Description of the "Zero" (No Project) Alternative for Roşia Montană

Prepared for:

S.C. ROŞIA MONTANĂ GOLD CORPORATION S.A.
321, Pietei Street 3385, Roşia Montană,
Alba County, Romania

Prepared by:

WISUTEC
Wismut Umwelttechnik GmbH
Jagdschänkenstr. 33
D-09117 Chemnitz
Germany

in collaboration with

WISMUT GmbH
Jagdschänkenstr. 29
D-09117 Chemnitz
www.wismut.de

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1 Introduction

1.1 Background and Objective

The Roşia Montană mine development project (the Project) will remove most of the pollution sources within the license area, clean up existing pollution and lead to a substantial improvement of the environmental situation.

Independently of the Project, the Rosiamin operations will be closed over the next years for economic reasons.

Under the "Zero option" for Roşia Montană, i.e., if the RMGC mine development would not take place, substantial environmental remediation works must be carried out, while funding will have to be provided by public sources (WB mine closure project or EU funds) and/or MINVEST from Romanian state budget.

The Study was issued by WISUTEC/WISMUT for comparing the "Project" with the "Zero" alternative, investigating which remediation works would be required within the Project License Area in order to prevent further environmental pollution and comply with national and international regulations, guidelines and best practice standards. Hereby it is assumed that environmental rehabilitation has to ensure:

- application of Best Available Technology (BAT) and Best Environmental Practice (BEP)
- compliance Romanian standards and regulations
- use of international experience from similar projects.

It follows from the purpose of this study that of all facilities which belong to the current mining operations which generate a negative environmental impact only those are considered which are located in the RMGC Project License Area (see also Section 2.2):

- Cetate and Cîrnic (Napoleon) open pits
- waste rock dumps (currently active dumps Valea Verde and Hop, 15 old dumps)
- underground mine including mine water effluents
- buildings, storage areas and other mining, production and administration infrastructures within the License Area

Consequently, the waste facilities Valea Salistei tailings pond (operating) and Gura Rosiei tailings pond (closed), the ore crushing and haulage structures from Gura Minei to the processing plant and the processing plant itself are not considered in this study.

1.2 Applicable Romanian and International Regulations and Guidelines

To ensure comparability between the "Zero" and "Project" alternatives, the rehabilitation concept for the existing mine operations, waste facilities etc. which is described in this study will follow the same standards and regulations, both Romanian and international, as described in the RMGC Mine Rehabilitation and Closure Plan for the closure and rehabilitation of the site at the end of the planned RMGC Project.

1.3 Sources of Information

Two studies (by AGRARO[i] and ECOIND[ii]) as well as the Environmental Baseline Reports of RMGC, a suite of documents describing the baseline conditions of a number of environmental factors such as soil, air and water quality prior to the RMGC project development, which were provided by RMGC to WISUTEC/WISMUT have formed the basis for the description of the current status, the identification of the most significant pollution sources and the formulation of priority remediation measures which must be implemented at closure of the S.M. Rosia Montana operations.

A synopsis of their findings is provided in Sections 2 and 3. However, this synopsis cannot by any means replace the more detailed representations of investigation results obtained by AGRARO[iii] and ECOIND[iv] and many companies and authorities so far. It is merely intended to provide a basis for a conceptual discussion of environmental impacts of the current mine and the identification of remediation measures if the mine is closed.

2 Site Conditions[1]

2.1 Site History

The history of the settlement is closely linked to existence of the gold resources and their mining. The village continues the old mining activities of the antique Alburnus Maior and to date maintains the same main occupation as in the Roman times.

Permanent gold mining has been carried out here from the 2nd century b.c. under emperor Traian and subsequently Hadrian. Mining was initially on surface with veins being followed underground, cutting workings in hard rock using hand tools, assisted by the application of fire. At that time, the name of the settlement was Alburnus Major, as noted in an epigraphic fragment.

The settlement, constituting the center of the Roman gold mining in the Apuseni mountains is situated on the Nanului valley and Carpen Hill. Around the village there was an area colonized by Dalmatians specializing in mining. The settlement would comprise several little villages (*vicus*), each including the dwellings zone, sacred zone and necropolis. The waxed boards dated year 167 B.C. discovered in the Roman gallery refers to such villages. For the Roman era there is an abundance of vestiges, however for the following eras there are no written sources, which is explicable for a time when gold mining had remained an occasional occupation, as a domestic activity of small producers.

It is only in the 15th/16th century that a strengthening of the financial position of the owners of stamp mills (facilities including gravity stamp and gib arm for ore grinding) occurs, supported by the feudal royals in the area.

The workings in the medieval times were mainly a continuation of the Roman workings using similar hand mining techniques.

In the 18th century German and French colonists came into the region to work in mines. Around the current gold mining center, the old traditional settlement took a cosmopolitan nature.

The first documented information dates back to 1592, when the settlement was an integral part of the Abrud township. Later on, in 1733 the name of Rosije (Rosie) appears in documents. Records indicate the existence of a scattered settlement without a precise delineation.

The Rosia Montana mining operation was set up in 1852. Most mining was by underground methods with an extensive network of tunnels and stopes being developed in the Cetate and Carnic massifs over a vertical interval of some 400 m. Ore was hauled by way of wooden mine cars.

Mining after the end of World War I had been limited, and is characterized by an extension of the existing underground workings along individual quartz veins, by room and pillar stoping in breccia and by systematic underground exploration. Underground mining activities ceased in 1985.

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[1] Substantial parts of Sections 2 and 3 have been taken and adapted from studies by AGRARO[1] and ECOIND[1]

In 1971, an open pit was developed on the Cetate breccia, recovering remnants from underground workings. The pit was extended southwest into the Cetate dacite. This pit has removed the upper 120 m of the Cetate Massif.

The Valea Verde and Hop dumps – used to store the waste rock resulting from the open pits – have been commissioned recently (Valea Verde less than 6 years and Hop dump less than 4 years). Prior to their commissioning the land they had taken up was forest land.

In year 2001, the gold ore mining and processing capacity at Rosia Montana was around 420,000 t/year of which 344,000 t were produced by surface mining in the Cetate pit.

2.2 Facilities Considered in this Study

The analysis will be conducted for those Rosiamin's sites which are within the RMGC project area, i.e.,

- Cetate and Carnic (Napoleon) pits;
- Gura Minei
- Mine workings, daylighting at the Sf. Cruce adit at 714 m ASL and at Rakos adit
- Waste rock dumps such as Hop and Valea Verde dumps, but also numerous smaller dumps.
- Production infrastructure, buildings, ore, explosives/fuel/lubricant and waste storage areas, power supply structures

Figure 2.1. Map with locations of individual sites discussed in this study

Insert map in A3 format from RMGC

These sites are briefly described in the following:

- Carnic Pit is located in the Carnic Hill in the southern part of the Rosia Montana village. At the moment, mining works are conducted only in the Napoleon Pit which has the mining level + 966 m ASL and relatively small size compared to the overall Carnic Pit and is located on the south-west slope of the Carnic Hill.
- Cetate Pit is located west of the Carnic pit, in its immediate vicinity, in the Cetate Hill. It is the largest active surface mining area (approx. 22 ha). Initially, the Cetate Hill had an elevation of 1004 m ASL and by excavation the minimum elevation of the pit has currently reached + 873 m ASL. The contour is approximately of elliptic shape with an average upper diameter of around 400 m. The mining method employed for both pits is open-cut mining. Ore is extracted using blast-hole drills and blasting chambers.
- The Gura Minei Site is located in the Cetate Massif at elevation + 714 m ASL (daylighting of the Sf. Cruce underground adit). The site is bordered by privately owned lands, the county road 742 and the Rosiei stream. The surface area is 6228.3 m^2 of which:
  - area with buildings: 1193.47 m2
  - area of haulage ways: 3602.98 m^2
  - open space: 1431.85 m^2.

The following facilities are also located within the Gura Minei site:

- crusher (in standby)
- rectifying station (S=129.86 m^2)
- workshop joined to the rectifying station (S=85.07 m^2)
- mechanic workshop (S=265.92 m^2)
- sawmill shed (S=45.94 m^2)
- forging shop (S=154.08 m^2)
- shed joined to the forging shop (S=54.33 m^2)
- office building (S=331.92 m^2)
- motion point (S=17.46 m^2)
- conveyor belt (S=54.33 m^2)
- storage building (S=27.93 m^2)
- semi-buried fuel storage facility
- compressor EC-10
- 5 electric mine locomotives, 3 diesel locomotives
- 300 meters of railway line

- Verkes Explosives Storehouse: The storehouse is located on the Cetate Pit mine road route and has a capacity of 5500 kg TNT- equivalents. The storehouse is operational, therefore all utilities are in place: rail track, flood equipment, ventilation plant, electric power supply. The explosives storage site is fenced in barbed wire fence installed on concrete steel poles; the perimeter length is 170m. The site is guarded by security personnel. The ventilation adit portal is also fenced over a length of 70m with barbed wire fence installed on concrete steel poles. The amount of explosives required for ore stripping is taken from the explosive storehouse and transported by truck to the pit site. Transport and handling of explosives shall be made in accordance with the legal provisions regarding the explosive materials regime and solely by authorized personnel.
- Gura Minei Central Explosives Storehouse: The storehouse is located on the mine road route, between Gura Minei and Aprabus Sites. The storage site is fenced in

barbed wire fence installed on concrete steel poles; the perimeter length is 200m. The storehouse has all required utilities in place but they are disconnected as the storage facility is not currently operational. A gate house is provided outside the storage site. There is no fencing at the ventilation adit portal.

- Fuel and Lubricant Storage Tanks: Fuels and lubricants used within the compressor station, Gura Minei, Gura Rosiei Processing Plant sites are stored in semi-buried tanks. An above ground lubricant storage tank is provided within the Cetate Pit Site. There is no available information regarding the type of stored fuel/lubricant, tank capacities and set-up of tank locations.
- In addition to the above mentioned storage facilities, a number of magazines and warehouses for materials used in ancillary activities are located within the investigated facilities. There is no available information regarding the type of stored materials, capacities, warehouse set-up/equipment.
- Ore bin located at the Gura Minei site - 50 t capacity;
- A network of underground mine workings consisting of recent main levels (connected with the surface through adits), intermediate levels and stopes occurs where the following mining techniques were employed: chamber mining, pillar working and stope mining. Currently, only levels 820 and 714 are operational and service the ore haulage system at Cetate and Napoleon pits. Level 714 is the main haulage level and also provides the water drainage.
- 17 dumps for stockpiling of dry waste rock - dacite and/or breccia type (**Error! Reference source not found.**). Some of the dumps are located adjacent to the open pits, while others are developed along the surface ore haulage route. Two of the 17 dumps are currently active, i.e. the Valea Verde Dump and Hop Dump.

Table 2-1. Overview of waste rock dumps in the Project area (as of 2003, from ECOIND[v])

No.	Dump	Dumped amount, 1000 m³	Dump Surface Area, ha
1	Valea Verde Dump	2015.3	14.5*
2	Hop Dump	1171.0	16*
	Subtotal active dumps (rounded)	3186	30.5
3	Verkes Dump	53.882	0.50
4	Rakosi Dump	26.850	0.23
5	Iuliana Dump	19.382	0.33
6	Afinis Dump	21.548	0.13
7	Aurora Dump	8.00	0.18
8	Gauri Dump	13.60	0.20
9	23 August Dump	69.047	1.30
10	Cirnicel Adit Dump + 910 m	9.582	0.12
11	Napoleon Dump + 984 m	5.537	0.20
12	Napoleon Dump + 959 m	8.615	0.15
13	Manesti Adit Dump + 959 m	28.40	0.50
14	Dump Adit + 887 m	9.645	0.22
15	Dump Adit + 938 m	20.147	0.15
16	Piatra Corbului Dump + 960 m	6.357	0.08
17	Piatra Corbului Dump	4.225	0.05
	Total (rounded)	3491	35

* Obviously erroneous figures from Table No. IV.1.3.6. of the ECOIND EBL II[vi] were corrected to make them consistent with other information[vii]

The characteristics of the two active dumps are as follows:

Table 2-2. Physical parameters of the Valea Verde and Hop waste dumps

Parameter	Value*	
stockpiled material	dry pit waste rock (dacite or breccia)	
bench angle	36o (slope angle about 1:1.4)	
final general angle	21o (slope of about 1:2.5)	
distance between benches	> 40 m	
distance between benches and pit	> 30 m	
	Valea Verde dump	Hop dump
stockpiling elevation	875m ASL	900m ASL
design capacity	7 million t	4 million t
amount stockpiled as of 2003	5.3 million t = 3.1 million m³	3.25 million t = 1.9 million m³
amount stockpiled in 2003	0.135 million t = 0.08 million m³	0.1 million t = 0.06 million m³
Extrapolation to 2006, assuming 2003 dump rate	5.7 million t = 3.4 million m³	3.6 million t = 2.1 million m³

* For the conversion from tons to m³, a bulk density of 1.7 t/m³ was assumed, correcting the implausible value of 2.5 t/m³ used in EBL II[viii].

