Tailings Facility Management Plan

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1 General Data

1.1 Introduction

The Tailings Facility Management Plan - TMFP - is a comprehensive plan that Roşia Montană Gold Corporation (RMGC) will implement in order to minimise the risks associated with the operation of the Roşia Montană Project Tailings Management Facility (TMF), in conjunction with ore processing operations.
The *Tailings Facility Management Plan* conforms to applicable international and Romanian standards for the operation of such facilities. It provides general information on the geological and geotechnical setting of the TMF; describes its overall design, operation, monitoring, and closure aspects; and addresses the specific measures RMGC will employ to manage the facility in a safe and environmentally conscientious manner over the life of the mining operation.
This management plan applies only to Roşia Montană Project activities. The Plan will be subject to annual review and update in response to internal and external reviewer comments, regulatory changes, changes in mining operations, stakeholder communications, internal performance verification and management review results, and other factors.

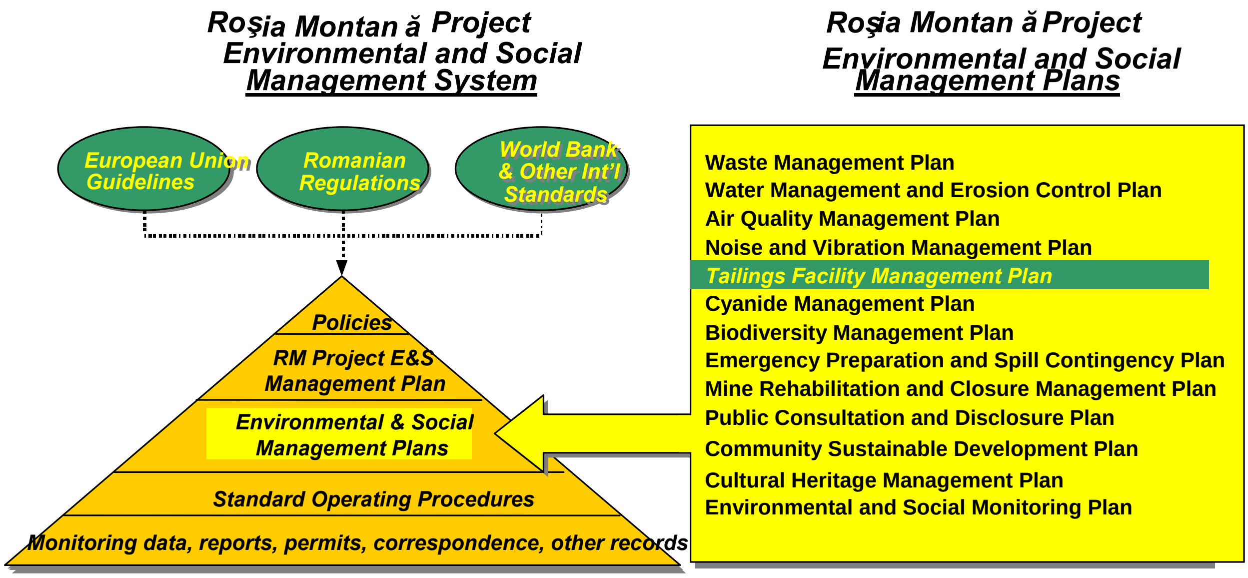


Figure 1.1. Structural Relationship of Management Plans in the Environmental and Social Management System

As noted in Figure 1.1, this plan is one of a suite of environmental and/or social management plans that have been developed to support the Environmental and Social Management System described in the current version of the *Roşia Montană Project Environmental and Social Management Plan.*

Implementation of the *Tailings Facility Management Plan* will also be supported by a suite of standard operating procedures. These procedures will be compiled in the *RMGC Standard Operating Procedures Manual*, the development, review, approval, distribution, and update of which is controlled by the *Roşia Montană Project Environmental and Social Management Plan* .

1.2 Identifying Information

Project Name:
ROŞIA MONTANĂ PROJECT

Information on the Title Holder, Designer, Expert
TITLE HOLDER: S.C. Roşia Montană Gold Corporation S.A. with Head Office at 321, Piata Street 517615, Roşia Montană, Alba County, Romania
TMF DESIGNER: MWH (Montgomery Watson Harza) USA
CERTIFIED EXPERT: Prof. Dr. Eng. Dan Stematiu
TAILINGS FACILITY MANAGEMENT PLAN DESIGNER - Review - February - March 2006: S.C. MINESA – Mining Research and Design Institute S.A., Cluj-Napoca 15-17 Tudor Vladimirescu Street, Phone: 0264-435015; Fax.: 0264-435030 email: minesa@minesa.utcluj.ro

TMF Location
The tailings pond generated by the Roşia Montană ore processing plant operation is located in the *Comuna* of Roşia Montană, Alba County, within the mining exploitation concession licensed to RMGC and the Roşia Montană impact area, along the Corna Valley, at approximately 1,350m upstream of the confluence with the Abrudel Valley.

1.3 TMF Functions Class and Category of Importance Technological Parameters

TMF Functions
The purpose of the Roşia Montană ore processing operations is the recovery of economic grade precious minerals, i.e. gold and silver.
The gold and silver grade of the ore is less than 10 g/t, the entire volume of extracted and processed ore can be considered as a form of waste material which needs to be managed in a manner that does not pose a risk to human health and the environment.
In accordance with worldwide practices employed for similar operating conditions and storage capacities a waste management method consisting of the deposition of process tailings to a Tailings Management Facility was adopted; this method is also recommended by BAT (Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities – Draft March 2004) [1]and the Best Environmental Practices also mentioned in the European Directive on the Management of Waste from the Extractive Industries [2]

The primary operational criteria for the TMF :

- storage of tailings generated by ore processing operations in a manner that minimizes potential hazards to human health and the environment;
- to ensure 100% recycling of the process water to the plant and "zero discharge" to environmental media under normal operating and climatic conditions;
- If necessary, an additional cyanide and weak dissociable acid detoxification process will be implemented to reduce these levels down to the maximum permissible limits for discharge into the receiving body of water;
- deposition of the sludge from the acid rock drainage (ARD) treatment plant during operations;
- containment of ARD run-off from the Corna Valley watershed.

Class and Category of Importance
In accordance with the provisions of STAS 4273-83 "Hydrotechnical Facilities – Classification within Importance Classes", the Tailings Dam is classified by the designer as Class I of Importance.
The Category of Importance established by the designer as per NTLH-021 "Technical Norms for Hydrotechnical Facilties" is Category B.

Technological Parameters
The main technological parameters for the Corna Valley TMF [3 4]:

- the flow rate of slurry discharging into the TMF is approximately 2,140 m^3/h at a liquid to solids ratio of 1.06 : 1 (approximately 1,575 m^3/h water and approximately 1,484 t/h solids) planned for approximately 8,760 operating hours per year.
- the recycled water flow rate ranges between 901 and 1,293 m^3/h, depending on the amount of water stored in the TMF basin;
- the starter dam construction provides a total capacity of 11,289,850 m^3 for tailings storage;
- the final volume of deposited tailings (volume of solids) will be approximately 159,188,889 m^3 ;
- the final storage capacity including tailings volume and operating water volume (as well as two PMFs) will be approximately 171,519,000 m^3;
- annual amount of tailings deposited in the TMF is approximately 13,000,000 tonnes;
- total amount of tailings deposited in the TMF is approximately 214,905,000 tonnes;

1.4 TMF Components and Staged Construction Characteristics

The Corna Valley TMF consists of the following main components:

- the TMF dam located across the Corna Valley consists of a low permeability starter dam above which the final tailings dam will be raised sequentially to a final elevation by the centerline method of construction and using competent waste rock resulting from mining operations;
- secondary containment dam, located downstream of the main dam;
- tailings retention/decant pond behind the dam structure;
- secondary containment pond, behind the secondary dam structure;
- tailings delivery and distribution system;
- TMF reclaim water system;
- recirculation system for the TMF seepage collected in the Secondary Containment System (SCS) to the TMF basin;
- semi-passive seepage treatment system post closure of the TMF;
- diversion and collection channels to divert un-impacted snow melt and precipitation runoff away from the TMF;
- Geotechnical, Environmental and Operational monitoring systems;
- service roads;
- electrical power supply;

- emergency response system;

The operation of the Roşia Montană mine will generate tailings at a nominal rate of 13 million tonnes/year for a period of 16 years.
From the perspective of water management, the purpose of the TMF is to contain process water in a manner that allows maximization of its recycle to the ore processing plant.
The TMF will capture and contain all contaminated run-off waters from areas in the Corna Valley basin that are impacted by mine operations.
The tailings slurry from the process plant will be treated in a cyanide detoxification plant to reduce the Weak Acid Dissociable (WAD) cyanide concentration. WAD cyanide concentrations in the treated tailings slurry will be reduced to applicable EU standards of 10 p.p.m [mg/l] using the SO_2/air treatment technology prior to discharge into the TMF[5] .
Tailings discharged to the TMF have approximately 49 % solids content.

Major Components of theTMF:

- **Main dam (Corna dam)** having zones of different permeability will be raised in lifts throughout the Roşia Montană Project life to accommodate the storage of tailings, process water, runoff from the PMP event and floods and provide freeboard for wave and ice protection. The TMF main dam will consist of:
  - starter dam and
  - final dam.
- tailings delivery and distribution system;
- tailings impoundment (TMF basin);
- reclaim decant water system;
- secondary containment dam and secondary containment sump.

Starter Dam

The main dam will have a low permeability core, the starter dam, will be developed during the first stage of construction prior to initiation of mining operations. As per the design criteria, the starter dam final elevation will be739 masl starting from an elevation of 640 masl providing tailings and process water storage for the first 15 months of operation. The starter dam will have a maximum height of 99 m and a crest length of approximately 540m. The upstream and downstream dam faces will have an overall slope of 2H:1V and 2.25H:1V, respectively. The starter dam crest will be 10m wide.
The starter dam is based upon a conventional design for water retention dams serving primarily as a water dam during the 15 months it is needed for supplying process water to the process plant. Therefore, the starter dam is designed as a low permeability dam with appropriate foundation preparation and seepage control measures for adequate structural and hydraulic stability in agreement with the best available techniques (BAT).
The starter dam design involves a central low permeability core with filter/transition zones, bentonite slurry wall and upstream and downstream rockfill zones (rockfill dam shells). The dam foundation will be prepared down to the bedrock surface with appropriate foundation treatment, including injection grouting (details in Section 4 and Drawings 12A and 12B).
The Starter Dam will be initiated with the construction of a cofferdam for retention of the Corna Valley surface water, located upstream of the starter dam with potential to discharge water downstream to the starter dam.
The starter dam will initially store a fresh industrial water volume of approximately 1,500,000 m^3 prior to the start of ore processing operations. When tailings discharge begin, tailings will initially be completely submerged. The starter dam will perform as a water dam until a substantial tailings beach is developed against the dam, which occurs toward the end of five quarters of operations (1.25 years), which is the storage period designed for the starter dam.

Inert non-acid generating materials are used for the construction of the starter dam. Section 4 and Drawings 05; 06; 07 provide details of the starter dam structure.

TMF Final Dam

The TMF main dam - Corna Dam - will be raised in stages using mine waste materials in accordance with the design criteria. The use of mine waste materials dictates a certain design approach for raising the tailings dam during operations. The optimum use of mine waste materials, in conjunction with stability and groundwater protection considerations, resulted in selection of the centre-line method of construction and a pervious dam design above the Starter Dam crest level. However, at a minimum, two downstream lifts will be constructed initially to allow time for adequate beach development prior to starting the centre-line lifts.

The use of waste rock to construct the dam lifts beyond the starter dam serves two purposes. First, it allows beneficial storage of waste rock without creating new waste rock stockpile footprints. Second, it provides a structural material for constructing the TMF dam without expanding existing borrow areas (aggregate quarry) or creating a need for new borrow areas.

The mine waste materials to be used for raising the tailings dam are potentially Acid Rock Drainage generating. Therefore, it has been assumed that runoff from the waste rock used in dam construction will be acidic and will contain metal ions. It has also been assumed that seepage through and under the tailings dam may be acidic containing metal ions. Therefore, a Secondary Containment System (SCS) is provided downstream of the main dam to collect runoff from the waste rock forming in the downstream half of the dam and also to collect any seepage that occurs through and under the main dam.

The Corna dam's final crest elevation will be +840 masl (meters above sea level), starting from an elevation of +640 masl and will provide storage for 214,905,000 tons of tailings, process water and runoff from hydrological events (rainfall, snowmelt etc.).

The Corna dam final crest height will be approximately 200m with a crest length of approximately 1,182 m. The downstream face will have an overall slope of 3H:1V, and the crest width will be 20m.

The plan arrangement of the final dam with final crest at an elevation of 840 masl is shown on Drawing 08. The principal section through the final tailings dam is shown on Drawing 09.

Prior to starter dam construction, all vegetation and topsoil will be removed within the footprint of the starter dam. Vegetation will be disposed of outside the limits of the TMF basin. Topsoil will be stockpiled for use during closure and reclamation. Within the TMF basin the surface of the colluvial layer, will be exposed after stripping the topsoil and used to seal the TMF basin. The compacted colluvial layer will achieve a relatively low permeability (10^{-8} m/sec). The extent of the basin preparation will be extended with the construction of each lift. The TMF basin preparation method is in agreement with BAT and complies with the Best Environmental Practices.

The compacted layer is intended to provide a barrier layer to reduce seepage from the TMF basin. In areas where the colluvial layer has been eroded or is not present, excess colluvial material within the basin and road construction areas will be used to cover these areas. The placed colluvial material will be compacted to achieve that same permeability as the native materials. This will result in a continuous barrier layer through the basin. To provide containment of the tailings and process water, a series of under-drains will be installed near the downstream toe of the dam and throughout the TMF basin. A sump is provided to collect the TMF basin drainage constructed with the cofferdam.

Side-slope riser pipes will be installed to allow pumps to be installed in the base of the under-drains and allow consolidation water to be removed as quickly as possible. Drawing 11 related to the TMF basin preparation shows the general arrangement of under-drains and pipes.

Pervious Dam Concept

One of the significant features of the Corna dam above the starter dam is that a pervious dam design concept has been selected. The option of choosing this concept is available since the secondary containment dam is provided during operations and after mine closure to collect the seepage that occurs through the pervious components of the dam. The pervious dam concept was selected for a number of reasons, including those listed below:

- Allows drawdown of the line of saturation in the higher part of the valley, thus further reducing the potential for seepage from the tailings basin to the adjacent valleys;
- Provides a higher margin of safety over the long term after mine closure, compared to a low permeability dam, since a lower line of saturation will be involved;
- Allows construction procedures during dam raising that are simpler than they would be for a low permeability dam;
- Is more cost effective (in terms of construction costs) because a cut-off trench is not required above the level of the starter dam.

Downstream Face

The downstream face of the ultimate tailings dam was selected at a stable angle of 3H:1V since mine waste rock is used for dam raising. This will ensure a very stable face with an increased factor of safety (international standards for rockfill dams vary from 1.5H:1V to 1.75H:1V) suitable for environmental rehabilitation and final access roads along the downstream slope.

Filter and Drainage Zones

The horizontal filter and drainage zones are also developed during the centerline lifts of the main dam body and are continued from those provided for the starter dam as shown on the Drawing 09. Furthermore, the dam will be lifted simultaneously with the raise of the filter/transition zones in the centerline and downstream shell of the starter dam with the continuation of the downstream drainage layer. The vertical Zone 2 filter material is required in the raised dam to ensure that no migration of tailings occurs into the downstream rockfill zone, particularly when tailings discharge from the dam crest is taking place resulting in a locally high line of saturation.

Foundation Preparation and Under-Drains

Foundation preparation for the staged raising of the tailings dam will involve removal of alluvial soils to bedrock within the flood plain area and stripping of topsoil and organics along the valley slopes to expose suitable colluvial/residual soil. The colluvial layer will be compacted to form a continuous barrier layer within the TMF basin.

The tailings deposition pond is provided with under-drains designed to ensure the maintenance of a lower line of saturation in the deposited tailings upstream of the dam centerline so that the potential for seepage to adjacent valleys is reduced. Drains that will facilitate consolidation of the tailings and removal of water from the basin are also provided.

Tailings Delivery and Distribution System

The tailings will be pumped from the processing plant to the TMF through a dedicated 800-mm high-density polyethylene (HDPE) pipe laid along the project road on the north perimeter of the tailings pond. The system will comprise a pump station at the process plant that conveys the tailings 4.35 km through an 800 mm outside diameter (OD) HDPE pipeline to the TMF and the tailings distribution system. The discharge will be through either one of two single point discharge lines, or through spigots on the dam (approximately 50 m spigot spacing). The spigot system will be used during normal operation of the pipeline, but the single or two point discharges are available for intermittent use. Each spigot will be controlled by a knife gate valve.

The tailings delivery line will be either placed on the surface (with soil berms covering the pipe at selected intervals to prevent excessive movement due to expansion and contraction) or it will be buried. If the pipe is placed at the surface, it will be placed in a lined ditch to provide containment for leaks and/or spills. The ditch will be graded to drain into either the TMF basin or into the plant site emergency spill containment pond. The system is designed for nominal and maximum flows of approximately 2,350 and 2,730 m^3/hr respectively, slurry solids content of up to 48% and a minimum discharge velocity of 1.5 m/s. The slurry pH is expected to be between 9 and 11. An earth dike will be constructed along the delivery pipeline to retain any spills.

Tailings Impoundment

The TMF watershed, including the Cârnic waste rock stockpile, will be approximately 689 hectares and it is composed of four main components: tailings pond, tailings beach, Cârnic waste rock stockpile and undisturbed land. Surface runoff from undisturbed areas will be diverted via diversion channels and, therefore, will not report to the tailings pond under normal operating conditions.

The diversion channels will divert non-impacted waters downstream of the secondary containment dam. The plan arrangement of the diversion channels is shown on Drawing 06. Guard ditches are provided on the slopes near the tailings impoundment which are moved periodically as the main dam is lifted.

Surface water quality monitoring and flow measurement stations will be installed downstream of the TMF.

Groundwater monitoring wells will be installed at the downstream toe of the Corna dam for groundwater monitoring. Both monitoring systems are designed to ensure that the discharged water complies with the requirements of the water management permit and environmental permit.

In case the above requirements are not met, the water will be diverted to the Secondary Containment System (SCS) Sump and pumped back to the TMF basin.

Selected design parameters of the TMF in the Corna Valley provide a full containment of all flood events, including two consecutive Probable Maximum Floods (PMF's). The TMF emergency spillway is sized to safely pass a 10-yr flood.

TMF Reclaim Water System

The reclaim water system will convey decant water from the TMF basin to the process water storage tank at the processing plant. The system design accommodates the rising pond level throughout the life of the project. Floating low-hydraulic lift pumps located on the TMF pond will transport the water a short distance to the on-shore booster pump station supply sump through a 150 meter long flexible hose and an additional 680 meters of HDPE pipeline. The second stage pumps will be connected directly to this supply sump. In order to accommodate the rising pond level, both a low elevation and high elevation booster pump station will be built to handle the pumping requirements throughout the project life. The main pipeline will consist of a 429 meter section of PN 16 HDPE pipe and 1,600 meters of PN 8 HDPE pipe.

The system is designed for an average and peak discharge of 1,520 and 1820 m^3/hr respectively and it will provide most of the processing water requirement.

Secondary Containment System (SCS) Dam and Sump

The SCS will be located immediately downstream of the main dam and will be designed to collect and contain seepage from the tailings impoundment. The system will consist of an 11-metre deep sump excavated into weathered rock. The zoned rock fill dam will be about 11 m high above the riverbed with an 11 m deep positive cut-off to minimize downstream seepage (total 22 meter dam height). The dam will include a broad crested emergency spillway for emergency discharges.

Hydrological studies indicate the SCD pond will contain all floods up to the 200-yr event. Spills during 500-yr, 1,000-yr floods and the PMF would be in the order of 2,160 m^3/hr, 9,000 m^3/hr and 90,000 m^3/hr respectively.

The seepage collection system under the SCD and the dam construction materials have been designed to minimise the chance of leaching materials to contaminate natural waters.

The SCS watershed is approximately 54 hectares, including the tailings dam downstream face.

Floating low-hydraulic lift pumps located on the SCS sump will transport water a short distance to the on-shore booster pump station supply sump through a flexible pipeline. The second stage pumps will be connected directly to this supply sump. The mainline will consist of approximately 1.0 km of 219 mm O.D. steel pipe discharging into the TMF basin. The secondary containment pumping system is designed for intermittent operation, which will depend on the water level in the pond.

Slope Runoff Diversion Channels

The diversion channels to be constructed on the north hillside and south hillside of the TMF basin will be used to collect and route the clean, non-impacted runoff from these hillsides to downstream of the Secondary Containment Dam.

The plan arrangement of the diversion channels is shown on Drawing 04.

Diversion channels are open and sized for a 10-yr, 6-hr peak flow resulting in flows of 7,200 m^3/s and 20,160 m^3/s for the northwest and southwest diversion channels, respectively.

In the case of flows exceeding their designed capacity values, such as the PMF event, the channels would report either to the tailings pond or the SCS.

TMF Service roads

The Project roads provide access to the two dams, monitoring systems including instrumentation, secondary containment sump and tailings pond pump stations, tailings delivery and water reclaim pipelines and the semi-passive treatment system (post-closure) downstream of the secondary containment dam.

Drawing 08 shows that the gradient of the main road constructed along the downstream half of the tailings dam will be 8%.

The road along the downstream half of the tailings dam will also provide erosion protection.

