it can, under certain conditions, support decision making of the current safety level of a dam. The question arises whether monitoring, even when carried out with high precision and detail, will yield enough accuracy in order to assess the stability properly given the available information status. Section 4.4

9. Also monitoring, if interpreted as a direct measurement of safety, could lead to a false sense of security. Monitoring results should not be presented in such a way that they give the impression of being a measured safety level. Monitoring provides raw sensor output on piezometric level, temperature or movement in one point, in one dam at one level at one moment. Interpretation is bound to thorough validation and verification, input from the current state, engineering practice and modelling and extrapolation. Given the current information level of the build-up, history and soil characteristics it is recommended to be cautious in the use of monitoring as a safety predictor. Section 4.4

10. During the visit the construction of reinforcement works was witnessed, mostly in the form of containment dams to contain tailings in case an existing tailing dam would break. These dams have been designed and are being constructed under great time pressure in order to comply with legislation and to reduce the areas at risk. Section 4.5

11. The Vale mining company has instated not only financial compensation programs for the affected people, but also an accompanying program of social support and facilitation. Compensation schemes have occasionally also had negative side effects, in some cases gravely so, in the sense that social problems were exacerbated by the sudden availability of large amounts of cash to citizens. Section 4.6

12. Meetings with regulatory bodies ANM, SEMAD, FEAM, with the Public Ministry and with the Vale company have led to the impression that the overall governance framework for the mining sector with respect to the safety of tailing dams can be improved. One important aspect is lack of staffing at the regulatory bodies. In addition to that, strong inter-institutional cooperation and communication is a common practice in the Netherlands, also across the boundary between the public and the private sector. Without wanting to deliver a blueprint, these experiences with the Dutch 'polder model' may have elements that could prove relevant for Brazil. This, in combination with investment in the build up of the regulatory bodies, could contribute to the creation of a renewed social contract between the mining industry and society at large. Section 4.6 and 4.11.

13. The reaction from the public sector after the Brumadinho disaster has been largely effective in achieving improvements in the security of the tailing dams, even though the speed with which new legislation was passed may also have resulted in some insufficiencies. More importantly, the capacity of the regulatory bodies is insufficient in terms of numbers of professional staff to cope with the regulatory and enforcement challenges. Public investment into organizational capacity appears to be necessary to reach adequate levels of regulatory oversight. In addition, the distribution of roles between the various agencies is not always clear. Section 4.7 and 4.8

14. The ABNT (Associação Brasileira de Normas Técnicas) NBR 13028, published in 2017, concerns the requirements for the design of tailings, sediments and/or water dams for the mining industry. This document has 22 pages and has a high abstraction level, mostly advising on best practices. It does have clearly stated safety factors for the tailings dams but is not detailed regarding the calculations which would lead up to those factors. It may be argued that the detail level of the ABNT NBR 13028 is appropriate for a document of this nature. However, a separate document detailing a systematic approach to analysing the safety of (tailings) dams is essential to further improve the safety assessments of tailing dams. Section 4.8

15. It is important to highlight that the calculated safety factor can vary extremely with the input of the calculations (geometry, materials, water, loading conditions). Some of these are very difficult to determine, especially in the case of limited site investigation and even more so when little is known about the dam construction process. Consequently, the calculated safety factor is not precise, but even more importantly, it may lead to a misinterpretation of the chief cause for a possible dam collapse. Section 4.9

16. SIGBM is the information system used by ANM, in which the mining companies have the obligation to input data about their TSF's for monitoring and decision making. The system is in active use and provides much practical use for ANM in terms of its regulatory task. There is scope for further development of SIGBM, e.g. the enhancement of the GIS base, the linking with risk modelling and management tools and the improvement of the prioritization rules. Section 4.10

17. Strategic Environmental Assessment is a framework facilitating multi stakeholder strategic planning that is part of the legal system in over 100 countries around the world. With respect to the current situation of polarization in the mining sector in Brazil, with society struggling to cope with the negative impacts of the dam disasters in recent years and the overall impact on communities in the broader sense, the SEA framework could provide a joint platform for strategic planning in which the interests of the mining companies, the government and society

are well balanced. As such it has the potential to renew the social contract between the mining sector and society. Section 4.11

The findings of the mission have been presented in workshops between 25 and 29 November 2019 in Belo Horizonte and Brasília. The workshop programs can be found in chapter 3. The outcomes of group discussions during the workshops can be found in annex 1.

**Conclusions and Recommendations – see chapter 5**

The mission concludes that there is a strong sense of urgency that the mining sector in Brazil has to make a great leap forward in terms of leaving behind the era of non-sustainable mining and tailing practices, and to establish a regulatory and planning framework that has the potential to create a new social contract between the mining industry and society.

In order to achieve this, extraordinary leadership will be required, from the mining industry itself, from the Brazilian government and from civil society.

The Netherlands might support such a leap forward by providing input on request of the Brazilian government. It is recommended to pursue an integrated package of support, as follows:

1) Based on the fact finding mission and the feedback received during the workshops in Belo Horizonte and Brasília, in particular the discussions with ANM staff, the DRR team believes that there is scope for **technical cooperation between ANM and Dutch knowledge institutes/governmental bodies** on dam safety related issues. Concrete topics for technical cooperation have been explored by ANM staff and DRR team during the workshop in Brasília. The table on the following pages presents the potential areas of technical cooperation between ANM and Dutch knowledge institutes. The four areas of potential cooperation encompass:
    a. Risk assessment
    b. Legislation, standards and guidelines
    c. Institutional development
    d. Strategic Environmental Assessment (SEA)

    It is recommended that these areas be explored through a scoping process that involves some of the potential Dutch partner institutions and ANM and other Brazilian partners. Based on the outcomes of such a scoping process an MOU between the Brazilian and Dutch knowledge partners involved could be instrumental to start this cooperation.

2) The presentation of the **framework of Strategic Environmental Assessment** by the Netherlands Commission on Environmental Impact was very well received. In Belo Horizonte the participating stakeholders, in particular those from the mining sector considered the SEA framework to be a prospective way forward of participatory planning that includes the mining industry, the government and civil society, and leave behind the present polarization to focus on a better future. In Brasilia the ANM staff shared this point of view, noting that it is helpful to distinguish the legacy of the past from the challenges of the future. Initial talks have been held with the Public Ministry of Minas Gerais (MPMG) to conduct a pilot SEA for the mining sector in the state. MPMG showed strong interest to take this further.

    It is recommended to further explore the support for a SEA of the mining sector in Minas Gerais, together with MPMG, ANM and other state regulatory bodies, the mining industry and civil society. NCEA or DRR can follow up by fielding a mission to define the scope and to explore the political and societal support for such a pilot SEA.

3) The mining industry itself will require further improvement of its methods and approaches if the sector is to survive the present negative public opinion. Another dam failure in the coming years will be catastrophic, mostly for those directly impacted by the disaster and for nature and the environment, but the resultant civil unrest will also affect the mining industry in Brazil and possibly elsewhere. In that light, provision of technical expertise and equipment from the private sector to the mining companies is an area of possible cooperation for specialized Dutch sector companies.

The consortium preparing a **'Partners for International Business'** (PIB) proposal to RVO are anticipating this market and the initiative appears to be timely.

It is concluded that the PIB proposal is timely and relevant for the developments in the mining sector in Brazil, Minas Gerais state and it is recommended that the PIB be considered part of the integral approach of supporting the mining sector in Brazil to develop in a socially and environmentally balanced way.

# 1 Introduction

## 1.1 Background of the mission

**Request**

An official request for the fielding of a DRR mission was made on July 29, 2019 by the National Mining Industry Agency ANM through the Federal Ministry of Mining and Energy of Minas Gerais, via the Embassy, to the Netherlands' Enterprise Agency RVO.

**Background**

On January 25, 2019, in Brumadinho in the state of Minas Gerais, a mine tailing dam from the Vale company failed. This collapse and subsequent mud flow killed almost 250 people and there are still many missing. The failure of this tailing dam resulted in the spilling of (toxic) waste of mining, in the form of water, sludge and soil, to the adjacent area. This has a large impact. In addition to fatalities and missing persons, the (ground)water is seriously contaminated. It also concerns the rivers that the areas inhabitants depend on, among other things, for their (drinking) water.

Urgency:

- There are around 700 tailing ponds in Brazil, of which 430 in the Minas Gerais (MG) state, located in an area of 100 km2 around the city of Belo Horizonte. This city has 5.5 million inhabitants and the area is densely populated and relies for its freshwater consumption on the rivers in the area;
- Of the 430 mines, 50 were built in the same way as the mine tailing dam in Brumadinho and the mine tailing dam in Mariana (Samarco mine), which has collapsed in 2015.
  The tailing dams are usually constructed from coarse tailing material across an existing river valley. In case of too much groundwater pressure, seepage or the triggering of liquefaction, the dam can collapse, allowing the tailing material behind the dam to flow out, like what happened in Brumadinho in 2019 and in Mariana in 2015;
- Currently there is a fear for more dam collapses, potentially leading to casualties and impact on the environment, including the rivers.

Link with national policy:

- There are approximately 80 mine tailing facilities like Brumadinho and Mariana throughout the country, which are 30 to 40 years old. Of the 50 mine tailing facilities, 30 are operational where waste is currently still being deposited in the tailing storage facilities. The other 20 TSF are filled up to their full capacity and not in use anymore;
- Whether the material in the tailing ponds is toxic depends on the type of mine. For example, the waste from iron-ore mines is less toxic than tailing material from gold mines;
- Following the failure in Brumadinho it was decided that within three years 37 mine tailing dams should be decommissioned and that another location has to be found for the storage of the mine waste.
- It has also been decided that within a three-year period 50 mine tailing facilities should be dismantled.
- In the meantime, new legislation is in place whereby other institutions are directly involved in monitoring of dams. This legislation concerns the (preventive) monitoring of the dams.

## 1.2 Partner organisation and other stakeholders

ANM – Autoridade Nacional de Minas is the partner organization for the DRR team. The team has worked closely together with the ANM staff in Minas Gerais.

In the course of the mission, interaction with other stakeholders has been part of the work. ANM prepared visits to three tailing dam sites operated by Vale. Vale's control room (monitoring centre)

was also visited, in which all monitoring information for their dams in Minas Gerais can be visualised. In addition, meetings were held with local stakeholders in the town of Macacos. The inhabitants of Macacos have been affected by the preventive evacuation of part of the town. Furthermore, a meeting was held with representatives of the Public Ministry of Minas Gerais. Back in the Netherlands, a meeting was attended at the Ministry of Foreign Affairs where spokespeople of the victims of the Brumadinho disaster were given a platform.

## 1.3 Acknowledgements

The team is thankful for the support of ANM, both at central level and in Minas Gerais. During the mission, the team met numerous staff members of the Vale mining company, all of whom showed great effort to provide the team with useful information and engaged openly in meaningful discussions. We are thankful to all of them, as well as to the community representatives that we met in Macacos town, and to the representatives of the Public Ministry in Minas Gerais.