The <u>Hop Waste Rock Dump</u> has an area of approximately 16 ha and is located in the south-west side of the Cetate Hill.
The <u>Valea Verde Waste Rock Dump</u> is located east of the Hop dump but somewhat southwards, being located on the south slope of the Cetate Hill. Area of this dump is approximately 14.5 ha.
The <u>15 inactive dumps</u> are vegetated in various proportions with grass and spontaneously grown birch trees, poplars, pine trees, willow trees, alder trees. The degree of vegetation covering is not consistent, ranging between 20-90 %. No special environmental protection measures are in place for the dumps.

- The Company Headquarters, with an area of 21746.46 m^2, is located in the Rosia Montana village and is bordered by privately owned lands, Campeni Forestry Office and public lands. The area consists of:
  - area with buildings: (3178.6 m²)
  - network area: (59.38 m²)
  - area of haulage ways (15584.85 m²)
  - open space (2903.63 m²)
- Electric power supply facilities: Transformers and condensers are located in tanks or spaces specifically designed for electric equipment without posing any soil contamination hazard by oil leakage. There is no information regarding any likely presence of oils containing PCB.

2.3 Local Conditions

General

The Rosia Montana Mining Subsidiary (Rosiamin) carries out its operations in an area which, from a physical-geographical standpoint, is part of the Apuseni Mountains group, e.g the Metaliferi mountains unit (Rosia Montana mountains subunit). Within these mountains, the interfluves are large, folded, supported on Cretaceous-Paleocene sedimentary rocks that are dominated by quartz andesite and basalt outcrops, at the base of large plateaus of andesite lava dominating the north, south and east sides via the Cotlau, Bradasel, Rotunda, Curmatura, Cetate, Carnic massifs. These hills with gentle or steep slopes particularly near valleys and stream are oriented east-westward corresponding to a number of sub-volcanic intrusive dacite bodies occurred in a sequence of sedimentary Cretaceous.

The elevations range between 550 m in the Abrud valley and 1253 m in the Curmatura hill. The general drainage of the entire area is north, north-east and southward. The main landscapes in the investigated area include:

- Hills with altitudes ranging between 800 and 1300 m. Altitudes exceeding 1000 m are encountered in the north-east part of the region, the main ridges being Piatra Corbului (1159 m), Carnic Hill (1084 m), Rotund Hill (1151 m), Tarina Hill (1033 m). The ridges around the village of Rosia Montana are holed by the old mining operations such that they show a unique landscape, specific for the region;
- The depression area is represented by the Rosia Montana depression with altitudes below 600 m. Minor relief occurs within this depression and also along some of the larger valleys being represented by the following relief: alluvial cones, detritus traces, etc. The anthropogenic relief (tailing dams which entailed minor changes in the topography of the area) is observed as minor forms of relief also.

The anthropogenic relief is characterised by the open pit mining operations (Napoleon, Cetate pits) which create a special landscape as a result of the mining of the complex ore layers and presence of the service roads scattered within the area. This landscape is in contrast to the largely rolled lands used as pastures and hay fields.

Hydrographic System

The main collector of this area is the Abrud river, right-hand side tributary to the Aries River, which together with the Rosia stream drains the north slopes of the mountains located in the central part of the Metaliferi Mountains. The Rosia stream springs originate from the Taul Tarina, Taul Mare and Taul Brazi lakes and along its course (L = 8.5 km) collects mine waters. The Rosia stream flow rate is 5 m^3/s. Other tributaries of the Abrud River draining the investigated area are: Salistei stream, which does not have a topographic code, with a length of 5.5 km and accommodating the Saliste tailings deposition dam, Corna stream with a length of 6.5 km and which together with the Rosia stream frames the investigated area.

Table 2-3. Abrud River Watershed Data – Rosia Montana

Watershed	Length (km)	Altitude		Average Gradient (‰)
		Spring (m)	Influx (m)	
Abrud	25	1142	537	25
Valea Buciumanilor Confluence	7	1142	643	71
Valea Buciumanilor (Valea Alba)	15	1080	643	29
Corna (Abrud) Confluence	11	1142	612	48
Corna	5	800	612	38
Rosia Montana Confluence	17	1142	575	33
Roşia Montană	8	1120	575	68
Stefanca Confluence	57	1108	521	10
Stefanca	7	1020	521	71
Valea Muscanilor Confluence	59	1108	518	10
Valea Muscanilor	8	1100	518	73
Valea Sesei Confluence	66	1108	494	9
Valea Sesei	10	940	494	45

Table 2-4. Abrud River Area Hydrological Data – Rosia Montana

Watershed	Area (km2)	Altitude		Forestry Area (ha)
		Spring (m)	Influx (m)	
Abrud	223	931		8,460
Valea Buciumanilor Confluence	14		886	305
Valea Buciumanilor	51	958		2,433
Corna (Abrud) Confluence	91		966	3920
Corna	10	833		236
Rosia Montana Confluence	189		961	7596
Rosia Montana	44	892		210
Stefanca Confluence	1039		993	48131
Stefanca	12	747		124
Valea Muscanilor Confluence	1055		989	48423
Valea Muscanilor	18	804		86
Valea Sesei Confluence	1130		981	50701
Valea Sesei	38	858		842

Geology

From a geological standpoint, the investigated area is part of the South Apuseni Mountains, which have a very complex geological structure (petrography mosaic) due to a large diversity of geological formations and extended evolution period.
In this region, are present in various structural relationships, metamorphic, Precambrian and even Paleozoic rocks along with magmatic products from the pre-Balkan and Hercynite tectonic-magmatic cycle (represented by mica schist, sericitic chloritoid schist, limestone and crystalline dolomite). In terms of geological age, rocks belonging to the Jurassic to the upper Neogene are encountered.

The sedimentary layer includes deposits of Mesozoic age belonging to the upper Jurassic (nodular limestone turning vertically in massive limestone, reef limestone), Cretaceous (silty schist and poorly metamorphosed clayey silts, micro-conglomerates, grit stone, mudstone).

The movements in the Neogene resulted in the formation of a system of fractures with the sinking of some small areas e.g. the Almas-Zlatna Depression, Rosia Montana Depression, and others.

The Neogene volcanism represents the last development stage of the alpine magmatic genesis, which took place in three phases with its products occurring intercalated among the sedimentary formations and being represented in the Rosia Montana area by epiclastic and pyroclastic deposits predominantly dacite, followed by a clastic formation possibly Sarmatian (100 – 200 m) and a Pliocene formation (60 m). The last phase of the volcanism was explosive in nature with formation of explosion columns and a system of fissures and fractures that allowed for circulation of hydrothermal solutions and build up of gold-silver mineralization in the breccia bodies. It has generated:

- In Badedian, intra and extra-crater dacite pyroclastite (tuffs, vent breccia, black breccia mixed breccia, etc.) possibly rhyolite also, dacitic domes and dykes from the Cetate and Carnic hills, Corna, Orlea-Tarina, etc. respectively.
- Andesite pyroclastite with pyroxene, Pannonian hornblende originating from the Rotunda and Surligata structures.

The Rosia Montana Depression covers a small area in the north side of the Metaliferi Mountains. Neogene formations were deposited in this depression as well as in the other depressions within the Metaliferi Mountains, consisting of calcareous-clastic formations, grey marls alternating with grit stones with occasional occurrence of gypsum, clayey marl, sporadically sandy, white and stratified.

Accordingly, brown clay with intercalations of lignite deposited in Pliocene also occur. The quaternary deposits are represented by coarse and fine alluvium from the alluvia plain and cliff areas and by colluvium deposits on the ridges. The alluvium deposits are constituted of fine grained cohesive soils either as clayey dusts or dusty clays, either as main constituent or as a matrix within coarser fractions including gravel and cobbles. The colluvium deposits are formed of variable texture soils including clay, dust and sand in various proportions. The thickness of the surface deposits is smaller on the slopes ranging from 2-5 m and greater in the valleys where it reaches up to 12 m.

Soil

An extensive discussion of the soil conditions at Rosia Montana is contained in the EBL I (ECOIND[ix]) and EBL II (AGRARO[x]) reports of 2003, which is not repeated here.

The most polluted areas may be present in near vicinity of the mining sites where the sources include specific solid wastes (waste rock), waste resulting from ancillary activities (metal wastes) and acid mine waters.

To assess the soil pollution degree as a result of the mining activities soil samples have been collected analyzed as part of the Environmental Balance Level II prepared by SC CEPROMIN SA Deva (1999).The analysis of the yielded results against the threshold values imposed by Order 756/1997 for lands with less sensitive use indicated the following:

- The soil samples taken within the **Cetate pit site** contain: Co, which ranges within normal values; metals as Zn, Cu, Pb, Cd, Ni, Cr which exceed the normal values but are below the alert threshold; Mn is above the alert threshold but below response threshold. For the soil sample taken from the Cetate pit perimeter area except for Co and Cr which range between normal values, the rest of the metals exceed these values however are below the alert threshold. The soil within the Cetate pit site is neutral and averagely clayey. The average quality grade for the soil within the mining site is 8.00.

- The soil samples taken within the **Valea Verde and Hop dump sites** have metal concentrations below the alert threshold except for manganese which exceeds the alert threshold but is below the response threshold. The soil within the two dumps is slightly alkaline and averagely clayey. The average quality grade of the soil is 8.00.
- The soil at the bottom of **Rakosi dump** (in vicinity of the mine adit) is moderately acid and averagely clayey. The manganese content exceeds the alert threshold. The other metals are below the alert threshold and chromium ranges within normal values. The average quality grade of the soil is 8.00.
- The soil sample taken within the S.M. Rosia Montana **headquarters site** indicates metal contents below the alert threshold. Cd, Co and Cr are within normal values. The soil has a neutral reaction and is good clayey. The average quality grade of the soil is 8.00.
- The soil sample taken within the **Gura Minei site** indicates contents above the alert threshold for metals such as Pb, Cu, Zn; the other metals are below the alert threshold. From a chemical standpoint, the soil is slightly alkaline and good clayey. The average quality grade of the soil is 6.00.

It must be noted that the information available does not allow for a vertical resolution of the soil quality.

The changes caused by topsoil removal, landslides and waste rock dumping are evident. The adjacent areas are unproductive in terms of farming and forestry development.

The soil shows a high degree of degradation as a result of the mining activities.

The extent and severity of this degradation has intensified over the last 30 to 40 years because of the inadequate use of technology.

The soil is affected by two categories of factors:

- physical stress factors:
  - temporary or permanent modification of the land use;
  - topsoil quality affected by stripping or air pollutant deposition;
  - disturbance of native forests, grasslands or farming vegetation;
- chemical stress factors: contaminants relevant to mining and processing activities - metals (Cu, Zn, Cd, Mn etc.) and semi-metals (As, Sb etc.) deriving from: stockpiling directly on the soil of raw materials (ore), products (concentrates) or waste rock, dust settling, ARD or seepage.

Hydrogeology

The geological investigation did not localize a significant aquifer in the analyzed area and a bearing layer containing an aquifer of some significance cannot be indicated based on the known geological data. The sedimentary rocks belonging to late Jurassic-Cretaceous era contain thin discontinuous layers of sandstones which cannot ensure a groundwater reservoir. The superficial geological deposits have significant aquifer potential however, are too thin to be used as water resource. The volcanic rocks (dacites and black breccia) and the majority of the Cretaceous sedimentary rocks have low permeability.

The Rosia Montana area is not rich in groundwater due to the geological structure with low fissuring degree where water reserves cannot develop. Numerous active springs are present after significant rainfalls, which dry out in summer of have flows that reduce down to slush effects. Some deposits are encountered at depths of 7.5 – 8 m however they are small in terms of water volume. The springs are encountered at the bottom of the slopes where sedimentary deposits join with compact rocks.

The ground water flow follows the topography of the area. The flow spectrum is three-dimensional, with the prevailing direction towards the main drain of the area, e.g. the Abrud river and the local components towards the nearest streams – Rosia, Salistei or Corna, as the case may be. On the slopes the ground water level is typically encountered at greater depths, over 10-12 m, while at the bottom of the slopes is encountered at smaller depths, less than 3-5 m. The hydraulic conductivity of the overburden is around 10^{-3} m/day and of the bedrock is 10^{-2} m/day.

The groundwater conditions reflect the permeability of the bedrock and overburden. There are numerous springs on the ridges which are associated with the drop in permeability from overburden to bedrock.

Considering the history of the area where mining activities have been carried out for a long time, all the generated soil pollution sources have become pollution sources for groundwater, too.

The only source of information for the analysis of the groundwater quality within the Rosia Montana Mine sites was the environmental database of RMGC. This database includes the results of groundwater analyses conducted in the years 2000 to 2003.

The conclusions drawn in the EBL I Report of ECOIND (2003)[xi] for the Rosia valley are summarized in the following:

In general, the groundwater meets the requirements set by 458/2002 and 311/2004 except for

pH which is slightly lower than permitted in some groundwater sampling points
metals such as Cd, Cu, Mn and Fe

ECOIND clearly assigned these impacts to the releases of mine water into the Rosia valley.