Electrical Power Supply

The overhead electrical network includes the power supply for equipment (pumps), control and automation electrical equipment, safety electrical equipment and lighting equipment.

Backup power will be provided for emergency operations - power generator(s) -which provides the required emergency back-up power needed to maintain un-interrupted operations at critical facilities such as the TMF.

Monitoring System

The TMF monitoring varies depending on the phase in the TMF life cycle - construction, operation, closure and post-closure.

Monitoring will be conducted in accordance with the specific procedures described in Sections 5, 6 and 7.

Emergency Response System

In order to take effective and prompt actions in an emergency situation, RMGC will develop a system based on clear and precise procedures established by a specific plan which will also be the basis of issuance of operating permits.

The information flow for emergency situations is described in the Emergency Preparedness and Spill Contingency Management Plan (Plan I).

Semi-passive Seepage Treatment System, after TMF closure

Seepage through the Secondary Containment dam may occur over an extended time period during the post-closure phase. For a period the quality parameters of the seepage may not comply with the applicable discharge criteria and requirements, monitoring results will determine compliance and treatment options.

Therefore, a research program will be conducted during the operational phase for the purpose of establishing a semi-passive seepage treatment system (aerobic - anaerobic) to ensure that the water quality parameters comply with the applicable regulatory requirements. The semi-passive treatment system will be located along the Corna Valley, downstream of the secondary containment dam as shown on Drawings 6.3 and 6.4 and shall be completed by the beginning of the closure phase.

1.5 TMF Operation

The Project water balance and supporting hydrological studies confirm that the TMF can be managed in both water deficit and water surplus conditions under all climatic conditions throughout the life of Project[6] Adequate storage will be provided in the TMF to contain the runoff from a PMP event. During spring runoff and after storm events, water in excess of process requirements will be stored in the TMF for later use in the process. The TMF will be managed to avoid discharges, however, should it become necessary, protocols will be developed, such that treatment to acceptable standards and the release to the environment can be initiated and monitored.

The construction schedule for embankment and basin staging will be completed to ensure that PMP storage requirements are available throughout the project life. The tailings pond will collect waters from direct precipitation and runoff that is not captured in the Cârnic waste drainage holding pond or the overflow of clean water from the diversion channels.

Water will be recycled from the TMF to the process plant via a floating barge located at the northeast end of the basin.

The discharge points for the treated tailings will be managed to keep the tailings supernatant pond centered around the reclaim barge and, to the extent possible, away from the tailings embankment.

Minor seepage through the Corna main dam is expected which will be collected directly in the SCS sump and pumped back to the tailings basin. The level in the SCS sump will be kept low to produce a gradient, therefore minimising the opportunity for uncontrolled potentially contaminated water seepage.

2 Site Characteristics and Completed Investigations

A series of investigations were carried out in view of developing a detailed understanding of the TMF site characteristics which provided information on the geology, hydrogeology and geotechnical conditions of the region and location of TMF dams (main and secondary dams)[7].

2.1 Geology

Regional Geology

The Roşia Montană Tenement is located within the Eastern Belt of the South Apuseni Mountains.

The regional rock consists of the following:

- metamorphic basement traversed by granitoid rocks;
- flysch sequence (sedimentary deposits of shale, sandstone and conglomerate);
- ophiolite sequence (maphic volcanic rocks) overlain by the lava layer.

Surficial Geology

Overburden soils in the Corna and Roşia Montană Valleys consist of three predominant soil types[8] ;

- alluvial deposits;
- colluvial soils;
- outcrops of other types of rock;

The unconsolidated materials consist of Quaternary alluvial deposits along the valley floors and colluvial soils along the valley slopes. The alluvial deposits are up to 12 m in thickness and contain a wide variety of soil types ranging from silty clay with intercalation of sand, to gravel and boulders being particularly restricted to the base of the valley.

The colluvial/residual soils on the valley slopes are typically 2 to 5 m thickness. The predominant rocks found in the valley watersheds are marl and sandstone. Harder ridges with East-West orientations dominated by marls interpreted as thicker sandstone units occur locally. Probably this flysch unit suffered intense deformations almost throughout the area, the results could be seen as outcrops.

A remarkable "slope fracture" occurred on one of the ridges that separates the Roşia and Corna Valleys. Marls outcrop at the base of the fracture, which are rocks typical of flysch 55

Figure 2.1. Schematic Geologic Cross Section - see Exhibits 2.50

A 10-50 m sequence of andesite pyroclastics, volcanic ash and andesites can be noticed above the fracture.

Geological Basement
The area consists largely of late Jurassic-Cretaceous sedimentary deposits (205 - 65 million years in age) predominately black shale with various degrees of sandstone interbedding.
The formations consist of:

- Upper Aptian (ap2) - Lower Albian (al1), comprising argillaceous marly schists with fine argillaceous – marly gritty clay intercalations;
- Upper Cretaceous -Maastrichtian (ma) represented by a complex of Interbedded micaceous sand in flysch facies.

The bedrock across the Corna Valley is the flysch series of the Maastrichtian on the left bank reposing over the flysch sequence of the Albian/Aptian on the right bank in a stratigraphic unconformity.
Drawing 7.1 illustrates a schematic geological cross section through the Corna Valley. There is a difference in age between the two sequences, the right bank material being significantly older in geological terms than the left bank material.
The flysch facies is a consequence of the competence and incompetence of the tectonic alteration, faulting and shear deformation of shale with sandstone and conglomerate intercalations.
Within the TMF site, the shale unit dips 30 to 55 degrees in a southerly direction, towards the left bank.
In general, the waste rock within the Roşia Montană tenement consists of the following:

- Black shales - this Cretaceous-aged sedimentary sequence, also described as flysch or argillaceous marl schist, typically consists of interbedded shale and fine to medium grain sandstone, and beds of local thin conglomerates more or less cemented. The rock is characterized by calcite veins within the sandstone, variable bedding orientation, and occasional weak and/or brecciated zones. This unit comprises the bedrock typical of Roşia Montană, Corna and surrounding valleys, outside the mineralised zones.
- Breccia - This type of rock consists of vent breccia, black breccia and mixed breccia (combined). Vent breccia is interbedded with conglomerates, clay and silts of the same composition. In general, this type of rock borders the perimeter and southern part of the Cetate pit and outlines the upper northern part of the sedimentary basin (residual). Black breccia is a dark-brown to black rock occurring in the southern part and between Cârnic and Cetate bodies. The breccia has a matrix of black shale and quartz grains, altered feldspar, bands of muscovite and biotite and has been emplaced syn-mineralisation within the maar diatreme between the 2 main dacite bodies. The breccia is considered to be phreatomagmatic in origin as it hosts clasts of basement gneisses and schist as well as dacite fragments in addition to Cretaceous age shale clasts. The mixed breccia occurs at Cârnic and Cetate and has a composition similar to the black breccia, less the black colour as it does not contain significant amounts of black shale. In the upper catchment of the Corna Valley within the the maar-diatreme complex occurs the magnetic Corna breccia which is also considered to be phreatomagmatic in origin and post mineralisation in age (11Ma). This breccia is very competent and has not undergone significant alteration or mineralisation due to it's age.
- Andesites, Pyroclastics Rocks: The andesites overlay the Cretaceous sediments and vent breccia surrounding the Cetate and Cârnic massifs. They are grey rocks with hornblende and feldspar phenocrysts.

- Andesitic volcanics occur in thin sheets (50m) on the hill tops surrounding the mining region. The andesitic volcanics are typically underlain by a thin breccia layer, probably representing a block and deposited ash. In the eastern part towards Roşia Poieni, the andesites are generally massive and possibly intrusive.

While not considered a primary rock type, there are local blocks of limestone outliers that were observed near the right abutment of the TMF.
In the geolgogical literature these exotic blocks characteristic to flysch like formations are known as *"olistolites"*. The limestone block is not altered and no karst formation occur.
Structure
The Resource Services Group – Australia – conducted an airborne magnetic survey over the Roşia Montană – Bucium concession area in 2001. An interpretation of the survey results revealed numerous linear features that were interpreted to be faults.
The survey results revealed two dominant conjugate sets of faults trending north-northwest and east-northeast. An older, north-south trending set of faults can also be traced and appeared to be associated with mineralization.
An inclined borehole was advanced across one of the north-northwest interpreted faults in the lower part of the valley to a depth of 90 meters (along the incline) with the objective of defining the presence and condition of this potential fault. A shear zone consisting of coarse-grain breccia was encountered and was identified as likely being a minor fault.
Due to the altered tectonic structure of the basement developed in flysch facies and associated mineralization it is likely that this type of fault zones be intercepted.
No movement of faulted/fractured zones occurred, perhaps after the intrusion of main dacite bodies and associated mineralization.

2.2 Hydrogeology

The Roşia Montană mining region is located near the headwaters of the Corna, Saliste and Roşia Valleys. The mine site is located within or near the Roşia, Corna and Săliştei Valley watersheds.
The Corna Valley watershed includes, within the Roşia Montană Project, the waste rock dump, Cârnic waste drainage holding pond, TMF also including the secondary containment dam. The Corna stream flows to the southwest into the Abrud River.
The watershed dividing the Corna Valley basin from the Roşia Valley basin will be located on the southern boundary of the Cetate and Cârnic pits. Based on the existing topography it appears that - partly - the watershed was running through the middle of the southern part of the Cetate and Cârnic pits.
Due to the development of the current pits, the watershed was moved towards the southern boundaries of the pits.
The Sălişte Valley watershed will include the south-western part of the ore processing plant site. Following the plant site construction the water will flow to the Roşia Valley basin.
The Sălişte Valley flows to the west including the tailings dam currently operated by the Roşia Montană mine.
The hydrogeology of the area was evaluated through an extensive drilling program that was conducted at the site in 2002[9] and was further developed in 2004 with new boreholes, flow measurement stations and piezometers[10] .
Water levels were measured in the piezometers by RMGC on a biweekly basis since April 2002. These water level data were used to generate a potentiometric surface map of the unconfined water table. The hydrographs for the period between April 2002 and May 2004 were developed using these data.
Surface water and groundwater reflect the hydrogeologic characteristics of underground deposits. The area is characterised by the presence of springs and valley slope runoff. The spring and runoff origin is uncertain, however it appears they are the result of differences in permeability. There are two situations:

- higher permeability of the pyroclastic and andesite deposits constrained by a lower permeability of the colluvial soils;
- higher permeability of the colluvium deposits constrained by a lower permeability of the gritstone and marl layers.

The primary stratigraphic units and their typical hydrogeologic properties are summarised in Table 2.-1.

Table 2-1 Primary stratigraphic units and their properties

Stratigraphic Units/Properties	Assignment	Hydrological Characteristics
Alluvium (Minor and major streambed)	Deposits of silty clay and sandy clay with significant and variable distribution zones of gravel and cobbles. Includes layers of gravel and clean sand located in the minor streambed. They have a width of 10-80 m and thickness of up to 12m.	Clean sand and gravel layers act as local aquifers. The mean hydrauliic conductivity is relatively high in the range of $2x10^{-6}$ to $3x10^{-4}$ m/s
Colluvium (with soil) (On the valley hillsides)	First silty sand and silty clay with small amounts of sand and gravel with thickness of 3 to 10.5m.	Low water storage capacity Hydraulic conductivity approximately $1x10^{-8}$ m/s
Upper bedrock (marl)	Highly weathered and fractured interbedded shale, sandstone, breccia and gouge in the upper 40 meters. Located under the alluvium and colluvium	Generally water bearing only through fracture network and has only low regional capacity. It may be moderately water bearing through the bedding planes. The hydraullic conductivity values in the range of $1x10^{-7}$ la $1x10^{-6}$ m/s
Lower bedrock (marl)	Interbedding of marl, gritstone with minor intervals of silty clay and breccia increasingly competent with depth	Low capacity. Hydraulic conductivity in the range of $6x10^{-9}$ and $1x10^{-7}$ m/s
Dacite and Andesite	Generally competent bedrock.	Low capacity. No piezometers were installed in this rock type. Hydraulic conductivity $<1x10^{-7}$ m/s
Volcanic breccias and black breccia	Typical soft rocks	Limited flow may occur through fractures or naturally formed zones of enhanced permeability Low hydraulic conductivity $<1x10^{-7}$ m/s

A hydro-ghaph analysis indicates that water levels are generally seasonally stable.
The period of record for water levels measured in the piezometers is relatively short and may not represent longer-term changes that may occur during drought or wet years.
However, the data indicate that the groundwater level in piezometers have reached a stable condition and are representative for the Project footprint conditions.
The flysch unit occurring within the TMF site in the Corna valley was differentiated in two types: upper bedrock and lower bedrock. The bedrock types were characterised with respect to the differences in the hydraulic conductivity, rock quality designation (RQD) (%), the percentage used for the dam core and borehole parameters observed during their completion and water pressure measurement – Drawing 03A and 03B.
A highly weathered and fragmented intercalation occurs within the upper bedrock in the northern hillside of the valley.
This intercalation is most likely associated with the presence of the „Lower Albian" and „Upper Aptian" formations in the northern hillside. The southern hillside appears less weathered and fragmented.
The mean hydraulic conductivities in upper bedrock is in the range of $1x10^{-6}$ to $8x10^{-7}$ m/sec.
In the area under investigation the groundwater follows the topography of the Corna Valley.
Water level data collected from April 2002 to January 2004 in the piezometers installed in the Corna Valley indicate that, in general, water levels are seasonally stable.
Water levels in some piezometers showed some seasonal variation. Hydraulic gradients within Corna Valley - within and near the TMF footprint -range from 0.08 to 0.40. The

gradient is lower along the axis of the valley (e.g. near the proposed dam), while the gradient is higher on the dam abutments.

The water table map also indicates that the Corna Valley flow increases downstream (i.e., receives water from the zone of saturation/groundwater) throughout the year during normal and wet precipitation years.

A comparison of the water levels in piezometers indicates that in general there is a response (up to 1 meter) in some piezometers to short-term precipitation events (Appendix A4 Engineering Review Report). For example, a rise in water level of up to one meter was observed in piezometer 02DH-C2-06/5 during an increase in flow of up to 0.3 m^3/s. Conversely, piezometers 02DH-C2-12/12 and 02DH-C2-12/29 apparently showed no response to the same precipitation events. However, the lack of response in some piezometers may be a function of the time lag between the precipitation event and when the water level was measured in the piezometer (i.e., the response in the well had occurred and dissipated by the time the water level was measured). It however may be a function of the short precipitation time which can not affect the groundwater level.

These data also indicate that the stream and alluvial groundwater are generally in direct connection with each other. In addition, as there are no significant sealing layers in the alluvium it can be assumed that the surface waters are also in direct connection with the groundwater within the colluvium and bedrock (i.e. this system forms a hydrostratigraphic unit).

A significant feature of the groundwater flow system is the presence of a downward vertical hydraulic gradient in the vicinity of the initial TMF Dam alignment. These gradients were measured by comparing water levels in 22 pairs of nested piezometers located in this area. The downward vertical hydraulic gradient is somewhat higher below the right abutment (0.6, downward), compared to the left abutment (0.4, downward), possibly due to the different bedrock formations at these locations. The vertical gradients along the Corna Valley axis were as follows:

- 0.17 (downward) upstream of the initial TMF Dam alignment;
- -0,01 (upward) to 0,04 (downward) in the Tailings Dam centreline;
- -0.01 (upward) to 0.3 (downward) near the Secondary Containment Dam centerline.

The location of the hydrologic and geotechnical investigation works is shown on Drawing 02 and borehole profiles are illustrated on drawings 03.

2.3 Geotechnical Conditions

The following discussion on the geotechnical conditions beneath the dam location in the Corna Valley is based on initial work conducted by SNC-Lavalin Consultants[11] and supplemental investigation work by MWH[12] focused on:

- defining and evaluating the hydraulic conductivity profiles;
- drilling, sampling and testing the “clay matrix” or soft rock layer; and
- delineating, sampling and evaluation of the local, non-acid generating construction materials (rocks).

Borehole and testing locations are shown on Drawing 02.

The cross-sections through the TMF are shown on Drawing 03.

It should be noted that during the optimisation study which followed the field investigations the TMF main dam centerline was moved approximately 250 m downstream and the secondary containment dam centerline was moved approximately 400 m downstream.

TMF Main Dam (Corna Dam)

Boreholes 03DH-C2-01, 03DH-C2-02, 03DH-C2-02A, 03DH-C2-03, 03DH-C2-07 şi 03DH-C2-07A were drilled along the dam alignment. A cross-section through the TMF and the borehole locations are shown on Drawing 03. The followings are shown on the cross-section: rock core recovery (REC in %), rock quality designation (RQD) and hydraulic conductivity given in Lugeon units.

Observations from boreholes 03DH-C2-01, 03DH-C2-07 and 03DH-C2-07A located along the Corna Valley creek bed indicate that the alluvial deposits are up to 12 m in thickness. The "n" values of the Standard Penetrometric Test (SPT) vary between 4 and 40 dependening on the particle size. Colluvial soils are not present along the valley floor. The SPT values increase with depth even if less dense intervals were observed.

In the test pits excavated within the TMF footprint, the alluvial deposits contain a wide variety of soil types ranging from silty clay as main component or as a matrix of coarse sand, fine to coarse gravel and cobbles. The predominant soil types are cohesive in nature and increasingly competent with depth. The competence of the materials exposed during test pit excavations varied from compact to hard.

The boreholes located outside the valley floor intersected colluvial soils with horizons ranging from 3 to 10 m (on the north hillside and south hillside, respectively). The difference in thickness is the result of different geological units as shown above. The colluvial/residual deposits consist mainly of fines with occasional mixes of coarse sand and cobble sizes. The coarse sand typically consists of sandstone which is more resistant in time to weathering than shale due to its composition of quartz and feldspar particles and cementation with silica and carbonate.

Following the laboratory tests the colluvial material was classified as silty clay of medium to low plasticity. The un-drained shear strength of the material with natural moisture content, measured with a qualimeter, vary between 75 kPa and 225 kPa.

The bedrock across the Corna Valley within the TMF site is a sequence of competent and incompetent foliated shale dipping south, towards the left bank, with intercalation of sandstone, breccia and weaker foliated shale. The frequency of sandstone intercalations increases below the 50m depth.

The core recoveries and sample rock quality designation have an average variability index between <10% and 100% and from 0 to 100%, for boreholes drilled with the valley axis (03DH-C2-01, 03DH-C2-07 şi 03DH-C2-07A). The boreholes located on the right slope (03DH-C2-02 and 03DH-C2-02A) returned very good to excellent recoveries (between 60% - 100%) with a few recoveries under 40%. However, the rock quality following the measurements using the rock quality designation (RQD) is invariably 0 with some intervals where RQD ranges from 10% to 40%.

The boreholes located on the left slope (03DH-C2-03 and 03DH-C2-03A) show a significant increase in the rock quality reflected by the higher core recovery and RQD. The rock quality on the left bank exceeds 50% at a depth of 11m and 70% at a depth of 25 m. The core recovery varies around 80% with 100% recoveries at depths between 25 m and 50 m.

Rock strength as per the results of field tests and previous triaxial testing presented by GRD Minproc Ltd and Knight Piesold 2001[13] shows a significant variation of the rock strength from soft to hard (5-100MPa). The areas with soft and very soft rock and low core recovery and RQD are associated with tectonic degradations and fragmentation.

The water table is found at the surface in the water-course bed at a depth of 12 - 14 m on the left valley slope and 14 - 18 m on the right slope.

Secondary Containment Dam Site

Boreholes 03DH-C2-04, 03DH-C2-05 and 03DH-C2-06 were drilled along the Secondary Containment Dam center-line. Drawing 03 illustrates the central section through the Secondary Containment Dam and borehole locations. The following are shown on the cross-section: rock core recovery (REC in %), rock quality designation (RQD) and hydraulic conductivity given in Lugeon units.

Observations from the boreholes downstream of the Corna Dam and TMF in the Corna Valley stream bed show that the thickness of alluvial deposits reaches the maximum thickness of 9m in the creek bed section and progressively decreases towards the slopes. The "n" values of the Standard Penetrometric Test (SPT) generally increase with depth, and

vary from 3 at the surface to 20 depending on the particle size. SPT values increase with depth even if intercalations are rarely observed. Higher "n" values were also obtained in areas where coarse grained fragments occur.
The bedrock was intercepted at a depth of 9 m in the flood plain area, 3m on the right slope and 11 m along the left slope. The bedrock consists of foliated shale. Recoveries along the valley axis are generally 0% in the first 10 m below the surface increasing to 40% or 60% at a depth of 25 m or to considerably more than 80% at depth. Recoveries and RQD for the 03DH-C2-05 borehole located on the right slope indicate a wide scatter down to the total depth of 50 m. Although at the depth of 30m a general increase of the recovery and RQD was recorded, random intervals with low recovery and RQD are still found. As noted above, the different formations and age are responsible for the significant differences in rock quality.
The water table was generally encountered within the valley floor between 12 and 14 metres below ground surface on the left valley slope and between 14 and 18 on the right slope.

2.4 Seismicity

A review of the regional seismicity of Romania and adjacent regions was assessed in the Feasibility Study and is presented in Section 4.5 Geology.
The seismicity within the Western Carpathian Mountains is moderate with earthquakes occurring at shallow depth. The majority of these earthquakes are magnitude 6 to 6.5.
The most active area in terms of seismic activity is Vrancea with earthquakes occuring at depths of 50-170 km. The distance between Vrancea and Roşia Montană is some 275 km.
Another active seismic area is found in the Timis County where shallow depth earthquakes occur of low or moderate magnitude (M4 to M6). The biggest earthquake recorded in the Timis County occurred in 1887 and was of magnitude M7.
In 2002 an earthquake of 4.2 magnitude on the Richter scale was recorded with the hypocenter at approximately 100 km south of Roşia Montană.
Professor Stematiu from the Technical Civil Engineering University of Bucharest reviewed the seismic hazard study prepared by DFS (Knight Piesold-2001b). The summarized results are presented in Table 2-2.