The mission would not have been possible without the facilitation of the NBSO office in Belo Horizonte, for which we are very grateful, as well as for the support from the Netherlands' Embassy in Brasília.

# 2 Mission Programs

## 2.1 Mission 1 (Fact Finding)

The DRR team arrived on Saturday 12 and Sunday 13 October in Belo Horizonte.

**Day 1 – Monday 14 October 2019**

10.00-10.30: Kick-off meeting (Mining Hub, Belo Horizonte)

The first day of the mission started with a meeting at the Mining Hub in Belo Horizonte. At the meeting, representatives of the most important stakeholders were present. The Dutch Ambassador opened the meeting. He welcomed everyone present and explained the objective of the DRR mission. He thanked ANM and Vale for their support and cooperation in the preparation of the DRR mission. He acknowledged all the other persons present for their interest and support. The Ambassador finalized by introducing the Dutch DRR team.

The DRR Team Leader introduced the DRR team members further, explained the details and objective of the DRR mission and thanked ANM and the other stakeholders for their support.

Welcome speeches and acknowledgements were further given by representatives of the following institutions:

- Ibram
- ANM
- Vale mining company
- Government State Minas Gerais
- SEMAD

11.00-14.00: Work session with ANM, FEAM and SEMAD

The purpose of this work session was for the DRR team to get informed and updated about the technical and legal issues and challenges that ANM, FEAM and SEMAD are facing with regards to the mine tailing dam facilities. ANM is the main regulator towards the mining industry, but also FEAM and SEMAD have increased responsibility towards new state laws regarding mine tailing facilities from an environmental viewpoint.

15.00-17.00: Work session with ANM

In this work session, the DRR team discussed with ANM in further detail the following items:

- SIGBM: this is the database where the mine operators need to fill in details of the tailing dams (in the form of a questionnaire). The DDR team are provided limited access by ANM to the SIGBM system for review purposes.
- Site visits: The site visits to the tailing storage facilities (TSF) in the next three days were discussed in detail, zooming in on the locations and the construction details. The TSF that ANM proposes to visit are Sul Superior (Mine Gongo Soco), B3/B4 dam (Mine Capão Xavier) and Maravilhas II (Mine do Pico).
- Expectations: both the DRR team and the ANM expressed their expectations towards the outcomes of the mission.

**Day 2 – Tuesday 15-10-2019**

This day consisted of a site visit to the TSF Sul Superior from the Vale mine Gongo Soco.

08.30-13.00: Technical presentations.

The presentations were on the slope stability issues of the north pit slope of the Gongo Soco mine and the geological context of the Gongo Soco mine. The second presentation was on the construction

history and geotechnical stability analysis and monitoring of TSF Sul Superior. An important presentation was on the safety issues related to the downstream self-rescue zone (ZAS) that came into effect after the TSF facility was classified as emergency level 3.

14:00-17:00: Visit to monitoring centre, viewpoint to TSF and construction site retention dam.

The local monitoring centre was visited. This monitoring centre was created to monitor the stability of the open pit slopes of the open pit mine and the stability of the TSF Sul Superior.

Next, the viewpoint to the TSF facility Sul Superior was visited. Access to the TSF was prohibited because of the emergency level. The lower TSF Sul Inferior could not be seen from the viewpoint. Finally, the construction site of the retention dam was visited. This retention dam is a temporary dam to prevent a possible mudflow from the TSF to reach the areas further downstream.

**Day 3 – Wednesday 16-10-2019**

This day consisted of a site visit to the TSF B3/B4 from the Vale mine Capão Xavier

08.00-13.00: Technical presentations

The presentations were about the mine operations, construction history and geotechnical stability analysis and monitoring of the combined TSF B3/B4. The mining complex was acquired by Vale including the TSF, which makes it a legacy facility.

14.00-17.00: Site visit to the B3/B4 dam site, preparatory construction works and retention dam.

The dam B3/B4 has been classified as a level 3 dam, the highest alert level, which means that access to the site is prohibited and the immediate downstream declared as self-rescue zone (ZAS) from which the inhabitants have been evacuated as a precaution. In order to carry out stabilization works (as part of the rehabilitation process) remotely controlled equipment will be used, which were demonstrated on-site.

The downstream construction site of the retention dam was visited, which consists of a rock-fill structure. For the construction of the dam a special (5 km) access road was constructed for the supply of the construction materials from the quarries and stockpile areas.

**Day 4 – Thursday 17-10-2019**

07.00-13.30: Site visit Maravilhas II (Mine do Pico) and Macacos (Nova Lima)

Today the DRR team decided in the morning to have a separate program. DRR team leader Ben Lamoree visited together with Willem Moraal (NBSO) a social rehabilitation programme in Macacos, Nova Lima, for the people who were evacuated downstream of the B3/B4 dam. Ben Lamoree and Willem Moraal subsequently had a lunch meeting with representatives of the Public Ministry prosecutors' office.

The rest of the DRR team made a site visit to the TSF Maravilhas II (Mine do Pico). The site visit consisted of a presentation on the construction history and geotechnical stability assessment of Maravilhas II dam, including the monitoring program. Subsequently, the Maravilhas II dam was visited. Near the Maravilhas dam is a gated community.

14.30-17.00: Meeting at Vale office (MAC) - Nova Lima

In the afternoon around the DRR team met at Vale's office 'MAC' (Minas Agua Claras) in Nova Lima, which is also the location of Vale's geotechnical monitoring centre.

First a presentation was given on the geotechnical monitoring centre. In the monitoring centre all the information from all the monitored TSF's of Vale are collected. The monitoring centre was only realized in in January 2019. Instrumentation of the TSF's started in 2014.

Subsequently a presentation was given of the economic and social development team of Vale to help the affected communities of the Brumadinho disaster, but also the evacuated people downstream of the critically stable TSF's (Barão de Cocais and Macacos (Nova Lima)).

**Day 5 – Friday 18-10-2019**

09.15-12.00: Work session

In the morning the DRR team dedicated their time to make a summary of the fact finding mission, to work out the main outline of the mission report and to propose the structure, subjects and target groups of the workshop to be held during the last week of November.

14.00-16:00: Feedback and summary of the mission with ANM and FEAM

In the afternoon the DRR team provided a summary of their main findings to the representatives of ANM and FEAM. The main findings were subdivided in 10 main topics, which are also presented in Section 4 of this mission report. Also, the proposed structure, subjects and target groups of the workshop was shared with ANM and FEAM. FEAM gave a presentation on their data management program for the TSF's. The presentation included the organisational structure of FEAM in relation to SEMAD and ANM, state legislation and management towards TSF's.

16.00-17.00: Departure of DRR team to airport

Back in the Netherlands the team leader and the chief representative of the NBSO office attended a meeting with victims of the Brumadinho disaster, organized by the Netherlands' Ministry of Foreign Affairs.

## 2.2 Mission 2 (Workshops)

The DRR team arrived on Saturday 23 November in Belo Horizonte. A two day workshop was held in Belo Horizonte involving stakeholders from government and the mining industry. Participants included:

- Representatives of (semi) public institutions: ANM; SEMAD; FEAM; Public Ministry of Minas Gerais State Government; the Economic Department of the State Government; the Planning and Management Department of the State Government; Civil Defence; State Assembly of Minas Gerais; sector organization IBAMA;
- Representatives of the mining industry: Vale; CSN mining; Kinross mining Brazil; FUGRO; various consultancy and construction companies

**Day 1 – Monday 25 November 2019 (Mining Hub, Belo Horizonte)**

09.00-09.30: Opening, Welcome and Presentation of the DRR Team members

- NBSO Chief Representative
- President FEAM
- ANM Representative
- DRR Team Leader

09.30-10.30: The Dutch approach to Risk Management and Dam Design

10.45-11.30: Methodology for dam safety

11.30-12.30: Round Table discussion 1 (see Annex 1 for reports on these discussions)

13.30-14.45: Best practices in operations and decommissioning

14.45-15.45: Good Governance of the Mining Sector through Development of Environmental Impact System Performance

16.00-17.00: Round Table discussion 2 (see Annex 1 for reports on these discussions)

**Day 2 – Tuesday 26 November 2019 (Mining Hub, Belo Horizonte)**

09.00-10.00: Case study 1: Dutch 'Room for the River' program of flood protection

10.15-11.15: Case study 2: SEA Mining Sector Lao Republic

11.15-12.00: Round Table discussion 3 (see Annex 1 for reports on these discussions)

12.00: Plenary closing

13.30-14:30: Geotechnical side event: Full Scale Dike Failure Testing Eemdijk, The Netherlands

14.45-15.30: Plenary discussion

**Day 3 – Wednesday 27 November 2019**

10.00-13.00: Travel from Belo Horizonte to Brasilia

15.30-17.00: Meeting of DRR team at Netherlands Embassy in Brasilia

17.00-18.00: Meeting of DRR team at ANM office, preparation for workshops

A two day workshop was held in Brasília with staff of ANM. For this event, ANM had invited all its dam inspectors from the whole of Brazil. All in all, together with the central ANM Dam Department staff, 26 ANM staff took part in the workshops. The discussions were lively and focused.

**Day 4 – Thursday 28 November 2019 (ANM, IBRAM premises Brasilia)**

08.30-09.00: Opening, Welcome and Presentation of the DRR Team members

- General Director of ANM
- Representative of the Netherlands Embassy
- DRR Team Leader

09.00-09.30: Opening address: The Challenge of Regulating the Mining Sector in Brazil (by ANM Director)

09.30-10.30: The Dutch approach to Risk Management and Dam Design

11.00-12.00: Methodology for dam safety and Dike Failure Test Eemdijk

13.30-14.30: Best practices in operations and decommissioning

14.30-15.30: Good Governance of the Mining Sector through Development of Environmental Impact System Performance + case study SEA Mining Sector Lao Republic

16.00-17.00: Round Table discussion 4 (see Annex 1 for reports on these discussions)

**Day 5 – Friday 29 November 2019 (ANM, IBRAM premises Brasilia)**

08.30-10:30: Open discussion of the DRR Mission Report (ANM staff and DRR team)

11.00-11:30: Presentation of findings and recommendations towards the SIGBM TSF database

11.30-12:00: Exercise on bowtie analysis (ANM staff and DRR team)

14.00-15.00: Round Table discussion 5 (see Annex 1 for reports on these discussions)

15.00-15.30: Closing address workshop (Representative of the Netherlands Embassy, ANM Director)

The DRR team left on Saturday 30 November from Brasilia.

# 3 Technical description of the visited TSF

## 3.1 Tailing dam Sul Superior

Sul Superior is an upstream dam located in the Gongo Soco mine, in Barão de Cocais (see Figure 1). Previously a gold mine, it has until recently been used for iron ore extraction. Vale took over the mine operations in 2001. The initial project and design information of the Sul Superior dam was not available, but Vale carried out a site investigation program after the take over and used these results to design the subsequent dam raises. Vale carried out 4 of the 8 dam raises; each dike is 10m high (total 80m) and made from compacted itabirite (with low iron content). The total volume (dam plus tailings) is 6.8 million $m^3$.