AGRARO[xii] states that the main cause of contamination of the well waters is the high mineralization of the area, however it may be due to anthropogenic activities as well – by settling of pollutant dusts or by infiltration in soil and then in groundwater table of the rain water that washes and carries away soluble contaminants from ground surface.

Air And Noise

Of air releases such as

- CO
- NO_x
- H_2S
- Dust

which are relevant during the operating period, only dust is a permanent concern after closure of the mining activities if the wastes are not covered.

Temporarily, during remediation works, the emission of exhaust gases (NO_x, CO) and noise may be a concern.

3 Identification of Environmental Pollution Sources at Closure

3.1 Cetate And Carnic Open Pits

The following impacts must be taken into account at the pit sites:

- Water contamination due to acid generation potential of the pit mine walls which may report to the underground mine workings and be discharged with ARD generated in the mine, via the channels of Rakosi and Main Level adits. Vertically, water flows through the mine workings in a largely uncontrollable fashion.
- The pit walls are likely to be geotechnically unstable over the long-term. Unless they are stabilized, public access to the pits must be restricted.
- The pits have currently a depth which does not allow a pit lake to form. As the geo-hydraulic model for the RMGC project has shown, the stationary groundwater level will be at approximately 720-745 m ASL. None of the pits which exist currently reaches this depth.

3.2 Mine Site And Mine Effluents

At the Gura Minei Site, the following environmental impacts are to be expected:

- The ARD mine water collected via the adit channel (elevation 714m) is discharged into the Gura Rosiei stream.
- Soil contamination is expected due to the activities carried out at the site such as ore handling, loading and hauling.
- Contaminated sediments must be removed from rivers where appropriate
- Contaminated Equipment must be dismantled, removed from the site and safely disposed of or recycled.

Mine water is discharged from the Rakosi adit (elevation + 820 m) and Sfanta Cruce adit (elevation = 714 m).

Water discharged via the Rakosi adit is released to the Ripa Alba creek (which has approximately the same flow rate as the mine water), a tributary to Rosia stream at around 200 m from the mine water draw off point. Basically the water discharged via the Rakosi adit is released to the Rosia stream. The flow rate of this water is in the order of maximum a few tens of cubic meters per day.

At level 714 water reports via channels both to the pumping station operating intermittently as well as to the Gura Minei facility where from is directed via channels to the Rosia stream. Water flow rate out of the Gura Minei site may reach 1100 m^3/day, 13 l/s respectively subject to the mining activity, season and precipitation rates (as per the Technical documentation for secure of the Water Management Permit for S.M. Rosia Montana – 2001).

The Environmental Permit no. 889/21.12.1999, Annex no. 8.3 – Annex I stipulates that the quality of the mine water released to the Rosia stream will be monitored by daily assay of the following physical-chemical parameters:

- pH
- suspended solids
- residue filtered at 105oC
- total ionic Fe
- Cu
- Zn
- Mn
- CN^-

The characteristics of the mine water samples shown in **Error! Reference source not found.** are also compared with the limit values stated in the Water Management Permit (WMP) no. 2/1999 and with the limit values set forth by NTPA 001/2002 – Regulatory Standard regarding the set forth of contaminant load limit values for industrial and domestic wastewater on release to natural receivers having considered that these waters are released to the environment.

Table 3-1. Mine water analyses performed in 1999 by CEPROMIN[xiii] (parameters exceeding WMP 2/1999 and/or NTPA 001/2002 limits printed bold face)

Sample Parameter	Rakosi Adit Mine Water	Gura Minei Adit Mine Water	Limit Values as per WMP no. 2/1999	Limit Values as per NTPA 001/2002
pH	2.46	2.22	6.5-8.5	6.5-8.5
Residue, mg/l	28903.2	8101.2	-	-
TSS, mg/l	374	312	100.0	35
Chloride, mg/l	56.8	42.6	-	500
Calcium, mg/l	284.0	260.0	-	300
Magnesium, mg/l	51.03	31.6	-	100
Copper, mg/l	9.23	2.86	0.1	0.1
Lead, mg/l	0.2	0.14	-	0.2
Zinc, mg/l	213.5	39.1	0.5	0.5
Cadmium, mg/l	4.04	0.47	-	0.2
Nickel, mg/l	5.6	1.44	-	0.5
Mercury, mg/l	BDL	BDL	-	0.05
Chromium, mg/l	0.25	0.05	-	0.1
Manganese, mg/l	833.4	314.8	0.1	1
Iron, mg/l	3035.7	522.3	5.0	5
Sulfates, mg/l	15589.5	4831.0	-	600
CCO-Mn, mg O2/l	438.1	70.3	-	40
Ammonium, mg/l	8.01	4.34	-	2
Nitrates, mg/l	9.25	4.24	-	25
Nitrites, mg/l	BDL	0.002	-	1
Sulphide, mg/l	BDL	BDL	-	1

The parameters CN^- and filterable residue which should have been measured as per Permit no. 2/1999 were not analyzed (CN is not a concern in this study as it does not include ore processing facilities).

Rosiamin also operates a self-monitoring system for several water parameters. However, the average values determined by Rosiamin for Fe, Zn and Cu differ from those shown in **Error! Reference source not found.** by some orders of magnitude. Based on the visual impression of the effluent, the Cepromin analyses (especially for Fe) seem more credible and will be used for the subsequent considerations.

For comparison, the results of the Water Baseline Report (RMGC)[xiv] are shown in **Error! Reference source not found.**. They qualitatively confirm the situation shown in the previous tables. The smaller sulphate concentration of the Rakosi Adit is notable, but does not significantly influence the subsequent conclusions.

Table 3-2. Mine water analyses from the RMGC Water Baseline Report (2004)

		Adit 714		Rakosi adit	
		best	worst	best	worst
pH	units	3.03	2.68	2.94	2.73
As total	µg/L	1852.00	65.00	96.24	8.60
As diss.	µg/L	1738.00	49.40	95.61	5.10
Cd total	µg/L	875.00	116.00	256.70	76.80
Cd diss.	µg/L	814.00	97.40	242.40	78.20
Ni total	µg/L	1132.00	507.00	666.30	151.00
Ni diss.	µg/L	732.00	483.00	619.90	118.00
Pb total	µg/L	266.00	5.29	64.20	0.00
Pb diss.	µg/L	246.00	3.21	45.10	0.00
Hg	µg/L	0.15	0.00	0.15	0.00
Cr total	µg/L	2710.00	52.00	4077.75	36.90
Se	µg/L	217.00	98.80	47.10	9.20
SO4	mg/L	2637.90	1736.42	1876.00	1216.00
HCO3	mg/L	0.00	0.00	0.00	0.00

The mine effluents must be treated before discharge into the environment in order to meet the requirements of Permit no. 2/1999 as well as NTPA 001/2002, for the following parameters:

- pH
- suspended solids
- heavy metals (Cu, Zn, Mn, Fe, Co, Zn, Cd, Ni)
- major ions (SO4)
- other parameters (NH_4, CCO-Mn)

The maximum flow rate of the mine effluent is approximately 100 m^3/h, while the long-term average is around 50 m^3/h.

Given the noncompliance with the mine water quality, the construction of a treatment plant for these waters was required in the Environmental Permit No. 889/1999, annex no. 8.6 regarding the Compliance Program with the commissioning date in the fourth quarter 2001. SC CEPROMIN SA Deva has prepared the design for the treatment plant however the project has never been completed.

To determine the impact caused by the release of mine water to receivers (Ripa Alba and Rosia streams) water samples were collected and analyzed as part of the Environmental Balance Level II by ECOIND. The results are presented in the EBL II Report. The results can be summarized as follows:

- Ripa Alba stream
    - upstream of the Rakosi adit mine water discharge the stream already shows contaminant contents (similar to the mine water), which is due to the leaching of the minerals in the deposits they intersect;
    - the pH were within the strongly acid range both upstream and downstream;
    - the values for residues, SO4, NH4+ and metals (Cu, Pb, Zn, Cd, Ni, Mn, Fe) rate this stream into quality category 5 as per Order no. 1146/2003 both upstream and downstream; the values for these parameters are higher downstream of the Rakosi adit mine water discharge than upstream which proves the pollution input of the mine waters.
- Rosia stream
    - Junction with Ripa Alba
        - pH values were within the strongly acid range both upstream and downstream of the Ripa Alba junction;
        - a slight increase downstream compared to upstream of the values determined for the majority of the analyzed parameters is confirmed;
    - Mine water discharge from Gura Minei adit
        - pH values were within the strongly acid range both upstream and downstream of the mine water discharge from the Gura Minei adit;
        - the values determined for the majority of the analyzed parameters are higher downstream than upstream, significant increase being recorded for the parameters: fixed residue, Zn, Mg, Mn, Fe, sulfates, CCO-Mn;
    - under Order No. 1146/2002, the pH and residue as well as metals (e.g. Cu, Pb, Zn, Cd, Mn, Fe) rate the Rosia stream into quality class 5 both upstream and downstream of the mine water discharge from Gura Minei adit; downstream the creek changes the quality class from class 1 to class 5 for sulfates and from class 4 to class 5 for Ni.

Data from RMGC's database are not reproduced here but confirm these findings for the Rosia stream. They also show a significant, negative combined impact on the Abrud and Aries rivers from the mine effluents, which are compounded with the effluents from the processing plant, and the Valea Salistei and Gura Rosiei dams rivers (see EBL II Report[xv] by ECOIND for details).

River sediments are also contaminated by the untreated mine water effluent. In a report by Fluvio[xvi] which is part of RMGC's Environmental Baseline Report, the following conclusions are relevant for this study:

- It is estimated that the maximum downstream extent of the geochemical footprint associated with mining activity in the Roşia Montana catchment lies between 24 km and 30 km downstream of the Roşia/Abrud confluence, that is between Valea Lupsei and Brazeşti.
- Water and sediment samples should be taken routinely at all river sites within the RMGC network so that contaminant dispersal patterns can be fully monitored, evaluated and modelled.
- Finally, additional sites have been identified on the Abrud and Arieş which RMGC should integrate within their existing sampling network.

The footprint of the uncontrolled mine effluent release is visually recognizable downstream of the mine effluent discharge points (especially Adit 714) and requires removal of the worst sediment contamination for environmental and visual/aesthetic reasons.

3.3 Waste Rock Dumps

The stockpiled materials have acid generation potential (the runoff water from these dumps is acidic, pH<3) and a significant metal load. After cessation of operations, the waste dumps, and mainly the Valea Verde and Hop dumps will continue to cause the following impacts:

- discharge of contaminated water (ARD) into the surface water receptors;
- ARD seepage from the dumps into the groundwater;
- airborne dust from the deposited material;

The Valea Verde waste rock dump and the south Cirnic hill waste rock dumps drain into the Corna watershed.

The Hop waste rock dump and the west Cetate waste rock dump zone drain into the Rosia valley.

Table 3-3. Quality of Cetate seepage water and typical field column leachate[xvii]

Parameter	Unit	Cetate Seepage (Station S031)	Field Column Leachate (VXB07)
pH	Std. Units	6.5	7,0
Conductivity	mS/cm	489	3340
Calcium	mg/L	62.4	327
Magnesium	mg/L	18.4	458
Sodium	mg/L	6.12	14.4
Sulphate	mg/L	140	2168
Arsenic	mg/L	0.0048	0.0093
Cadmium	mg/L	0.0024	ND
Chromium	mg/L	0.0019	0.0181
Copper	mg/L	0.0058	0.0171
Iron	mg/L	1.1	0.06
Manganese	mg/L	0.675	0.50
Nickel	mg/L	0.0049	0.0397
Selenium	mg/L	0.0092	0.0426
Zinc	mg/L	0.0226	0.186

Error! Reference source not found. shows the results of water quality measurements performed by Knight
Piesold and AGRARO which are relevant for the this study.