Table 2-2 Study of seismic risk

Return Period	[P] Probability of Exceedance	Maximum Acceleration (g)[1&3]	Intensity (MM)[1&4]
1:50	29.1	0.035	V
1:100	15.7	0.050	VI
1:200	8.2	0.062	VI
1:475	3.5	0.082	VI-VII
1:1000	1.7	0.102	VII
1:2000	0.8	0.115	VII
1:5000	0.3	0.134	VII-VIII
1:10000	0.2	0.151	VIII

Notes:

1 - Data from (Knight Piésold 2001b, Table 2-8[14]

2 - Probability of Exceedance Calculated for an assumed design life of 17 years

$$q = 1 - \left(\frac{T-1}{T} \right)^{L}$$

where: q - probability of exceedance;
T - return period in years
L - design life in years

3 - Maximum accelerations for bedrock

4 - Modified Mercalli Intensity

It was determined that a Maximum Credible Earthquake (MCE) of magnitude 8.0, causes a maximum bedrock acceleration of 0.14 g.

In the stability analysis of the Corna Dam the following values were used: OBE = 0.082g (Operation Basis Earthquake), Maximum Design Earthquake (MDE) and Maximum Credible Earthquake (MCE): MDE = MCE = 0.14g; the analysis is presented in Section 4.5[15].

3 Tailings Geochemistry

3.1 Available Data

In order to assess the TMF water quality - decant water and seepage through the and under the tailings dam - specific testwork was conducted summarized in the „Tailings management facility geochemistry and water quality Report 2005" by the MWH Inc Mining Group[16]. Testwork aimed at identifying the main factors influencing the water quality during both the operational and after-closure phase of the waste facility.

At the end of the operational period a volume of approximately 159,000,000 m^3 of consolidated tailings and tailings pore water and about 6,000,000 m^3 of decant water will be stored in the TMF in areas where there are no beaches.

During operations and an additional period after the deposition of tailings has ceased, the process water will be in contact with the tailings.

All the surveys showed that in time the tailings stored in the TMF have the potential for ARD generation. The water pH may be in the range of 2 to 7 depending on the pyrite content, exposure of tailings to water and oxygen and time.

The surveys also focused on the residual cyanide reporting to the TMF.

The main environmental impact during the operational stage relates to the geochemistry of the deposited tailings, and from the potential of seepage through and beneath the dam. These issues are discussed further below:

- Deposited tailings characterization
- TMF decant water chemistry
- Seepage chemistry and modelling

3.2 Tailings Characterization

The tailings assessment focused on the following three key issues:

- tailings potential to generate acid rock drainage (ARD);
- changes in tailings chemistry over time due to exposure of the deposited tailings to environmental conditions that may generate ARD due to the chemistry of the leachate generated by the dissolution of soluble minerals in the tailings..

It is evident that the tailings have potential for ARD generation. As the operating and TMF closure methods are BAT the potential for ARD generation will be minimised and controlled, as specified in Section 3.5. The process water discharged with the solid tailings into the TMF will largely dominate the TMF water chemistry. If the tailings are drained (in the tailings beach) and re-moistened through precipitation a different quality water will result due to the dissolution of soluble minerals in tailings.

The tailings and waste rocks contain a wide range of metallic minerals. In an oxygen free environment, minerals do not oxidize, sulphides are thermo-dynamically stable and have low chemical solubility. Exposure to oxygen supplied from air initiates a series of bio-geo-chemical processes in the above surface rocks which may result in ARD generation. The effect of the exposure intensifies with the grain size decrease as a result of specific surface area increase. Therefore, the sulphides in milled tailings are susceptible to oxidation.

If the tailings contain neutralizing minerals - such as carbonates - the resulting acid may react with these minerals, it is used up and the medium becomes neutral. The solute metals precipitate and are not therefore discharged from the system. Other acid-consuming minerals are the aluminium silicates such as potash feldspar. The aluminium silicate dissolution is kinetically controlled and can not maintain a neutral pH.

The interaction between the acid generating oxidation of sulphide minerals and dissolutions of acid-consuming minerals dictates the pore water and drainage water pH which influences the metal mobility.

The test results indicated that the tailings have the potential to become acidic in the presence of oxygen and water. At the same time a process for inhibiting ARD generation was identified, inhibition caused by the secondary precipitation of some minerals on the sulphide grains thus covering their active surface.

The sulphide content of tailings is 1-2%, rarely higher.

The presence of carbonates in tailings inhibits the ARD generation process, however the carbonate content is very low, between 0.2% and 0.8%, rarely reaching 1.5%.

The tests confirmed that in an early phase when the process water pH is alkaline and there is a neutralizing potential in the tailings ARD generation does not immediately occur. The pH will drop from 8 - 8.5 down to approximately 6.5 only after 26 tailings moistening - dewatering cycles, as per the tests conducted by MWH[17] .

Due to the rapid deposition of the tailings in the TMF and flooding of most of the tailings, a significant oxidation which may facilitate ARD generation is not likely to occur. A significant generation of ARD in the TMF is not expected in the operational phase.

The short-term leaching tests indicated that the storm water in contact with tailings will generate a water which meets the requirements of the Romanian Technical Norms for Water Protection - NTPA 001/2005 - with the exception of a minor exceedance of the pH. The long-term tailings leaching tests indicated that manganese levels may also be exceeded.

The ARD Treatment Plant sludge deposited within the TMF in a sludge/ore processing tailings mass ratio of 1:4,000 (0.025%) has the potential to generate a leachate which does not comply with the requirements of NTPA 001 with respect to sulphate, calcium and total dissolved solids content and pH levels. However, due to the small amount it is not expected to generate a significant impact on the TMF water quality.

Tables 3-1 and 3-2 summarize the leaching test results for tailings and Cetate ARD Treatment Plant sludge. The leaching method employed for testing aimed to determine the leaching potential of the metals contained in tailings and ARD Treatment Plant sludge as a result of the contact between tailings and rain water or snow.

Table 3-1. Synthesis of leaching tests completed on tailings and slurry resulted at the ARD treatment plant

TABLE 3.5
SYNTHETIC PRECIPITATION LEACHING PROCEDURE (SPLP) TESTING RESULTS FOR TAILINGS AND ACID ROCK DRAINAGE TREATMENT PLANT SLUDGE -- METALS

Sample Identification:			RM1	RM2	RM3A	APPS *	Method	Practical	Romanian	World
Lab Sample Number:			L45557-01	L45557-02	L45557-03	L45557-04	Detection	Quantitation	TN001	Bank
Analyte	Method	Units					Limit	Limit	Limits	Guidelines
Aluminum	M6010B ICP	mg/L	0.17 B	0.15 B	0.19 B	3.63	0.03	0.2	5	---
Antimony	M6020 ICP-MS	mg/L	0.0049	0.0065	0.0041	--- U	0.0002	0.001	---	---
Arsenic	M6020 ICP-MS	mg/L	0.0117	0.0083	0.0655	0.0005 B	0.0005	0.0025	0.1	1
Barium	M6010B ICP	mg/L	0.01	--- U	--- U	--- U	0.003	0.01	---	---
Beryllium	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.002	0.01	---	---
Cadmium	M6020 ICP-MS	mg/L	--- U	--- U	--- U	--- U	0.0001	0.0005	0.2	0.1
Calcium	M6010B ICP	mg/L	10.0	13.3	11.3	547	0.2	1	300	---
Chromium	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.01	0.05	1	1
Copper	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.01	0.05	0.1	0.3
Iron	M6010B ICP	mg/L	0.02 B	--- U	--- U	0.04 B	0.01	0.05	5	2
Lead	M6020 ICP-MS	mg/L	0.0004 B	0.0002 B	--- U	--- U	0.0001	0.0005	0.2	0.6
Magnesium	M6010B ICP	mg/L	0.7 B	1.8	0.4 B	1.0 B	0.2	1	100	---
Manganese	M6010B ICP	mg/L	0.212	0.318	--- U	--- U	0.005	0.03	1	---
Mercury	M7470 CVAA	mg/L	--- U	--- U	--- U	--- U	0.0002	0.001	0.05	0.002
Nickel	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.01	0.05	0.5	0.5
Potassium	M6010B ICP	mg/L	3.7	3.4	3.6	1.5	0.3	1	---	---
Selenium	M6020 ICP-MS	mg/L	--- U	--- U	--- U	--- U	0.002	0.008	0.1	---
Silica	M6010B ICP	mg/L	2.9	2.2	4.4	--- U	0.2	0.5	---	---
Silver	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.005	0.03	0.1	---
Sodium	M6010B ICP	mg/L	3.6	7.2	8.7	1.3	0.3	1	---	---
Thallium	M6020 ICP-MS	mg/L	0.0002 B	0.00040	0.001	0.0061	0.00005	0.0003	---	---
Zinc	M6010B ICP	mg/L	--- U	--- U	--- U	--- U	0.01	0.05	0.5	1

Notes:
Samples RM1, RM2 and RM3 are prepared tailings samples
Shading indicates exceedance or Romanian TN001 Units
* = Acid Rock Drainage Plant Precipitate Slurry
Samples submitted to laboratory on April 8, 2004
U = Concentration of analyte was not detected at or above Method Detection Limit (MDL).
B = Concentration of analyte was detected above the MDL, but at or below the Practical Quantitation Limit.

Table 3-2. Synthesis of leaching tests completed on tailings and slurry resulted at the ARD treatment plant, water quality parameters

TABLE 3.6
SYNTHETIC PRECIPITATION LEACHING PROCEDURE (SPLP) TESTING RESULTS FOR TAILINGS AND ACID ROCK DRAINAGE TREATMENT PLANT SLUDGE -- GENERAL WATER QUALITY PARAMETERS

		Sample Identification:	RM1	RM2	RM3A	APPS*	Method	Practical	Romanian	World
		Lab Sample Number:	L45557-01	L45557-02	L45557-03	L45557-04	Detection	Quantitation	TN001	Bank
Analyte	Method	Units					Limit	Limit	Limits	Guidelines
Acidity	SM2310B	mg/kg	6 B	--- U	--- U	--- U	2	10	---	---
pH	M150.1	units	8.3	8.2	8.8	9.2	0.1	0.1	6.5 - 8.5	6.0 – 9.0
Bicarbonate as $CaCO_3$	SM2320B	mg/L	9 B	13	12	14	2	10	---	---
Carbonate as $CaCO_3$	SM2320B	mg/L	--- U	--- U	3 B	6 B	2	10	---	---
Hydroxide as CaCO3	SM2320B	mg/L	--- U	--- U	--- U	--- U	2	10	---	---
Total Alkalinity	SM2320B	mg/L	9 B	13	15	20	2	10	---	---
Hardness as $CaCO_3$	SM2340B	mg/L	28	41	30	1370	1	7	---	---
Chloride	M325.2	mg/L	6	3 B	3 B	--- U	1	5	500	---
Conductivity @25C	M120.1	umhos/cm	85	126	115	1920	1	10	---	---
Cyanide	M335.4 tric	mg/L	--- U	--- U	--- U	na	0.01	0.05	0.1	---
Fluoride	SM4500F-C	mg/L	0.1 B	0.2 B	--- U	0.5 B	0.1	0.5	5	---
Nitrate	Calculation: NO3NO2	mg/L	0.05 B	--- U	0.02 B	0.03 B	0.02	0.1	25	---
Nitrate/Nitrite as N	M353.2	mg/L	0.05 B	--- U	0.02 B	0.03 B	0.02	0.1	---	---
Nitrite as N	M353.2	mg/L	--- U	--- U	--- U	--- U	0.01	0.05	1	---
Nitrogen, ammonia	M350.1	mg/L	0.2 B	1.0	1.3	--- U	0.1	0.5	2	---
Total Dissolved Solids	M160.1	mg/L	70	90	80	2180	10	20	2000	---
Sulphate	M375.3	mg/L	30 B	60	50	1510	10	50	600	---

Notes:
Samples RM1, RM2 and RM3 are prepared tailings samples, sample APPS is acid rock drainage treatment solids.
Shading indicates exceedance of Romanian TN001 limits
* = Acid Rock Drainage Plant Precipitate Slurry
Samples submitted to laboratory on April 9, 2004
U = Concentration of analyte was not detected at or above Method Detection Limit (MDL).
B = Concentration of analyte was detected above the MDL, but at or below the Practical Quantitation Limit.

3.3 TMF Decant Water Chemistry

A significant volume of process water resulting from the settling of the solids in the tailings slurry will be stored in the TMF during the operational phase. The TMF surface water will be continuously recycled to the ore processing plant. In this way a closed circuit will be developed and no waste water will be discharged to the existing stream channels or groundwater system during normal operations or even extreme rainfall events. The TMF provides full containment of two consecutive Probable Maximum Floods (PMFs). In case of an extreme precipitation event when the TMF storage capacity is exceeded (the probability of this event to occur is very low), water surplus conditions may require discharge in order to maintain the normal operating volume in the tailings pond. For this situation a cyanide detoxification plant is provided to reduce the WAD cyanide concentration in diluted waters to acceptable regulatory levels.
The estimations for the general decant water chemistry and cyanide concentration chemistry are described below.

TMF Decant Water Chemistry
In order to assess the chemistry of the decant water testwork was conducted in 2004 on the same RM1, RM2 and RM3 samples which were submitted for various detoxification tests. Table 3-3 shows the decant water quality resulting from the conducted tests.
The tests results showed that calcium, sulphate and ammonium are the only constituents exceeding the requirements of the NTPA 001/2005. Arsenic, copper and molybdenum occur in concentrations permitted by the standard or slightly below permissible limits. Any dilution due to rainfalls will reduce these concentrations below permissible limits. Also, the cyanide concentration exceeds the permissible limits, however this issue will be discussed in the following section.

Table 3-3. Composition of TMF clarified water

	Sample(2)			TN001 Standard		Sample(2)			TN001 Standard
	RM1	RM2	RM3			RM1	RM2	RM3	
Total Cyanide(3)	1.13	5.09	3.29	0.1	Manganese	0.3	0.8	<0.1	1
WAD Cyanide(3)	0.37	0.77	0.22	...	Molybdenum	0.4	0.3	0.4	0.1
Thiocyanate	70	69	91	...	Sodium	725	900	705	..
Cyanate	390	390	350	...	Niobium	<0.1	<0.1	<0.1	...
Thiosalts	<2	<2	2.50	...	Neodymium	<0.01	<0.01	<0.01	...
Ammonia	6.6	7.3	25	2	Nickel	0.20	0.40	0.20	0.5
Gold	0.0085	0.043	0.0165	---	Phosphorus	<1	<0.5	<1	...
Silver	<0.05	<0.05	<0.05	0.1	Lead	<1	<1	<1	0.2
Aluminium	<0.2	0.2	0.20	5	Praseodymium	<0.005	<0.005	<0.005	...
Arsenic	0.30	<0.2	0.20	0.1	Rubidium	0.35	0.35	0.50	...
Boron	0.20	0.2	0.40	...	Sulphur	660	1030	962	...
Barium	<0.05	<0.05	<0.05	...	Sulphate(1)	1980	3090	2886	600
Beryllium	<0.02	<0.05	<0.02	...	Antimony	0	0.28	0.06	...
Bismuth	<0.02	<0.02	<0.02	...	Scandium	<0.5	<0.1	<0.5	...
Calcium	401	675	707	300	Selenium	<5	<5	<5	0.1
Cadmium	<0.5	<0.1	<0.5	0.2	Silicon	8	6	8	...
Cerium	<0.01	<0.01	<0.01	...	Samarium	<0.01	<0.01	<0.01	...
Cobalt	0.40	0.40	0.80	1	Tin	<0.2	<0.2	<0.2	...
Chromium	<0.2	<0.2	<0.2	1	Strontium	1.4	2.1	2.1	...
Cesium	<0.02	<0.02	<0.02	...	Tantalum	<0.005	<0.005	<0.005	...
Copper	0.10	0.10	0.10	0.1	Terbium	<0.005	<0.005	<0.005	...
Dysprosium	<0.01	<0.05	<0.01	...	Tellurium	<0.1	<0.1	<0.1	...
Erbium	<0.01	<0.05	<0.01	...	Thorium	<0.01	<0.01	<0.01	...
Europium	<0.002	<0.05	<0.002	...	Titanium	<0.2	<0.2	<0.2	...
Iron	0.20	1.4	1.0	5	Thallium	<0.01	<0.01	<0.03	...
Gallium	<0.2	<0.1	<0.2	...	Thulium	<0.005	<0.005	<0.005	...
Gadolinium	<0.05	<0.05	<0.05	...	Uranium	<0.01	<0.01	<0.01	...
Germanium	<0.5	<1	<0.5	...	Vanadium	<0.5	<0.5	<0.5	...
Hafnium	<0.1	<0.1	<0.1	...	Tungsten	<0.1	<0.1	<0.1	...
Mercury	<0.01	<0.01	<0.01	0.05	Yttrium	<0.01	<0.01	<0.01	...
Potassium	142	136	132	...	Ytterbium	<0.01	<0.01	<0.01	...
Lanthanum	<0.01	<0.01	<0.01	...	Zinc	<0.2	<0.1	<0.2	0.5
Lithium	<0.1	<0.1	<0.1	...	Zirconium	<0.1	<0.1	<0.1	...
Magnesium	5.4	14.4	8.2	100					

Notes: (1) Calculated based on the assumption that total sulphur is sulphate
(2) Units in mg /l
(3) Results are obtained in lab conditions and may not be the same in practice
< Indicates untraceable within the limits of the testing method

Cyanide Degradation Chemistry in the TMF Decant Water

Investigations were carried out in order to determine the cyanide occurrence in the TMF and cyanide concentration and persistence. It is recognized that cyanide tends to reduce its concentration by precipitation of some cyano-metal complexes and by volatilization of hydrocyanic acid from the decant water. Free cyanide (uncomplexed) will directly volatilize, while other cyano-metal complexes require ultraviolet light to degrade[18] Many of the factors which influence the cyanide concentration attenuation are locally specific, thus the estimations of cyanide attenuation levels have significant uncertainties associated with them. Therefore, in order to predict responses for this parameter for such a process a specific model was developed by Botz and Mudder who are internationally recognized experts in the use of cyanide in the mining industry and associated environmental impacts[19].

The following conclusions resulted from the cyanide degradation modelling but it should be noted that these conclusions are only informative and may not be considered final, as specified in the MWH Report[20]

The decrease of cyanide concentration is a complex process that may include volatilization, oxidation, photolysis, hydrolysis, precipitation, complexing and adsorption. However, the

primary method for cyanide removal is the volatilization of the hydrocyanic acid (HCN) from the water surface.
It was found that HCN removal from the supernatant water is done according to a linear equation which means that HCN loss is directly proportional to the HCN concentration in solution. Mathematically, this is reflected by the following equation (1):

$$\frac{d[HCN]}{dt} = -k[HCN] \qquad (1)$$

where:

[HCN] is the HCN concentration in the TMF basin supernatant solution.

t – time

k – a first order coefficient

The k coefficient for a TMF supernatant considered as fully mixed is given by the following formula:

$$k = \left(\frac{A}{V}\right)k_v \qquad (2)$$

where:
A - supernatant surface exposed to atmospheric conditions

V - supernatant volume

K_v – first order volatilization coefficient for HCN

Performing the replacements in equation (1) it results:

$$\frac{d[HCN]}{dt} = \frac{A}{V}k_v[HCN] \qquad (3)$$

The HCN volatilization coefficient is primarily a function of temperature, solution mixing and wind.
For the purposes of this model the K_v[HCN] coefficient was considered dependent solely on temperature.
Due to the high stability of iron cyanic complexes in the surface water and groundwater they are only slightly dissociated in ambient conditions, except when they are exposed to ultraviolet and visible radiations (sun light). Then, these complexes dissociate by photolysis with generation of free cyanide. In absence of sun light, the cyanic complexes of iron are stable and natural attenuation occurs at low rates. Iron cyanide photolysis equation i:

$$\frac{d[Fe - CN]}{dt} = -k_p[Fe - CN] \qquad (4)$$

where: [Fe-CN] is the iron cyanide concentration in solution
k_p – photolysis coefficient which is a function of sun light intensity, pH, temperature, iron cyanide concentration, supernatant free surface and supernatant depth.
Complex cyanide dissociation to free cyanide which can re-complex with other metals, such as copper or can volatilize from solution as HCN is achieved according to equation (3).
Iron can form complexes with cyanide in both ferrous and ferric form, however, ferric complex is normally predominant.
Equations (3) and (4) are the fundamental formulas used by Botz and Mudder in their study to estimate the cyanide removal rate from the TMF decant water as a result of HCN photolysis and volatilisation.
The decant water cyanide removal modelling was based on the following assumptions:

- decant water was assumed fully mixed;
- pH of TMF decant water was assumed consistent throughout the TMF area and during the entire period (pH=8-8,5);
- it was assumed the chemistry of the tailings deposited in the TMF is similar to the chemistry of the detoxified slurry discharged into the TMF;
- three potential scenarios were considered in relation to the total content of cyanide, WAD cyanide and metals in the tailings slurry stored in the TMF.