*Figure 1. Sul superior dam*

Both dry and wet processes have been applied to the iron ore in this mine. Until 2004, Vale applied a dry process because they were extracting from the hematite deposit, which has an iron content higher than 65%. Between 2005 and 2008, they applied a wet process because they were extracting from the itabirite deposit, which has an iron content of about. 45%. After 2008, they applied a dry process once again. The tailings within the Sul Superior dam are supposed to have a 35 to 40% iron ore content.

The design of the dam did not include a drainage system. Now no seepage is observed in the dam.

The initial dam stability calculations showed a sufficiently high safety factor. However, after review at the site investigation and upon request of the assistance of Dr. Scott Olson, it was concluded that the safety factor for liquefaction was lower than the initial assessment and insufficient, causing the emergency level of this dam to be immediately raised to 3 (the highest level).

Because of the danger associated with the dam, the following safety procedure was initiated:

1. Nobody can access the area between the dam and the point downstream of the dam which the tailings would take 20min to reach in case of a dam collapse.
2. The area downstream of that point is called ZAS (Zona de Auto-Salvamento, or: Self-Rescue Area), and can be accessed because people would have 20min or more to escape. A containment dam is being constructed in this area.

3. In case of a dam collapse, the people at the monitoring centre (either the one at the Gongo Soco mine or the one at the MAC, or both) would see it on the cameras and immediately inform the people in the ZAS (who need to carry a chip with GPS information), who would follow the evacuation instructions.
4. Everyone who enters the ZAS is required to follow a specific training (regardless of employer). Simulations are carried out every week with all employees who work in this mine.
5. People who drive to the mine are required to leave their car keys in the ignition, to make the escape easier/quicker.
6. The piezometers installed in the dam are read via a helicopter because access to the dam is prohibited..
7. A drone is used to check if any seepage is taking place in the dam.

As a mitigation measure in case the Sul Superior dam collapses, an RCC (rolled-compacted concrete) containment dam is being constructed downstream of the dam (see Figure 5). This dam has a volume of 175 000 $m^3$ and is built in lifts of 40cm (35cm after compaction). The concrete lifts poured using a ramp, thus avoiding joints.
Another mitigation measure consists of wells, excavated outside of the danger area. The objective is to lower the water level within the dam.

About 450 people have been evacuated, from 4 communities.

## 3.2 Tailing dam B3/B4

B3/B4 is an upstream dam located in the Capão Xavier mine complex (see Figure 2). The main elements of this mine complex are:

1. The Capão Xavier mine, the only one still active in the complex;
2. The Mutuca mine, deactivated for many years, now used for in-pit disposal;
3. The Mar Azul mine, located close to the B3/B4 dam. Activity has stopped in this mine because it may cause a trigger for the collapse of the B3/B4 dam (due to traffic or blasting).


*Figure 2. Capão Xavier mine complex*

Vale took over the mine operations in 2006. Initially it was thought that the B3/B4 dam was a dry stack, but it soon became clear that it was an upstream dam. Vale never used this dam in production; it was constructed and used only by its previous owner(s). The estimated volume of tailings is 3.2 million $m^3$; the total volume (dam plus tailings) is 3.7 million $m^3$. The iron ore extracted from this mine complex is used in BRBF (Brazilian Blend Fines).

Two site investigations were carried out, one in 2013 and another in 2017. According to Vale, the results of these investigations were difficult to interpret. Similar to the case of the Sul Superior dam,

initial calculations indicated a sufficiently high safety factor, but recent revisions to the calculations revealed a lower safety factor. Like the Sul Superior dam, this dam has received emergency  level 3, thus similar safety procedures have been taken into effect..

Vale believes there is some seismic activity in the area, but because it never caused any problems, it was never studied. This has now changed, and the seismic loading is now considered a trigger factor.

The calculation results are dependent on the geohydrologic assumptions. Vale has data from some piezometers, but for some of them it is not clear from which depth the head is measured.

Vale is now engaging  phase 1 of decommissioning. This includes remotely executed excavation works. as well as reinforcement works. The excavation works will be done by remotely operated equipment, since these works will be carried out in the danger area,. As a mitigation measure in case the B3/B4 dam collapses, a rockfill containment dam is currently being constructed downstream of the dam, with a volume of 200 000 $m^3$. The entire decommissioning process might take 4 years. The precise duration is unknown, because it will depend on the dissipation rate of the of excess porewater pressures.

About 300 people have been evacuated from the downstream area.

## 3.3 Tailing dam Maravilhas II

Maravilhas II (see Figure 3) is an upstream dam located in the Vargem Grande mine complex. This complex comprises 6 mines, 15 dams, 3 cargo terminals, ca. 2800 employees and produces 43 million tons of iron ore per year. The entire complex has been deactivated since February 2019.

*Figure 3. Maravilhas II dam*

Within this complex, the Vargem Grande dam is in emergency level 2 (due to risk of liquefaction) and the Maravilhas II dam is emergency level 1. Vale has now cleared the drainage system of the Vargem Grande dam, which results in an increase in the safety factor and in a future decrease in emergency level from 2 to 1.

The Maravilhas II dam was started in 1994/1995 and is the largest in the region (92m high), including two lateral closure dykes. The dam includes 6 downstream raises, with a total capacity of 102 million

$m^3$ (at the moment, the entire TSF contains 90 million $m^3$). It was taken over by Vale in 2007, who has carried out the last 2 raises.

On the left shoulder, seepage has been reported. This is attributed to the poor behaviour of the drainage system and seepage through the underlying fractured quartzite rocks..

Vale has performed a pseudo-static analysis of the dam. They are planning to carry out a geophysical survey soon. If the factor of safety becomes acceptable, Vale will be able to continue mining operations and thus continue with tailings disposal behind the dam.

Mitigation measures for this dam may include jet grouting of the shoulder(s) or the construction of a stabilising embankment. Vale is not yet certain what the best stabilisation measure should be.

# 4 Observations and findings

This chapter focuses predominantly on the outcomes of the fact-finding mission in October. In the second mission in November, expertise on Environmental Impact Assessment and Strategic Environmental Assessment was added to the team and the workshop program. The considerations with respect to EIA and SEA, and the reactions through the workshops, can be found in the final section of this chapter.

## 4.1 Overall

The dam disasters Mariana and Brumadinho could be for Brazil what the large flood in 1953 has been for the Netherlands. It has been a shock to the community, the country as a whole and all stakeholders involved. In the flood of 1953, the Dutch lost 1836 lives; 100.000 inhabitants lost their house and belongings and 2000 $km^2$ of land was flooded. For the Dutch society, this disaster has been an important wake-up call and also the trigger for a nation-wide program of dike improvements and the construction of an integrated flood defense systems.

During our visit to Minas Gerais the DRR team made several general observations:

- Tailing dams are often raised to such a high level that they become with a very large risk. With crest levels rising to 100 m and volumes exceeding 100 million $m^3$, the dimensions are enormous.
- Significant steps are being taken as a result of new legislation and increased public awareness;
- The risks for communities, water supplies, cities, forests and environment as well as the economic importance of the industry for the State of Minas Gerais make the structural improvement in safety of these structures extremely important and urgent;
- When visiting mining company Vale, the people we have talked to - including geotechnical engineers, mining engineers and operators - seemed willing and eager to improve safety and to internalize higher standards of safety;
- Containment works, monitoring and the execution of evacuation plans are to date the most prevalent measures that are taken, structural improvements to the vulnerable dams are not taken in short notice;
- From a social and economic perspective, the economy and society of the State of Minas Gerais are influenced by- and intertwined with the mining industry.

## 4.2 Risk management and safety chain

Since the Mariana dam failure at the Samarco mine in 2015 and especially after the Brumadinho disaster at the Vale mine in 2019, there is overall a great awareness of the risks that tailing dam facilities pose. Particularly the images recorded by the monitoring cameras at Brumadinho have been seen by many people and added much to the awareness.

Since these disasters, actions are being taken both by authorities and mining companies, but it appears that there is scope for improvement of the management strategy. The actions appear to be to a large extent prompted by new federal and state legislation. There is now also a clear and imminent awareness of the financial and legal risks faced by companies but also individuals (both in industry and government) if there is any liability linked to their actions or lack thereof.

Previously the risks associated with the construction of a tailing dam were less known, so TSF's were created upstream of populated areas and vulnerable river and ecological systems. However, now the new legislation creates a situation where there is a sudden strong focus on risk aversion (to avoid liability and preserve reputation). This situation is understandable but gives an impression that

sometimes excessive measures are taken, while at the same time there is inertia and lack of focus in other areas.

For instance, from a legislative point-of-view, there is currently a clear focus on the risk of upstream dams, while downstream dams are seemingly perceived to have a much lower risk or no risk. The dams that failed were upstream dams and inherently the construction of upstream dams is less safe than downstream or centre-line dams. But this does not mean that all downstream dams are safe, and all upstream dams are unsafe. The risk for every TSF is different and unique and there will be upstream dams that pose a lower risk than certain downstream dams. This opinion is shared by the ANM.

Another proposed solution for the storage of tailing material is the dry-stacking option. This is considered a safe solution, but storing large amounts of material, even if it is in a 'dry' form does not form necessarily a safe solution in the long term. Any amount of loose and fine-grained material that is disposed of in large quantities in any catchment will eventually, due to rainfall and erosion, be transported downstream of the catchment area. Only under very dry (desert-like) conditions, this material may be stable for longer periods of time, but considering the average climate in Brazil, this is likely not the case. The saturation of the deposited material can still lead to an unstable situation. Thus, all storage facilities, whether they are tailing dams or dry stacks, should be considered as running the risk of instability and its consequences must be considered.

In-pit disposal (the storage of tailing material in abandoned open pit mines) appears to be a better solution, since the material will remain contained and thus stable for a much longer period. From a strategic point-of-view, operators often do not favour this solution, because it restricts possible future access to their mineral resources even though currently it is not economically viable to continue mining. Still it deserves consideration from a safety perspective.

The mitigating measures currently taken are clearly at the end of the safety chain. Vale is constructing large retention dams downstream of the TSF's (to stop a possible mudflow in case of a dam break) and the population in the potentially affected areas (self-rescue zones) downstream have been evacuated. These are drastic measures and create an important impact on the local communities and the environment.

The actions are aided towards mitigating the impact of dam failures based on a general assessment of the stability of the TSF. Based on several criteria, some quantitative, but mostly qualitative, the TSF's are classified and the information is stored in a database of the ANM, called SIGBM. Mine operators are required to deliver the information to the regulator (ANM), which then evaluates the information on a regular basis.

The mine operators are also required to provide a regular assessment of the stability of the most critical TSF's. This assessment needs to be checked or prepared by an external auditor. What the requirements of this assessment are is not clear to the DRR team. Vale has presented to the DRR team on three occasions (during the site visits) an overview of the (geotechnical) stability calculations that probably form the basis of the required stability assessment. The geotechnical stability calculations yield a safety factor, which should remain above 1.5 for the TSF to be considered stable, according to the current law. This background of the stability analysis is further elaborated in Section 4.3.