Table 3-4. Surface water quality in mining area, cited after Table 4.10 in AGRARO 2003[xviii])

Area*	pH	Mo	Cu	Ba	Ni	Fe	Mn	Crtot	Zn	Pb	Co	Cd	Ag	Se	Hg	As	Cond.	Sat.	Res.
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µS/cm		mg/l
IV		0.01	0.08	0.01	0.04	6.96	6.14	0.02	0.31	0.01	0.02	0.00	0.00	0.05	BDL	0.05	1066.00	0.50	520.00
IV	7.20	0.01	0.00	0.01	0.00	0.07	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.05	BDL	0.05	123.70	0.10	58.00
V	5.40	0.01	0.30	0.02	0.57	125.90	342.70	0.07	8.36	0.06	0.38	0.02	0.00	0.05	BDL	0.05	3740.00	1.90	1810.00
V	5.21	-	-	0.01	0.40	104.40	158.50	0.09	4.10	0.01	0.44	0.00	0.00	0.05	BDL	0.05	3100.00	-	-
V	-	-	-	-	0.02	0.00	4.59	0.11	0.37	0.01	0.00	0.00	0.00	0.05	BDL	0.05	2840.00	1.40	1400.00
V	-	0.01	0.05	-	0.20	62.20	127.00	0.02	2.55	0.02	0.14	0.07	0.00	0.05	BDL	0.05	2850.00	1.50	1420.00
V	-	-	-	0.01	0.02	0.07	7.26	0.01	0.12	0.01	0.01	0.00	0.00	0.05	BDL	0.05	746.00	-	-
V	6.22	0.01	0.09	-	0.47	84.35	214.60	0.09	6.05	0.05	0.08	0.00	0.00	0.05	BDL	0.05	3490.00	1.80	1730.00
V	6.20	0.01	0.03	0.00	0.21	0.01	3.17	0.11	0.78	0.01	0.00	0.00	0.00	0.05	BDL	0.05	1777.00	0.80	801.00
V	6.72	0.01	0.03	0.02	0.00	0.07	1.37	0.17	0.43	0.02	0.00	0.00	0.00	0.05	BDL	0.05	766.00	0.30	335.00
V	6.95	0.01	0.03	0.01	0.02	0.03	2.48	0.18	0.74	0.06	0.00	0.00	0.00	0.05	BDL	0.05	885.00	0.40	394.00
VI	3.54	0.01	0.53	0.01	0.14	90.22	66.83	0.06	4.62	0.01	0.10	0.00	0.00	0.05	BDL	0.05	1615.00	0.80	865.00
VI	6.52	0.01	0.05	0.02	0.04	0.27	4.13	0.08	1.08	0.01	0.01	0.00	0.00	0.05	BDL	0.05	504.00	0.20	243.00
VI	8.03	0.01	0.01	0.05	0.05	0.22	0.00	0.01	1.11	0.03	0.00	0.00	0.00	0.05	BDL	0.05	443.00	0.20	210.00
VI	7.73	0.01	0.01	0.04	0.00	0.26	1.79	0.05	0.63	0.05	0.00	0.00	0.00	0.05	BDL	0.05	477.00	0.20	210.00
VI	4.50	0.01	-	-	0.03	0.41	12.91	0.01	0.83	0.01	0.02	0.01	0.00	0.05	BDL	0.05	665.00	-	-
VI	3.20	0.01	0.06	0.00	0.04	1.72	6.06	0.02	0.20	0.01	0.02	0.00	0.00	0.05	BDL	0.05	1059.00	0.50	514.00
VII	3.06	0.01	1.17	0.00	0.24	200	63.52	0.08	3.56	0.04	0.00	0.00	0.00	0.05	BDL	0.05	2450.00	0.90	949.00
VII	8.46	0.01	0.01	0.03	0.02	0.11	0.08	0.13	0.00	0.08	0.01	0.00	0.00	0.05	BDL	0.05	323.00	0.10	143.00
VII	7.63	0.01	0.00	0.04	0.00	0.01	0.01	0.22	0.00	0.01	0.01	0.00	0.00	0.05	BDL	0.05	298.00	0.10	136.00
VII	7.27	0.01	0.00	0.08	0.00	0.32	0.06	0.01	0.01	0.01	0.00	0.00	0.00	0.05	BDL	0.05	150.10	-	-
NTPA 1/2002	6.5/8.5	0.1	0.1		0.5	5.0	1.0	1.0	0.5	0.2	1.0	0.2	0.1	0.1	0.05	0.1			

* Numbering of source areas according to AGRARO[xix]

Zone IV: Hop waste rock dump
Zone V: Valea Verde waste rock dump
Zone VI: south Cirnic hill waste rock dumps
Zone VII: west Cetate waste rock dumps zone

Seepage from the waste dumps is diffusively discharging into the local streams. There is no point-like discharge which could practically be collected and treated. Under these circumstances, the only mitigation measure is to minimize the source by either removing or covering a waste dump.

The waste dumps also lead to soil contamination, according to the findings of AGRARO[xx]. The biggest soil contamination problems are caused by the two active dumps which are also the largest in size, e.g. Hop and Valea Verde.

In case of the old waste rock dumps, their impact on the soil is greatly reduced. It is noted that the majority of the old dumps are already covered by spontaneous vegetation which, in some cases, makes it difficult to identify the dump within the natural landscape.

The dumps also pose potential slope stability problems and need to be stabilized after a detailed stability analysis.

3.4 Administration Head Office

The administrative buildings do not represent a serious contamination source, compared with the mine effluent or the waste dumps but must be removed at closure. Possibly, some soil contamination may be detected beneath the foundations (e.g., from oil/lubricants stored in the basement) which will have to be removed.

3.5 Ore Bins, Fuel and Lubricant Storage Tanks

An assessment of the raw material and materials storage operation indicates the following potential pollution sources for soil, subsoil and water table:

- Fuel and lubricant residues may seep from storage tanks into the soil and groundwater.
- Around ore bins, soil may be contaminated with ore which may lead to groundwater and/or soil contamination
- These storage tanks and bins must be removed and the soil beneath be cleaned up, if a detailed investigation shows that it is contaminated.

3.6 Conclusions on the Environmental Impacts and Proposed Measures

ECOIND pointed out that closure of activities and decommissioning of a number of facilities will not lead to immediate elimination of all pollution sources such as

- discharge of untreated mine water
- discharge of ARD generated by waste dumps

and has therefore proposed remediation actions to prevent a continued pollution of the environment. However, ECOIND also pointed out that the proper design of environmental rehabilitation measures requires more studies that determine the impacted areas and degree of pollution, i.e.,

- soil and groundwater quality within the operating sites and the extent of the pollution as area and future development cannot not be estimated;
- impacts on the aquatic ecosystems within the surface waters in the area.

By and large, AGRARO[xxi] confirms these findings with minor modifications which can be neglected for the purpose of the present study.

The following list contains a summary of the recommendations based on the findings by AGRARO[xxii] and ECOIND[xxiii] (designated with an asterisk) and complemented by WISUTEC/WISMUT.

General measures

- Set up an authorized waste disposal area designated for waste resulting from demolition, environmental rehabilitation, etc.*
- Design and implementation of an overall and integrated water and sediment quality monitoring system*
- Identification and topographical localization of acid water sources in the area of past/current underground and/or surface mining sites *
- Clean up of any water diversion and stormwater ditches*

Underground mine workings

- Salvage of underground equipment, plants and platework by cutting, loading and transport (sale as scrap)
- Sealing of mine adits and portals*
- Geotechnical stabilization of underground workings (risk of subsidence)*
- Capture and treatment of mine effluents*
- Remove contaminated sediments in the Rosia creek downstream the mine effluent discharge

Open pits

- Geotechnical stabilization of pit slopes and construction of pit crest safety berms, erecting warning signs at steep sloped*
- Manage water in pit by either collecting and treating the water or draining it through a channel into the Rosia valley (possibly through underground mine workings)

Waste dumps

- Reshaping waste rock dumps following a geotechnical stability investigation program (particularly Valea Verde and Hop dumps)*
- Placement and revegetation of cover on waste dumps*
- Capture and treatment of waste rock seepage* (probably not practically feasible due to mostly diffuse flow patterns)

Buildings, equipment, infrastructure

- Salvage of metal subassemblies by cutting, loading and transport (sale as scrap)*
- Dismantle buildings, production structures, storage areas and equipment and dispose of rubble, according to its degree of contamination
- Investigate soil contamination beneath demolished structures and remove as appropriate

4 Potential Remediation and Rehabilitation Measures (BAT)

4.1 General Remarks

The description of the potential remediation and rehabilitation measures for the "Zero alternative" will be conducted on a pre-feasibility level. The preferred, "best-suitable" remediation concept will be described at a degree of detail so as to allow a first and basic cost estimation. The description of the remediation activities will be structured according to the individual objects discussed in Section 3 on a generic level.

Since the accuracy of the cost estimation is rather limited at this time a contingency factor of 20 % will be applied.

Cost estimates presented below are based on the Consultant's experience and a EU price basis. These prices may have to be refined and adapted to the local conditions, perhaps using a simple scaling factor.

4.2 Open Pits

Description of the Preferred Remediation Option

Remediation measures at the Cetate open pit include the geotechnical stabilization of the pit walls and the construction of pit crest safety berms. In addition, warning signs will be erected at the crest of the pit walls. Surface water which is collected within the pit will be drained off through the ore chute to the underground galleries where they report to the general mine drainage flow.

Pit wall stabilization measures cannot be defined properly based on the data available and the limited time available for this study. As a first step, a detailed geotechnical investigation is required for which a lump sum is assumed in

. Based on the investigation results, technical measures can be defined for which no costs are contained in

, however, due to the considerable uncertainty.

The pit walls and bottom will be revegetated by hydro-seeding or planting climbing plants in order to prevent further erosion and enhance the visual appearance of the pits.

A road will be constructed which leads into the pit and provides access to monitoring points as well as to points of public interest such as exhibits reminding of the mining history, a hiking and/or educational trail or similar uses.

The Carnic pit is much smaller and shallower than the Cetate pit, so that it is assumed that less remediation works are required which is neglected in the cost estimates for the moment. For revegetation of the pit walls and bottom, an area of 8 ha is assumed.

Measures to guarantee quality assurance, work safety, and environmental impact reduction include fencing of the construction sites to prevent the access of unauthorized persons, management and treatment of contaminated effluents and dust prevention.

Cost Estimate
The costs for the stabilization of Cetate pit are estimated in the following table.

Table 4-1. Cost estimate for the remediation of the Cetate and Cirnic pits

Complex	Position	Amount	Unit Cost (€ per unit amount)	Total Cost
Stabilization of pit walls	Geotechnical investigation, walkover survey, design (no works included)	lump sum		50,000 €
Construction of pit safety berm (2 km long, 7m wide, 2 m high) including inspection road	supply material	16,000 m3	2.50	40,000 €
	material placement and berm construction	16,000 m3	2.50	40,000 €
	Erosion control (seeding)	16,000 m²	0.50	8,000 €
	Road into pit for inspection and to provide access to points of interest (hiking trail, educational trail), 3.5 m wide	2,000 m	150	350,000 €
Erection of warning signs		50	100	5,000 €
Hydraulic works within the pit (seepage drainage into underground mine)	Surface water management, repair/upgrade ore chute in pit to mine galleries for water drainage into underground mine	lump sum		50,000 €
Revegetation of Cetate pit slopes	Hydroseeding, climbing plants	22 ha	0.50	110,000 €
Revegetation of Carnic pit slopes	Hydroseeding, climbing plants	8 ha	0.50	40,000 €
Subtotal construction				693,000 €
Engineering (10 %)	Design planning, permitting, tendering, project management			69,300 €
Technical support (2%)	quality assurance, work safety, monitoring			13,860 €
Contingency (20 %)				138,600 €
Total construction				914,760 €

Table 4-2. Cost estimate for monitoring and maintenance of the rehabilitated open pits

Complex	Position	Amount/ year	Unit cost (€ per unit amount)	Total cost (€ p.a.)
Monitoring/ maintenance				
Total Yrs 1-5 after completion	annual visual inspection of the rehabilitated sites incl. report, controlling and possibly repair of the vegetation, maintenance of water diversion ditches, stability control of pit walls	30 ha	500,00	15,000
Total Later than yr 6 after completion	annual visual inspection of the rehabilitated sites incl. report, maintenance of water diversion ditches, stability control of pit walls	30 ha	100,00	3,000

4.3 Waste Rock Facilities

Description of the Preferred Remediation Option

The preferred remediation option for the waste rock facilities includes the following:

The Valea Verde and the Hop Dumps with a recent total volume of about 4 million m³ (see **Error! Reference source not found.**) and a total area of about 30 ha will be stabilized in situ since transportation to an alternative location (preferably the Cetate open pit) would cause substantial extra cost and additional environmental impacts (noise, dust, exhaust gases) without gaining an adequate environmental benefit.[2]

Slope areas must be reshaped/flattened to slope angles not exceeding 1V : 3H to ensure sufficient stability for the cover system to be constructed. The waste rock volume to be moved during reshaping is estimated to be 10… 20 % of the total dump volume, for the cost considerations an average of 15% will be used.

Waste rock from the 15 other inactive dumps which account for an additional volume of about 300 Tm³ should be relocated to the Valea Verde/Hop Dumps, wherever possible with reasonable effort. As a whole these wastes are considered to be a spatially “scattered”, potentially water-contaminating source, and their relocation will limit the need of long term water management/ treatment, especially in the Corna catchment area. As described above the majority of these old dumps is already covered by vegetation which, in some cases, makes it difficult to identify them within the natural landscape. It is assumed that the objects equal or bigger than 20 Tm^3 with a total area of approx. 3 ha can be identified and relocated. They account for a volume of about 200 Tm^3 (two thirds of the inactive dumps material, according to **Error! Reference source not found.**).

Waste material from reshaping and the additional material from relocation of the minor dumps will be deposited on and besides the existing dump perimeter, expanding the footprint of the dumps by an estimated 30% from 31 to 40 ha.

Within a small delineated area on the waste rock dump, an authorized waste disposal site will be constructed, to accommodate additional material from site clean-up, mine closure and remediation. These materials include waste resulting from demolition, environmental rehabilitation, and residues from water treatment. No virgin land will be used for this disposal area.

The final landform will be modelled to aesthetically fit onto the surrounding landscape. This requires slightly higher costs than just dozing the waste heap surface into a geotechnically stable shape, but serves the purpose to create a beneficial after-use of the waste heaps by the public.