Case	Cu	Fe	Ni	Zn	Total Cyanide	WAD Cyanide
Case 1	0.8	0.9	0.22	<0.01	3.9	1.4
Case 2	5.0	1.0	0.3	0.1	8.0	5.2
Case 3	10.0	1.0	0.3	0.1	13.0	10.2

- it was assumed that the seepage metal and cyanide content is the same as for the slurry discharged into the TMF, affected by a dilution factor (F). This factor depends on certain processes such as anaerobic biological processes, adsorption and complexing. Three factors were considered in the modelling: 0.9; 0.7 and 0.5.
- MWH indicated that the water contained in the ARD treatment plant sludge deposited in the TMF has the same chemistry for common pollutants as the TMF decant water;
- the following supernatant monthly temperatures and ice cover levels were assumed over a period of one year:

Month	**Temperatures (^{0}C)**	**Ice cover %**
January	4^{0}C	95%
February	4^{0}C	95%
March	4^{0}C	95%
April	8^{0}C	50%
May	12^{0}C	0%
June	16^{0}C	0%
July	20^{0}C	0%
August	24^{0}C	0%
September	20^{0}C	0%
October	16^{0}C	0%
November	12^{0}C	0%
December	8^{0}C	50%

- the water balance provided by MWH was taken into consideration.

Modelling Results

The conclusions drawn from the numeric modelling of the cyanide degradation process are as follows:

- for degradation of cyanide in an effluent with a pH level of 8 and a WAD cyanide concentration of 10 mg/l, the concentration in the TMF pond during operation, taking into account natural degradation and dilution, is estimated between 2 -6 mg/L CN_{WAD}.. The concentration level varies depending on the season. A time period of around 3 years after closure is assumed for the Cyanide concentration to drop below 0.1 mg/l.
- a more significant decrease of the concentration occurs for higher initial concentrations. Lower concentrations will be obtained during summer months; during winter the cyanide concentrations will be higher as the low temperatures and frost will inhibit reduction of cyanide concentrations;

The following table shows the estimated levels for the cyanide content of the decant water during operation and post-closure, as a function of the content of the slurry discharged into the TMF:

Case	Cyanide Content of Detoxified Slurry		Cyanide Content of Decant Water during Operation (Years 1-16)		Cyanide Content of Decant Water after Closure (Year 20)	
	Total (mg/l)	CN_{WAD}^- (mg/l)	Total (mg/l)	CN_{WAD}^- (mg/l)	Total (mg/l)	CN_{WAD}.$^-$ (mg/l)
1	3.9	1.4	1.5-3	0.8-1.1	<0.01	<0.01
2	8.0	5.2	2-5	1.5-3	<0.01	<0.01
3	13.0	10.2	3-8	2-6	<0.01	<0.01

It is estimated that WAD cyanide concentrations will be below 1% of the initial cyanide concentration in a period of one year after closure (below 0.1 mg/l).
It is estimated that a similar level of concentration decrease will be also achieved for total cyanide; this is only in part applicable as it is estimated that a significant part of the total cyanide is WAD and only a small part consists of ferro-cyanic complexes.
Similar to WAD cyanide, total cyanide concentration will drop below 1% of the initial concentration 1 to 3 years after closure.
pH levels in the TMF are expected to be 8 up to 8.5.
It is estimated that for this pH range only minor changes of the CN_{WAD}^-.concentrations may occur.
If pH drops to 7.5 the volatilization process will intensify resulting in lower cyanide concentrations in the TMF during summer months.
For any pH value between 7.5 and 8.5, cyanide degradation quickly results in concentrations below 1% of the initial cyanide concentration during the first three post-closure years.

- With respect to seepage it was concluded that the dilution factor during operation has no significant effect while the total post-closure cyanide concentration drops below 0.1 mg/l in a period of one year after slurry discharge to the TMF has ceased.
- The tested model proved not to be very sensitive for acceptable variation ranges of the seepage dilution, decant water temperature or ice cover persistence time.

Impact of probable maximum floods (PMF) may be a concern for the TMF decant water. The TMF is designed to provide full containment of two consecutive PMF events, however it may be required to discharge excess water to the environment in a controlled manner in order to ensure the normal operating level in the TMF. In case 1 or 2 extreme precipitation events occur there is sufficient storage capacity in the TMF pond and the potential dilution may be much higher. However, in order to return the reclaim pond to the original operating limits, a cyanide detoxification plant is provided for the treatment of low cyanide concentration water prior to discharge to the environment.

3.4 Seepage Chemistry and Modelling

TMF seepage will occur in relation to the drainage system and foundation materials. During operations all seepage will be collected in the secondary containment basin and pumped back to the TMF, thus no release to the environment should occur under normal operating conditions.

In order to assess the potential impact of a release or to develop treatment alternatives it is important to understand the seepage chemistry and evolution with time.
The TMF will be initially filled with 1-2 million m^3 of fresh water to ensure start-up of gold ore processing. Initially tailings discharge will be carried out from the main dam crest (Corna dam) and the slurry will mix with the water stored in the TMS.
Therefore, the initial seepage will consist of fresh water and will subsequently contain increasingly higher amounts of process water. It is likely that no seepage occurs in the initial phase, in particular when the hydraulic head upstream of the starter dam is relatively low.
Seepage modelling was performed by MWH[21] in order to estimate the seepage flow rate and chemistry.

Starter Dam Seepage
Three cross sections, one on the right abutment, left abutment, and the centerline, were developed for the TMF Dam seepage modelling. The centerline section was idealized to include the lowest points at the upstream, core, and downstream extents of the dam. A section of the TMF dam similar to the idealized section used is shown in Drawing 07.
Medium tailings are assumed to be within 180 meters of the dam, and fine tailings within 380 meters. The TMF was analyzed for 5 cases.

- Case 1, the dam was analyzed with an upstream liner;
- Case 2, the dam was analyzed without an upstream liner;
- Case 3, the dam was analyzed with a 40 m deep by 1 m wide grout curtain with a permeability of 10^{-7} m/sec;
- Case 4, a 30 m deep by 2 m wide slurry wall, with a permeability of 10^{-8} m/sec
- Case 5, includes an upstream sump.

All the materials in the analysis were assumed to be isotropic, except for the bedrock, which was assumed to be 10 times as permeable in the horizontal direction as in the vertical direction. Seepage properties used for the analysis are shown in the table 3-4.

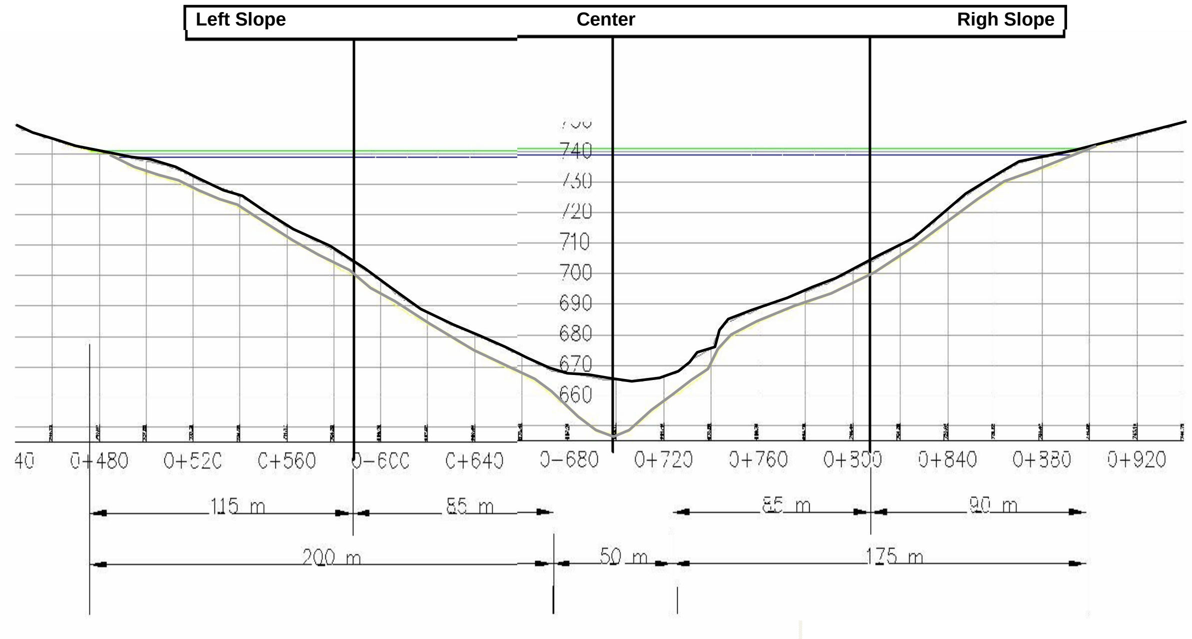
Table 3-4. TMF Foundation and Fill Materials Seepage Properties

Zone	Material Specification	Seepage Engineering Properties					
		Centerline		Right		Left	
Fill, Grout Curtain and Tailings		kh (cm/s)	b (m)	kh (cm/s)	b (m)	kh (cm/s)	b (m)
Core (Zone 1)	TMF footprint, basin and core trench excavation or pre-stripping La Piriul Porcului Sandstone	1x10-6 (3)	-	-	-	-	-
Filter (Zone 2) Drain (Zone 5) Transition (Zone 3)	La Piriul Porcului Sandstone	1x10-1 (3)	-	-	-	-	-
Shell (Zone 4B)	TMF Starter- Alluvium excavation-overburden and shale	1x10-6 (3)	-	-	-	-	-
Shell (Zone 4)	Slightly weathered to fresh Sulei Andesite or La Piriul Porcului Sandstone	1x10-1 (3)	-	-	-	-	-
Grout Curtain - Tailings Dam	Cement Grout	1x10-5 (4)	-	-	-	-	-
Slurry Wall	Bentonite Slurry Wall	1x10-6 (4)	-	-	-	-	-
Fine Tails	Silty clay	1x10-6 (3)	-	-	-	-	-
Medium Tails	Fine Sand	[illegible]		-			-
Coarse Tails	Sand	5x10-4 (3)	-	-	-	-	-
Liquefied Tails	Fine to Coarse Sand	NA	-	-	-	-	-
Foundation							
Colluvium Liner		1x10-6 (3)	2	-	-	-	-
Overburden	Alluvium	1x10-3 (3)	13	-	-	-	-
Overburden	Colluvium	-	-	1x10-6 (3)	5	1x10-6 (3)	8
Weathered Bedrock 2	Shale	-	-	2x10-4 (3)	10	-	-
Upper Bedrock 2	Shale	8x10-5 (3)	27	6x10-5 (3)	25	1x10-4 (3)	32
Lower Bedrock 2	Shale	1x10-5 (3)	70	3x10-5 (3)	70	5x10-6 (3)	70

Notes:
(1) kh is horizontal coefficient of permeability
(2) Vertical permeability (kv) is 10 times less than the horizontal permeability
(3) MWH 2003 Laboratory Test Results or Literature Survey
(4) Seepage Analysis
(5) B is thickness of unit flux length

In order to determine the amount of seepage over the entire alignment of the dam, the seepage values determined in the three sections were applied over those portions of the dam. The centreline flux was applied to the middle 50 metres of the alignment. Half of the right abutment flux was applied to the 90 m section from the right abutment. The average of the centreline flux and the right section flux was applied to an 85 metre wide section on either side of the centre section. Half of the left abutment flux was applied to the 115m section from the left abutment – figure 3.1.

Figure 3.1. Corna valllez cross section



The results of the seepage analysis for each of the five cases are shown in the table 3-5:

Table 3-5. Starter Dam Seepage Rates

Case	Seepage (m^3/hr)
Case 1	10.1
Case 2	11.6
Case 3	9.77
Case 4	6.41
Case 5	8.79

Final Dam Seepage

The TMF main dam (Corna Dam) was analysed for the same cases as the starter dam with one additional case[22]:

- Case 6, was analysed with the TMF holding the PMF for an extended period.

The results of each case analysed are presented in the following table:

Table 3-6. TMF Final Dam Seepage Rates

Case	Seepage (m^3/h)
Case 1	82.4
Case 2	76.2
Case 3	81.9
Case 4	83.4
Case 5	45.4
Case 6	1.490

Secondary Containment Dam Seepage

Three scenarios were examined for the Secondary Containment Dam such that the water level in the Secondary Containment Pond was set at the minimum normal operating level at the 642 m elevation and at maximum normal operating level of 646 m elevation and the rainfall event with a return period of 100 years when the level in the SCS sump is at 650 m elevation.

The effects of seepage from higher heights and peripheral drainage collection were ignored. The bentonite slurry wall at the Secondary Containment Dam is 3 m thick and 1 m wide. The seepage characteristics used for the analysis are presented in the table 3-7.

Table 3-7. Summary of the Seepage Characteristics through the SCS Dam

Zone	Material Specification	Centerline Seepage	
Rockfill, Grout Curtain and Tailings		K_n (cm/s) (1)	b (m) (5)
Core (Zone 1)	SCS Dam sump excavation and stripping La Piriul Porcului sandstone	$1x10^{-6}$ (3)	-
Filter (Zone 2) Drain (Zone 5) Transition (Zone 3)	La Piriul Porcului Sandstone	$1x10^{-1}$ (3)	-
Shell (Zone 4)	Slightly weathered to fresh Sulei Andesite	$1x10^{-1}$ (3)	-
Slurry Wall	Bentonite Slurry	$1x10^{-6}$ (4)	-
Foundation			
Overburden	Alluvium	$1x10^{-3}$ (3)	10 la 13
Overburden	Colluvium	-	-
Weathered Bedrock 2	Shale	-	-
Upper Bedrock 2	Shale	$1x10^{-4}$ (3)	12 la 18
Lower Bedrock 2	Shale	$2x10^{-5}$ (3)	14 la 21

Notes:
(1) k_h is horizontal coefficient of permeability
(2) Vertical permeability (k_v) is 10 times less than the horizontal permeability
(3) MWH 2003 Laboratory Test Results or Literature Survey
(4) Assumed for Seepage Analysis
(5) B is thickness of unit flux length

The results obtained by modelling are presented in the table below:

Table 3-8. Results of seepage modelling through the SCD

Case	Minimum sump level	Maximum sump level	100-yr Flood
Location	Seepage (m^3/sec.)	Seepage (m^3/sec.)	Seepage (m^3/sec.)
Core	1.15×10^{-5}	3.37×10^{-5}	6.37×10^{-5}
Upper Bedrock	7.66×10^{-5}	1.87×10^{-4}	3.03×10^{-4}
Lower Bedrock	6.80×10^{-6}	1.61×10^{-5}	2.56×10^{-5}
Total	9.49×10^{-5}	2.37×10^{-4}	3.92×10^{-4}

Modelling of Contaminant Transport[23]

The TMF basin and dam were designed to minimize seepage. For this purpose within the TMF basin a compacted colluvial layer which will provide a barrier layer to reduce seepage from the TMF basin, a low permeability core and a drainage channel at the base of the starter dam will be developed. However, the potential still exists for seepage at the downstream dam end.

Therefore, a secondary retention dam was designed downstream of the tailings dam. This will include a cutoff trench at the dam foundation and a sump behind the dam. The water level in the sump will be maintained at a lower elevation with respect to the groundwater level and will be used to collect groundwater.

Seepage will reflect the composition of the process water retained within the pores of the tailings. However, the chemical reactions resulting from the tailings exposure to atmospheric oxygen and carbon-dioxide should also be considered.

The tailings will accumulate in the TMF at a rate of deposition of approximately 4-8m/year. At this accumulation rate there is minor opportunity for oxidation and ARD generation by Year 16 of Project operations and even a short period afterward. During ore processing operations the tailings will be permanently covered by fresh tailings and therefore the saturation level will be maintained high, reducing oxygen ingress and oxidation. Testing has indicated that ARD generation will be slowed down by moistening - dewatering successive cycles with the probability that ARD generation will not occur during operations.

In year 16 of operations the gold ore processing will cease and approximately 159,189,000 m^3 of tailings will be deposited in the TMF. Table 3.4.2-1 indicates that seepage flow rates are of approximately 45,4 m^3/h during operations. Typically, the ARD generation process consists of the following chemical reactions:

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

for pyrite oxidation;

$$FeS_2 + 15/4\ O_2 + 7/2H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

for oxidation with ferric hydroxide precipitation; and

$$FeS_2 + 14Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2SO_4^{2-} + 16H^+$$

for oxidation with ferric ion.

All these reactions will produce acidity and sulphate ions. Solute iron may result, but it will precipitate as hydroxides and hydroxi-sulphate.

ARD generation is a cyclic process with limited sulphide oxidation in both dry and wet climatic conditions[24]. The process may start with drying of wet pyrite grains. As the grain surface dries out, the grains are exposed to an optimum mixture of water and oxygen and oxidation occurs. Bacteria may also play an important role as a catalyst for this pH dependant reaction. In the maximum oxidation condition, the resulting ARD has little mobility being captured within the pores either as fluids and retained by capillarity forces or as highly soluble mineral salts formed with mineral grains. Some mineral salts can migrate to the tailings surface. During the subsequent precipitation ARD retained within the pores and dissolved mineral salts may flow downward through the interstitial capillary columns. Acidic salts reaching the upper part of the tailings may be washed and therefore reach the decant water area.

The ARD generation potential is decreased by neutralization allowing for ARD generation in the deeper zones. When the tailings permeability is low, minerals such as carbonates and feldspar may, if present, contribute to the ARD neutralization. This process is indicated by the high concentration of potassium and silica ions. As the acid flow advances, many other secondary minerals previously formed will be dissolved and mostly precipitated and the acidity is neutralized. An effect of the acid flow migration may be the formation of the "hard shale" layer. This "hard shale" layer will decrease the tailings permeability and can significantly limit the ARD generation at depth and slow down the ARD generation and migration by limiting the water and oxygen ingress. This type of layer was studied and observed in a number of tailings deposition ponds[25] .

ARD generation is also slowed down by the drawdown of the dried tailings area.
TMF closure will start shortly after completion of ore processing. The main component of the closure will be the placement of a subsoil and topsoil layer on the tailings surface. The cover will be designed to reduce seepage and exposure to oxygen which will result in the reduction of oxidation and ARD generation and transport of contaminants.

In order to estimate the time when seepage containing cyanide will reach the secondary containment sump, MWH has modelled the contaminant transport based on the PHREEQC model of the US Geological Survey[26] . The modelling objectives were as follows:

- estimation of cyanide concentrations in the sump downstream of the starter dam during years 1 and 10 after commencement of the slurry discharge into the TMF containing 22 or 10 mg/l cyanide (WAD cyanide);
- estimation of the time required for the seepage collected in the sump downstream of the starter dam to reach a cyanide concentration of 0.01 mg /l.

The modelling was also based on the following aspects:

- spatial geometry of each hydro-stratigraphic unit and tailings material;
- types of rocks and hydraulic conductivities;
- starter dam configuration;
- hydraulic head conditions in the tailings deposition pond;
- a constant hydraulic level at the upstream end of the TMF at elevation 736 masl simulating the decant water level;
- a constant hydraulic level at the downstream end at elevation 615 masl simulating the level in the sump behind the Secondary Containment Dam.

All other conditions were assumed to be the same as for seepage modelling.
In summary, the modelling results show that within 5 years the cyanide concentration will not reach 0.01 mg /l in the SCS sump. This concentration can be reached between years 7.5 – 8 of the Project life considering an initial concentration of both 10 mg/l and 22 mg/l.
As per the MWH Report this modelling is for information only. The actual TMF operation conditions may lead to significant changes due to the following:

- actual hydraulic conductivities may differ for each geological unit due to the heterogeneity caused by the changes in particle size and fracturing;
- cyanide degradation may occur at rates higher or lower than those expected;
- tailings saturation varies within the TMF (in the tailings beach and decant water areas);
- changes also occur with respect to the distance from the dam to the decant water area.

4 TMF Technical Characteristics

4.1 Design criteria for TMF

From the point of view of its construction the TMF has two steps:

- step one corresponds to the construction phase of the starter dam and all the other components of the Roşia Montană Project
- step two overlaps the operation phase, as: the main dam is being continuously built, by successive lifts; the print of the TMF pond and the foot-print of the main dam are being continuously prepared and additional materials is placed to raise the dam crest. The tailings distribution system for the process tailings is remade with each new lift; the diversion ditches on the sides are rebuilt as required. The semi-passive treatment lagoons for the semi-passive treatment of the disorption water will be built in the second part of the operation phase. These will be tested during the operational phase with the objective of utilizing them in closure. During the first phase, the starter dam, the secondary dam and the other systems necessary for the TMF commissioning together with the commissioning of the process plant, are built.

The design criteria adopted for the main dam, the secondary retaining sump and for the Corna dam, were the following[27]:

- The TMF pond assures the complete storage of the maximum probable rainfall for the entire duration of the project;

The TMF drainage basin will including the Carnic waste dump, will have a surface of approx. 698 ha and will comprise 4 main types of surfaces: the deposited tailings pond, the tailings beach, the Carnic waste dump undisturbed surface areas.

- the cofferdam for the starter dam will be designed to handle 24 hour rainfall events, with the return possibility of 1:10 year event;
- the crest height of the initial dam will be designed to store the volumes from both the process tailings deposited and the water containment during the first 15 month of operation (the containment of 95 percentile of the reclaim pond volume from the probablistic water balance and two times the probable maximum flood volume);
- the maximum height of the dam crest for tailings will be designed to contain of 214,4 million tons of tailings and the precipitation from back to back PMF's.and allowing for an additional 34 million tons of deposited tailings (contingency capacity) or freeboard water volumes.
- the containment pond for the starter dam and the tailings pond were designed to have a sufficient capacity over the normal operation capacity, to handle the determined volume of two probable maximum floods over a 24 hour period;
- the classification of the TMF dam will be a 1st Importance Class – B category, according to Romanian standards;
- the clarified water will be recycled from the TMF pond for use within the process plant;
- use of the tailings for subsequent dam lifts until the maximum design elevation;
- the minimum safety factors for the static loading conditions during the execution of the starter dam and during the subsequent lifts are 1.3 for the starter dam and1.5 for the final dam;

- seismic loading is based on an earthquake with an occurrence possibility of 1:475 years: a = 0.082g for the finalization of the starter dam and a = 0.14g for the lift periods and the final dam;
- was designed based on the following criteria[28].