Based on what was presented by Vale, it appears that the geotechnical stability analyses that were conducted were generally using very limited input and location specific information. It appears also that the geotechnical models lead to a bipolar safety image (Safe or Unsafe). This approach is understandable, considering the risks the structures pose, however, this approach also prevents the execution of additional site investigations for the dams considered to be unsafe, since a low factor of safety can force the regulator to classify the TSF as unstable, which immediately means that no further access to the TSF is allowed. In this way a situation is created where drastic mitigating measures are taken, based on very limited information. In retrospect it is important to note that the failed Brumadinho dam was not considered a high-risk level 3 dam. Besides, the use of limited information which is not well studied in calculations can have as a consequence that the most likely

failure mechanism is not discovered, and therefore that the mitigation measures applied are not the most adequate. The question of how to apply safety in geotechnical calculations is a complex one, which has fortunately been well studied; in the Eurocode, for instance, partial factors of safety are applied, and these differ depending on the failure mechanism.

The conclusion is that if more (site investigations) were conducted in the past or were allowed in the present, the risk could be assessed in a better way, and improved measures could be taken. It is advised to follow the Deming Cycle or PDCA cycle in this case. PDCA (Plan-Do-Check-Act) is an iterative, four-stage approach for continually improving processes, products or services, and for resolving problems. It involves systematically testing possible solutions, assessing the results, and implementing the ones that have shown to work.

## 4.3 Site investigations and design practice

### Types of tailing dams

Tailing dams have in the past been constructed in different ways, but the most flexible and therefore economical way is the upstream method. The upstream method means that a starter dike is constructed first, usually within a valley, thus the valley walls constrain the tailings from the sides. The tailing material is then placed hydraulically (with water) in the area behind the starter dike (pond). Once the pond is filled a new dike is constructed, partly over the existing tailing material and partly over the starter dike. The TSF can be subsequently filled in several stages using the same method, whereby significant heights and volumes can be reached (see Figure 4. ). The upstream method is inherently the most instable method of construction, since the dam is resting partly on tailing material, which is weak material, usually saturated and prone to static liquefaction.

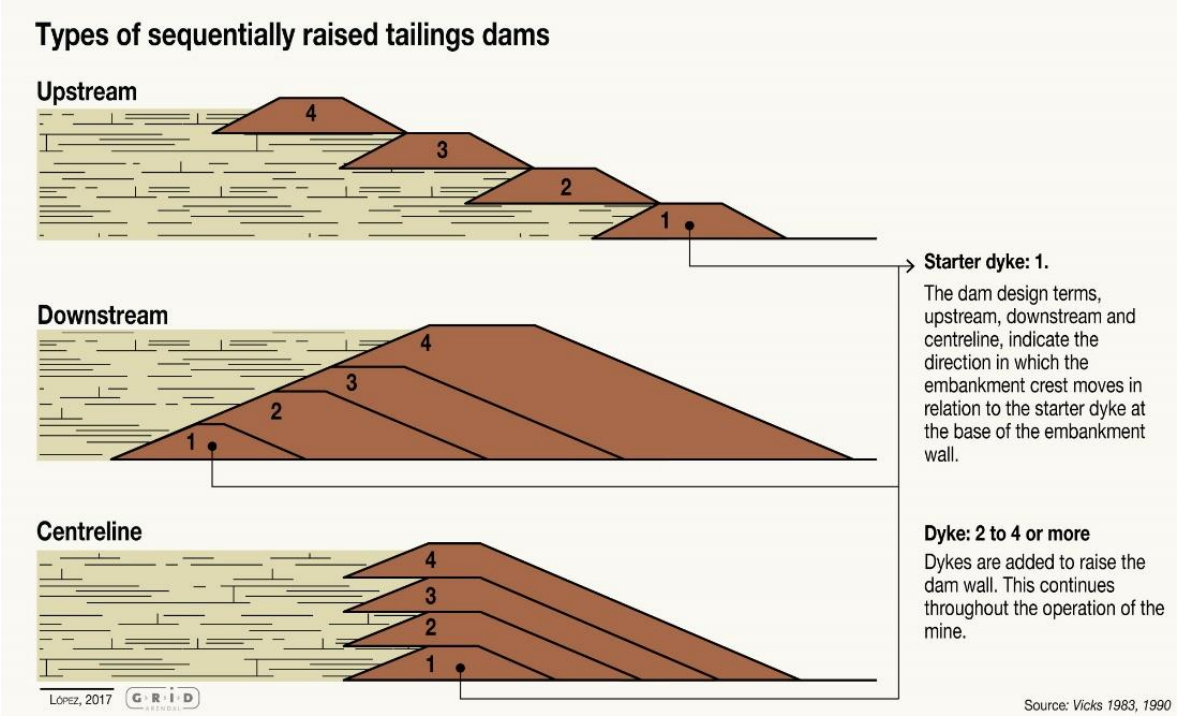


*Figure 4. The three type of tailing dam construction sequences generally encountered (From: www.grida.no)*

It is not clear how many TSF's there are. It also depends on the definition by law. According to the new state-wide law all facilities below 10 m need to be considered. There are in the state of Minas Gerais about 800 that fulfil this criterion. Nationwide there are possibly 200 or more TSF's with a height of more than 15m that could have stability issues. Now there are about 40 TSF's that required

decommissioning (“de-characterisation”): this means closure and removal. How many of these are upstream dams is not clear.

Upstream tailing dams are perceived as a larger risk and are not allowed to be used anymore given the new legislation on tailings storage in Brazil. The upstream tailing dams also need to be “de-characterised”, which means that they should be abandoned and removed. Downstream tailing dams are still allowed to be used and constructed. Inherently, downstream tailing dams could be more stable than upstream tailing dams. However, also here it remains important that a proper (best) design practice is followed and the right materials are used. In the design of the latest (2019) Maravilhas III dam the common design practise has not led to big changes in slope design (1:3 or 1:4). Considering the enormous dimensions of the newest TSF and the storage capacity this is noteworthy.

What became also apparent during the fact-finding mission is that not only the method of construction is important to the risk of instability, but the slopes of the tailing dams are often very steep, which increases the risk. Slopes of 1:2 are very common, irrespective of the slope material, foundation characteristics or location. In the Dutch experience, dealing with soft soil, embankments this steep are rarely used, only for temporary embankments. The design practise of using steep slope is of course economical, but on the other hand it becomes very difficult to reach a stable geotechnical situation, even under optimal conditions.

**Site investigations**

It also appears that geotechnical site investigations (using for instance CPTu or sampling by drilling or SPT) to analyse the stability of the TSF is generally limited. Also, the investigations of the geological foundation and shoulders of the tailing dams appear to be often overlooked, while this can have an important impact on the stability and development of seepage and piping issues. The incorporation of drainage (blankets) appears to be limited and not sufficiently anticipated to future raises.

The stability analyses presented by Vale are all based on 2D limit equilibrium calculations with software Slope/W. This is a common analytical software tool and as such well-accepted in the geotechnical design practise. However, more sophisticated geotechnical tools are 2D and 3D Finite Element Models like Plaxis, which is often used in Dutch design practice as well. From the presentations given by Vale, it was not always clear how the geotechnical design values for the different geotechnical units were derived. Previously, static liquefaction was not considered, while nowadays this needs to be incorporated. Vale showed that the undrained shear strength parameters were derived from CPT data using Olson’s correlations. Obviously, the undrained analysis leads to lower safety factors than before. This has been the reason why some dams had to be suddenly re-classified from stable to unstable.

It appears also that most of the design parameters are derived from CPT data. This is not necessarily a bad approach. In Dutch design practise this is very common. However, it is also common practice to still obtain samples to verify the derived characteristics with laboratory tests. Taking samples from the tailing materials is not very straightforward because of its non-cohesive nature. Nevertheless, it is advised to carry out a sampling and testing programme, since the relations that are common for normal (natural) soils may not always be applicable to the tailing material. Tailing material contain often large amounts of fine-grained (metal) ore material, sometimes up to 20% or more. It is likely that this affects the geotechnical and geohydrological behaviour and this can influence the conventional empirical relations between CPT data and geotechnical parameters. Also, other in-situ tests as SPT can provide further insight.

**Knowledge about the TSF structure and foundation**

One of the main issues with the currently considered critical upstream dams is that it is not clear how they were designed, constructed or operated. Sometimes, the dam raises were executed differently or to larger heights than originally planned. Changes made to the original design have not been subject to legislation, according to ANM. Often, the tailing dams are legacies from previous owners and proper documentation on design, construction methods and operations are lacking. This means that the structure of the TSF and geotechnical characteristics of the materials are largely unknown. Also,

the geohydrological condition and history is often unknown. In many cases, only the recent groundwater levels are known based on recently installed piezometers and standpipes. The long-term behaviour remains therefore unknown, which means it becomes difficult to anticipate for (extreme) rainfall events. In order to monitor the stability of a tailing facility, it is important to know what the geotechnical and geohydrological characteristics of the TSF area, otherwise it is not clear how and what needs to be monitored (see also Section 4.4).

In addition, there are various factors that are difficult to quantify and be incorporated in the geotechnical or geohydrological models. For instance, the geology of the subsurface or the shoulders of the TSF can have an important impact on the overall stability. The presence of dolomite in the subsurface can indicate toward the presence of karst. This could lead to unwanted leakage pathways underneath the dam, sinkholes, local instability and piping, eventually leading towards global failure. Also, as presented by Vale, a more fractured and thus permeable quartzite rock mass had at Maravilhas II TSF already led to oversaturation of a part of the dike structure, which impacted the stability. Measures are now developed to mitigate this issue.

## 4.4 Monitoring

The team learnt that monitoring was intensified following legislative changes and the need to improve safety following the failure of the Brumadinho tailing dam early in 2019. However, standards on monitoring were not defined at the same time, it seems. The monitoring center at the MAC (Vale Headquarter) is equipped with large screens with real-time images and a dedicated room that is operational 24/7. The monitoring taking place there is intended to support the responsible managers for the respective tailing dams on site.

In general, monitoring can be a good addition to the safety chain:

1. as a source of input for prioritization and safety checks;
2. as input for an early warning system.

**Source of information**

In the Netherlands, real-time monitoring of critical infrastructure such as dams and dykes is not standard practice. High water levels and high waves as a result of storm surges at open sea are monitored and soil structure and visual inspection are conducted on a yearly basis, because we do not perceive much change in the current state of dykes. During dyke reinforcement or other large projects in the area of critical infrastructure, we use monitoring to assess the safety during these operations.

In the Netherlands, most effort is put in the first stages of the safety chain. We like to have an elaborate soil investigation plan and a lot of field data to assess the current situation, because we perceive a large variability in soil structure and materials as a result of meandering of rivers, deposits and big differences in the compaction of soils as a result of previous loading cases. Based on this site investigation, design is conducted, and construction works are carried out according to the design. Safety checks are conducted in line with the expected loading cases.