Cover System

The cover system on the Valea Verde and Hop dumps consists of a three layer cover which effectively minimizes infiltration and oxygen ingress, consisting of a 40 cm compacted clay barrier, a 20 cm drainage layer (including 10 cm sand on top of the drainage layer to prevent clogging) and a 100 cm recultivation layer (10 cm topsoil and 90 cm subsoil).

The cover design is based on model calculations for the water and oxygen transport for different variant of cover system configurations[xxiv] and a cost-benefit comparison among these variants:

[2] Costs for complete relocation would be in the order of about 20 million €, which would almost triple the total remediation costs for the waste rock remediation measures, according to the cost estimates presented in section 0.

- The infiltration rates of a single-layer store and release cover (SRC) are relatively high under the site-specific conditions (around 10-25% or 80-200 mm/a at a precipitation rate of 800 mm/a). For the further comparisons, 20% or 160 mm/a infiltration is assumed. Oxygen ingress into the ARD generating waste rock material is only weakly affected (estimated 18 kg/a per m²).
- If a drainage layer is included (with a protection layer of 0.2 m sand to prevent clogging), the infiltration rate is of the order of 5% or 40 mm/a. Oxygen ingress is minimized, too, to an estimated 50 g/a per m²).
- The additional cost for a cover including a drainage layer is mainly determined by the material costs (18.50 €/m³ for the drainage layer and 12.50 € for the sand protection layer) and placement costs (2 €/m³) of that additional layer. Taking into account the layer thicknesses described above, additional costs of 4.95 €/m² for the cover system are estimated.

On the other hand, water treatment costs are reduced which pays off over the long term. From Section 0, it can be derived that marginal water treatment costs are around 1.63 €/m³ if all limits of the NTPA 001/2005 standard are to be met. The reduction of the infiltration rate from 160 to 40 mm/a means a reduction of water treatment costs per m² surface of the waste dumps of 0.2 €/a. The extra cost of 4.95 €/m² for the more sophisticated cover design is amortized within 25 years.

In addition, the minimized infiltration and oxygen flux into the waste rock material adds an environmental benefit by minimizing ARD generation in the future.

Immediately after completion of the earth works the cover surface will be vegetated by grass to ensure stability against erosion. Reforestation is possible, natural succession can be allowed but should be controlled if a certain forest type is required under specific usage scenarios (e.g., sale of the reforested areas for wood production).

A system of trails, small roads and resting areas will be constructed on the cover to allow some tourist after-use. This may also include educational or hiking trails, information signs and posters, viewpoints etc. These measures serve as a potential beneficial after-use of the mine waste heaps, as required by the Mine Waste Directive 2006/21/CE and good practice in mine closure and rehabilitation.

Contaminated seepage from both the Valea Verde and Hop dump will be drained into the underground galleries which will lead the contaminated mine and seepage water to the portal of Adit 714 for subsequent treatment (see section 4.6, where an infiltration well is assumed which drains the seepage into the mine).

Measures to guarantee quality assurance, work safety, and environmental impact reduction include fencing of the construction sites to prevent the access of unauthorized persons, management and treatment of contaminated effluents and dust prevention.

The long-term monitoring after placing the final cover consists of

- controlling and possibly repair of the vegetation
- in-situ measurement and continuous registration of water content and water tension in the final cover as well as the cumulative volume of infiltration water directly under the final cover of the plateau surface with an appropriate automated monitoring-station (Lysimeters, see section 4.7).
- annual visual inspection of the rehabilitated sites.

In the initial phase (some years after completion of the physical remediation works), maintenance works consist of re-sowing in case there are gaps in the vegetation cover. If erosion patterns in the cover occur before the vegetation is fully developed, they must be repaired. With full development of the vegetative cover, erosion will no longer be a problem.

Cost Estimate
The costs for the remediation of Valea Verde and Hop waste dumps including the partial relocation of waste from the inactive dumps are compiled in the following table.

Table 4-3. Cost estimate for the remediation of Valea Verde and Hop waste dumps, including relocation of 200 Tm³ of waste from the inactive dumps

Complex	Position	Amount	Unit Cost (€ per unit amount)	Total Cost
Inactive dumps				
Work site preparation	7 individual locations (Verkes, Rakosi, Iuliana, Afinis, 23 August, Manesti Adit, and Adit 938 dumps), lump sum: 10,000 € each	7	10,000	70,000 €
Removal of vegetation		30,000 m2	1.50	45,000 €
Relocation of waste rock	Excavation, relocation (<2 km) and compacted disposal	200,000 m3	6.00	1,200,000 €
Site reclamation	Supply of mineralic/ humic soil, material cost incl. delivery to the site, thickness 0.3 m	9,000 m³	7.50	68,000 €
	Placement of soil material, 0.3 m	9,000 m³	2.00	18,000 €
	Erosion control (seeding)	30,000 m²	0.50	15,000 €
Valea Verde /Hop dumps				
Work site preparation		lump sum		30,000 €
Partial removal of vegetation	10 hectares, i.e., a third of surface of existing waste dumps	100,000 m2	1.00	100,000 €
Reshaping of waste rock material	Excavation, relocation (<1 km) and compacted disposal, landscaping of waste dump surface	600,000 m3	4.00	2,400,000 €
Cover construction, 40 ha	Supply of cohesive barrier material, material cost incl. delivery to the site, thickness 0.4 m	160,000 m³	7.50	1,200,000 €
	Supply of drainage layer material, material cost incl. delivery to the site, thickness 0.2 m	80,000 m³	18.50	1,480,000 €
	Protection layer (sands), 0.1 m	40,000 m³	12.50	500,000 €
	Supply of recultivation material, material cost incl. delivery to the site, thickness 1.0 m	400,000 m³	7.50	3,000,000 €
	Placement of compacted clay barrier	160,000 m³	2.00	320,000 €
	Placement of drainage and protection layer	120,000 m³	2.00	240,000 €
	Placement of storage/ recultivation layer	400,000 m³	2.00	800,000 €
	Erosion control (seeding)	400,000 m²	0.50	200,000 €
	Road and hydraulics construction (including resting areas, hiking/educational trails), estimated per dump area	400,000 m²	2.50	1,000,000 €
Subtotal construction				12,686,000 €
Engineering (10 %)	Design planning, permitting, tendering, project management			1,268,600 €
Technical support (2%)	quality assurance, work safety, monitoring			253,720 €

Contingency (20 %)				2,537,200 €
Total construction				16,745,520 €

Table 4-4. Cost estimate for monitoring and maintenance of the remediated Valea Verde and Hop waste rock dumps

Complex	Position	Amount/ year	Unit cost (€ per unit amount)	Total cost (€ p.a.)
Monitoring/ maintenance				
Total Yrs 1-5 after completion	annual visual inspection of the rehabilitated sites incl. report, controlling and possibly repair of slope systems and vegetation, maintenance of water diversion ditches	44 ha [3]	500,00	22,000
Total Later than yr 6 after completion	annual visual inspection of the rehabilitated sites incl. report, maintenance of water diversion ditches	40 ha [4]	100,00	4,000

4.4 Abandoned Industrial Areas

Description of the Preferred Remediation Option
The abandoned industrial areas include the Gura Minei site, the Verkes and Gura Minei central explosives storehouses, fuel and lubricant storage tanks, a number of magazines and warehouses, the ore bin located at the Gura Minei site, the Company Headquarters, and electric power supply facilities.

Soil contamination is expected due to the activities carried out at the sites, such as ore handling, loading and hauling. The entirety of the buildings, facilities and operational areas besides the company's headquarter have to be demolished and cleaned-up.

The following technologies are planned for demolition, site reclamation and disposal:

- Demolition of buildings, structures and facilities incl. their foundations using mechanical equipment (backhoe mounted rams, breakers, pneumatic hammers, gripping devices)
- dismantling of metallic structures (pipes, galleries, stairs) by help of gas cutting, release of non-contaminated scrap for recycling
- transport and disposal of the demolition debris to the disposal area
- excavation of contaminated soil using bulldozers and excavators
- transport and disposal of contaminated soil to the disposal area,
- preparation measures at the disposal site (excavation, re-shaping) using bulldozers, erection of "mini"-dams to construct cells ("cassettes") for placement of soil, debris, and contaminated scrap metal in layers of 1 m maximum thickness, interim covering of the cells
- external disposal of hazardous waste/ mixed debris, contaminated with organic contaminants

[3] Valea Verde and Hop Dumps after reshaping and placement of relocated wastes (40 ha) plus footprint areas of relocated dumps (3 ha)
[4] Valea Verde and Hop Dumps after reshaping and placement of relocated wastes (40 ha)

- site reclamation, final covering (placement of inert soil material 0.3 m, erosion control (seeding)

The disposal area will be finally covered as a part of the waste rock reclamation measures (see section 4.3).

Removal of scrap metal is neglected in the cost estimates. The specific cost component for dismantling steel scrap in the total demolition costs[xxv] (181 €/t, consisting of 61 €/t equipment cost, 80 €/t Romanian labor cost, approx. 40 €/t transportation) are approximately covered by the proceeds from the sale of steel scrap (approx. 180 €/t[xxvi]).

With the same reasoning, the removal of electric power supply facilities will be neglected in the cost estimates (proceeds are likely to even exceed the costs due to the high copper and steel content).

The amounts of contaminated soil which must be excavated and disposed of are assumed to be 8%, or 500 m^2, of the Gura Minei site, and an average depth of soil contamination of 2 meters. This results in 1000 m^3 of contaminated soil.

Measures to guarantee quality assurance, work safety, and environmental impact reduction include fencing of the construction sites to prevent the access of unauthorized persons, management and treatment of contaminated effluents and dust prevention.

Cost Estimate

Table 4-5. Cost estimate for demolition and site clean-up of the industrial areas

Complex	Position	Amount	Unit Cost (€ per unit amount)	Total Cost
Gura Minei site				
Work site preparation		1	20,000 lump sum	20,000 €
Demolition of buildings	per m³ of buildings5	6,000 m³	7.50	45,000 €
Demolition of foundations		360 m³	50	18,000 €
Transport and disposal of the demolition debris to the disposal area	loading and transport and disposal, 2 km transportation distance	2,000 m³	7.50	15,000 €
Excavation of contaminated soil		1,000 m3	10.00	10,000 €
Transport and disposal of contaminated soil to the disposal area		1,000 m3	7.50	7,500 €
External disposal of contaminated material	mixed debris, contaminated with organic contaminants	200 t	100	20,000 €
Site reclamation	Supply of mineralic/ humic soil, material cost incl. delivery, thickness 0.3 m on 6200 m²	1,860 m³	7.50	13,950 €
	Placement of soil material, 0.3 m, on 6200 m²	1,800 m³	2.00	3,600 €
	Erosion control (seeding)	6,200 m²	0.50	3,100 €
SubtotalGura Minei				156,150 €
Verkes and Gura Minei Explosives storehouse, Fuel and Lubricant storage tanks, other magazines and storehouses, ore bin	rough estimate based on the assumption that remediation of entirety of smaller facilities leads to costs comparable with those of the Gura Minei site			160,000 €
Subtotal demolition/ construction				316,150 €
Engineering (10 %)	Design planning, permitting, tendering, project management			31,600 €
Technical support (2%)	quality assurance, work safety, monitoring			6,000 €
Contingency (20 %)				63,000 €
Total construction				416,750 €

4.5 Underground Mine

Description of the Preferred Remediation Option

The system of underground mine workings consisting of recent main levels (connected with the surface through adits), intermediate levels and stopes. Currently, only levels 820 and 714 are operational and service the ore haulage system at Cetate and Napoleon pits. Level 714 is the main haulage level and also provides the water drainage.

[5] Gura Minei buildings covering an area of 1193 m² (see Section 2.2), with an average height of 5 m (2 story buildings)

The underground galleries are accessible via the the Rakosi adit (elevation + 820 m) and Sfanta Cruce adit (elevation = 714 m) which are discharging contaminated mine water to the Roşia valley. In addition there are about 10 adit portals/ outcropping drifts which connect the Cetate pit with the underground mine.

As a minimum, closure activities require:

- Dismantling and removal of contaminated equipment from the underground galleries, transport to/disposal at the disposal area at Valea Verde/Hop dump, or recycling
- Stabilization/closure of the adit portals to prevent unauthorized access to the underground mine
- Restoration of the water management facilities at Sfanta cruce and Rakosi adits to ensure proper collection of the contaminated mine water and pumping/gravitational drainage to the water treatment plant
- Removal of contaminated sediments from the Ripa Alba and Roşia creeks

According to BAT[xxvii], adit portals must be secured or plugged using one of the following approaches:

a) Securing of the adit opening with a lockable lattice or steel door. This option is mainly chosen if the adit has to be used further on.
b) Plugging of the adit opening with a wall or a concrete dam.
c) Plugging of the adit opening with a concrete section.
d) Plugging of the whole adit until the end of the tunnel, or at least over partial ranges with cohesive backfill, which is stable against erosion.
e) Closure of the adit opening by blasting of the host rock or by material deposition in front of the mouth (“overwhelming”).