The secondary catchment pond was designed based on the following criteria:

- sufficient containment capacity to store a1:100 year storm event for 24 hours plus the initial designed storage volume required during operations;
- the run off disorbtions and the collected seepage waters are repumped in the tailings pond;
- availability of a spillway with sufficient capacity to handle runoff from a 1:1000 year storm event;

The secondary catchment dam will be designed based upon the following criteria:

- the classification within the 1st Importance Class – B category, according to the Romanian standards;
- the use of inert, non-ARD material for its construction;
- the minimum safety factors are 1.3 for the finalization of the construction and 1.5 for the operation and closure period, and 1.1 for the seismic loading related to the pseudo-static loading;
- seismic loading based on an earthquake with an occurrence possibility of 1:475 years: a = 0.082g for the finalization of the construction dam and a = 0.14g for the operational and closure period dam;
- a crest spillway for the secondary dam, with a width of 27 m, is designed to handle the largest flood that may occur:
    - 1:500 years, with an overflow of 0.6 m^3/sec.;
    - 1:1000 years, with an overflow of 2.5 m^3/sec.;
    - The Probable Maximum Rainfall, with an overflow of 24.7 m^3/sec.

4.2 Dam Raises (Lifts) Construction Data and Material Specifications

The tailings impoundment will be formed by an embankment with different permeability zones that will be built in phases in order to provide appropriate containment of the tailings and satisfy the design and operational criteria of the TMF. The TMF starter dam and Secondary Containment Dam will be constructed out of inert non-ARD materials. Subsequent lifts of the TMF dam will be constructed with waste rock with the potential to generate ARD runoff which will be captured behind the Secondary Containment Dam and the water will be managed based on the water quality characteristics, as follows: if the Romanian discharge standards are met, the water will be released into the Corna Valley, if the discharge requirements are not met the water will be pumped back to the TMF decant pond.

The use of waste rock to construct the dam lifts once the starter dam is complete serves two purposes: first, doing so allows for storage of waste rock without creating a new or expanded waste rock stockpile and provides a structural material for constructing the TMF dam without expanding existing borrow areas or creating a need for a new borrow source.

The starter dam will form the first lift before operations begin and subsequent lifts will be constructed during operations. The starter dam will be of sufficient height to provide tailings storage and appropriate additional water management capacity during the first 15 months of operation; the starter dam will act primarily as a water retention dam during this period. Therefore, the starter dam will incorporate a low permeability core, filter/transition zones, and rockfill shells.

Prior to starter dam construction, all vegetation and topsoil will be removed within the footprint of the starter dam and containment basin. Vegetation will be disposed of outside the limits of the TMF basin and topsoil will be stockpiled for use during closure and reclamation. The surface of the colluvial layer will be compacted to achieve a permeability of approximately $1x10^{-6}$ cm/sec. The compacted layer is intended to provide a barrier layer to reduce seepage from the TMF basin.

The extent of the basin preparation will be extended with the construction of each lift. In areas where the colluvial layer has been eroded or is not present, excess colluvial material within the basin will be used to cover these areas. The placed material will be compacted to achieve that same permeability as the native materials.

The low permeability core extends to the bedrock surface with appropriate foundation treatment, including contact grouting. The starter dam will initially store water to about 697 m elevation (1,500,000 m^3 of water storage) at start of operations. The tailings will initially be completely submerged and water will be impounded against the dam above the level of the submerged and saturated tailings. The starter dam will have to perform as a water dam until a substantial tailings beach is developed against the dam, which only occurs toward the end of the 1.25-year storage period for which the starter dam is designed.

Stability considerations require removal of all alluvial soils to the bedrock surface and stripping of organics and topsoil on the valley slopes to expose suitable colluvial/residual soil. In addition, after this initial excavation, about 2 m of bedrock excavation below the alluvial soil in the flood plain and about 1 m of bedrock excavation along the valley slopes will be completed. Directly following the bedrock excavation, the bedrock surface will be cleaned with air jets and a slush grout layer will be placed. Once the bedrock is exposed, a detailed fracture map will be compiled of the surface by a qualified engineer. If required, the engineer may direct injection grouting to seal discontinuities. Clay core placement will immediately follow the slush grouting process to ensure a good seal between the clay core and the exposed bedrock.

The starter dam core forms Zone 1 and has a low permeability of about 10^{-8} m/sec. The construction material shall comprise suitable clay overburden obtained from the process plant and access road areas. The Zone 1 material shall be placed in horizontal layers compacted at 95% of Standard Proctor value.

Zone 2 is a filter zone and is provided on both sides of the starter dam core. Zone 2 also extends as a filter bed under the downstream half of the starter dam.

Zone 3 is a transition zone provided on the downstream side of the core, immediately downstream of the filter Zone 2 and extends above the filter zone under the downstream half of the starter dam.

Zone 4 forms the rockfill body of the dam and consists of durable dacite mine rock on the upstream and downstream side of the starter dam core, with a 1.6H:1V slope downstream and 1.75H:1V slope upstream.

Zone 4 will also include the cofferdam constructed initially in order to create conditions for construction of the starter dam. The cofferdam slopes are constructed at angles of 2H:1V downstream and 3H:1V upstream. The upstream slope is provided with an outer low permeability zone, zone 4B, constructed of the same material as the core and a transition zone between the cofferdam body and the low permeability side on the upstream face (see Drawing 07B).

Zone 5 is a granular drain placed under the filter zone under the downstream half of the starter dam in the base of the Corna Valley.

In order to provide access and also for erosion protection purposes a two shelf access road will be constructed along the downstream slope of the dam at a gradient of 10%.

Zone 4 (and 4B) is the dam shell and consists of rockfill.

Zone 5 is the drain area under the dam body and within the tailings deposition pond.

Drawings 07 (Sheets A and B) show details of the Starter TMF and SCD Starter Dam Cross Sections with the composing zones and materials to be used for each zone.
The construction materials for the dam differ according to the dam zones and the zone purpose.
For an optimum selection of the construction materials, MWH prepared the Study "Geotechnical Assessment Report for Dam Construction Materials - Final Report, March 2005" [29] whereby potential sources were identified, samples were collected, testwork was conducted and the requirement for each rock type was estimated.
The Study showed that both the waste rock and rocks from the Sulei (sandstone) and Pârâul Porcului (andesite) quarries are suitable for providing the materials for drain, filter, transition, rockfill and concrete aggregate zones. Materials resulting from topsoil removal and colluvium overburden excavation from the TMF footprint and basin area and material from the stripping of the La Pârâul Porcului quarry were selected for construction of the low permeability core.
Based on the conducted survey, MWH estimated the amount of material required for each zone of the starter dam and secondary containment dam in the Corna Valley. The material volumes and specifications are shown in Table 4-1.

Table 4-1. Amounts of materials required and material specification for the starter dam and secondary containment in the Corna Valley

Zone	Required Compacted Volume (m^3)	Material Specification
Core (Zone 1)	363526	Low permeability fine breccia or clay overburden
Filter (Zone 2)	132377	Crushed andesitic rock or sand and gravel which shall not contain more than 5% by weight of material passing sieve #200 (0.074 mm).
Transition (Zone 3)	215593	Crushed and sieved dacitic rock material free from dirt, organic matter and other impurities. Fresh inert unaltered hard rock
Shell (Zone 4 and 4B)	1713337	Fresh or slightly altered/weathered rock
Drain (Zone 5)	57418	Crushed hard andesite

The crest width of 10 m selected for the starter dam is provided to allow the following:

- Appropriate berm along the upstream slope;
- Space for location, installation and regular maintenance of the tailings pipeline;
- Downstream safety berm;
- One traffic lane for service vehicles.

The tailings dam (Corna dam) will be lifted in stages using mine waste materials. The optimum use of mine waste materials, in conjunction with stability and groundwater protection considerations, resulted in selection of the centerline method of construction and a pervious dam design above the starter dam crest level. At a minimum, two downstream lifts will be constructed initially to allow time for adequate beach development prior to starting the centerline lifts.
The final elevation of the tailings dam is 840 masl and the total height is of approximately 200 masl. As the mine waste materials to be used for raising the tailings dam are potentially acid generating a secondary containment system will be provided downstream of the tailings dam.
Since the Secondary Containment Dam is provided during operations and after mine closure to collect the seepage that occurs through the pervious components of the dam made available the option of choosing the pervious dam design concept above the starter dam.
The pervious dam concept was selected for the following reasons:

- Allows drawdown of the line of saturation in the higher part of the valley, thus further reducing the potential for seepage from the tailings basin to the adjacent valleys;
- Provides a higher margin of safety over the long term;
- Allows construction procedures during dam raising that are simpler than they would be for a low permeability dam;
- Is more cost effective (in terms of construction costs) because a cut-off trench is not required above the level of the starter dam.

The downstream slope of the ultimate tailings dam was selected at a conservative angle of 3H:1V since mine rock is readily available for dam raising during operations. This slope is recommended by BAT[30] for the following reasons: the tailings dam reaches 180 m at its final height; the rock that will be used to construct the dam may be subject to degradation and strength reduction with time; after mine operation the slope will be rehabilitated and vegetated; and it will reduce visual impact. Exhibit 2.47 shows a cross section through the final dam and the amount of material required annually for dam lifts.

The Secondary Containment System will be located immediately downstream of the main dam and will consist of a 11-metre deep sump excavated into weathered rock. The rock fill dam will be about 11 m high above the riverbed with a 11 m deep positive cut-off, thus the total dam height will be 22 meter; the dam will be able to retain all seepage through the tailings impoundment and all floods up to the 500-yr event.

Spills during 500-yr, 1,000-yr floods and the PMF would be in the order of 0.6 m^3/s, 2.5 m^3/s and 25 m^3/s, respectively. The cut-off under the SCD and the dam construction materials were designed to minimise the chance of leaching materials to contaminate natural waters. The SCS watershed is approximately 54 hectares, including the tailings dam downstream face.

In the SCS sump a floating low-hydraulic lift pump station will be located which will transport water a short distance to the on-shore booster pump station supply sump. The water will be discharged in the TMF basin through an approximately 1.0 km of 219 mm O.D. steel pipe.

The schedule for raising the crest of the dam has to take into consideration two important factors:

- allowance for alternating tailings deposition from the crest of the dam and raising the crest of dam, and
- maintaining adequate freeboard with respect to the PMF event.

The scheduled dam crest elevation allows for an annual cycle of spigotting from the crest of the dam in the first part of the year and crest raising toward the end of the year. Optimization of this cycle requires that a crest lift of 20 m be completed by the end of the second year of operation and that an additional 10-metre lift is required by the end of the third year of operation.

4.3 Seal and Drainage Works

Stability considerations require removal of all alluvial soils to the bedrock surface and stripping of organics and topsoil on the valley slopes to expose suitable colluvial/residual soil. After this initial excavation, additional excavation for the core trench is required. This involves excavation through the colluvial/residual soil on the valley slopes and excavation of an upper zone of bedrock along the base of the core trench. It is estimated that about 2 m of bedrock excavation will be required below the alluvial soil in the flood plain and that about 1 m of bedrock excavation will be required along the valley slopes. Directly following the bedrock excavation, the bedrock surface will be cleaned with air jets and a slush grout layer will be placed. In case fractures on the bedrock are found injection grouting will be carried out to seal discontinuities. Clay core placement will follow the slush grouting process. Drawing 07 (Sheet A and B) shows the ground preparation procedure.

The granular drain is a 2-metre thick layer of clean stone (with filter material on each side), which is placed as a drainage layer below the downstream slope of the dam within the limits of the flood plain.
The horizontal filter and drainage zones below the downstream stage raised shell of the tailings dam are continued from those provided for the starter dam. Also, the raised dam requires a vertical filter and transition zones that are continued from the corresponding zones in the starter dam. The vertical zone filter material is required in the raised dam to ensure that no migration of tailings occurs into the downstream rockfill zone, particularly when tailings discharge from the dam is taking place resulting in a locally high line of saturation.
For stage raising the surface of the colluvial layer, which will be exposed after stripping the topsoil within the TMF basin and under the tailings dam will be compacted to form a continuous barrier layer.
Due to the dam permeability no cut-off trench is required along the centerline of the tailings dam above the crest of the starter dam. In order to maintain a lower line of saturation in the deposited tailings under-drains are provided in the TMF basin consisting of two 300 mm HDPE pipes where 150 mm HDPE side drains discharge. The under-drains are located in trenches excavated at 0.75 m under the compacted layer and covered with filter and geotextile material. Side drains are installed in 0.5 m deep trenches covered with filter and geotextile material. The drains are not required for stability purposes. However, they will facilitate consolidation of the tailings and removal of water from the basin.
Drawing 2.49, shows the general arrangement of under-drains in the TMF basin and sump water discharge pipes.

4.4 Dam Stability

MWH prepared the following studies for dam stability testing[31]:

- Starter Dam Slope Stability Analysis, March 2004 ;
- TMF Final Dam Slope Stability, April 2004;
- Secondary Containment Dam – Slope Stability Calculations, April 2005.

The items listed below were used as input parameters for the stability analysis.

Starter Dam:

- A soft rock layer (0.5 m) was assumed in the dam foundation and andesite rockfill was used as Zone 4 fill material for all stability cases;
- The Spencer slope stability method was used in the calculations which satisfies both moment and force equilibrium;
- SLOPE/W Version. 5.1 slope stability software[32] was used to run the computations for all load cases;
- Pseudostatic coefficients for Operation Basis Earthquake (OBE), Maximum Design Earthquake (MDE) Maximum Credible Earthquake (MCE) were (OBE = 0.082g, MDE = MCE = 0.14g) and were used for pseudostatic stability analysis;
- Loading cases, and assumptions are described below;
- Total strength parameters were used for colluvial liner, clay core, and soft bedrock for end of construction cases (Case 1 and Case 2); Effective strength parameters are used in all other cases;
- Total and effective strength parameters used for the analyses are presented in Table 4-2.

Table 4-2. Summary of the engineering properties of the foundation and fill materials

Zone	Material Specification	Engineering Properties				
Fill, Grout Curtain, and Tailings		γ (kN/m^3)	c_T (kPa)	ϕ_T	c' (kPa)	ϕ'
Core (Zone 1)	TMF footprint, basin and core trench excavation or Pre-stripping La Piriul Porcului Sandstone	21.9^{+}	0^{+}	15^{+}	0^{+}	30^{+}
Filter (Zone 2), Drain (Zone 5), Transition (Zone 3)	La Piriul Porcului Sandstone	21.5*	[33]			
Shell (Zone 4B)	TMF Starter-Plant site required excavation-overburden and shale	20.0^{+}	0^{+}	20^{+}	10^{+}	30^{+}
Shell (Zone 4)	Slightly weathered to fresh Sulei Andesite or La Piriul Porcului Sandstone	20.0*	[34]			
Grout Curtain-Tailings Dam	Cement Grout	NA	NA	NA	NA	NA
Grout Curtain-SCD	Cement grout	NA	NA	NA	NA	NA
Fine Tailing	Silty Clay	16.5*	NA	NA	0^{+}	20^{+}
Medium Tailings	Fine Sand	17.0*	NA	NA	0^{+}	22^{+}
Coarse Tailings	Sand	17.5*	NA	NA	0^{+}	25^{+}
Liquefied Tailings	Fine to coarse Sand	17.5*	NA	NA	0^{+}	4.4^{+}
Foundation						
Overburden	Alluvium	19.0*			0.0^{+}	26.0^{+}
Overburden	Colluvium	20.0*	0^{+}	17^{+}		
Soft Rock Layer	Shale	23.0*	0^{+}	16^{+}	86.2^{+}	20.0^{+}
Upper Bedrock	Shale	26.0*	[35]			
Lower Bedrock	Shale	26.0*	[36]			

$^{+}$ 2003, MWH, Laboratory Results or Literature Survey
* 2003 SNC LAVALIN, TMF Design Report, Appendix E: Stability Analysis

The different physical and operational configurations analysed as part of the stability analysis were as follows:
Case 1, End of Construction: No water is impounded and the piezometric surface is below the soft rock. Total strengths were used for the colluvium liner, core, and soft rock. Analyses were completed for both static and pseudostatic cases (OBE) for both downstream and upstream slopes.
Case 2, End of Construction: Water impounded to elevation 700 masl (meters above sea level) and the piezometric elevation is at 700 masl at the core face, total strength was used for the colluvium liner, core and soft rock. Static and OBE pseudostatic conditions for both the downstream and upstream slopes were analysed;
Case 3, Operational Condition: The downstream toe is at elevation 642 masl, the impoundment pool elevation is at 736 masl, and the piezometric elevation is at 730 masl at core face. The impoundment is full of tailings. Effective strength was used for static, OBE, MDE and loading conditions on the downstream slope;
Case 4, Probable Maximum Flood: The downstream dam toe is at elevation 642 masl, , and the piezometric elevation is at 730 masl at the core face. The impoundment is full of tailings. Effective strengths were used for static, OBE, MDE and loading conditions on the downstream slope;
Case 5, Liquefaction after Construction: Not applicable for analysis;
Case 6, Tailings Beach Saturated: The dam downstream toe is at elevation 642 masl, and the piezometric elevation is at 739 masl at the dam core face, and the tailings were fully saturated. Effective strengths were used for static, OBE, MDE and loading conditions on the downstream slope;
Case 7, Liquefaction with all tailings: The dam downstream toe is at elevation 642masl, the pool elevation 738 masl, and the piezometric elevation is at 739 masl at the core face. Fully saturated tailings were assumed with fully liquefied tailings and 2/3 of the Maximum Credible Earthquake (MCE) was used on the downstream slope;
Case 8, Unexpected Dam Failure: was not applied.

The results of the stability analyses completed for each case analyzed are shown in Table 4-3.

Table 4-3. Stability analysis, the starter dam

Loading Condition		Lowest Calculated Safety Factor	Minimum Required Safety Factor
Downstream			
Static	End of Construction (no water impounded in the tailings pond). Case 1a	1.5	1.3
	End of Construction (water impounded in the tailings pond). Case 2a	1.4	1.3
	Operation and Closure. Case 3a	1.8	1.5
	Flood. Case 4a	1.7	1.3
	Saturated Tailings Beach	1.7	1.3
OBE	End of Construction. Case 1b	1.2	1.1
	End of Construction. Case 2b	1.1	1.1
	Operation and Closure. Case 3b	1.4	1.1
	TMF. Case 4b	1.3	1.1
	Saturated Tailings Beach. Case 6b	1.3	1.1
MDE	Operating Conditions. Case 3c	1.2	1.1
	Probable Maximum Flood. Case 4c	1.1	1.1
	Saturated Tailings Beach. Case 6c	1.1	1.1
Liquefaction	Operation. Case 7c	1.3	1.1
Upstream			
Static	End of Construction (no water impounded in the tailings pond). Case 1a	1.9	1.3
	End of Construction (water impounded in the tailings pond). Case 2a	1.7	1.3
OBE	End of Construction. Case 1b	1.6	1.1
	End of Construction. Case 2b	1.4	1.1

All cases analysed meet or exceed the recommended minimum factors of safety (FOS) required by MWH designed structures.

Final Dam

Foundation loadings, foundation rock, strength, and other engineering parameters for the materials are presented in Table 4-4.

Spencer limit equilibrium method was used in the calculations. This method satisfies both moment and force equilibrium;

Pseudostatic coefficients for the Operation Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE) are OBE = 0.082g, MDE = MCE = 0.14g.

The different physical and operational configurations analysed as part of the stability analysis were as follows:

Case 1, Construction: End of construction is not applicable for analysis;

Case 2, End of Construction with Rapid Water Filling: Not applicable for analysis;

Case 3, Operational Condition: The downstream dam toe is at elevation 632 masl, the pool elevation is at 837.5 masl, and the piezometric elevation is at 733 masl at the dam core face. The impoundment is full of tailings. Effective strength parameters were used in conjunction with static, OBE, and MDE loading conditions for the downstream slope.

Case 4, PMF: The downstream dam toe is at elevation 632 masl, the pool elevation is at 839 masl, and the piezometric elevation is at 763 masl at the core face. The impoundment is full of tailings. Effective strength parameters were used in conjunction with static, OBE, and MDE loading conditions for the downstream slope.

Case 5, Liquefaction: Liquefaction is not applicable for this case since the dam does not have liquefiable materials.

Case 6, PMF: The downstream dam toe is at elevation 632 masl, the pool elevation is at 839 masl, and the piezometric elevation is at 763 masl at the core face. The impoundment is full

of tailings. Effective strength parameters were used in conjunction with static, OBE, and MDE loading conditions for the downstream slope.
Case 7, Liquefaction with Tailings Beach Saturated: The downstream dam toe elevation was at elevation 632 masl, the pool elevation was at 839 masl, and the piezometric elevation was at 763 masl. The impoundment was assumed to be full of saturated tailing that liquefied. A pseudostatic load of 2/3 of the MCE was applied to the downstream slope.
Case 8, Rapid Drawdown: Tailings will not be removed from the impoundment; therefore, this case is not applicable for analysis.
The results of the stability analyses completed are shown in Table 4-4.