In order to make monitoring successful, it is critical to have a very detailed and elaborate site-investigation program and large detail of the design and subsequent operation steps in order to know what to look for during monitoring. When we know the characteristics of a dam, monitoring can add a valuable source of information on the current state and safety of the structure because we can check assumptions and schematization of the safety checks done. Based on the design calculations and real-time measurements we can try to estimate a current level of safety. When used in this way, monitoring results can even be used to do design optimization (observational method).

Based on the current state of a dam several parameters can be measured to give valuable information on the dam state, for instance:

- measurements of the phreatic water level in the dam, the tailings and/or the soil structures below;

- measurements of the vertical and horizontal displacement over time;

- measurements of vibrations;

- visual information about the traffic, visitors, or works that are carried out on or next to the dam;

- etc.

**Monitoring plans**
Based on the design, threshold values are included in the monitoring plans for the parameters that are measured; there is a direct link to the stability calculations. During the visit, the team found no clear evidence of the link between monitoring plans and feedback loops, which makes it hard for the monitoring team to contribute to decision making. The trigger thresholds have not been determined through calculations, or only through extremely simple calculations. The monitoring center still seems to rely heavily on the visual input from geotechnical engineers at the dams to prioritize.

The staff at the monitoring center explained in detail the measurements that are undertaken and the direct feedback to the geotechnical engineers in the monitoring center and on site. It also reported that at the moment the biggest challenge is to translate the measurements into predictions or current safety state of the structure. Therefore, the monitoring seems to be a valuable source of information but not yet a measure to predict near-failure.

**Feedback loops**
It should always be kept in mind that monitoring is a measure at the end of the safety chain. It is a welcome addition to the safety chain. The success of monitoring as an early warning system relies heavily on the feedback loop with the design. Based on the assumptions and input used in the safety calculations of the dam monitoring can, under certain conditions, support decision making of the current safety level of a dam.

For instance, when we know the soil structure, soil characteristics, geometry and design water levels, including design phreatic water levels and design piezometric levels we can try to predict the current level of safety of a dam. If the model or the input is limited, monitoring results do barely contribute to the in-depth knowledge of the soil structure, because the measured results cannot be interpreted or explained.

**Level of detail of monitoring**
The monitoring takes place with high precision and level of detail. Deformation is monitored with radar, robotic total stations and occasionally in boreholes with inclinometers. The piezometric heads are also monitored, sometimes still manually, but increasingly in an automated way. From what was shown it was not always clear which piezometric head was measured, the head in the tailings or in the foundation layers below the TSF. It is important to distinguish between the different piezometric heads, especially when there are less permeable layers present, since this can have an important impact on groundwater flow within the TSF and thus on the occurrence of liquefaction and seepage.

**Sense of accuracy and security**

The question arises whether monitoring with such high precision and detail also yield enough accuracy in order to assess the stability properly. There are threshold values set, but it is not clear based on what. Normally a monitoring plan is made, based on different geotechnical and geohydrological scenarios. Even with very sophisticated models and high level of detail of the ground investigations, the definition of threshold values is very difficult. Highly detailed monitoring and precise trigger values based on low detail models may create a false sense of accuracy.

Also monitoring, if interpreted as a direct measurement of safety could lead to a false sense of security. When monitoring results are presented as a measured safety level the image can be created that we know the current safety level. Monitoring provides raw sensor output on piezometric level, temperature or movement in one point, in one dam at one level at one moment. Interpretation is bound to thorough validation and verification, input from the current state, engineering practice,

modelling an extrapolation. Given the current information level of the build up, history, soil characteristics and it is recommended to be cautious in the use of monitoring as a safety predictor.

## 4.5 Reinforcement works

The latest safety report of Vale states:

“The upstream deactivated dams, whose Self-Rescue Zones (ZAS) had already been evacuated for having emergency levels 2 and 3 of the Mining Dams Emergency Action Plan (PAEBM), remain with negative DCEs [editor: DCE = Stability Condition Declaration]. These are: Sul Superior dam of Gongo Soco Mine; B3/B4 dam of Mar Azul Mine; and Forquilha I, Forquilha II, Forquilha III and Group dams of Fábrica Complex. In addition to keeping reservoirs dry and minimizing water supply to these structures, initiating the process of de-characterization. Vale is also carrying out containment works downstream of the dams, reinforcing the safety measures for the population, animals and the environment.” [Source: http://www.vale.com/EN/aboutvale/news/Pages/vale-informs-on-stability-condition.aspx article date: 01-10-2019 d.d. 23-10-2019]

The DRR team visited two reinforcement works downstream of the Sul Superior dam of Gongo Soco mine and of the B3/B4 of Mar Azul Mine. In both places a downstream Self Rescue zone is issued. Because of the perceived increased risk level, the mining company is building downstream containment structures, which are basically dams built across the valley to halt the possible mudflow resulting from a dam breach.

Once completed, these structures are reported to retain most of the volume of tailings from the Sul Superior dam and B3/B4 dam in case of a dam breach, thus containing the displacement of material within a more restricted area.

Several observations can be made:

- technical measures are taken in short notice with a large investment and short preparation and design time (we were told contracting, design and construction happened in parallel);
- impact of both the ZAS and the containment structures are large in terms of footprint, social impact and also environmentally;
- structures are built as a result of the increased safety level, based on the safety assessment with the negative DCE and the high score on the prioritization list of the ANM, both are determined based upon limited understanding of both the failure modes as the current state of the dams.
- the fact that the failing dam in the Brumadinho disaster had an emergency level 1 introduces a lack of confidence in the assessments of the current safety levels. This has also resulting in increased doubt from different sides about either optimistic and pessimistic assessments of the stability and safety levels.

*Figure 5. Containment dam downstream of Sul Superior dam*

*Figure 6. Containment dam downstream of the Sul Superior dam*

*Figure 7. Training facility for remote controlled equipment for decommissioning.*

*Figure 8. Rockfill dam downstream of tailing dam B3/B4*

## 4.6 Social impact and mitigation

It is obvious that the impact of the Mariana and Brumadinho dam failings has been very large, in particular because of the casualties from both mine employees and citizens living in the vicinity of the dams. Measures that were taken after the Mariana disaster were reinforced after the Brumadinho disaster.

Vale established compensation and social facilitation programs that aim to encompass all those affected directly or indirectly by its TSF infrastructures. This includes not only compensation to victims of the Brumadinho disaster, but also those affected by evacuation or otherwise impacted.

Part of the team had the opportunity to speak with two community leaders in the town of Macacos, not far from Belo Horizonte, and the head teacher of a relocated primary school in the same town. Findings of these frank conversations include:

- The tourism industry in the town has almost completely collapsed due to the evacuation and other effects;
- The relocation of the school has increased the sense of security of the families that have children in the school, a total of 140 children at the time of the visit. 20% of the children in this school have been directly impacted by the evacuations
- The number of children with learning and behavioural problems has tripled since the evacuation was carried out on 16 February of 2019
- Compensation schemes for the inhabitants of Macacos have also had negative side effects, in the sense that social problems were exacerbated by the sudden availability of much more financial means than previously

The Vale mining company has instated not only financial compensation programs for the affected people, but also an accompanying program of social support and facilitation, ranging from psycho-social support through the existing network of health centres, to services to support the wise usage of money received by those who were entitled to large sums of compensation through professional financial planning. Often this attention is geared towards the recovery of a sustainable livelihood. A total of 780 families are eligible for these assistance programs, as presented to the team during a visit to the Vale head quarters in the MAC area of Belo Horizonte.

## 4.7 Organisational challenges of the regulatory bodies

Part of the team had a meeting with two representatives of the Prosecutors' Office of the Public Ministry (PM) of Minas Gerais state. The following findings emerged from this meeting:

- the finding, earlier in the week, that legislative enforcement has in the past been instrumental to achieve better safety assessments by the mining companies (which first emerged in discussion with Vale staff at the B3/B4 dam on 15 October) was confirmed
- The PM has instated independent auditing services from international recognised engineering consulting companies to supplement the existing auditing system. The criteria which the PM uses to select a company as capable to provide these independent services is unknown. The PM controls these audits which are being paid for by the mining companies
- The PM is aware of the need to achieve a higher level of security for the population and of the fact that this will require a more effective sector wide governance approach. An open discussion was held about the Dutch approach of flood safety through the public sector and how some aspects of the overall governance approach of the Netherlands (the so called 'Polder model' of strong inter-institutional cooperation and cross sector dialogue) might be useful for the Brazilian situation of the mining sector.

From the above and from the interactions with other stakeholders, notably with ANM the following key findings emerged:

- The reaction from the public sector after the Brumadinho disaster has been largely effective in achieving improvements in the security of the tailing dams. However, the capacity of the regulatory bodies is insufficient in terms of numbers of professional staff to cope with the regulatory and enforcement challenges. Investment into organizational capacity appears to be necessary to reach adequate levels of regulatory oversight. In addition, the distribution of roles and responsibilities between the various agencies is not always clear.
- There is scope for better cooperation between the involved public sector parties, including the legislators, the public ministry, the ANM, SEMAD and FEAM (and possibly others who have roles in the monitoring of dam safety).

## 4.8 Legislation and safety standards

In Brazil, both federal (country-wide) and state legislation must be applied. In the case of tailings dams, there are discrepancies between these two types of legislation, which results in confusion and uncertainty when and how laws must be applied. This is caused by a state law issued days after the Brumadinho dam collapse, as a quick reaction to the disaster. The local branches of the ANM, SEMAD and FEAM in Minas Gerais are currently applying for changes to this law, because they regard it now as impracticable.

The ANM (as well as SEMAD and FEAM) has a limited capacity in manpower. Their employees are required to supervise hundreds of dams in the state of Minas Gerais alone. In practice, this means that each mining company is (together with its auditor) responsible for stating whether their dam is safe or not safe; the role of the governmental bodies is to ensure that the mining companies are complying with the law (not to ensure that the dams are safe). Still, this is a large amount of work for the governmental employees, who are unable to inspect all dams every year, let alone to check the design and check the safety assessments.

The ABNT (Associação Brasileira de Normas Técnicas) is the organisation which develops and publishes technical norms. ABNT NBR 13028, published in 2017, concerns the requirements for the design of tailings, sediments and/or water dams for the mining industry. This document has 22 pages and is quite conceptual (high abstraction level), more a guideline on best practices. It does have clearly stated safety factors for the tailings dams but is not sufficiently detailed regarding the calculations of those safety factors.

It may be argued that the detail level of the ABNT NBR 13028 is appropriate for a document of this nature. However, a separate document detailing a systematic approach to analysing the safety of (tailings) dams is essential; this would be a guideline to be followed by dam designers/auditors and employees of mining companies. This document could include explicit advice on, for instance:

- which method to use for stability calculations (Spencer, Bishop, Uplift Van, etc), acknowledging the differences between these methods and proposing different required safety factors;
- partial factors of safety to be applied in loads, material properties and resistances;
- progress of the phreatic level across the dam and safety strategy regarding development of porewater pressures;
- minimum grid distances of locations for geotechnical site investigations;
- minimum quantities of samples to be tested in the lab, and which testes should be carried out.

