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WP4 - SATELLITE REMOTE SENSING

DELIVERABLE D4.3
SATELLITE MISSION PLANNING
FOR THE DEMO SITES

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SEVENTH FRAMEWORK PROGRAMME

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Abbreviations

AAS	Atomic Absorption Spetrophotometry
AMD	Acid Mine Drainage
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CHRIS	Compact High Resolution Imaging Spectrometer
DEM	Digital Elevation Model
DMP	Dry Matter Productivity
ETM	Enhanced Thematic Mapper
EO	Earth Observation
fAPAR	fraction of Absorbed Photosynthetically Active Radiation
GFMO	University of Mostar, Faculty of Civil Engineering
IFOV	Instantaneous Field Of View
IMIN	Institute of Mineralogy
LAI	Leaf Area Index
MIR	Mid-wave Infrared
MODIS	Moderate-resolution Imaging Spectroradiometer
MSS	Multi-Spectral Scanner
MODIS	Moderate-resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NIR	Near Infrared
NOAA	National Oceanic and Atmosphere Administration
PCA	Principle Component Analysis
RGB	Red-Green-Blue
SWIR	Short Wave Infrared
TIR	Thermal Infrared
TOA	Top Of Atmosphere
TSA	Time Series Analysis
TSP	Total Suspended Particulates
UBB	Babes-Bolyai University
ULRMC	Ukrainian Land and Resource Management Centre
VIS	Visible
VITO	Flemish Institute for Technological Research
VNIR	Visible and near infrared
WP	Work Package
XRF	X-Ray Fluorescence

1 INTRODUCTION AND OBJECTIVES

The objective of the ImpactMin project is to develop new methods and a corresponding toolset for the environmental impact monitoring of mining operations using Earth Observation (EO). In WP4 the basis for this development is laid by generating a scientific knowledge pool of methods derived from mineral resources exploration methods, satellite EO-based environmental monitoring techniques and by "translating" research results from other field of science with a possible applicability in ImpactMin. Furthermore, this work package consists of the preparatory work for future work in work packages 6 (Tools and services) and 7 (Demo-site implementation).

This report (D4.3) summarizes the results of the work performed under WP4.4: Preparatory work for demo-site implementation. In the ImpactMin project, four demo-site regions are considered: Kristineberg (Sweden), the Vihovici mine in Mostar (Bosnia & Herzegovina), Rosia Montana (Romania), and two mining sites in the Orenburg region (Russia) (Figure 1-1). Since no satellite remote sensing techniques will be applied for environmental impact monitoring at the Kristineberg demo-site in Sweden, no preparatory work for demo-site implementation was performed, and this demo-site is therefore not included in this report. The preparatory work for demo-site implementation based on airborne campaigns is described in D5.3. In the Orenburg region (Russia), two demo-sites are considered in this report: Karabash and Mednogorsk.