Table 4-4. Stability analysis, final dam

Loading Condition		Lowest Calculated Safety Factor	Minimum Required Safety Factor
Static	Operation and Closure. Case 3a	2.0	1.5
	Probable Maximum Flood. Case 4a	1.9	1.3
	Saturated Tailings Beach. Case 6a	1.9	1.3
OBE	Operation and Closure. Case 3b	1.6	1.1
	Probable Maximum Flood. Case 4b	1.4	1.1
	Saturated Tailings Beach. Case 6b	1.4	1.1
MDE	Operation and Closure. Case 3c	1.3	1.1
	Probable Maximum Flood. Case 4c	1.2	1.1
	Saturated Tailings Beach. Case 6c	1.2	1.1
Liquefaction	Operation. Case 7c	1.4	1.1

All cases analysed meet or exceed the recommended minimum factors of safety (FOS) required for MWH-designed structures.

Secondary Containment Dam
Spencer limit equilibrium method was used in the calculations.
Pseudostatic coefficients for the Operation Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE) are OBE = 0.082g, MDE = MCE = 0.14g.
The different physical and operational configurations analysed as part of the stability analysis were as follows:
Case 1, End of Construction - No water is impounded - excess pore water pressure in dam core and alluvium.
Case 3^1, Operation Base Case - minimum pond level in the Secondary Containment Pond at Elevation 642 masl.
Case 3^2, Maximum Normal Operating Level (pond level at Elevation. 650 masl).
Case 8, Rapid Drawdown (pond level at El. 650 masl).
The material parameters are listed in Table 4-2.
The results of the stability analyses completed are shown in Table 4-5

Table 4-5. Stability analysis, secondary containment dam

Loading Condition		Lowest Calculated Safety Factor	Minimum Required Safety Factor
Downstream			
Static (a)	End of Construction. Case 1a	1.8	1.3
	Operation and Closure. Case 3^1a	1.9	1.5
	Operation and Closure. Case 3^2a	1.8	1.5
OBE (b)	End of Construction. Case 1b	1.4	1.1
	Operation and Closure. Case 3^1b	1.5	1.1
	Operation and Closure. Case 3^2b	1.4	1.1
MDE (c)	Operation and Closure. Case 3^1c	1.3	1.1
	Operation and Closure. Case 3^2c	1.3	1.1
Upstream			

Loading Condition		Lowest Calculated Safety Factor	Minimum Required Safety Factor
Static (a)	End of Construction. Case 1a	1.8	1.3
	Operation and Closure. Case 3[1]a	2.2	1.5
	Rapid Drawdown. Case 8a	1.9	1.1
OBE (b)	End of Construction. Case 1b	1.4	1.1
	Operation and Closure. Case 3[1]b	1.6	1.1
	Rapid Drawdown. Case 8b	1.6	1.1
MDE (c)	Operation and Closure. Case 3[1]c	1.3	1.1

All cases analysed exceed the recommended minimum factors of safety (FOS) required for MWH-designed structures.

5 TMF Operation

The proposed TMF design will provide for adequate tailings material storage volumes during the planned operating mine life. The proposed design requires a series of concurrent operating and construction/development plans and activities in stages providing for continuous oversight of the operating parameters and design limits. Operational awareness of process water and tailings volumes in a manner that recognizes BAT-BEP and associated international standards for the development, construction, operation and closure of large tailings facilities will determine the level and frequency of technical intervention and oversight.

5.1 TMF Preparation for Operation

During the construction phase the TMF basin is prepared and the starter dam and secondary containment dam are constructed as specified in Section 4. In addition, all utilities associated with the TMF are constructed:

- Tailings Delivery and Distribution System;
- Reclaim Water System;
- Electrical Power Supply;
- TMF Lighting;
- Monitoring, Inspection and Emergency Response System;
- Construction of Guard Ditches and Diversion Channels on the Slopes;
- Access Roads on the Dams and along the Pipeline Route.

In this stage training will also be provided for RMGC operational, emergency response and internal audit personnel.

A very important objective is the obtaining of the water management permit and integrated environmental agreement. These two documents will lay down the TMF specific operating conditions which should be duly observed.

Following the completion of the construction-installation and assemblage works, the TMF will be commissioned in accordance with the applicable Romanian regulations and RMGC specific procedures.

An intermediate phase for the retention of fresh industrial water (approximately 1,500,000 m^3) behind the starter dam will follow the commissioning phase.

This water volume is required for the commissioning of the processing plant in order to quickly achieve all process parameters.

5.2 TMF Start-up Procedures

Start-up procedures for the TMF will be implemented during construction of the TMF and the associated facilities.

These procedures describe the work required to begin operations of the TMFand are described in the Standard Operating Procedure TF-01, “Operations Start-Up.”

Initial start-up of the tailings management facility will involve pumping of a volume of industrial water of approximately 1,500,000 m^3 through the tailings pipeline into the tailings impoundment. Water will be used for processing plant commissioning until the design parameters are achieved and to ensure that the following systems are functioning properly:

- Tailings Delivery Pipeline: the pipeline will be checked to make sure that there are no leaks;
- Valves: valves will be checked to ensure that they are not leaking and functioning properly;
- Spigots and dropbars: spigots will be checked to make sure that they are discharging in a manner consistent with the design philosophy;

- Reclaim Water Barge and Pump: the barge and pump will be checked to ensure that the barge flotation is adequate and the reclaim water pump is functioning within manufacturer specifications;
- Tailings Reclaim Water Pipeline: the reclaim line will be checked to ensure that there is no leakage; and
- Instrumentation: all instrumentation related with the tailings delivery system and water reclaim system will be checked to ensure that it is functioning properly.

After the system has been checked and the required start-up water volume has been accumulated in the impoundment, actual tailings will be pumped through the system. Once again, all the systems mentioned previously will be checked to ensure they are functioning properly.

The process tailings will be pumped from the processing plant through a 800 mm dia. high density polyethylene pipe 4.35 km in length located along the northern part of the TMF. The HDPE will be protected against ultraviolet rays. There are two alternatives for the TMF discharge: the discharge will be carried out at one or two points located on the TMF slopes for intermittent running, or it will be discharged using a distribution system located on the dam crest with distribution points located 50m apart and each point is controlled by a gate valve. The fixed overflow points will be used during the earth dam lift stage.

To prevent excess movements caused by expansion or contraction, certain sections of the tailings transport system will be covered with earth berms. The sections of the pipeline that remain uncovered will be placed in ditches to ensure the collection of any leakage. These ditches will report to either the TMF retention basin or the emergency retention basin at the processing plant.

The tailing transport system will be designed and rated for maximum flow-rates of 2350 m^3/h and 2730 m^3/h respectively and a maximum solid content of 48.5% in the pulp and minimum transport speed of 1.5m/s; the pulp pH is expected range between 9-11. An earthen berm(s) will be installed along un-contained sections of the tailings transport system. In the event of an transport incident in this system RMGC will immediately shut down flow to the TMF and respond to the event in an appropriate manner to contain the release.

The water recycling system will take the clarified water from the TMF to the process water storage tank at the processing plant. The system includes a low pressure pumping station located on a floating barge which can deliver the water under pressure through a flexible 150 m pipe and a HDPE 680m pipe to the high pressure supply basin of the pump station. The high pressure pump station will deliver the water through a pipe that is 2029 m long (429 m PN 16 HDPE and 1,600m PN8 HDPE). The recycling system has been designed for average and maximum flow-rates between 1,520 m^3/h and1,820 m^3/h and will cover most of the process and project water requirements.

The processing tailings deposition behind the dam will be carried out in a classic manner, by under water deposition.

Tailings will initially be discharged from the embankment crest to form a sub-aerial beach along the embankment toe. Long polyethylene dropbars will extend down the face of the starter embankment to carry tailings to the embankment bottom in order to prevent erosion of the embankment face.

5.3 Normal Operating Procedures

Normal operating procedures for the TMF are addressed in TF-02, “Normal Operating Procedures- Tailings Deposition” and TF-03, “Normal Operating Procedures- Tailings Water Management.”

The tailings deposition procedure (TF-02) discusses discharge of tailings from spigots and dropbars and how to change discharge points in order to optimize the impoundment filling efficiency.

The critical aspects of the distribution system are as follows:

- avoid erosion of the basin and embankment;
- provide control for maintaining the supernatant pond on the southeast side of the impoundment to ensure proper functioning of the reclaim water system;
- minimize the thickness of each tailings depositional layer to maximize drying and consolidation; and
- maintain the supernatant pond size as small as possible to maximize the beach thereby promoting maximum identification of tailings.

Tailings water management procedure TF-03 addresses normal operation of the barge mounted reclaim water pump that will withdraw water from the impoundment and pump it back to the process plant. In general, the decant pond at the TMF will be operated with a pond volume in between 1,000,000m^3 and 4,000,000m^3. Regulation of the decant pond volume will be accomplished by controlling the amount of make-up water being taken from the Arieş River.

Tailings Delivery and Distribution System.
The tailings slurry detoxified within the processing plant site will be pumped to the TMF through a dedicated 800-mm high-density polyethylene (HDPE) pipe. The total pipe length is approximately 4,350 m.

The delivery pipeline will comprise a mainline reaching the starter dam crest where the tailings are discharged through spigots on the dam (approximately 50 m of space per spigot) as specified in Section 4. Each spigot will be controlled by a knife gate valve.
When tailings discharge starts, the tailings will initially be completely submerged until a substantial tailings beach is developed against the starter dam, at which point the final dam lift will commence.

In order to lift the dam the tailings discharge into the TMF will not be carried out from the starter dam crest, but through either one of two single point discharge lines located on the TMF slopes and controlled by knife gate valves.

Two downstream lifts will be constructed initially:

- the first lift, will be completed by the end of the second year of operation; and
- the second lift, will be completed by the end of the third year of operation.

The subsequent lifts will be constructed by the centreline method.
The normal lift cycle consists of two phases:

- Tailings discharge into the TMF from the dam crest, to be carried out in the first part of the year when the beach reaches a level suitable for dam lifts;

- Lifts of the tailings dam to be carried out toward the end of the year, so that at the beginning of the cold season the lift is completed.

Geotextile will be placed on the tailings surface prior to fill placement to reduce loss of fill by displacement into the tailings and to enhance stability of the fill with respect to shear displacement in the upstream direction.
The dam will be raised simultaneously with the lift of the filter/transition zones downstream of the starter dam and the crested emergency spillway for emergency discharges.
Drawing 09 shows a cross-section through the main dam and secondary containment dam. The drawing also shows details of the main dam components, the first two rockfill lifts by the downstream method and the subsequent dam lifts to the final elevation by the centreline method.
The amounts of waste rock material required for each lift of the main dam are also shown in drawing 09.
Drawing 09 shows curves of elevation versus year of operation for the volumes of tailings deposited in the TMF and also for the total TMF storage capacity considering the tailings, operational water and two PMF events.
In the final years of operation, tailings deposition will be arranged in a manner to ensure a beach consistent with the beach required at closure, with a 0.5% slope towards the final decant water area that will be pumped into the pits.

Process Water, Precipitation and Upstream Flood Management
From the flood flow direction standpoint the operational parameters of the TMF basin and SCS sump are consistent throughout the project life. However, the size of the TMF, the tailings deposit volume and available flood storage volume will change during the project life until closure.

The monthly water balance under normal operating conditions for both the TMF basin and SCS sump for each year of the 16 years of operation is presented in Table 5. The design criteria for the TMF are presented below[37]:

- The TMF pond provide a full containment of all flood events, including the Probable Maximum Flood (PMF) throughout the project life;
- The TMF 5m wide crested spillway located on the main dam crest is sized to safely pass a 10-yr flood occurring immediately after the PMF. The spill over the TMF during this event would be in the order of 2.3 m^3/s;
- the SCS pond has sufficient capacity to store the runoff volume from a 24 hour rainfall event with a return period of 100 years;
- The 27 m wide crested emergency spillway is designed to contain the flood from the events with the following return periods:
- 500 years, spill is in the order of 0.6 m^3/s;
- 1000 years, spill is in the order of 2.5 m^3/s;
- PMP, spill is in the order of 24.7 m^3/s

A concrete spillway channel with a capacity of approximately 5 m^3/s, 10m wide and a flow stream depth of 0.4 m (the channel depth is minimum 1 m) will be provided for the post-closure period (after reconstruction of the deposited tailings geometry and covering of the tailings facility with soil so that a gradient of 0.5% toward the right slope is developed). An energy disperser will be provided at the downstream end of the spillway.
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TMF Seepage Management

Two scenarios are available for the seepage from the TMF reporting to the secondary containmnent pond.

It is anticipated that for a period at the beginning of operation, the seepage is conventionally clean water which can be discharged into the Corna Valley.

Immediately after contaminant if concentrations greater than the permit limits are detected in the seepage water, seepage will then be collected in the secondary containment sump and pumped back to the TMF basin. The treatment method will be identified based on the composition of the seepage water in view of achieving the permit levels for discharge into the receiving stream.

Development of a treatment system for the seepage from the tailings impoundment is a very important component of the long-term TMF water management. This system will be an important aspect of the closure and post-closure phase.

Table 5-1. Evolution of TMF Parameters

Year	Production (tonnes)	Cumulative Production (tonnes)	Density (tonnes/m^3)	*Cumulative Required Tailings Storage* (m^3)	Maximum Operating Water Storage 95 Percentile Summer (m^3)	Winter (m^3)	2 times Winter PMF (m^3)	Total Water Storage Required (Operating+2 PMFs) Summer (m^3)	Winter (m^3)	Largest Water Volume Required (m^3)	*Cumulative Required Total Storage* (m^3)
1	11.762.000	11.762.000	1,25	9.409.600	2.526.505	2.492.225	5.500.000	8.026.505	7.992.225	8.026.505	17.436.105
1,25	3.253.500	15.015.500	1,250	12.012.400	2.544.859	0	5.500.000	8.044.859	5.500.000	8.044.859	20.057.259
2	9.760.500	24.776.000	1,250	19.820.800	2.599.921	2.500.000	5.500.000	8.099.921	8.000.000	8.099.921	27.920.721
3	13.320.000	38.096.000	1,250	30.476.800	2.659.218	2.500.000	5.500.000	8.159.218	8.000.000	8.159.218	38.636.018
4	13.190.000	51.286.000	1,250	41.028.800	2.701.515	2.500.000	5.500.000	8.201.515	8.000.000	8.201.515	49.230.315
5	13.300.000	64.586.000	1,250	51.668.800	2.783.760	2.508.992	5.500.000	8.283.760	8.008.992	8.283.760	59.952.560
6	13.515.000	78.101.000	1,258	62.083.466	2.862.680	2.585.275	5.500.000	8.362.680	8.085.275	8.362.680	70.446.146
7	14.248.000	92.349.000	1,266	72.945.498	2.986.635	2.651.657	5.500.000	8.486.635	8.151.657	8.486.635	81.432.132
8	13.990.000	106.339.000	1,275	83.403.137	3.059.203	2.695.740	5.500.000	8.559.203	8.195.740	8.559.203	91.962.340
9	14.881.000	121.220.000	1,283	94.481.684	3.172.163	2.785.234	5.500.000	8.672.163	8.285.234	8.672.163	103.153.846
10	15.413.000	136.633.000	1,291	105.835.012	3.268.979	2.887.796	5.500.000	8.768.979	8.387.796	8.768.979	114.603.991
11	15.317.000	151.950.000	1,300	116.884.615	3.459.059	3.076.608	5.500.000	8.959.059	8.576.608	8.959.059	125.843.674
12	13.712.000	165.662.000	1,308	126.652.905	3.717.439	3.375.770	5.500.000	9.217.439	8.875.770	9.217.439	135.870.344
13	14.212.000	179.874.000	1,316	136.682.371	4.153.369	3.824.804	5.500.000	9.653.369	9.324.804	9.653.369	146.335.740
14	14.250.000	194.124.000	1,325	146.508.679	4.618.426	4.323.788	5.500.000	10.118.426	9.823.788	10.118.426	156.627.105
15	13.463.000	207.587.000	1,333	155.729.182	5.113.524	4.911.224	5.500.000	10.613.524	10.411.224	10.613.524	166.342.706
16	7.318.000	214.905.000	1,341	160.257.271	5.724.856	5.583.479	5.500.000	11.224.856	11.083.479	11.224.856	171.482.127
17	0	214.905.000	1,350	159.188.889	6.428.623	6.831.070	5.500.000	11.928.623	12.331.070	12.331.070	171.519.959
Total	214.905.000										

Notes:
1. Production based on IMC Mine Plan Report 04/06
2. Maximum operating water storage based on 95 th percentile from the water balance prepared by MWH (JET Rev 14.0)
3. Densities based on assumed values.
4. Assume larger (Winter) PMF for storage requirements.
5. Design accounts for two PMFs

Available Flood Storage Capacity

6 TMF Organizational Structure And Monitoring System

6.1 Configuration, Roles and Responsibilities of Various Organizational Structures

The TMF management should be effective and aim at minimizing both the environmental impacts and operating costs.
The organisational structure of the TMF management is part of the Project organisational structure and is directly subordinated to the Production Manager.
An efficient management requires data input from the Production, Engineering and Environmental Staff. Also, output data is directed primarily toward these departments.
A department directly subordinated to the Processing Plant Manager will be set up for the management of the TMF and associated facilities.
Figure 6.1 shows the organizational structure of the personnel responsible for the TMF operation, maintenance and monitoring. The roles, responsibilities and authority of each member of the organizational structure are presented in Table 6.1.

Figure 6.1 Organisational Structure

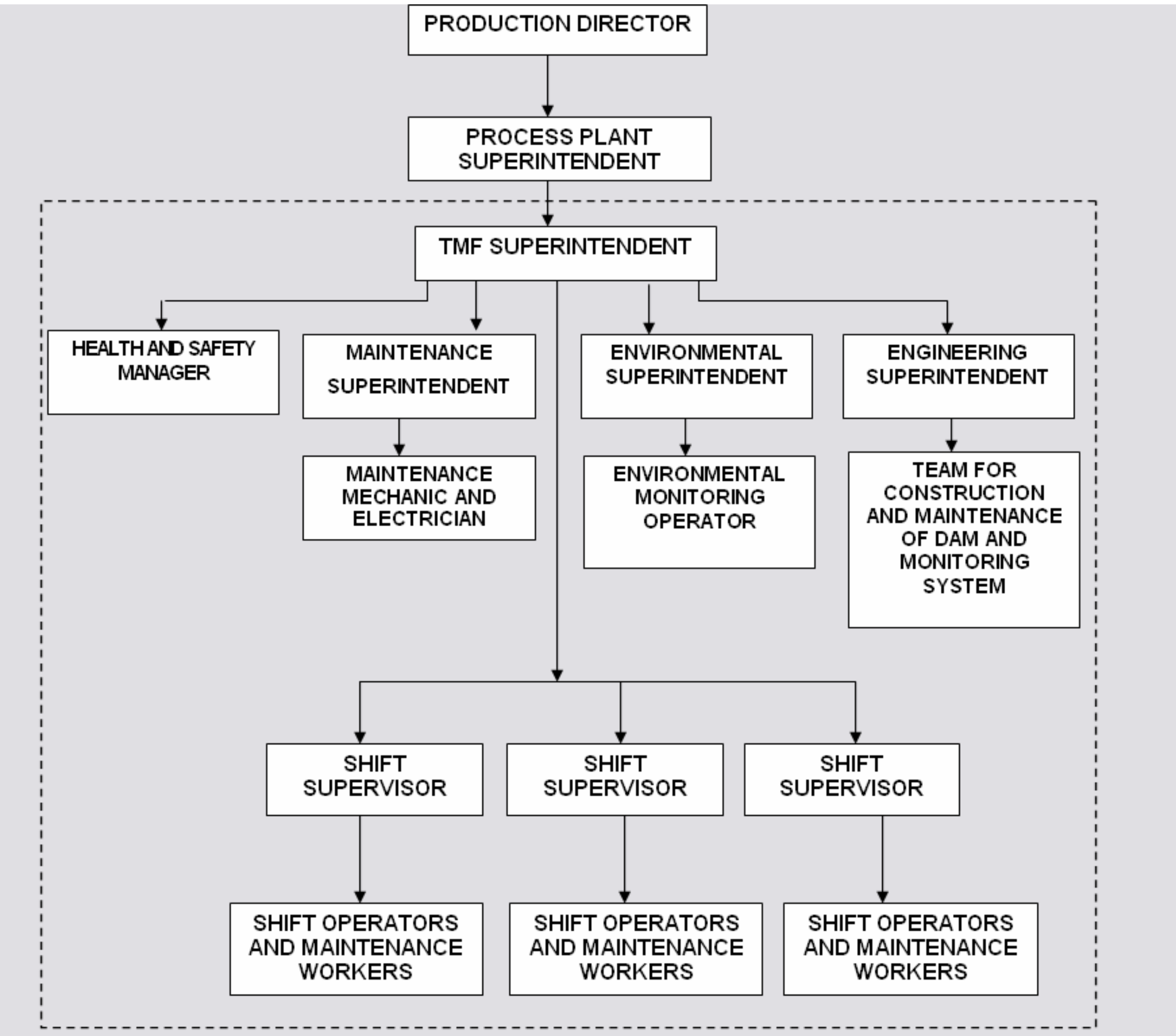

Table -6.1. Roles and Responsibilities of the TMF Operations, Maintenance and Monitoring Staff