Much would be gained if a panel of experts were to develop such a guideline:

- much uncertainty would be eliminated from the calculations; the “human element” would be less relevant (less factors of the calculation would be highly dependent on who is performing the calculation);
- calculations would be much more uniform; it would be easier to compare calculations of different dams, thus making prioritisation of dams easier;
- it would be less likely for items to be missed, because designers would be required to follow a check-list;
- dam designers would feel more confident about their calculations, because they would know they were following a proper guideline.

To develop such a guide, the Canadian (CDA - Canadian Dam Association) and/or Australian (ANCOLD - Australian National Comittee On Large Dams) guidelines should be consulted. There is also a recent global initiative to tackle this problem: globaltailingsreview.org.

## 4.9 Stability calculations

Stability calculations are performed to determine the safety factor of the dams. If the calculated safety factor of the dam is lower than required by the technical norm, the auditor cannot certify that the dam is stable.

It is important to highlight that the calculated safety factor can vary much with the input of the calculations. Some of these inputs which have an important influence in the calculated safety factor of a dam are:

- Geometry (elevation of natural soil, size and position of dykes, extent of tailings, etc);
- Materials (properties of dykes and tailings; because of the nature of the construction process, these materials tend to be heterogeneous, which makes the problem more complex);
- Water (phreatic level and porewater pressure, whose head may vary within the dam; excess porewater pressure).
- Loading conditions, such as traffic or seismic activity.

Some of these starting points are difficult to determine, especially in the case of limited site investigation and even more so when it is not clear how the dam was constructed. Very extensive investigation and monitoring are required to gain the necessary in-depth understanding of the dam. When these are not available (as is often the case in tailing dams), the calculations become less reliable. This means that the calculated safety factor is not accurate but more importantly, it may lead to a wrong assumption of the main mechanism of a possible dam collapse.

Safe or unsafe: The Mariana and Brumadinho dam disasters have increased the awareness to the problem of stability of tailings dams. On the one hand, it is relevant to highlight that both dams were considered safe. On the other hand, other dams have been considered unsafe for a few years now and have not failed up to this moment.

Undrained calculations: The recent introduction of undrained calculations is noteworthy; up to recently, only drained calculations were performed. Also, the verification of safety for liquefaction is only carried out recently. However, there is still much work that needs to be done. For instance comprehensive stability calculations by taking into account all failure mechanisms, have to date not been performed for all the existing tailings dams in the state of Minas Gerais.

## 4.10 SIGBM

The DRR team was given access by ANM to their database on the mine tailing facilities: SIGBM. The DRR team was asked by ANM to provide high-level observations of the SIGBM database with recommendations for possible improvement. During the second DRR mission (on Friday 29-11-2019) the observations and recommendations were also shared with ANM in an interactive presentation. Here, a description is provided of the SIGBM database.

The SIGBM database is an online tool that allows the ANM to prioritise inspection and provides support to their workflow in their supervisory role. Owners and operators of the TSF's also must provide information about their facilities to ANM and are required to enter and update this information in the database. The database consists of 14 main categories, which are provided in Table 1. These categories are providing data, information and reports on the physical characteristics of the TSF, potential damage, risk category, inspection reports, stability statements and legal matters.

*Table 1. List of main SIGBM identification categories describing the TSF's. Each main category consists of several sub-items.*

| | |
|---|---|
| 1. | Tailings Disposal with barrier |
| 2. | Coordinates of the Crest Center |
| 3. | Type of Waste Stored |
| 4. | Technical Characteristics |
| 5. | State of Conservation |
| 6. | Security Plan |
| 7. | Associated Potential Damage |
| 8. | Technical Responsible |
| 9. | Mining Dam Accidents / Incidents |
| 10. | Regular Inspection Extract |
| 11. | Stability Condition Statement - RISR |
| 12. | Special Inspection Extract |
| | a. IE - Conservation Status with score 10 |
| | b. IE - Inspection Requirement / Exceptional Event Occurrence |
| 13. | Periodic Review and DCE - Review |
| 14. | Emergency Plan |

The SIGBM database consists of an online user interface. The main user interface consists of a query screen that allows the user to select TSF's based on different criteria (see Figure 9). Based on the query a list of TSF is generated, which can be ranked based on different criteria. With regards to the prioritisation, the ANM has developed a point-based system (Puntuação, see second field from the left in Figure 10) that is the result of a summation of points given to 22 database items and criteria. The higher the amount of points, the larger the priority or risk. The 22 database items and criteria are given in Table 2.

*Table 2. Database items that receive with a certain value, the higher the value the higher the contribution to the risk. All values are added, and the total scoring is provided as a value in the TSF query list (see Figure 10).*

| | |
|---|---|
| 1. | Current Maximum Height (m) |
| 2. | Current Reservoir Volume ($m^3$) |
| 3. | Conservation Status (Reliability of extravasating structures) |

| | |
|---|---|
| 4. | Conservation Status (Percolation) |
| 5. | Conservation Status (Deformations and Repression) |
| 6. | Conservation Status (Deterioration of slopes / vestments) |
| 7. | Class |
| 8. | Risk Category (CRI) |
| 9. | Potential Associated Damage (DPA) |
| 10. | Dam inserted in the National Dam Safety Policy (PNSB) |
| 11. | Stored waste is hazardous |
| 12. | Mining process has waiver request |
| 13. | Mining process has suspension request |
| 14. | Mining Process Has PAE Modification Request (LI / LO) |
| 15. | Dam construction method |
| 16. | Current volume equal to or greater than project volume (LO Authorized) |
| 17. | Has PSB (Dam Safety Plan 70,389 / 2017) |
| 18. | Has regular inspection reports within PSB |
| 19. | Has caveats in Regular Inspection Extract |
| 20. | Delivered the Stability Condition Statement within the legal timeframe Established |
| 21. | Delivered Declaration of Stability in Mining Process Not Agreeing with Stability |
| 22. | Has PAEBM (Mining Dam Emergency Response Plan) (on PSB: Dam Safety Plan) |

CRI (Risk Category) of a TSF or dam refers to aspects of the dam itself that may influence the likelihood of an accident: design aspects, integrity of the structure, condition, operation and maintenance, and compliance with the Safety Plan. DPA (Associated Potential Damage) is the damage that can occur due to rupture, leakage, soil infiltration of dam or TSF malfunction, regardless of its probability of occurrence, and can be graded according to loss of life and social impacts, economic and environmental impact. The CRI and DPA range from Low to High (C to A) and the combination of CRI and DPA yield 5 risk classes (A to E), where A is the highest risk class. These risk and damage categories (CRI and DPA) are defined by the National Water Agency (ANA).

ANM announced that they will shortly release a publicly accessible version of the SIGBM database. This does not have all the information but provides to the general public an overview of all the TSF's, for instance where they are located and who the owners are.

The SIGBM database provides much information on the TSF's and provides a good basis for a risk management system. Now the SIGBM database is mainly used as data input tool and workflow management system for both the mining companies and the ANM. By integrating SIGBM with other (geographic) data, for instance within a Geographic Information System, hazard, impact and risk assessments could be carried out as well.

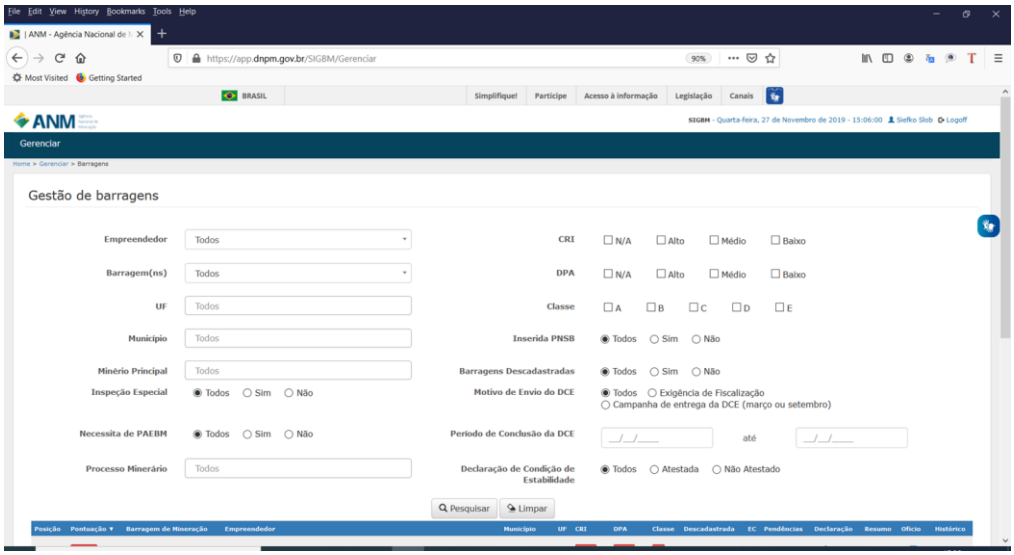


*Figure 9. Main query screen of the online SIGBM user interface*

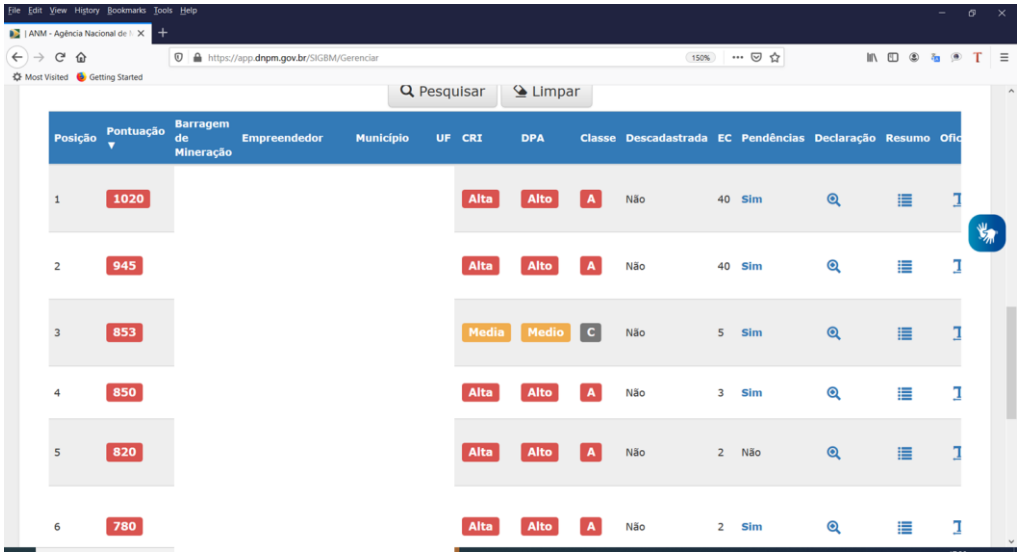


*Figure 10. The query result listing screen. The database items are blanked out for reason of confidentiality. The second field item from the left is the point system (Puntuação) based on which the ranking can be carried out.*

## 4.11 Strategic Environmental Assessment Framework

**Good governance of the mining sector through Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA)**

In the second mission to Brazil expertise was added to the DRR team on the topic of EIA and SEA, with the objective to engage with the public and private parties in the mining sector. The discussions in Belo Horizonte (multi stakeholder setting) and Brasília (with ANM) were very productive.