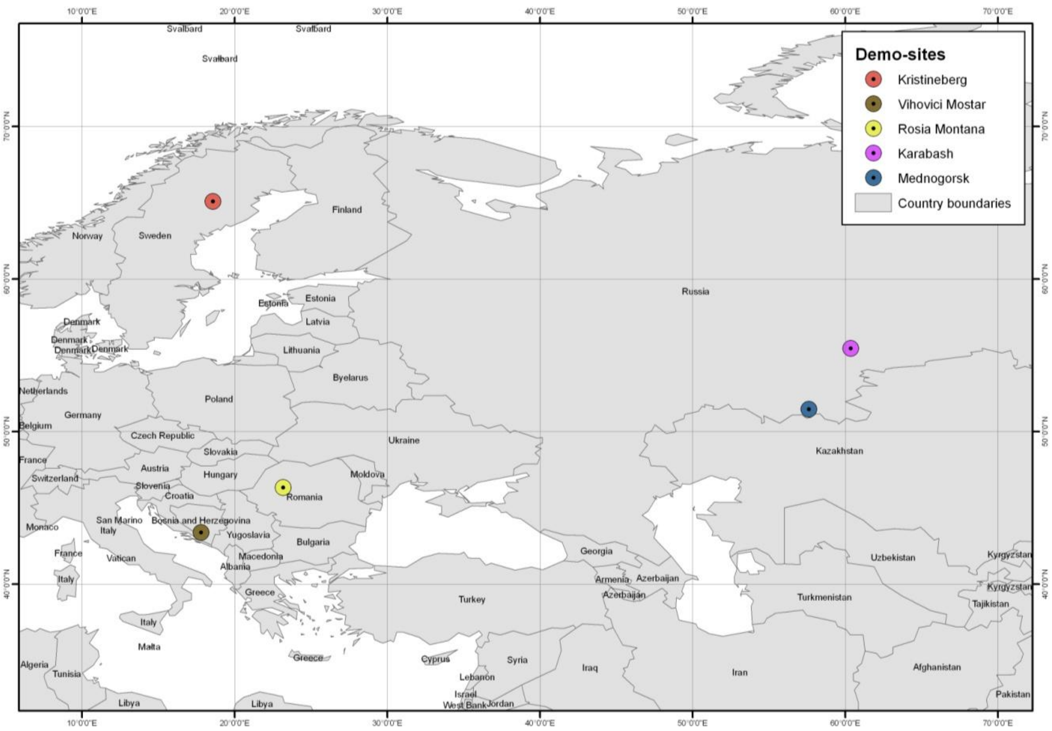


Figure 1-1 Location of the ImpactMin demo-sites

There is a large variability in the environmental effects of mining at the different demo-sites. In work package WP4.1, environmental variables, soil and surface variables that are associated with mining activities and detectable with satellite earth observation methods were identified (Figure 1-2). The findings of WP4.1 were included in deliverable D4.1. Variables (or impacts) are effects on natural resources and on the components, structures and functioning of affected ecosystems. The variables are separated into direct and indirect variables. Direct variables are related to direct and predictable effects of mineral mining operations itself, occurring at the same time and place. Indirect variables are caused by mineral mining operations, but occur later in time or farther removed in distance. Indirect variables may include cumulative effects related to induced changes in the pattern of land use and related effects on soil, air and water and other natural systems.

The following direct variables are considered:

- *Minerals*: Minerals play a key role in all stages of mining and their behavior, as part of the environment, due to mining-related activities is hence a primary factor in the process of monitoring mining related environmental impact. The identification of diagnostic minerals at the surface is one of the most important tools for the recognition of rocks that are potentially mineralized. Most high spatial resolution satellite sensors lack the spectral resolution for successful mineral mapping. Lower spatial resolution sensors as Landsat or ASTER are widely used and have proven to be useful for mineral mapping at regional scale, although in case of Landsat, only broad groups of minerals can be identified. The SWIR bands of the ASTER sensor are a great benefit, allowing the identification of individual minerals and gradual changes. Unfortunately, since April 2008 there are no good observations in the SWIR range, because the detector saturates (ASTER Science Office, 2009). Theoretically, the Hyperion sensor would be of great use for regional mineral mapping, but the low signal to noise ratio is a large limitation. Also, the chance that ImpactMin will be able to obtain these data is limited: currently no images for the project demo-sites are available, and so far all data acquisition requests have failed.

- *Acid mine drainage (AMD) and ferruginous materials*: Acid drainage is formed when certain sulphide minerals in rocks are exposed to oxidizing conditions. In certain mines where ores have high sulfur content, drainage from mine workings and waste heaps can become highly acidic. A common side-effect of sulphide oxidation is metal leaching. As a result, high concentrations of dissolved heavy metals will be released to the environment. Although the spectral resolution of Landsat and – in particular – ASTER theoretically can be used to discriminate between different minerals related to acid mine drainage, the low spatial resolution will complicate the mapping of individual minerals or gradients of acid mine drainage. The minimum mapping unit will however depend on the scale and severity of acid mine drainage processes. Nevertheless, ImpactMin expects that Worldview-2 might be suitable for the mapping of several minerals (in particular iron oxides/hydroxides), since the spatial resolution is superior and Worldview-2 has 8 bands, although only in the VNIR spectral range.