Position	Role	Responsibilities	Authority
Director, Production General Manager	Overall Coordination	• Senior TMF operations and construction oversight • Provide recommendations for improvement of the tailings operations • Co-ordinate with other areas or departments of the mine that may interact with the tailings operations • Maintain relationships with external stakeholders related to the TMF	• Authorisation of dam annual operation plan and sustaining capital budgets
Process Plant Superintendent Process Manager	Overall Management	• Senior TMF operations and construction oversight • Co-ordinate with other areas or departments of the mine that interact with the tailings operations • Provide recommendations for improvement of the tailings operations • Evaluate the TMF periodic reports.	• Assignment of resources to Tailings Superintendent consistent with capital and operational budgets • Hiring/supervision of Tailings Superintendent • Directly coordinates emergency response actions • Approves the annual, quarterly and monthly TMF work program
Tailings Superintendent Supervisor	Manager of Tailings System	• Participate at the periodic and final acceptance of TMF construction works • Participate in start-up and commissioning • Sustains the proposed capital and operational budgets • Take all necessary measures for TMF operations, maintenance and monitoring • Communicate potential problems related to the tailings operation to upper level management • Co-ordinate with other areas or departments of the mine that interact with the tailings operations • Co-ordinate work of sub-contractors to operate and maintain the TMF • Directly co-ordinate annual, quarterly and monthly work programmes for TMF operations, maintenance and monitoring • Revises on an annual basis: – Emergency Preparedness and Spill Contingency Plan – Preliminary Closure Plan • Ensure strict observance according to schedules of the measures established by authorities or internal auditors • Ensures compliance of TMF operation with the permits issued by the competent authorities • Carry out monitoring activities as per the Environmental and Social Monitoring Plan and operational requirements • Periodically review and improve the Standard Operating Procedures and Equipment Maintenance Procedures • Provide and review inventory of equipment, spares and materials • Perform maintenance and repairing of equipment, pipes, access roads, diversion channels etc.	• Hiring/supervision of TMF operational staff • Establish tasks, responsibilities and duties for the subordinated staff

Position	Role	Responsibilities	Authority
		• Decide, follow-up, supervise and verify the activity of the directly subordinated personnel • Prepare and update training programs for TMF personnel Update the TMF water balance	
Engineering Superintendent	Directly co-ordinate the construction, repair and maintenance of the main dam Periodically inspect dam stability	• Propose and implement the schedule for the main dam lift and associated works • Propose and implement the maintenance and repair schedule for monitoring equipment • Propose investment plans • Provide technical support for all coordinated activities • Interpretation of operational monitoring results	• Recommend actions to Tailings Superintendent resulting from interpretation of dam monitoring data • Establish tasks, responsibilities and duties for the subordinated staff to be submitted to the approval of the Tailings Superintendent • Supervise observance of health and safety rules by the subordinated staff
Environmental Superintendent	Oversee compliance with environmental regulations and provisions of environmental and water management permits	• Implement activities as required by TMF environmental permits • Perform monitoring according to environmental permit and internal RMGC plan and procedure requirements • Provide environmental training and technical support for exclusive tailings facility personnel • Interpret, record and report environmental monitoring data • Validate environmental laboratory test results • Inspect the proper operation of measurement, analysis and testing equipment in accordance with the relevant regulations	• Provide recommendations to the TMF Superintendent with respect to environmental monitoring • Provide recommendations for improvement of procedures • Supervise and report on the research activity for determining and finalizing the semi-passive seepage treatment system • Supervise observance of health and safety rules by the subordinated staff
Maintenance Superintendent	TMF pumps, electrical and piping maintenance	• Ensure repair and maintenance activities during each shift • Provide spares and materials for repair and maintenance • Ensure compliance with RMGC internal programs, plans and procedures • Emergency response in accordance with given instructions • Propose improvements to the repair and maintenance Plans, Manuals and Procedures • Establish, supervise, co-ordinate and inspect the training activities for the subordinated staff • Provide recommendations for improvement of the tailings operations	• Supervise observance of health and safety rules by the subordinated staff • Establish tasks, responsibilities and duties for the subordinated staff • Inspect and accept contracted repairing works
Health and Safety Manager	Facility and personnel health and safety	Ensure TMF considerations are incorporated into the overall RMGC *Occupational Health and Safety Plan,* and that the *Plan* is properly implemented • Detect and communicate potential Health and Safety problems related to the tailings operation to upper level management • Provide health and safety training for TMF personnel	• Stopping of activities deemed imminently dangerous • Take measures and report in case of accidents as per the Procedures
Shift Supervisor	Primary operations responsibility (day to day)	• Supervise all TMF operations during his shift in accordance with the Standard Operating Procedures and Manual • Provide daily reports on the operations carried out on his shift • Provide recommendations for improvement of the tailings operations	• Responsible for observance of all occupational Health and safety rules by the subordinated staff • Establish and supervise the work schedule for each shift

6.2 TMF Monitoring System and Actions

TMF monitoring activities are in agreement with the overall objective to minimize the impact on the environment, human health and property during all phases of the Roşia Montană Project life cycle and long term post mine closure.
The general requirements of the environmental and social monitoring program are documented in the *Roşia Montană Project Environmental and Social Management Plan.* This Plan is a management tool designed to support RMGC in maintaining an accurate understanding of all monitoring and reporting requirements for each phase in the Project life cycle. The *Environmental and Social Monitoring Plan* is periodically benchmarked against applicable legal and regulatory requirements.

Construction Phase Monitoring
Construction phase monitoring activities include site inspections and collection and analysis of associated monitoring data.
Such inspections, analyses, and monitoring are required in order to ensure:

- appropriate construction management techniques are being employed in accordance with the design criteria, environmental factors are protected and impacts are minimized, and human health and property are not affected;
- continued compliance with regulatory requirements and approved construction practices; and
- appropriate mitigation measures are properly specified, implemented, and functioning.

Exhibit 2.53 shows the surface water and ground water monitoring locations during pre-construction and construction.
Air quality, noise and biodiversity monitoring locations will be set near the following work areas: roads, dams, TMF storage pond, diversion channels within the Project footprint, near protected areas, with wind directions in accordance with the *Air Quality Management Plan*, *Biodiversity Management Plan* and *Occupational Health and Safety Plan*.

Operational Phase Monitoring
The tailings management facility (TMF) requires extreme care from the mining operator (RMGC).
The Engineering Design for the TMF and associated facilities should include specific construction, inspection and acceptance procedures for all completed works.
The environmental impacts and quality of completed works should be monitored as early as the construction phase.
Monitoring of environmental impacts, quality of works and equipment condition will continue throughout operation and closure.
The overall monitoring, inspection and reporting/recording activity will be conducted based on specific procedures to be developed.
The TMF Corna dam will be instrumented as follows:

- Vibrating wire piezometer;
- Hydraulic piezometer;
- Slope indicators;
- Deformation monitoring stations;
- Piezometer nests for groundwater monitoring; and,
- V-notch weir for flow measurements.

A total of six vibrating wire piezometers are planned for installation in each of the three elevation locations within the central core of the starter dam section. In addition, two vibrating wire piezometers will be located at different elevations downstream of the grout curtain. Two additional vibrating wire piezometers are proposed at two locations in the downstream shell of the dam to determine if there is an unexpected rise in the line of saturation for this area. These piezometers will monitor the under-drainage system.

Nine hydraulic piezometers will be installed in the upstream tailings beach. The piezometers will tentatively be located about 200 m apart from each other across the valley. Five piezometers will be located 100 m upstream of the dam centreline and three piezometers will be located 200 m further out on the beach with one planned closer to the right abutment. The hydraulic piezometers will be installed from the beach and will be lifted in advance of the tailings beach. The purpose of the piezometers is to determine the line of saturation in the tailings and to determine the rate of water level drop after the spigots for tailings are moved to another area.

Two temporary slope indicators are planned for installation on the downstream slope of the starter dam and on a lower berm of the final dam. The purpose of the slope indicators is to check for possible downstream shear deformation at shallow depth in the bedrock. A permanent nest of piezometers will be provided on each ridge of the Corna Valley, upstream of the tailings dam, for monitoring groundwater levels and quality. An existing nest on the left ridge will be used for this purpose and a new nest will be installed on the right ridge.

A V-notch weir will be provided in the valley channel just upstream of the sump. During sustained dry periods, the flow at this weir should be indicative of the seepage rate through and under the tailings dam.

Two sets of vibrating wire piezometers will be located in the secondary containment dam, both upstream and downstream of the grout curtain. These piezometers will assess the hydraulic containment of the secondary containment dam. Survey deformation stations will be established on the dam to monitor any potential movements.

Downstream of the dam, it is planned to monitor groundwater levels and quality from the existing piezometer nest.

Table 6-2 lists typical monitoring parameters and recording frequency that will be used to evaluate the TMF performance. Drawing 12A and 12B indicates the location and type of instrumentation that will be installed in the dams.

Table- 6.2 TMF Monitoring

Parameter	Frequency
Precipitation	Daily
Vibrating Wire Piezometer	Weekly
PM-10	Monthly and Quarterly
Total Tailings Slurry Volume	Continuous
pH of tailings slurry	Continuous
Slurry Concentration (Density)	Continuous
Tailings Line Pressure	Continuous
Dilution Water Flow Rate (to cyclone)	Continuous
Water Reclaim to Mill	Continuous
Tailings Stored Volume (from topographic survey)	Annual
Tailings Chemistry	Weekly
Supernatant Volume in the TMF	Monthly
Supernatant Water Quality	Monthly, Quarterly, and Bi-Annual
Seepage Total Volume	Weekly
Seepage Chemistry	Weekly
Survey Profiles of Dam	Monthly
Visual Inspection of Dam	Daily
Expert Review of TMF	Annual

In addition to the above parameters, the following will be monitored:

- Air quality within the Corna dam area;

- Surface water flow rates and quality in the Corna Valley downstream of the TMF (Exhibit 6.3);
- Groundwater flow rates and quality along the Corna Valley downstream of the TMF and on the north hillside (Exhibit 6.3);
- Wildlife mortality downstream of the Corna Valley;
- Personnel health status and safety conditions.

The quality parameters of surface water and groundwater that will be determined are presented in Table 6-3.

Table-6.3 - Surface Water and Groundwater Quality Parameters and Determination Method

No.	Parameter	Analytical Method	Maximum Permissible Limit
Site Parameters		*Data Acquired using Specific Instrumentation*	
1.	Mitigation Potential	Data acquired with CONSORT P601 in accordance with manufacturer's instructions	N/A
2.	Conductivity	Data acquired with HACH SENSION 156 in accordance with manufacturer's instructions	N/A
3.	pH	Data acquired with HACH SENSION 156 in accordance with manufacturer's instructions	N/A
4.	Turbidity	Data acquired with SPEKOL spectrometer in accordance with manufacturer's instructions	0.1 NTU
5.	Temperature	Data acquired with HACH SENSION 156 spectrometer in accordance with manufacturer's instructions	N/A
Laboratory Parameters			
6.	Suspended particulates	STAS 6953/81	0.5 mg/l
7.	Sodium	STAS 3223 – 1/91	5 µg/l
8.	Potassium	STAS 3223 – 2/91	15 µg/l
9.	Calcium	STAS 3662/90	3 µg/l
10.	Barium	APHA Standard Methods (1992), method 3113.B	1 µg/l
11.	Magnesium	SR ISO 7980/86	10 µg/l
12.	Antimony	APHA Standard Methods (1992), method 3114.B	0.05 µg/l
13.	Arsenic (total)	APHA Standard Methods (1992), method 3114.B	0.05 µg/l
14.	Arsenic (dissolved)	APHA Standard Methods (1992), method 3114.B	0.05 µg/l
15.	Chlorides	STAS 3049/88	0.40 µg/l
16.	Sulfate	STAS 3069/87	0.40 µg/l
17.	Iron (total)	SR 13315/96	25 µg/l
18.	Iron (Fe^{2+})	SR ISO6332/96	10 µg/l
19.	Manganese	APHA Standard Methods (1992), method 3113.B	1 µg/l
20.	Lead (total)	APHA Standard Methods (1992), method 3113.B	1 µg/l
21.	Lead (dissolved)	APHA Standard Methods (1992), method 3113.B	1 µg/l
22.	Copper (total)	APHA Standard Methods (1992), method 3113.B	1 µg/l
23.	Copper (dissolved)	APHA Standard Methods (1992), method 3113.B	1 µg/l
24.	Cadmium (total)	APHA Standard Methods (1992), method 3113.B	1 µg/l
25.	Cadmium (dissolved)	APHA Standard Methods (1992), method 3113.B	1 µg/l
26.	Zinc (total)	APHA Standard Methods (1992), method 3113.B	1 µg/l
27.	Zinc (dissolved)	APHA Standard Methods (1992), method 3113.B	1 µg/l
28.	Nickel (total)	APHA Standard Methods (1992), method 3113.B	1 µg/l
29.	Nichel (dissolved)	APHA Standard Methods (1992), method 3113.B	1 µg/l
30.	HCO_3/CO_3	SR ISO 9963 – 1	N/A
31.	Nitrate	STAS 3048 – 1/77	20 µg/l
32.	Fluoride	STAS 3048 – 2/77	50 µg/l
33.	Selenium	APHA Standard Methods (1992), method 3114.B	0.05 µg/l
34.	Cobalt	APHA Standard Methods (1992), method 3113.B	1 µg/l
35.	Cyanide (total)	STAS 10847/77	2.5 µg/l
36.	Mercury	STAS 8045-79	0.1 µg/l
37.	Molybdenum	APHA Standard Methods (1992), method 3113.B	1 µg/l
38.	Chrome (total)	SR ISO 9174	1 µg/l
39.	Chrome (sexavalent)	STAS 7884/91	10 µg/l
40.	Phenols	STAS R 7167/92	10 µg/l
41.	Phosphates	SR ISO 10304/99	10 µg/l
42.	Biological oxygen consumption	STAS 6560/82	N/A
43.	Chemical oxygen consumption	SR ISO 6060/96	N/A
44.	Silicone Oxide	STAS 9375/75	N/A
45.	Residue (dissolved Salts) at 105°C	STAS 6953/81	0.5 µg/l

The main purpose of the TMF is to contain process water in a manner that allows it to be recycled to the plant, prevent accidental tailings and process water discharges to the environment, capture and contain contaminated waters from areas in the Corna Valley basin that are disturbed or impacted by mine operations and to provide a full containment of all flood events, including the Probable Maximum Flood (PMF), and to accommodate the safe long-term (hundreds of years) deposition of tailings post mine closure.
These objectives of the TMF may be reached by complying with the following:

- Operation of the tailings distribution system will be performed in accordance with procedures TF-01 "Operations Start-up", TF-02 “Normal Operating Procedures – Tailings Deposition” and TF-03 “Normal Operating Procedures - Tailings Water Management”;
- Operation of the reclaim water system in accordance with procedures TF-01 and TF-02;
- monitoring of the water quality in the tailings in accordance with the operational and environmental requirements established for the current approved version of this Tailings Management Facility Plan; sampling, analysis and reporting of water quality in the tailings will be conducted in accordance with the Environmental and Social Monitoring Plan;
- monitoring and reporting groundwater and surface water quality at the predetermined control points downstream of the TMF, to ensure compliance with environmental and water management permits; such activities will be performed in accordance with the requirements of the Project Stream Flow Measurement Process Operation Manual and the Roşia Montană Environmental Database;
- monitoring surface water flow in the Corna Valley downstream of the TMF to ensure compliance with the requirements of the environmental permit and water management permit;
- reviewing and updating the procedure for tailings deposition in the TMF: TF-02, “Normal Operating Procedures – Tailings Deposition”;
- reviewing and updating the TMF water balance according to WT-01, “Preparation, Review and Periodic Update of Project Water Balance”
- maintaining records of the tailings that go into the impoundment with respect to flow and concentration;
- maintaining records of the sludge from the ARD treatment plant that goes into the impoundment with respect to flow and concentration;
- maintaining records of the flow of water recycled by pumping from the Secondary Containment Pond;
- maintaining and inspecting clean surface water diversion channels so that they continue to operate at design capacity;
- maintaining records of the flow of recycled water delivered to the processing plant;
- periodically reviewing and updating supernatant water quality standards in response to changes in operational and environmental requirements.
-

Inspections and Reporting
Operational inspections of the TMF will be completed on regularly scheduled intervals in accordance with procedure TF-04, “Tailings Management Facility-Operations Inspection.”

This procedure addresses the detailed inspection requirements and schedule for inspection of the:

- embankment;
- impoundment;
- surface water ditches;
- diversion channels;
- tailings delivery and discharge system;
- tailings water reclaim system;
- compaction level of waste rock fill for dam lift;
- slope angle of downstream half of the tailings dam;
- monitoring instrumentation.

The majority of the inspections will involve assessment of the physical and operational soundness of these systems.

Standard reports will be completed in accordance with the protocols presented in procedure TF-05, “Tailings Management Facility- Operations Reporting” that summarize the inspections that have been made on the various facets of the TMF. Reporting will be completed on standard forms (see TF-05) to ensure that all the correct elements for the TMF are inspected and that there is uniformity and comparability in the inspection data even though different personnel may have performed the inspection.

After required reports are completed, they will be filed in accordance with MP-12, “Management of Environmental and Social Management System Records.”

In addition, reports that are required by the mine permit will be forwarded to the necessary regulatory agencies in accordance in accordance with MP-02, “Identification of Legal and Regulatory Requirements.”

6.3 Closure Phase Monitoring

The closure phase involves decommissioning of all equipment and facilities followed by the environmental reconstruction of the site. The preliminary closure plan is in the process of being prepared, however it will be finalized during the last year of operation. The Closure and Post-Closure Monitoring Plan will also be finalized during this period.

The following factors will be monitored during closure: groundwater and surface water quality and quantity; local biodiversity; seepage quality and quantity; air quality and noise in work areas and at TMF boundary; quality of TMF regrading works; quality of the cover system and revegetation; quality of slope runoff management; quality of works for the semi-passive seepage treatment system.

The closure monitoring plan will be finalized at the end of operations and will take into account the requirements of the local authorities and regulatory agencies.

6.4 Post-closure Phase Monitoring

The following environmental factors will be monitored after the TMF closure:

- groundwater will be monitored in the same manner as during operations using vibrating wire piezometers;
- surface water monitoring will be similar to the operational phase;
- air quality will be monitored at the Meteorological Station;
- the condition of the TMF surface, dam faces and berms will be monitored using slope indicators and deformation monitoring stations.

RMGC will develop by the end of operations a specific and complete monitoring plan which will include specific procedures for any type of monitoring and the methods for recording and reporting of monitoring results.
This monitoring plan will be part of the final closure plan which will be submitted to the competent authorities for approval.

7 TMF closure

At the end of operational period the Tailings Management Facility will be prepared for closure.

The preparatory work for TMF closure will primarily consist of modification of the tailings disposal system to achieve the final landform required by the cover system.

At the end of the operational period, after tailings delivery has ceased, the TMF pond will store a volume of approximately 6 million m^3 of supernatant water in the TMF and have additional storage capacity for two probable maximum floods.

After treatment of the TMF reclaim pond, it is planned to pump the supernatant water stored in the TMF pond to the Cetate Pit. In addition, it is planned to carry on TMF seepage water management until the water meets the permit levels for discharge into the receiving stream.

7.1 Assessment of Water Management Associated with the TMF during Closure and Post-closure

Supernatant Water Management and Treatment
The composition of the expected supernatant water in the tailings pond was determined based on laboratory testing on three samples and is presented in Table 7-1.

Table 7-1. Expected Supernatant Water Composition

	Sample[2]			TN001 Standard		Sample[2]			TN001 Standard
	RM1	RM2	RM3			RM1	RM2	RM3	
Total Cyanide[3]	1.13	5.09	3.29	0.1	Manganese	0.3	0.8	<0.1	1
WAD Cyanide[3]	0.37	0.77	0.22	...	Molybdenum	0.4	0.3	0.4	0.1
Thlocyanate	70	69	91	...	Sodium	725	900	705	..
Cyanate	390	390	350	...	Niobium	<0.1	<0.1	<0.1	...
Thiosalts	<2	<2	2.50	...	Neodymium	<0.01	<0.01	<0.01	...
Ammonia	6.6	7.3	25	2	Nickel	0.20	0.40	0.20	0.5
Gold	0.0085	0.043	0.0165	---	Phosphorus	<1	<0.5	<1	...
Silver	<0.05	<0.05	<0.05	0.1	Lead	<1	<1	<1	0.2
Aluminium	<0.2	0.2	0.20	5	Praseodymium	<0.005	<0.005	<0.005	...
Arsenic	0.30	<0.2	0.20	0.1	Rubidium	0.35	0.35	0.50	...
Boron	0.20	0.2	0.40	...	Sulphur	660	1030	962	...
Barium	<0.05	<0.05	<0.05	...	Sulphate[1]	1980	3090	2886	600
Beryllium	<0.02	<0.05	<0.02	...	Antimony	0	0.28	0.06	...
Bismuth	<0.02	<0.02	<0.02	...	Scandium	<0.5	<0.1	<0.5	...
Calcium	401	675	707	300	Selenium	<5	<5	<5	0.1
Cadmium	<0.5	<0.1	<0.5	0.2	Silicon	8	6	8	...
Cerium	<0.01	<0.01	<0.01	...	Samarium	<0.01	<0.01	<0.01	...
Cobalt	0.40	0.40	0.80	1	Tin	<0.2	<0.2	<0.2	...
Chromium	<0.2	<0.2	<0.2	1	Strontium	1.4	2.1	2.1	...
Cesium	<0.02	<0.02	<0.02	...	Tantalum	<0.005	<0.005	<0.005	...
Copper	0.10	0.10	0.10	0.1	Terbium	<0.005	<0.005	<0.005	...
Dysprosium	<0.01	<0.05	<0.01	...	Tellurium	<0.1	<0.1	<0.1	...
Erbium	<0.01	<0.05	<0.01	...	Thorium	<0.01	<0.01	<0.01	...
Europium	<0.002	<0.05	<0.002	...	Titanium	<0.2	<0.2	<0.2	...
Iron	0.20	1.4	1.0	5	Thallium	<0.01	<0.01	<0.03	...
Gallium	<0.2	<0.1	<0.2	...	Thulium	<0.005	<0.005	<0.005	...
Gadolinium	<0.05	<0.05	<0.05	...	Uranium	<0.01	<0.01	<0.01	...
Germanium	<0.5	<1	<0.5	...	Vanadium	<0.5	<0.5	<0.5	...
Hafnium	<0.1	<0.1	<0.1	...	Tungsten	<0.1	<0.1	<0.1	...
Mercury	<0.01	<0.01	<0.01	0.05	Yttrium	<0.01	<0.01	<0.01	...
Potassium	142	136	132	...	Ytterbium	<0.01	<0.01	<0.01	...
Lanthanum	<0.01	<0.01	<0.01	...	Zinc	<0.2	<0.1	<0.2	0.5
Lithium	<0.1	<0.1	<0.1	...	Zirconium	<0.1	<0.1	<0.1	...
Magnesium	5.4	14.4	8.2	100					

Notes: (1) Estimated on the assumption that total sulphate is sulphate
(4) Units in mg /l
(5) The results were obtained at laboratory-scale and may be different in practice.
< Indicates undetectable within testing method limits

Exceedances of the NTPA 001/2005 standard for the expected supernatant water were observed for the following critical parameters:

CN_{tot}	10 - 50 times
NH_4	3 -13 times
As	2 - 3 times
Ca	1.3 - 2.3 times
Mo	3 - 4 times
SO_4	3 – 5 times

In the early TMF closure phase the supernatant water will be removed as quickly as possible for the following reasons:

- to stabilize the tailings surface where heavy equipment will be operated by surface re-grading and covering with suitable soils.
- to provide flooding of the Cetate pit so that potentially ARD generating exposed surfaces are submerged as soon as possible.