**Practice with respect to EIA:**
In Brazil, Environmental Impact Assessment (EIA) is legally required since 1986. For EIA requirements for the mining sector, see box 1, indicating which type of projects require EIA.

**Box 1:** EIA Regulations: Resolutions of the National Environment Council - CONAMA 01/1986; 06/1987; 09/1987; 01/1988; 237/1997; 279/2001 (source, website IBAMA)

Mining:
- Exploration
- Open pit mining, including alluvial
- Underground mining
- Artisanal small-scale mining

The DRR team has not assessed EIA performance in the mining sector in Minas Gerais as part of its fact finding as the EIA expert did not join the fact-finding mission. To get an impression of EIA performance in the mining sector, the results of an assessment carried out by the Inter-Governmental Forum of Mining and Minerals (IGF) has been presented and discussed[1]. The IGF

[1] IGF: Background document - Issues in Legal Frameworks of ESIA in the Mining Sector (January 2019). The DRR team would like to emphasize that the IGF assessment of EIA performance in the mining sector was based upon a research of 22 of the 70 countries that are member of IGF. Brazil is a member of IGF but was not included in this assessment.

study identified the following main shortcomings in the EIA legal framework and practice IGF around the world:

- Lack of coordination between EIA approval authority and Mine permitting authority;
- Often automatic approval of EIA because short timelines are often not met;
- Participation of impacted communities in the EIA-process is not assured because:
    - Consultation is taking place after submission of the EIA;
    - No requirements of consultation (closure & rehabilitation plans);
    - Scope of consultation is limited;
- Exploration mining permit is often automatically followed by an exploitation permit. EIA is often not considered in this decision-making process.

These main shortcomings were recognised by the audience in Belo Horizonte and Brasilia. Two preliminary conclusions can be drawn based upon the discussions in Belo Horizonte and Brasilia.

Firstly, it was concluded that the EIA legislation needs to be improved. It was suggested that the independent position of the authority responsible for EIA review could be strengthened.

Secondly, the coordination and cooperation between the authorities responsible for approval of EIA / environmental permits and the authorities responsible for approval of the mining permits could be improved.

**A new instrument: SEA**

Strategic Environmental Assessment (SEA) is a relative new tool that aims to support environmental and social issues to be taken into consideration in strategic government planning and policy making. SEA is legally adopted by a growing number of countries. Brazil has not yet legally adopted SEA but did gain some experience with voluntary SEA's.

An introduction on SEA as well as a case study on SEA for the mining sector in Lao Peoples Democratic Republic have been presented by the DRR team / NCEA. These presentations raised attention and interest by representatives of the ministry of mining, ministry of environment as well as from the mining companies. Especially, the following potential SEA benefits raised interest:

- SEA can support strategic decision-making within the mining sector;
- SEA contributes to the development of for example a Mining Strategy, that is more environmentally friendly and socially more acceptable;
- SEA can contribute to trust building between government, mining companies and civil society / affected communities;
- SEA contributes to more transparency and accountability between the key stakeholders;
- SEA contributes to coordination and cooperation between the authorities responsible for mining-, environmental- and social issues, such as health.

Two options for a government plan that can benefit from an SEA have been discussed: (i) A spatial development plan for the State of Minas Gerais and (ii) a Mining Strategy for Minas Gerais. As Brazil has no experience with spatial planning at state level this option was considered as too complex because in that case all sector authorities need to be involved and a spatial plan as well as SEA is new. Therefore, the idea to develop a Mining Strategy for the short, medium and long term (at least for 20 years) for Minas Gerais that can benefit from a SEA was widely supported. The following first ideas or building blocks of a SEA have been identified:

- SEA can assess some growth scenarios for the future of the mining sector in Minas Gerais.
- SEA can provide a voice to all key stakeholders in the mining and by mining influenced sectors as SEA is a transparent and participatory process;
- SEA can support a balanced development of mining with other types of land use such as for example residential areas, agriculture, use of drinking water and environmental flow, biodiversity;
- SEA can for example support a mining strategy with information on:
    - Flood prone areas of all the existing mines and TSFs;
    - Vulnerability assessment of the TSFs;
    - Early warning systems;
    - Mine waste disposal methods;
    - Prioritisation of tailing dams that need to be decommissioned;
    - Guidance for future / new mining activities through spatial zoning;
    - Alternatives in pacing mining concession rounds and awarding exploration/exploitation licenses;
    - Policy on rehabilitation and decommissioning of mines and TSFs;
    - Policy on resettlement and compensation through developing different forms of conflict resolution or alternatives for compensation systems;
    - Assess funding mechanisms to secure closure and post mining maintenance of TSFs.

# 5 Conclusions and Recommendations – Proposed Follow up

The mission concludes that there is a strong sense of urgency that the mining sector in Brazil has to make a great leap forward in terms of leaving behind the era of non-sustainable mining and tailing practices, and to establish a regulatory and planning framework that has the potential to create a new social contract between the mining industry and society.

In order to achieve this, extraordinary leadership will be required, from the mining industry itself, from the Brazilian government and from civil society.

The Netherlands might support such a leap forward by providing input on request of the Brazilian government. It is recommended to pursue an integrated package of support, as follows:

1) Based on the fact finding mission and the feedback received during the workshops in Belo Horizonte and Brasília, in particular the discussions with ANM staff, the DRR team believes that there is scope for **technical cooperation between ANM and Dutch knowledge institutes/governmental bodies** on dam safety related issues. Concrete topics for technical cooperation have been explored by ANM staff and DRR team during the workshop in Brasília. The table on the following pages presents the potential areas of technical cooperation between ANM and Dutch knowledge institutes. The four areas of potential cooperation encompass:
    a. Risk assessment
    b. Legislation, standards and guidelines
    c. Institutional development
    d. Strategic Environmental Assessment (SEA)

    It is recommended that these areas be explored through a scoping process that involves some of the potential Dutch partner institutions and ANM and other Brazilian partners. Based on the outcomes of such a scoping process an MOU between the Brazilian and Dutch knowledge partners involved could be instrumental to start this cooperation.

2) The presentation of the **framework of Strategic Environmental Assessment** by the Netherlands Commission on Environmental Impact was very well received. In Belo Horizonte the participating stakeholders, in particular those from the mining sector considered the SEA framework to be a prospective way forward of participatory planning that includes the mining industry, the government and civil society, and leave behind the present polarization to focus on a better future. In Brasilia the ANM staff shared this point of view, noting that it is helpful to distinguish the legacy of the past from the challenges of the future. Initial talks have been held with the Public Ministry of Minas Gerais (MPMG) to conduct a pilot SEA for the mining sector in the state. MPMG showed strong interest to take this further.

    It is recommended to further explore the support for a SEA of the mining sector in Minas Gerais, together with MPMG, ANM and other state regulatory bodies, the mining industry and civil society. NCEA or DRR can follow up by fielding a mission to define the scope and to explore the political and societal support for such a pilot SEA.

3) The mining industry itself will require further improvement of its methods and approaches if the sector is to survive the present negative public opinion. Another dam failure in the coming years will be catastrophic, mostly for those directly impacted by the disaster and for nature and the environment, but the resultant civil unrest will also affect the mining industry in Brazil and possibly elsewhere. In that light, provision of technical expertise and equipment from the private sector to the mining companies is an area of possible cooperation for specialized Dutch sector companies. The consortium preparing a **'Partners for International Business'** (PIB) proposal to RVO are anticipating this market and the initiative appears to be timely.

It is concluded that the PIB proposal is timely and relevant for the developments in the mining sector in Brazil, Minas Gerais state and it is recommended that the PIB be considered part of the integral approach of supporting the mining sector in Brazil to develop in a socially and environmentally balanced way.

## Potential areas of technical cooperation between ANM and Dutch knowledge institutes

| | Topics raised by ANM staff on 29 November 2019 | Potential Dutch knowledge partners |
|---|---|---|
| **1.** | **Risk assessment**: Further development of SIGBM, development of inundation maps and other assessment tools, and integration with SIGBM and GIS<br><br><u>ANM staff:</u><br>▪ How to interpret and verify the correctness of inundation maps that are provided by the mining companies? There is a distinct impression that sometimes these maps from the mining companies are not accurate or correct at all<br>▪ Further development of SIGBM, strengthening the GIS base. Improving its prioritization algorithm by providing more enhanced risk assessment methodologies and criteria | ▪ Deltares<br>▪ Faculty ITC, University of Twente |
| **2.** | **Legislation, standards and guidelines**: development of technical standards and guidelines and integration with proper legislation<br><br><u>ANM staff:</u><br>▪ need for improved legislation, in particular technical norms and guidelines, involving ABNT (National Institute for Technical Norms) as partner;<br>▪ Guidelines and ToR on how to plan decommissioning of dams;<br>▪ Design guidelines for new tailing dams – best practices;<br>▪ Minimum education standards for professionals to be allowed to design a dam | ▪ Adaptation of existing norms or development of new guidelines can be done through knowledge exchange or consultancy, e.g. CUR/CROW |

| | | |
|---|---|---|
| **3.** | **Institutional development**: Organizational/management advice, capacity building, research, training programs<br><br><u>ANM staff:</u><br>▪ How to organize the Dam Department of ANM?: minimum number and qualifications of staff, ICT systems; assess the current working methods and advise on improvements (see guideline of current functioning); clearly define the domains of responsibility of ANM in comparison with the mining companies, e.g. in relation to monitoring data and the responsibility for action<br>▪ Joint and multi-disciplinary research between ANM staff and universities and research institutes on topics that are relevant for ANM's tasks in relation to dam safety; possible creation of an independent institute / center of excellence, financed by the mining industry, to strengthen the knowledge base of both the public and the private sector (and to engage with civil society?). Involve IBRAM, CBDB<br>▪ Knowledge on new mining technologies and new methods of handling tailings<br>▪ Create a 'Mining Fund' based on a tax per m3 of tailing; to be used for measures to rehabilitate current and future damages | ▪ Delft University (Faculty CiTG, Geoscience and Engineering: Resource Engineering<br>▪ Dutch State Supervision of Mines (ministry Economic Affairs) could be a partner to reflect on their current situation. State Supervision of Mines have gone through similar organizational issues with respect to inspection and regulation<br>▪ Deltares/TU Delft: capacity building and research |
| **4.** | **Strategic Environmental Assessment** (SEA) for a Mining Strategy of Minas Gerais state; An integrated and participatory assessment of the environmental and social costs and benefits of mining<br><br><u>ANM staff:</u><br>Include ANM in this new approach | ▪ Netherlands Commission for Environmental Assessment NCEA (Commissie MER) |

# Annex 1 – Outcomes of the Round table discussions

Given the relatively large number of participants, round tables were organised for the discussion of the presentations. This contributes to the goal of promoting open conversation in a more intimate environment than in a plenary context, and allows everyone time to share their opinion.
The DRR experts prepared topics for discussion based on their presentation themes; these are listed below.