Detailed knowledge about the specific situation is necessary to make a proper decision about the optimum technology. The most important factors are:

- Position of the adit to the surface
- Geological and hydrogeological conditions at the adit route (fault zones, overburden rock, seepage/ infiltration water)
- Present functionality of the adit (haulage, ventilation system, mine water drainage)
- Type of construction, status of the adit between the opening and end (support, installations, collapsed areas).

For this study we suppose the following closure options, because they seem most likely:

- Rakos and Sfanta Cruce adits – option a)
- adits/ galleries at the bottom/flanks of the Cetate pit – option c)

Additional stabilization measures at shallow mine workings might be necessary to exclude collapsing and damage to the surface.

Cost Estimate
The cost estimates are unavoidably beset with uncertainties. Therefore the Consultant has used experience-based cost estimates from similar closure and remediation projects[xxviii].

Table 4-6. Cost estimate for closure of the underground mine

Complex	Position	Amount	Unit Cost (€ per unit amount)	Total Cost
Stabilization of adit portals				
Rakos adit	lockable lattice/steel door	lump sum		10,000 €
Sfanta Cruce adit	lockable lattice/steel door	lump sum		10,000 €
Adits/galleries at the bottom/flanks of Cetate pit	Work site preparation	lump sum		50,000 €
	Complete plugging of 10 portals, estimated cross section of 7m2 each, concrete plug length of 20 m each	1,400 m³	100	140,000 €
Investigation/stabi-lization of shallow underground workings				
Drilling for investigation/backfilling	estimated meters to be drilled	500 m	100	50,000 €
Backfill	estimated volume to be backfilled with concrete	5,000 m³	100	500,000 €
Reconstruction of water collection and drainage at 714 mine adit	200 T€ (lump sum from similar works at WISMUT)	1	200,000	200,000 €
Reclamation of contaminated river bed	Excavation of contaminated river bed at Rosia stream, refill of excavated volume with uncontaminated material (2 meters broad strips on right and left bank, 2 m broad riverbed, 0.5 m excavation depth), temporary water diversion	500 m	45	22,500 €
	Transport and disposal to disposal area on Cetate waste dump	1,500 m³	7.50	11,250 €
Subtotal construction				993,750 €
Engineering (10 %)	Evaluation, design planning, permitting, tendering, project management			99,375 €
Technical support (2%)	quality assurance, work safety, monitoring			19,875 €
Contingency (20 %)				198,750 €
Total construction				1,311,750 €

4.6 Water Treatment

Characterization of the Mine Drainage

The acid mine drainage at the Gura Minei Adit (Adit 714 m asl) was already characterised in **Error! Reference source not found.**. However, these raw data show some deficiencies due to unbalanced ionic composition which makes it difficult to design a water treatment process. Therefore, in a first step the water composition was adjusted pr re-balanced using assumptions from a previous study[xxix]. The result is shown in **Error! Reference source not found.**. The further considerations focus on the 714 Adit only, while the Rakos adit effluent is neglected for the moment due to the much smaller flow rate.

Table 4-7. Characterization of the effluent at Gura Minei Adit, and re-balancing the ionic composition (elements exceeding the NTPA 001/2005 standard are printed bold face)

Parameter	All parameter in mg/l unless stated otherwise			Limit (NTPA001/2005)
	R 0865 used in WISUTEC Studyxxx	CEPROMIN (see Error! Reference source not found.)	Re-calibrated ionic balance	
pH	3	2.22	2.22	6.5 - 8.5
Conductivity mS/cm	3,812.5	-	3,812.5	
Redox potential (mV)	406.7	-	406.7	
Total Dissolved Oxygen	5.8	-	5.8	
Suspended matter	199.7	-	199.7	
Chloride	97.6	42.6	42.6	500
Sulphate	2237.4	4,831	4,831	600
Bicarbonate	0	-	0	
Carbonate	0	-	0	
Silicate	45.2		45.2	
Nitrate	29.2	4.24	4.24	25
Nitrite	-	0.002	0.002	1
Phosphate	2.2	-	2.2	
Ammonia	-	4.34	4.34	2
Calcium	283.6	260	260	300
Magnesium	105	31.6	31.6	100
Sodium	15.8	-	15.8	
Potassium	7.1	-	7.1	
Aluminium	-	-	367.8	
Fluor	1.4	-	1.4	
Iron	581.1	522.3	522.3	5
Manganese	282.1	314.8	314.8	1
Nickel	0.76	1.44	1.44	0.5
Chromium	0.27	0.05	0.05	0.1
Arsenic	0.62	-,	0.62	0.1
Copper	4.01	2.86	2.86	0.1
Lead	0.1	0.14	0.14	0.2
Zinc	55.5	39.1	39.1	0.5
Cobalt	0.55	-	0.55	1
Molybdenum	0.007	-	0.007	0.1
Antimon	0.2	-	0.2	
Selenium	0.16	-	0.16	0.1
Cyanide	0.001	-	0.001	
Cadmium	0.36	0.47	0.47	0.2
Mercury	0.00003	-	0.00003	0.05

The re-calibration approach is briefly described in the following:

- Chemical constituents missing in **Error! Reference source not found.** are complemented with data from the sampling point R 0865 used in a previous study[xxxi].
- The plausibility of the dataset was checked using the ionic balance. It exhibits a strong deficit of cations which cannot be explained by tolerances of the chemical analyses.
- The ionic balance was restored by assuming an Aluminium concentration of 367 mg/l. This seems justified, because Aluminium is missing from the existing data altogether while its presence must be expected in typical acid mine drainage.

For the further considerations, the mine water composition shown in Column 4 of **Error! Reference source not found.** is used. They are compared with the discharge limits according to NTPA 001/2005. also shown in **Error! Reference source not found.** (last column).

The average flow rate is approximately 50 m³/h, while the maximum flow rate during prolonged wet periods may reach 100 m³/h.

Characterization of the Waste Rock Drainage

Error! Reference source not found. lists the pH and heavy metal concentration in a number of seepage waters and surface waters impacted by waste rock seepage. Typical sulphate, calcium, magnesium and sodium concentrations are listed in **Error! Reference source not found.**.

Like the mine effluents, the waste rock seepage must be re-calibrated with respect to the ionic balance, in order to obtain a plausible water composition. The following approach was chosen:

- The water composition is assembled from comlumns 2 and 3 of **Error! Reference source not found.**. With respect to heavy metals, the concentrations are conservatively assumed to be the maximum of both columns.
- The plausibility of the data was checked using the ionic balance. The ionic balance in the raw data of **Error! Reference source not found.** exhibits a pronounced deficit of anions which cannot beis errors. explained by analysis tolerances.
- The ionic balance of the neutral seepage was restored by assuming a bicarbonate concentration of 386 mg/l.

Table 4-8. Characterization of the waste dump seepages, and re-balancing the ionic composition (only heavy metals exceeding NTPA 001/2005 are shown, components exceeding the NTPA 001/2005 are printed bold face)

Parameter	All parameter in mg/l unless stated otherwise			Limit (NTPA001/2005)
	Error! Reference source not found.	Error! Reference source not found.	Re-calibrated ionic balance	
pH	7	6.5	7	6.5 - 8.5
Sulphate		2,168	2,168	600
Bicarbonate	n.d.	n.d.	386	
Calcium		327	327	300
Magnesium		458	458	100
Sodium		14.4	14.4	
Iron	342	1.1	342	5
Manganese	0.57	0.67	0.67	1
Arsenic	1.17	0.0048	1.17	0.1
Lead	8.36		8.36	0.2

Since a number of components exceed the allowable discharge concentrations, the waste rock seepage must be treated.

The Valea Verde an Hop waste rock heaps have a footprint of around 30 ha. Assuming an annual precipitation rate of 721 mm and an infiltration rate of the cover of approximately 10%, the seepage flow rate of both heaps is approx. 2.5 m^3/h.

Water Management

The Gura Minei Adit (714 Adit) effluent dominates the site-wide water management strategy, for both quantity and quality. It is therefore sensible to locate the ARD treatment plant closely downstream of the 714 Adit.

The area needed for the ARD treatment plant is on the order of 1000 m^2.

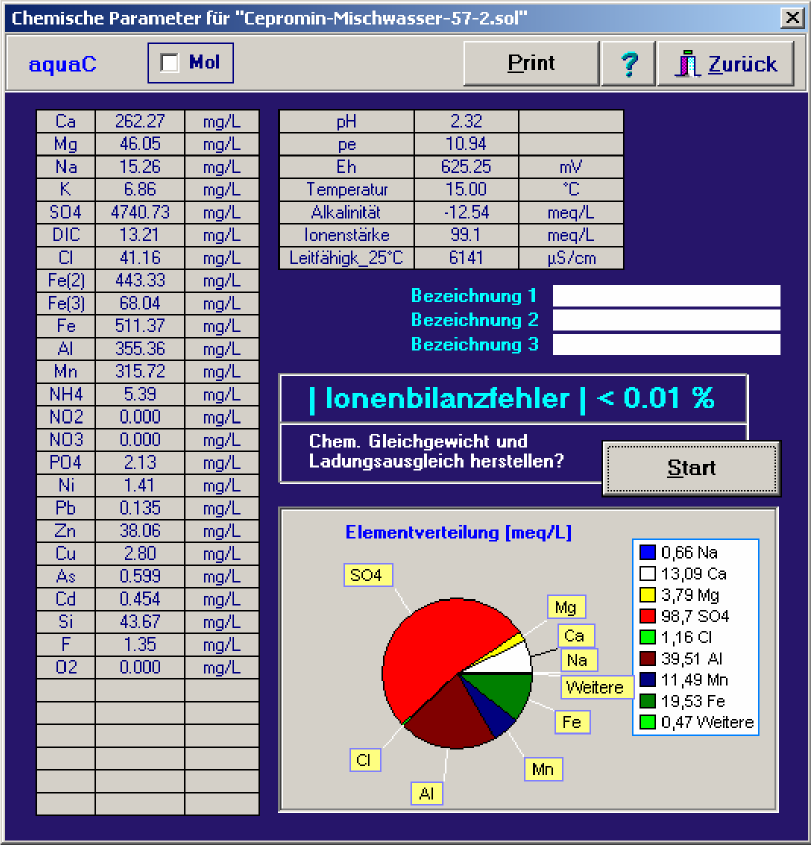
With respect to the waste rock seepage, the following measures are foreseen:

- The seepage will be captured in a deep drainage rigole along the circumference of the waste dumps.
- Through a borehole, the collected seepage will be drained into the underground workings which report to the 714 Adit. This has the advantage that the seepage is gravitationally drained towards the water treatment system without the need of perpetual pumping or a separate treatment plant.
- Uncontaminated surface runoff will be captured, drained away and discharged into the Corna or Rosia valley without treatment.

The composition of the mine effluent which is collected at the 714 Adit is calculated as a mixture of the water qualities in **Error! Reference source not found.** and **Error! Reference**

source not found.. The resulting, thermodynamically equilibrated[6], composition is shown in **Error! Reference source not found.**.

Table 4-9. Predicted mine water quality, resulting from 50 m³/h mine water and 2 m³/h waste rock seepage, drained into the underground mine



Chemische Parameter für "Cepromin-Mischwasser-57-2.sol"

aquaC | Mol | Print | ? | Zurück

Ca	262.27	mg/L
Mg	46.05	mg/L
Na	15.26	mg/L
K	6.86	mg/L
SO4	4740.73	mg/L
DIC	13.21	mg/L
Cl	41.16	mg/L
Fe(2)	443.33	mg/L
Fe(3)	68.04	mg/L
Fe	511.37	mg/L
Al	355.36	mg/L
Mn	315.72	mg/L
NH4	5.39	mg/L
NO2	0.000	mg/L
NO3	0.000	mg/L
PO4	2.13	mg/L
Ni	1.41	mg/L
Pb	0.135	mg/L
Zn	38.06	mg/L
Cu	2.80	mg/L
As	0.599	mg/L
Cd	0.454	mg/L
Si	43.67	mg/L
F	1.35	mg/L
O2	0.000	mg/L

pH	2.32	
pe	10.94	
Eh	625.25	mV
Temperatur	15.00	°C
Alkalinität	-12.54	meq/L
Ionenstärke	99.1	meq/L
Leitfähigk_25°C	6141	µS/cm

Bezeichnung 1
Bezeichnung 2
Bezeichnung 3

| Ionenbilanzfehler | < 0.01 %

Chem. Gleichgewicht und Ladungsausgleich herstellen? | Start

Water Treatment Technology

In order to achieve the limits of NTPA 001/2005 for all constituents, the ARD treatment process consists of three mutually optimized stages:

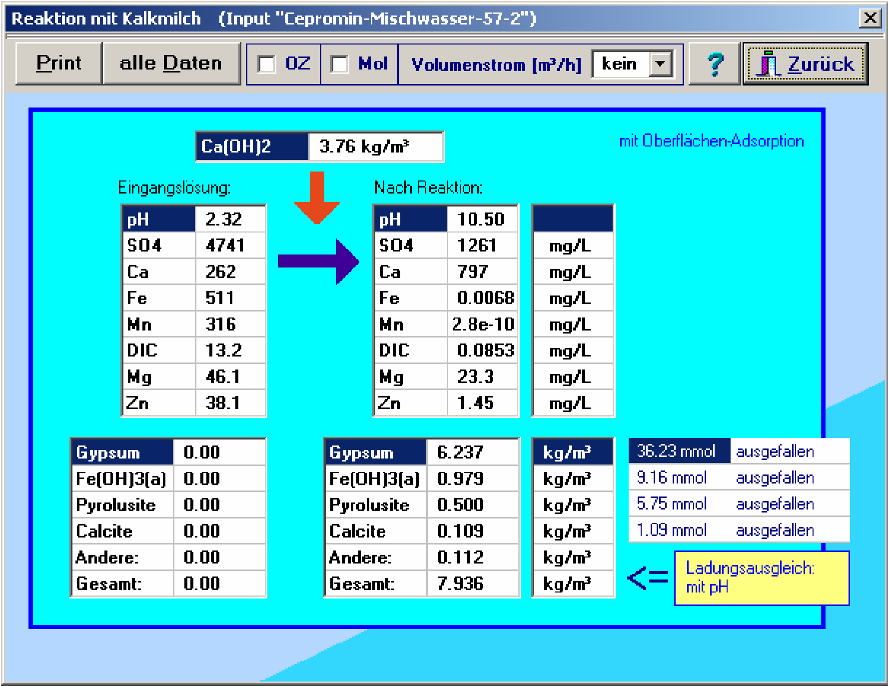
- Removal of the heavy metals by lime addition at pH=10.5. All relevant heavy metals are precipitated as hydroxides, except Aluminium and Zinc which form soluble Aluminates and Zincates, respectively. The sulphate concentration corresponds to the solubility limit of Gypsum.
- Further reduction of the sulphate and calcium concentrations below 600 mg/l and 300 mg/l, respectively, is achieved by adding Calcium Aluminate (Ettringite precipitation or Walhalla process)

[6] For all hydrochemical calculations, the thermodynamic process modelling code *aquaC* (based on the thermodynamic database phreeqC 2.2 of the US Geological Survey) is used. See also website http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/ (phreeqC-A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations)

- The high pH of the Ettringite precipitation stage must be neutralized to the window 6.5-8.5, using carbon dioxide. Using hydrochloric acid would lead to an exceedance of the chloride concentration with respect to the NTPA 001/2005 limit).

The compositions of the inflow and outflow of the first stage are shown in **Error! Reference source not found.** and **Error! Reference source not found.**.

Table 4-10. Balance schematic for lime precipitation at pH 10.5

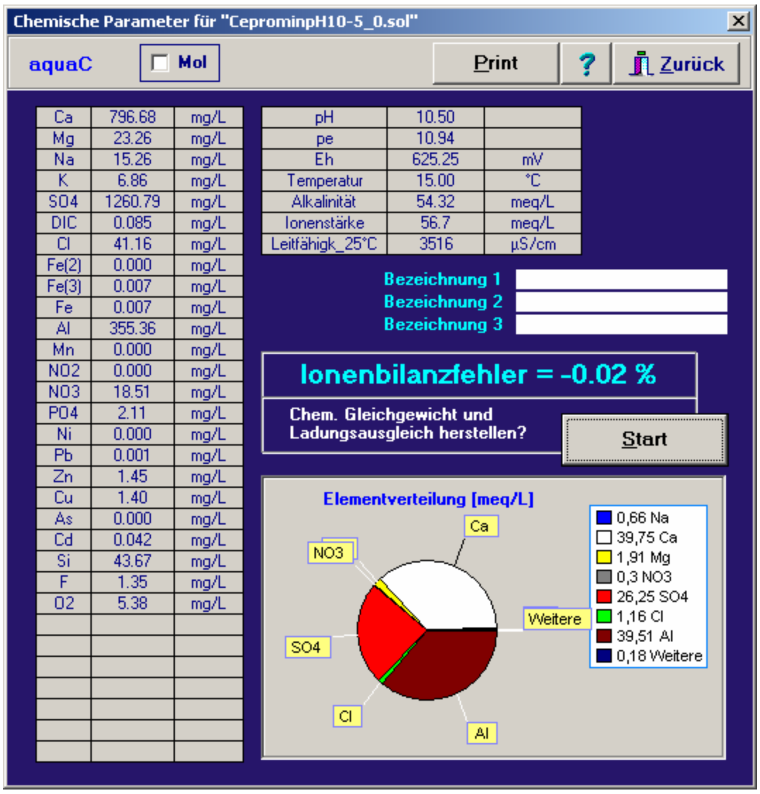


Eingangslösung		Nach Reaktion		
pH	2.32	pH	10.50	
SO4	4741	SO4	1261	mg/L
Ca	262	Ca	797	mg/L
Fe	511	Fe	0.0068	mg/L
Mn	316	Mn	2.8e-10	mg/L
DIC	13.2	DIC	0.0853	mg/L
Mg	46.1	Mg	23.3	mg/L
Zn	38.1	Zn	1.45	mg/L

Gypsum	0.00	Gypsum	6.237	kg/m³	36.23 mmol ausgefallen
Fe(OH)3(a)	0.00	Fe(OH)3(a)	0.979	kg/m³	9.16 mmol ausgefallen
Pyrolusite	0.00	Pyrolusite	0.500	kg/m³	5.75 mmol ausgefallen
Calcite	0.00	Calcite	0.109	kg/m³	1.09 mmol ausgefallen
Andere:	0.00	Andere:	0.112	kg/m³	
Gesamt:	0.00	Gesamt:	7.936	kg/m³	

The solids of the first treatment stage (mainly gypsum sludge) are removed by sedimentation.

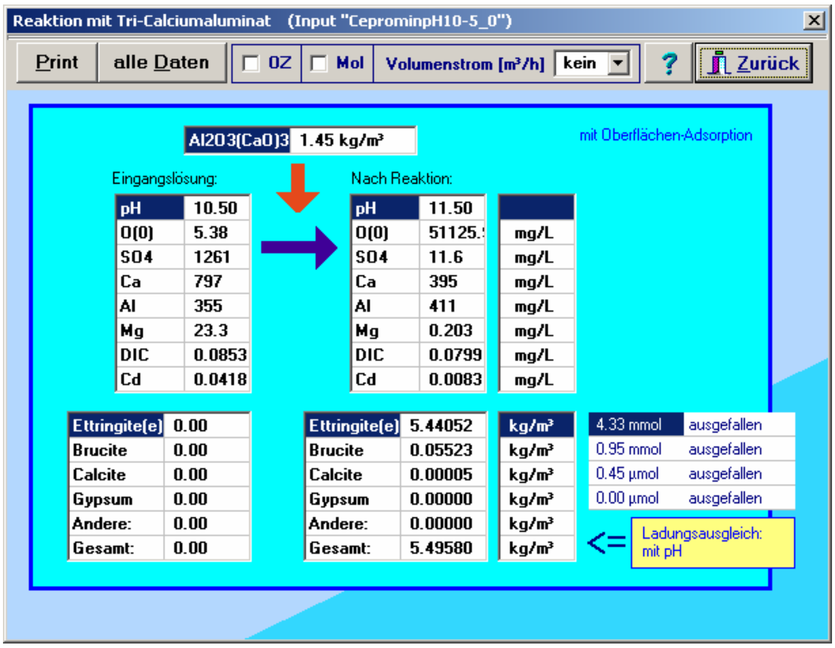
Table 4-11. Detailed composition of the outflow of treatment stage 1



Ca	796.68	mg/L
Mg	23.26	mg/L
Na	15.26	mg/L
K	6.86	mg/L
SO4	1260.79	mg/L
DIC	0.085	mg/L
Cl	41.16	mg/L
Fe(2)	0.000	mg/L
Fe(3)	0.007	mg/L
Fe	0.007	mg/L
Al	355.36	mg/L
Mn	0.000	mg/L
NO2	0.000	mg/L
NO3	18.51	mg/L
PO4	2.11	mg/L
Ni	0.000	mg/L
Pb	0.001	mg/L
Zn	1.45	mg/L
Cu	1.40	mg/L
As	0.000	mg/L
Cd	0.042	mg/L
Si	43.67	mg/L
F	1.35	mg/L
O2	5.38	mg/L

pH	10.50	
pe	10.94	
Eh	625.25	mV
Temperatur	15.00	°C
Alkalinität	54.32	meq/L
Ionenstärke	56.7	meq/L
Leitfähigk_25°C	3516	µS/cm

Table 4-12. Balance schematic of the Ettringite precipitation at pH=11.5



Reaktion mit Tri-Calciumaluminat (Input "CeprominpH10-5_0")

Print | alle Daten | OZ | Mol | Volumenstrom [m³/h] kein | ? | Zurück

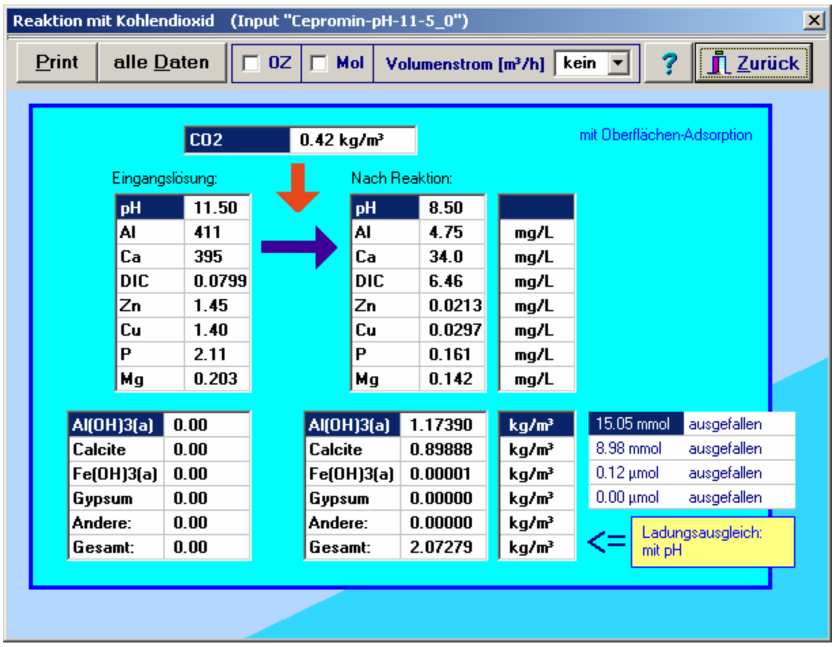
Al2O3(CaO)3 1.45 kg/m³ — mit Oberflächen-Adsorption

Eingangslösung:		Nach Reaktion:		
pH	10.50	pH	11.50	
O(0)	5.38	O(0)	51125.!	mg/L
SO4	1261	SO4	11.6	mg/L
Ca	797	Ca	395	mg/L
Al	355	Al	411	mg/L
Mg	23.3	Mg	0.203	mg/L
DIC	0.0853	DIC	0.0799	mg/L
Cd	0.0418	Cd	0.0083	mg/L

Ettringite(e)	0.00	Ettringite(e)	5.44052	kg/m³	4.33 mmol	ausgefallen
Brucite	0.00	Brucite	0.05523	kg/m³	0.95 mmol	ausgefallen
Calcite	0.00	Calcite	0.00005	kg/m³	0.45 µmol	ausgefallen
Gypsum	0.00	Gypsum	0.00000	kg/m³	0.00 µmol	ausgefallen
Andere:	0.00	Andere:	0.00000	kg/m³		
Gesamt:	0.00	Gesamt:	5.49580	kg/m³		

<= Ladungsausgleich: mit pH

Table 4-13. Balance schematic of the re-neutralisation with CO2 to pH=8.5



Reaktion mit Kohlendioxid (Input "Cepromin-pH-11-5_0")

Print | alle Daten | OZ | Mol | Volumenstrom [m³/h] kein | ? | Zurück

CO2 0.42 kg/m³ — mit Oberflächen-Adsorption

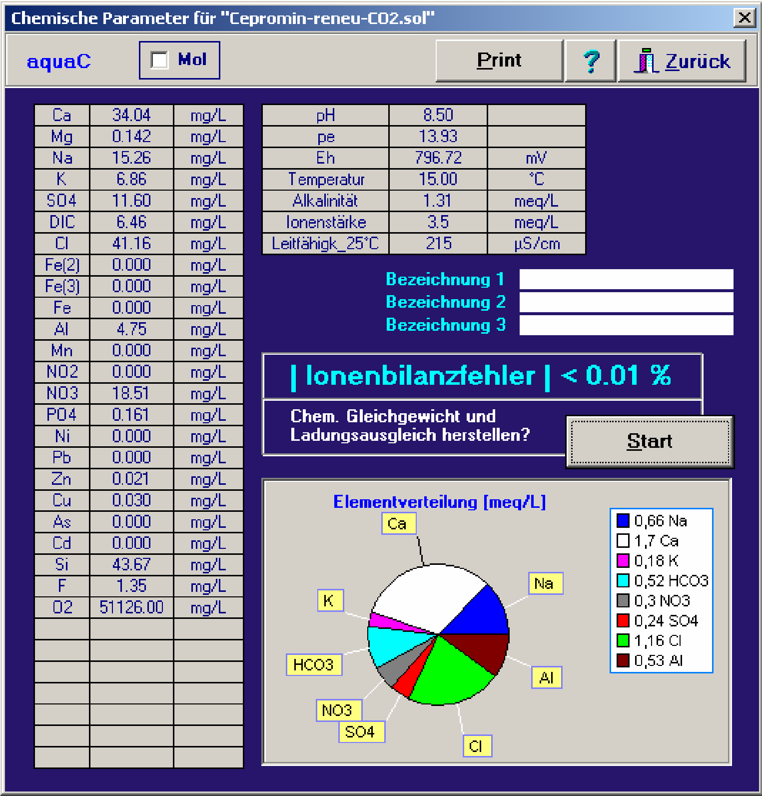
Eingangslösung:		Nach Reaktion:		
pH	11.50	pH	8.50	
Al	411	Al	4.75	mg/L
Ca	395	Ca	34.0	mg/L
DIC	0.0799	DIC	6.46	mg/L
Zn	1.45	Zn	0.0213	mg/L
Cu	1.40	Cu	0.0297	mg/L
P	2.11	P	0.161	mg/L
Mg	0.203	Mg	0.142	mg/L