There are two alternatives for an advanced treatment of the supernatant water at closure:

- Cyanide removal by active treatment - prior to the discharge into the pit. For this reason, the pulp cyanide treatment plant used during the operational stage for the treatment o the waste pulp delivered to the TMF will have to be modified. A feasible technology to reach the maximum admissible cyanide content as per NTPA – 001/2005 – 0.1 mg/l may consist of a combination of the followings:
  - SO_2/air method used during the operating stage;
  - Peroxide technology;
  - CN ultraviolet degradation;
  - Active carbon refining

- Natural Degradation - following cessation of tailings discharge for the pond water to reach the NTPA 001/2005 parameters. The modelling process described in Section 3.3 shows that cyanide natural degradation is a process that could result in compliance with the discharge regulatory limits after a period of 0.6 - 1 year.

Both alternatives are feasible and can also be combined in order to optimize the treatment method.

TMF Seepage Management and Semi-passive Treatment during Closure and Post-closure [
During the TMF closure as well as during operations, any seepage will be captured by the SCS sump and will be pumped back to the tailings basin until the supernatant water is completely pumped into the Cetate pit at closure.
After pumping of the supernatant water from the TMF is completed, this alternative can no longer be applied and a system for ARD treatment of seepage from the TMF valley will be implemented.
As the cyanide concentrations in the seepage may be detectable, RMGC will conduct laboratory-scale tests to determine the best active-passive cyanide concentration reduction techniques based upon realistic operational results. The preferred seepage treatment method will be determined during the operational phase to allow time for the design and construction of the treatment system. The chosen treatment system will be operational for use during the post closure phase of the project.
The PIRAMID Consortium[38] recommends semi-passive treatment of water containing residual cyanide associated with the RMGC TMF based upon a reducing hydrolysis (anaerobic) process. Such anaerobic biotechnology has proven to be effective for the treatment of water with cyanide concentrations ranging between 14 and 300 mg/l An advantage of this system is that it can be buried and maintained in operation even during cold seasons being commonly used for the passive ARD treatment as best environmental practice.
Thus an integrated system is developed for the treatment of both residual cyanide and ARD. However, this technology generates by-products that require further treatment. These by-products include: low content of dissolved oxygen; high biological oxygen consumption; high concentrations of nutrients (e.g. nitrate) and ammonium occurring as by-products specific to anaerobic cyanide degradation.
The by-products will be treated in a second aerobic treatment stage using limestone for pH adjustment. Metal removal is the result of pH adjustment, sulphate reduction and sulphide precipitation in the first anaerobic treatment stage and oxidation in the second aerobic treatment stage.

One of the concerns in closure may be the long-term seepage from the tailings contained in the TMF which has low concentrations of residual cyanide and is acidic The seepage modelling is presented in Section 3.4, with the conclusion that seepage flow rates of approximately 50 m^3/h through the main dam are to be expected. The seepage water will be managed with respect to cyanide, acidity, sulphate and metal content. The management procedures are presented below.

Cyanide
During operations the process plant water is detoxified using the SO_2/air technology. Cyanide concentrations will be reduced using the SO_2/air process to a level below 10 ppm mg/l]. Degradation and volatilization on the TMF surface will reduce the cyanide concentration in the tailings pore water. The following processes occurring through the mass of tailings and dam body up to the seepage area, i.e.: cyanic compounds adsorption, precipitation, oxidation, biodegradation, formation of thiocyanate and hydrolysis/ will reduce the cyanide concentration of the seepage. Adsorption will retard cyanide occurrence in seepage, however in the long-term the adsorption capacity will diminish. The chemical transformations of the cyanide along the seepage path are very difficult to predict. Reduction of cyanide concentration below the permissible level may occur, but it is not certain. Therefore, a long-term seepage treatment should be considered. This is also required due to the occurrence of nitrates as by-products in the cyanide degradation process.

ARD Water and Metal Content
If operations and closure are carried out as per the design there is no concern with respect to ARD generation. The rapid accumulation in the TMF of the submerged and saturated tailings will restrict ARD generation during operations. Seepage will be dominated by the process water chemistry. This will also continue after the end of the operational period. If ARD water occurs in the TMF seepage, it will occur first as neutralised ARD water.
If TMF closure /cover is carried out properly, no significant ARD may occur in the seepage water. However, the tailings deposit contains materials with ARD generation potential which may occur in the seepage. For this reason a long-term seepage treatment system is required downstream of the main dam. Given the actual ARD amount and chemistry a passive treatment and control system is sufficient.

Sulphate
Sulphate will be an important constituent of the water during operations and post-closure. Sulphate is the result of oxidation of sulphides in ore and waste rock and is a constituent of the ARD water and process water accumulating within the pores of the tailings.
By ARD neutralization, the metals associated with this acidic water precipitate and become inert, but the sulphate remains in solution and is mobile.
As sulphate impacts on the human health only in elevated concentrations, the most effective way for removal is the discharge (up to permissible levels).
It should be noted that the passive treatment technology using anaerobic systems for metal removal will result in the formation of metal sulphides.
The reduction of sulphate concentrations is another result of this technology.
However, sulphate is still a concern and research works will be conducted during operations with the purpose of determining which suitable seepage treatment technology will properly address this aspect.

Seepage Collection and re-pumping system and return pipes

The transport pipeline and the distribution system of the processing tailings, the re-pumping barges and the technological water return pipes : the overhead transport pipelines and the distribution system of the processing tailings will become useless after the ore processing termination The pipes will be flushed, (the resulting water will be directed to the tailing management facility) demolished and cut to sizes allowing their easy handling, removed from the work site and sold as recycled scrap. The processing tailings re-pumping system and the associated pipes will be removed once the tailings consolidation and dewatering process has been completed prior to soil coverage and re-vegetation. The pumping system will be sold, and the barge and pipes will be either sold or dismantled for their reclamation.

As shown previously, the system for the collection of seepage produced within the main dam body of the tailing management facility will be operating throughout the entire dewatering and vegetal soil coverage stages. As soon as the monitoring results demonstrate that there is no potential for the generation of acid waters and that the seepages and leakages from the vegetal soil surface do not contain any longer, residual cyanides , the collecting system, the pumps and the return pipes will be removed and sold or cut and reclaimed as iron scrap. As indicated above, the final constructive alternatives regarding the treatment lagoons may be kept after closure to ensure the continuous semi-passive treatment of the run offs or seepage resulted at the old mining sites.

7.2 Tailings Cover and Revegetation

Covering of the tailings deposited in the TMF is BAT and is required for the following reasons:

- reduces the amount of seepage from the TMF;
- reduces the tailings potential to generate ARD;
- consolidation of deposited tailings;
- prevention of dust blown off the tailings;
- improvement of visual appearance;
- integration in the landscape;
- use of land according to local community needs (about 300 ha).

The tailings cover system will consist of the following successive layers:

- 30-40 cm subsoil of compacted clayey silt as an oxygen barrier. Due to compaction, the oxygen barrier maintains a high pore saturation and thus effectively inhibits oxygen diffusion. Use of this type of oxygen barrier is BAT. Long-term stability of the oxygen barrier can be guaranteed if frost cracking, root penetration and other long-term perturbation effects are safely precluded.
- 80-140 cm subsoil of clayey silt;
- 10 cm topsoil.

Revegetation will be achieved using native species with shallow roots to prevent penetration of the oxygen barrier. Based on the initial closure plan the discharge of tailings in the final years of operation will be optimized so that at closure the lowest point of the tailings beach where decant water will be removed should be moved towards the north-eastern extremity of the TMF (see Drawing 08). This deposition method will also assist in the development of a slope of minimum 0.5% to facilitate surface water flow. In order to achieve a configuration of the tailings surface which prevents water accumulation on the TMF rehabilitated surface, the tailings surface will be remodeled prior to the cover placement, so that all surface water can report to a concrete spillway to be constructed on the right hillside and which will discharge downstream of the semi-passive treatment lagoons downstream of the secondary containment dam.

Figure 5.1. Post Closure TMF

8 Utilization of Best Available Techniques (BAT) and Best Environmental Practices (BEP)

The best available techniques have been used in the design of the TMF in order to prevent or reduce emissions and also to prevent or reduce the effects of accidents.
This Section will compare all the techniques against the European Commission Document ""DRAFT REFERENCE DOCUMENT ON BEST AVAILABLE TECHNIQUES FOR MANAGEMENT OF TAILINGS AND WASTE-ROCK IN MINING ACTIVITIES" - Final Draft - march 2004[39]".

8.1 General Principles of BAT:

- waste minimization is the result of the mining method selection. Given the specific nature of the gold and silver ore with very low useful mineral grades, the resulting waste can not be minimized.
- waste reuse. No other potential use has been identified for the waste.

As the waste resulting from ore processing activities can not be minimized or reused due to its physical and chemical characteristics and lack of market, it requires a specific management strategy designed to provide the following:

- a safe, stable and effective waste management, with minimum risk of discharges to the environment for the short, medium and long term;
- minimization of the amount and toxicity of contaminates leaving the containment of the TMF;
- progressive risk reduction with time.

8.2 Management throughout the Project Life

The mining operator - RMGC - commits to apply risk minimization measures during the TMF design, construction, operation, closure and post-closure, according to the best available techniques.
The following sections summarize the methods and measures considered throughout the life cycle of the Roşia Montană Project which are consistent with BAT and BEP.

Design Phase
A wide range of studies, tests, modelling was developed for the proper assessment of the Project baseline conditions.

Environmental Baseline Studies

- Mineral Resource Study
- Field investigations
    - geotechnical
    - geological
    - hydrogeological
    - hydrological
    - survey
    - biological, ecosystem identification

- regional economy (occupations, culture, demography, health etc.)

- Climatic Studies
- Studies on the quality of environmental factors

Tailings Characterisation Studies
This types of studies are very important as they provide the basis for the waste management strategy during operation (deposition methods, safety measures etc.), closure and post-closure (predictions on the long-term behaviour).
The following studies were developed:

- characterisation of ore, low-grade ore, waste rock and borrowed rocks:
  - mineralogy
  - chemical properties
  - physical and geo-mechanical properties
  - ARD generation potential
  - soluble contaminants
  - particle size
- waste characterization:
  - waste balance on years of operations
  - mineralogy
  - gradation limits
  - slurry dilution (% solids)
  - physical and geochemical properties of solids
  - chemical and geo-chemical properties of solids
  - chemical properties of liquid
  - ARD generation potential
  - settling and consolidation performance
- studies regarding processing method
  - reagents used (concentrations, quantities)
  - process water recycle
  - cyanide detoxification

TMF-related Studies and Plans
Studies were prepared for:

- site selection

With respect to site selection it should be stressed that the economic factor was determinant, the location in the Corna Valley being more favorable in terms of capital and operating costs. In addition, the Corna Valley site provides adequate storage space for the volume of tailings generated throughout the mine life.
The Roşia Poieni and Valea Sălıştei alternatives or a combination thereof seem more advantageous in terms of environmental impacts as these areas have already been disturbed by similar activities.
The Roşia Poieni site would have had the advantage of a limestone quarry in the proximity which can be used as rockfill source for dam construction with positive effects on the

neutralization of ARD water seeping through the dam There are no important localities at close distance downstream of the site.

- Environmental Impact Assessment
- Risk Assessment
- Emergency Preparedness and Spill Contingency Plan
- Water Management Plan, including TMF Water Balance
- Cyanide Management Plan
- Initial Decommissioning and Closure Plan
- Seepage Analysis (quantities and quality)
- Modelling of Contaminant Transport
- Dam Stability Analysis (including seismic stability)
- Evolution of Decant Pond Volume and Dam during Operation

Design of TMF and Associated Facilities

For the development of the design options available data resulting from field investigations, testing of the tailings, waste rock and construction rocks (borrowed), climatic studies etc. were considered.

In order to detail some of the design options additional investigations are required prior to the commencement of construction works or during these works (e.g. investigation of the dam footprint after removal of all soil to the bedrock surface) and studies for the final completion of the semi-passive treatment system for the seepage water during post-closure.

Investigations with respect to design options adopted for the construction of structural elements of the TMF - such as the main dam - will be conducted during operation and closure (e.g. conformity tests of the materials etc.).

TMF Monitoring and Control

The Projects comprises the required control and monitoring systems covering the entire TMF life cycle with respect to the control of releases and associated impacts, as well as to the stability of dams.

Specific internal procedures have been developed or are to be developed for each phase, starting with the design (testing, recording of data and decisions) and continuing with the construction works (monitoring, inspections, acceptance etc.), operation (control, monitoring, actions, measurements, tests, reviews, reporting, responsibilities, records etc.), closure and post-closure.

Construction Phase

Monitoring and control for the TMF construction is unique in that the construction phase extends during operation for some structures such as: main dam, tailings distribution system, sealing and drainage system for the TMF basin, run-off diversion channel and guard ditches, emergency spillway, crest lighting system etc.

All options will be permanently recorded and documented in comparison to the initial design and/or modified and approved design options.

Internal procedures for execution, monitoring, testing, acceptance, recording, decision and actions, training of relevant personnel etc. will be developed.

Operational Phase

During the operation phase, the TMF will be operated in accordance with the design criteria and the provisions of the OPERATION, INSPECTION AND MAINTENANCE MANUAL which will be prepared prior to the commissioning and will include as a minimum the following:

- detailed description of the construction options contained in the TMF design and local natural conditions (geological, hydrogeological, hydrological, climatic etc.);
- emergency response plans based on specific and clear procedures to be fulfilled, including cooperation with local authorities;
- risk management plan for the TMF of Category A of Importance, as per the EU Mine Waste Directive[40];
- water management plan, including management of floods or ice;
- environmental monitoring plan containing the sampling locations, supervision, periodical inspections;
- requirements of the operating permits issued by the competent authorities;
- recording methods and dissemination of information, decisions and reports;
- independant audit plan.

Closure and Post-closure Phase
The TMF design also includes the initial TMF closure design, as well as a presentation of the post-closure monitoring works. The design will be updated regularly by RMGC to ensure that there are no risks associated with closure and no hazards will occur on the very long term. The initial TMF closure design complies with the provisions of the EU Mine Waste Directive . The options for the cover system and revegetation of the tailings surface using species with shallow roots were identified in the closure design. The cover layer will consist of topsoil and subsoil previously removed from the area of all facility footprints and stockpiled for use during closure and reclamation activities. Slopes of minimum 0.5% will be constructed towards the discharge channel to facilitate the flow of water which will be collected in a spillway channel and directed downstream of the secondary containment dam.
The design also contains the plan for TMF monitoring until the regulatory parameters for seepage water are achieved and TMF surface is stabilized. It is planned to maintain the drain and drainage pipes for the deposited tailings, as well as the semi-passive treatment system downstream of the secondary containments dam and the pumping system to the ARD treatment plant.

8.3 Acid Rock Drainage Management - ARD

The design includes measures for ARD prevention, reduction and control. During operations due to the rapid deposition of the tailings in the TMF and flooding of most of the tailings, a significant oxidation which may facilitate ARD generation is not likely to occur. Water collected in the SCS sump will be pumped back into the TMF basin.
ARD generation after closure is slowed down by the drawdown of the desiccated tailings surface area and the placement of a tailings cover. ARD waters generated after closure will be treated through a semi-passive treatment system using organic matter in cells/lagoons to precipitate heavy metals and to reduce the sulphates content in discharges to the receiving body of water. The contaminant transport model indicates that ARD water can be controlled until the regulated discharge permit levels are achieved.

8.4 Cyanide Management

The design provides the best available techniques for cyanide management. Cyanide modelling was conducted by Botz and Mudder[41] with the purpose of estimating the cyanide concentration in the seepage water. The modelling results indicate that immediately after the end of operations (1 year) cyanide concentrations in the TMF seepage drop below 0.1 mg/l.

ANNEX 1

List of Standard Operating Procedures and Manuals to be Prepared with respect to the TMF Operation and Monitoring by the Mining Operator - RMGC

MP-02	"Identification of Legal and Regulatory Requirements"
MP-12	"Management of Environmental and Social Management System Records"
TF-01	"Operations Start-up"
TF-02	"Normal Operating Procedures - Tailings Deposition”
TF-03	“Normal Operating Procedures - Tailings Water Management”
TF-04	"Tailings Management Facility - Operations Inspection"
TF-05	"Tailings Management Facility - Operations Reporting”
TF-06	“Tailings Management Facility - Emergency Maintenance/ Inspection”
TF-07	"Tailings Management Facility - Emergency Response Action”
TF-08	“Tailings Management Facility - Emergency Notification Requirement”
TF-09	“Tailings Management Facility - Health and Safety Monitoring”
TF-10	“Tailings Management Facility - Risk Analysis”
TF-11	“Tailings Management Facility - Health and Safety Monitoring”
TF-12	“Tailings Management Facility - Groundwater Monitoring”
TF-13	“Tailings Management Facility - Surface Water Monitoring”
TF-14	“Tailings Management Facility - Air Monitoring/Meteorological Facility”
TF-15	“Tailings Management Facility - Dam Stability Monitoring"
Plan I	"Emergency Preparedness and Spill Contingency Plan"
Plan (TBD)	"Occupational Health and Safety Plan"
Plan D	"Air Quality Management Plan"
Plan J	"Mine Rehabilitation and Closure Plan"
Plan P	"Environmental and Social Monitoring Plan"
Plan A	"Environmental and Social Management Plan"
Plan G	"Cyanide Management Plan"
Plan E	"Air Quality and Noise Management Plan"
Plan H	"Biodiversity Conservation Plan"
Plan Y	"Special Monitoring of TMF Behaviour with Time Plan"

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[4] MWH 2005 ERR Annex P - Final Summary Report - Pumping and Piping

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[22] MWH 2005 ERR Annex J - Seepage Modelling for TMF and SCD and MWH 2005 ERR Annex K - Seepage Modelling for Cetate Dam

[23] MWH 2005 ERR Annex O - Contaminant Modelling Transport

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Law 347/2004 “Law of Mountain Region”;

GD no. 638/1999 regarding the approval of the Regulation on protection against flood, extreme meteorological events and accidents at hydrotechnical structures and Norms for equipping with materials and other means of protection against flood and ice;

MO 699/1999 regarding the approval of the Procedure and Authorities for issuing of water management endorsements and permits;

EO no. 244/2000 on Dam Safety, adopted and amended by Law 466/2001;

Joint Order 115/2888 of the MWEP and MLPTL for approval of the methodology for determination of the importance categories of the dams NTLH-021 (Technical Norms for Hydrotechnical Works);

Ministerial Order (MWEP) No. 116/289 (NTLH-022, NTLH-023) (6 March 2002): Methodology regarding the evaluation of secure operation of hydropower-dams and –lakes and Methodology regarding the evaluation of secure operation of dams creating deposits of industrial waste;

Ministerial Order (MWEP) No. 118 (NTLH-032) (11 February 2002): Procedure for issuing approvals and authorizations for the safe operation of dams;

Ministerial Order (MWEP) No. 119 (NTLH-033) (11 February 2002): Procedure and regulations for decommissioning, putting to care and maintenance or abandon dams and for their post-operational use;

Ministerial Order (MWEP) No. 120 (NTLH-034) (11 February 2002): Quality standards for contracting/performing works connected with safe tailings deposit operation

MO (MWEP) 121/2002, for approval of Dam Registration File – NTLH -035;

Ministerial Order (MWEP) No. 147 (NTLH-036) (12 February 2002): Procedure for public declaration of the general characteristics of importance categories and the corresponding levels of risk of dams;

GD 188/2002 for approval of the norms regarding the wastewater discharge conditions in the aquatic environment:

NTPA-011 regarding collection, treatment and discharge of urban wastewater;

NTPA-002/2002 regarding the requirements for wastewater discharge in the sewerage systems of localities and directly to the treatment plants;

NTPA-001/2002 laying down the limits for industrial and municipal wastewater pollutant concentrations at discharge into natural receivers.

MO MEWM 2/2006 for approval of the "Methodological Norms on Site Endorsement".