## Topics for the discussion in groups

### Set 1:

Topic 1: What differences between the situation in Netherlands and Brazil do you find most relevant?
Topic 2: What should be changed in the Brazilian dam safety legislation?
Topic 3: What probability of dam collapse do you think is reasonable for the situation in Brazil?
Topic 4: Do you think better geotechnical standards are necessary to deal with the risks of TSFs?
Topic 5: Do you think deterministic analyses are adequate to establish the risk of TSF collapse?
Topic 6: Is it true that downstream dams are always safe?
Topic 7: Do we generally have a good perception of the risks associated with intervention in a dam prior to execution? If not, what may be the consequences?
Topic 8: How does the cost of completing all six steps (desk studies, field studies, analysis, plan, risks and monitoring) compare to the consequences of skipping one or more of them?

### Set 2:

Topic 1: Good collaboration between all parties is necessary for the future of the mining sector. True or false?
Topic 2: Dry stacking is not always the best solution. True or false?
Topic 3: Is the use of remotely operated machines the fastest and safest way to decommission TSFs?
Topic 4: Good Environmental Impact Assessment practice could contribute to the improvement of the mining sector. True or false?
Topic 5: Do you think SEA could contribute to participatory regional planning, balancing the interests of the mining sector and those of society?
Topic 6: SEA can facilitate a dialogue between key stakeholders in strategic planning of mining in Minas Gerais. True or false?

## Discussions Group Outcomes

### Day 1, 25-11-2019, Set 1, morning (Belo Horizonte)

*Group 1*

The first discussion was about Topic 1, more specifically the governmental and cultural differences between The Netherlands and Brazil. In the Netherlands, the dikes are government property and thus there is a broad responsibility. In Brazil most of the dams are privately owned, that changes the setting. In Brazil, the risk governance principles are still being developed and regulations with regards to the tailing dams are being made and updated momentarily.

On the other hand, there are many well-built hydropower dams in Brazil, for instance Itaipu, which is one of the largest in the world and commonly regarded as an example of engineering excellence. It is agreed by the group that the problem lies with the mentality within the mining engineering profession. In the civil engineering profession, design for safety is inherent, but that is not always necessarily the case in mining engineering.
About Topic 2 and Topic 4, it is believed that the culture in terms of design and legislation in the mining industry need to change in Brazil. However, it is noted that in Brazil there is a structural lack of personnel to carry out dam inspection. If more regulations are implemented, more work force will be required; a five-year program at least is required to have this in place.
It would be a possibility to set up an (insurance) fund, to which mining companies would be obliged to contribute. In case of bankruptcy of mining companies or abandoned mine sites, this fund could be used for compensation of damages. This would address ANM's problems in relation to abandoned dams, for instance.

### *Group 2*

The discussion in this group was restricted to Topic 1.
It was mentioned that a big difference between the Netherlands and Brazil is who are responsible for the dams. While in the Netherlands that is a public entity, in Brazil it is the mining companies.
Another noted point is the difference in treatment of legislation, as in the Netherlands there is a larger framework of rules that help companies build and take care of dams. In Brazil, the legislation is weak, loose, more flexible, although Brazilian engineering is considered excellent. The approach of the public prosecutor is to charge and sanction in case of incidents and accidents, if necessary. In contrast, it was mentioned that this approach could also be harmful, as it may demotivate technical experts who end up not pursuing this field of work and even delay the implementation of required safety measures.
It is observed by one of the Brazilian participants that the Netherlands learnt from disaster; team work and dissemination of information (transparency) are considered beneficial. There is room for evolution in Brazil in terms of transparency.
Another comment is that studying the dams in Brazil is essential to improve method and safety.

### *Group 3*

Regarding Topic 1, it was noted that in the Netherlands the communities and universities are more frequently included in the discussion of problems. Also, there is more transparency. It was generally agreed that Brazil could benefit from adopting this open attitude regarding these points. A website which people could access to know if they live within a flooded area in case of a dam break would be a good step.
Regarding Topic 2 and Topic 4, it was mentioned that Brazilian legislation is vague and not appropriate: there are important gaps in it. More and better legislation makes life easier and is desired by everyone, including industry. Existing legislation is very recent, published shortly after the Brumadinho disaster; besides, it does not provide the required structured response to the problem. Even though it is clear that Brazilian legislation has been improving in the last few years, there is ample room for progress. It is noted that the profit generated by the mining industry is not reflected in the legislation made to regulate it. It is agreed that organising a committee consisting of industry, knowledge institutions and government members to develop legislation would be positive. Also, a

Knowledge Centre could be created to study the problem in depth; however, leadership and initiative are currently lacking to bring this idea forward.
Regarding Topic 5, it is considered that both deterministic and probabilistic analyses are important.

### Day 1, 25-11-2019, Set 2, afternoon (Belo Horizonte)

#### *Group 1*

In the context of Topic 2, alternative tailing disposal techniques were discussed, such as in-pit disposal and dry stacking. Mining companies are not keen on in-pit disposal. Dry-stacking is currently obliged by law for new developments, but it is not favoured either, because it is expensive, and safety may not be guaranteed in the long-term.
Regarding Topic 5, it is agreed that it is urgent to talk about regional planning; there appears to be willingness from both politics and industry to start such a process, at least in the State of Minas Gerais. Some people in the round table discussion, however, observe a 'state of war' between the (mining) sector and the environmental sector. It is stated that many environmental impact studies are cut-and-paste. This attitude needs to change, and these sectors need to communicate and cooperate. A SEA is a structured process of dialogue based on trust. If there is trust, it will work everywhere, as long as there is an overarching coordination and dialogue. The focus of ANM is not the environment, but the industrial (mining) activity. There is a need to improve interaction with the environmental sector. For instance, closer cooperation between ANM and SEMAD. SEMAD could also focus more on the mining sector.

#### *Group 2*

The discussion started with Topic 1. It is noted that there is not much effort put into promoting a greater interaction between companies, government and universities in the search for solutions. There are already some initiatives, but it is observed that the field is very large and has much to expand.
Regarding Topic 2 (the use of dry stacking), much is said about the problems of adopting this type of solution, as new techniques need to be developed to achieve efficiency. Also, the current trend goes towards larger tailings generation, as ore percentage is lower in new deposits. However, some people believe dry stacking is the only way to guarantee safety. Another important aspect is the need to adapt all mining processes to the new vision of filtered tailings, changing the genesis of the techniques developed so far, as it will represent a profound transformation in the way to extract ore. Lack of knowledge in an issue, it is generally felt that there is a lot to learn.
About Topic 3, it is believed that remote operation (required due to the fact that some dams are not considered safe) is expensive, but that it is the mining companies' problem. Monitoring is regarded as necessary for safety. It is also agreed that it is necessary to better assess risks by deepening technical research on the subject so that these solutions really can be applied. There also comes a greater need for communication and correct dissemination of the problem so that not only the people who work in the company but also the population understand what is really at stake.
As far as Topic 6 is concerned, the SEA is seen as a tool that can improve the current situation and increase cooperation. That way, dam safety can be increased.

#### *Group 3*

Starting with Topic 1, it is agreed that responsibilities need to be shared more equally and decisions more based on technical advice. Public opinion and the public prosecutor play major roles in decision-making. Recovering trust is an important task that the mining industry has to face; up to

now this industry has not been successful in branding itself. Creating a multidisciplinary committee to discuss the problem would be beneficial; at the moment there are individual parties who do not work together. Policies and plans are very dependent on the government, which makes decisions based on short time-spans.
Regarding Topic 2, it is agreed that dry stacking is not always the best solution. There is no experience in Brazil of large-scale filtered solutions. Also, dry stacking is often used in countries with less rainfall. It is noted that the belief that dry stacking is safer does not result from a technical analysis. It is agreed that the best solution depends on the project-specific conditions; in any case, the cost of closure should be included in the project (even though that is very difficult to assess at an early stage) from the licensing stage. It is the general opinion that a dry process is currently not viable in 90% of the mines in Minas Gerais. In-pit disposal has the important disadvantage of blocking access to ore located deeper down.
As far as Topic 3 is concerned, it is pointed out that, as certain dams are deemed unsafe, it makes sense to demand interventions to be carried out using remote technology. However, there are people in Brazil working in maybe even more dangerous circumstances, such as 100m depth, contaminated air, etc - if something fails, it also results in death of these workers. It is also important to highlight that the cause to raise dams to emergency level 3 is a re-calculation and not an actual change in dam conditions. It is also relevant that the alert of raise in emergency level is given by the mining companies themselves; they have an incentive to make others aware of the risk. It is in any case difficult to communicate to Work Inspection that the decision of not allowing workers onto the dam can compromise the safety of many more people (since an intervention lasts longer, so the dams with a low safety factor will be in place for a longer period, amongst other reasons). It is agreed that ideally, people would still be allowed to access the emergency level 3 dams, as long as a good contingency plan is in place.
When discussing Topic 4, it is noted that the time required to obtain a license (can be 10 years) is a major issue for mining companies. If an SEA could help in this process, it would be very welcome.

### Day 5, 29-11-2019, Sets 1 and 2, afternoon (Brasilia)

#### *Group 1*

Regarding Topic 1 of Set 1, it is agreed that many differences separate the Dutch and Brazilian situations. Not only are Brazilian tailing dams and Dutch flood defences different, but also it is clear that the Dutch dykes have a higher level of safety.
As far as Topic 2 of Set 1 is concerned, it is believed that legislation could be improved and complemented with technical practice guides and standards. As for specifications and technical standards, the Brazilian electricity sector seems to be better prepared than the mining sector. A question that has been raised is the effectiveness of the dam's stability statement which is at this moment required to mining companies.
Regarding Topic 3 of Set 1, it is believed that the likelihood of dam collapse should be the same as in the electricity sector: 1 to 100,000.
Concerning Topic 6 of Set 1, it is agreed that not all downstream dams are safe.
Regarding Topic 1 of Set 2, it is believed that cooperation between different parties is essential in addressing the current issues.
As far as Topic 5 and Topic 6 of Set 2 are concerned, it is agreed that an SEA could represent an improvement to the Brazilian situation.

### *Group 2*

The discussion in this group was restricted to Topic 1 of Set 1.

It was mentioned that in Brazil there is a lesser sense of collective interests and less confidence in the government. Also social inequalities play a role. The risk perception is different in the two countries. It is also stated that public pressure drives a lot of the decision-making process. The fact that the mining industry has such a bad reputation does not make things easier.

The ANM faces several challenges. Mining companies often see all required documentation as a piece of bureaucracy, failing to understand that these are a tool which should lead to increased safety. There is generally a lack of respect for the ANM, although this has been improving recently. The lack of personnel is an enormous problem for this entity.

Overall, there has been in recent years a larger effort towards transparency, but there is still a long way to go. The ANM has a lot of data on the dams which is accessible to the general public.