Al(OH)3(a)	0.00	Al(OH)3(a)	1.17390	kg/m³	15.05 mmol	ausgefallen
Calcite	0.00	Calcite	0.89888	kg/m³	8.98 mmol	ausgefallen
Fe(OH)3(a)	0.00	Fe(OH)3(a)	0.00001	kg/m³	0.12 µmol	ausgefallen
Gypsum	0.00	Gypsum	0.00000	kg/m³	0.00 µmol	ausgefallen
Andere:	0.00	Andere:	0.00000	kg/m³		
Gesamt:	0.00	Gesamt:	2.07279	kg/m³		

<= Ladungsausgleich: mit pH

Error! Reference source not found. shows the composition of the treated water which complies with the discharge limits of NTPA 001/2005.

Table 4-14. Detailed composition of the treated mine effluent



The specific reagent consumption and the specific waste generation are shown in **Error! Reference source not found.**.

Table 4-15. Specific consumption of reagents and specific residue (waste) generation in the water treatment process

Process stage	Ca(OH)2 kg/m³	CA* kg/m³	CO2 kg/m³	Residues kg (solids)/m³
Gypsum precipitation at pH=10.5	3.8			7.9
Ettringite precipitation at pH=11.5		1.5		5.5
Re-neutralisation to pH=8.5			0.42	2.1
Total	3.8	1.5	0.42	15.5

* Calcium Aluminate

The sludge is dewatered by a decanter before disposal.

Sludge Deposition

The sludge resulting from the ARD treatment is disposed of on the waste rock heaps, in cells which are kept open as long as the need for water treatment continues. As they fill up, the cells will be closed (covered) with the cover system described in Section 0.

The annual amount of dewatered sludge is approximately 6800 tons per year (15.5 kg per m³ of treated water, 50 m³ per year). Over a 20 year operation period of the ARD treatment plant, the amount is around 200,000 tons. If the cells on the waste rock heap have an area of 4 hectares (which is small compared to the total footprint of the waste rock heaps), the sludge may be stacked in layers of 0.5 meters each, possibly with a gravel layer between them. This would result in a total height of the sludge cells of 5 meters.[7].

The labour cost for sludge dewatering is accounted for in **Error! Reference source not found.**. The unit cost for sludge disposal on the waste rock dump cells is assumed to be 12 € per m³ of dewatered sludge, or 0.15 € per m³ of treated water[8].

The cover system for the sludge disposal area has already been taken into account in Section 0, because it is part of the cover system for the entire waste rock heaps.

Cost Estimate

Table 4-16. Cost estimate for the construction of a water treatment plant

Complex	Position	Amount	Unit Cost (€ per unit amount)	Total Cost
Collection and drainage of waste rock seepage				
Drainage system	Deep rigole along dump perimeter	2500 m	65	162,500 €
	Drainage pipe from dumps to infiltration well, in trench	750 m	60	45,000 €
	Infiltration well into underground mine, 6" steel pipe casing	150 m	190	28,500 €
Water treatment plant	2 line system for high availability 20,000 € per m³/hxxxii	100 m³/h	20,000	2,000,000 €
	Decanter for sludge dewatering	2	250,000	500,000 €
Subtotal construction				2,736,000 €
Engineering (10 %)	Design planning, permitting, tendering, project management			274,000 €
Technical support (2%)	quality assurance, work safety, monitoring			55,000 €
Contingency (20 %)				547,000 €
Total construction				3,612,000 €

Table 4-17. Cost estimate for consumables and energy consumption of water treatment plant

Complex	Position	Amount/m³	Unit cost (€ per unit amount)	Total cost (€/m³)
Reagents				
	Lime	3.80 kg	0.07	0.24
	Calcium Aluminate	1.50 kg	0.67	0.99
	Flocculant	0.006 kg	4.17	0.03
	Carbon dioxide	0.42 kg	0.33	0.14
Electrical energy		1 kWh	0.08	0.08
Sludge disposal				0.15
Total				1.63

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[7] A similar technology is used, for example, by WISMUT to dispose of the sludge of a mine effluent treatment plant.
[8] Assuming a density of the dewatered sludge of 1.2 t/m³ and 15.5 kg solid sludge per m³ of treated water.

Table 4-18. Estimate of staff numbers in ARD treatment plant annual cost estimate of water treatment plant and ARD treatment sludge disposal

Position	Supervisor	Water treatment	Sludge treatment	Total
Morning shift:	1	1	2	4
Day shift		1	2	3
Night shift		1		1
Subtotal				8
Factor for 24x7 week				1.6
Total staff				13

Table 4-19. Summary annual cost estimate of water treatment plant and ARD treatment sludge disposal

Complex	Position	Amount	Unit cost (€ per unit amount)	Total cost (€/a)
Reagents, energy, sludge disposal	1.50 €/m³, 50 m³/h	-50 m³/h	1.63 €/m³-	714,000
Personnel	16 staff (see table above)	13	10,000	130,000
Maintenance	4% of plant capital costs (3 million €)			120,000
Total				964,000

4.7 Overall and Integrated Water and Sediment Quality Monitoring System

Description of the Set-Up of the Monitoring System
The monitoring system to be implemented includes:

- 6 groundwater monitoring wells to monitor ground water contamination at selected positions downstream Valea Verde and Hop dumps as well as in the Rosia Valley
- 6 surface water monitoring stations within the Rosia and Corna catchments
- 3 monitoring stations at the perimeter of Valea Verde/ Hop waste rock dumps to monitor flow rates and quality of contaminated seepage water
- 2 monitoring stations to monitor the performance of the cover construction at Valea Verde/ Hop dumps, including a weather station.

The costs will be mainly determined by the number of monitoring stations to be operated.

Cost Estimate

Table 4-20. Construction cost estimate for ground and surface water monitoring

Complex	Position	Amount	Unit Price	Total Price
Groundwater monitoring	planning, tendering	lump sum		5,000 €
	preparation	6 pieces	2,500	15,000 €
	construction ground water well, DN 100, 20 m depth	6 pieces	14,000	84,000 €
	Hydrogeological testing	6 pieces	3,000	18,000 €
Surface water monitoring	planning, tendering	lump sum		2,500 €
	preparation	9 pieces	300	2,700 €
	construction surface water stations	6 pieces	6,000	36,000 €
	construction seepage water stations	3 pieces	4,000	12,000 €
Cover monitoring	planning, tendering	lump sum		6,000 €
	preparation	2 pieces	1,500	3,000 €
	construction monitoring stations incl. instrumentation	2 pieces	50,000	100,000 €
	construction weather station incl. instrumentation	1 pieces	23,000	23,000 €
Subtotal construction				307,200 €
Technical support (2%)	quality assurance, work safety, monitoring			6,000 €
Total construction				313,200 €

Table 4-21. Cost estimate for operation and maintenance of ground and surface water monitoring

Complex		Amount/ year	Cost per unit amount	Total Cost/ year
Ground water monitoring	Field measurements	24 mandays	40,00	960 €
	Analytics	24 samples	200,00	4,800 €
	Report	10 mandays	60,00	600 €
	Maintenance	10 mandays	40,00	400 €
	Extra costs	5 %		340 €
Surface water monitoring	Field measurements	24 mandays	40,00	960 €
	Analytics	108 samples	200,00	21,600 €
	Report	10 mandays	60,00	600 €
	Maintenance	10 mandays	40,00	400 €
	Extra costs	5 %		1,180 €
Cover monitoring	Field measurements	24 mandays	40,00	960 €
	Analytics	12 samples	200,00	2,400 €
		24 samples	100,00	2,400 €
	Report	20 mandays	60,00	1,200 €
	Maintenance	1 day	40,00	40 €
	Extra costs	5 %		350 €
Total				39,190 €

5 Conclusions

In conclusion, the cost estimates for mine closure activities required at the existing RosiaMin operations in order to achieve an environmental standard comparable to that achieved by the RMGC project can be summed up as follows:

Table 5-1. Summary of construction costs (rounded)

Remediation measure	Construction cost (million €)
Open pits	0.9
Remediation of waste rock dumps	16.7
Clean-up of abandoned industrial areas	0.4
Underground mine	1.3
Water treatment plant	3.6
Monitoring system	0.3
Total (rounded)	23.2

For the calculation of the net present value of activities which reach far into the future such as water treatment of monitoring, two different discounting rates (3% and 5%) have been assumed.

Table 5-2. Summary of annual operating and maintenance costs (rounded)

Remediation measure	Annual operational and maintenance costs (T€)	
	Years 1-5 after closure	Year 6 and later
Cetate Pit	15	3
Waste rock dumps	22	4
Abandoned industrial areas	None/insignificant	
Underground mine	None/insignificant	
Water treatment	964	
Monitoring system	39	
Total (rounded), no discounting	perpetual costs of around 1 million € per year (mainly for water treatment)	
Total (rounded), discounted at 3%	32,700	
Total (rounded), discounted at 5%	21,100	

6 References

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[i] Environmental Balance Level II & Report to the Environmental Balance Level II for C.N.C.A.F. Minvest S.A. Deva – Roşiamin Subsidiary, Rosia Montana Village, Alba County, Prepared by AGRARO CONSULT s.r.l. February 2003

[ii] Environmental Balance Level I. INCD ECOIND - NATIONAL RESEARCH – DEVELOPMENT INSTITUTE FOR INDUSTRIAL ECOLOGY, Bucharest, October 2003

[iii] Environmental Balance Level II & Report to the Environmental Balance Level II for C.N.C.A.F. Minvest S.A. Deva – Roşiamin Subsidiary, Rosia Montana Village, Alba County, Prepared by AGRARO CONSULT s.r.l. February 2003

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[xiii] S.C. CEPROMIN S.A., Deva: Environmental Balance Level II, 1999, also cited by Agraro Consult as Table 4.2

[xiv] REPORT ON WATER BASELINE CONDITION, ROŞIA MONTANĂ PROJECT. S.C. AGRARO CONSULT S.R.L., Bucharest, Revision C, March 2, 2005

[xv] Environmental Balance Level I. INCD ECOIND - NATIONAL RESEARCH – DEVELOPMENT INSTITUTE FOR INDUSTRIAL ECOLOGY, Bucharest, October 2003

[xvi] Identification and environmental assessment of the Roşia Montana geochemical 'footprint' in the Abrud / Arieş catchment. Fluvio/University of Wales, Aberystwyth, 2004

[xvii] MWH, 2005; Engineering Review Report, Appendix B – Geochemistry Characterisation Study, Table 4.2

[xviii] Environmental Balance Level II & Report to the Environmental Balance Level II for C.N.C.A.F. Minvest S.A. Deva – Roşiamin Subsidiary, Rosia Montana Village, Alba County, Prepared by AGRARO CONSULT s.r.l. February 2003

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[xxiii] Environmental Balance Level I. INCD ECOIND - NATIONAL RESEARCH – DEVELOPMENT INSTITUTE FOR INDUSTRIAL ECOLOGY, Bucharest, October 2003

[xxiv] Water and Oxygen Transport Modelling for Cover Systems on Waste Rock Facilities and Tailings Pond at Rosia Montana. WISUTEC/WISMUT, March 2006

[xxv] U. Schulz: Resource planning for final-costing analysis for selected remediation works". Diploma Thesis. Chemnitz University of Technology and WISMUT GmbH, 1997

[xxvi] See http://www.eurofer.org/statistics/scrap.htm for current spot prices for steel scrap

[xxvii] see, for example: Province of Ontario Regulation 240/00 made under the Mining Act: Mine Development and Closure under Part VII of the Act. The Ontario Gazette, 13 May 2000, p. 953

[xxviii] see for example: "Remediation Concept for the Uranium Mines of the State Enterprise Almaz in Lermontov, Russia" (EUROPEAID/116483/C/SV/RU of the European Commission), executed by the consortium WISMUT/WISUTEC/C&E/GEOS (Germany), 2004-2005

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