- *Atmospheric pollution and windblown particles*: Pollution of the atmosphere in mining areas can be complex, as it is often not just a phenomenon restricted to mining itself, but also extends to activities around the mine, such as refining, smelting, other related industries, and human settlement. Significant levels of dust, above 3 kg/t of ore mined, and ranging from 0.003 to 27 kg/t, may be generated by extraction activities, crushing, ore beneficiation, transport and traffic, and wind-borne losses (World Bank Group, 1998). Significant releases of dust containing metals, including mercury, may result from the drying of the ore concentrate. Large scale atmospheric pollution has been monitored using MODIS imagery, which has a high spectral but low spatial resolution, and using ASTER or even Landsat imagery (e.g. for monitoring urban air quality). Most studies however focus on the secondary effects from atmospheric pollution (land cover change and vegetation stress). Hyperion imagery may be used to study mineralogy of particulates in windblown dust. Nevertheless, the applicability of satellite remote sensing for monitoring atmospheric pollution depends on the severity and the spatial scale of the event.

- *Temperature increment due to (underground) coal fires*: Subsurface and surface coal fires are a serious problem in many coal-producing regions. Combustion can occur within coal seams (underground or at the surface), in piles of stored coal, or in spoil dumps at the surface. Coal fires can be ignited in different ways: by forest fires, coal mining accidents, burning trash on the coal seam outcrop, lightning strike, or spontaneous combustion of coal (Zhang et al., 2004). Primary factors in the applicability of satellite remote sensing for the detection of temperature increment due to underground coal fires depends on the background temperature, the quality of the remote sensing data, and the significance of the coal fires. Thermal infrared bands of Landsat, ASTER and even NOAA-AVHRR imagery were successfully used in large scale underground coal fires in China, Australia and India (e.g. Mansor et al., 1994; Zhang et al., 1997). For small scale events, the size of an individual fire will be smaller than the IFOV of the satellite, but sub-pixel detection might be possible, depending on the surrounding background.

The following indirect variables are considered:

- *Land use and land cover change*: The importance of mapping land use and monitoring their changes has been widely recognized in the scientific community and the mining of natural resources is invariably associated with land use and land cover changes (Prakash and Gupta, 1998). Therefore, mining is an important factor of anthropogenic influence on the environment, causing alteration of the landscape (Rigina, 2002), including land use and land cover change, urbanisation and industrialisation, land degradation and erosion. For successful monitoring of land use and land cover change related to mineral mining and their dynamics, observations with frequent temporal coverage over a longer period of time are required. The scale and characteristics of land use and land cover change will determine at which spatial resolution the processes can be monitored. Landsat imagery is widely used for monitoring conversions from natural vegetation to surface mines, and afterwards to secondary vegetation after reclamation. However, the extent of land use and land cover change is often larger than the mine itself. Vegetation indices or other transformations are frequently used. Also time series of low resolution imagery (e.g. NOAA-AVHRR) have been used to monitor large scale land use and land cover change induced by mineral mining (Latifovic et al., 2005).

- *Vegetation stress*: Mining induced vegetation stress is mainly an indirect consequence of altering environmental variables. Many mine wastes are structureless, prone to crusting, and low in organic matter and essential plant nutrients (P, N, K). They mostly have low water-holding capacity, and contain contaminants such as salts, metals, metalloids, acid, and radionuclides. Furthermore, conservative, non-reactive ions such as sulfate, nitrate, manganese, magnesium, and calcium may migrate into the local aquifer and surface waters. Vegetation indices are used to monitor mining induced vegetation stress. Depending on the scale of the impact, high spatial resolution QuickBird or IKONOS, medium resolution Landsat or ASTER, or low resolution MODIS or NOAA-AVHRR is applied. Hyperspectral imagery from Hyperion facilitates a more detailed study of pigment concentration changes.

- *Contaminated surface waters, sediment load and metal contamination*: Open pits and underground mining operations commonly extend below the water table, and require dewatering during mining. Unwanted or used water needs to be disposed of constantly during mining, mineral processing and metallurgical extraction. When this water comes in contact with broken rock and ore, it picks up particulate matter, as well as products of oxidation or reduction and dissolution, including acids or alkalis and metals. When mine water reaches receiving water bodies, such as streams or lakes, mine water can cause undesirable turbidity and/or sedimentation, its chemical composition can have toxic effects on vegetation and animals, and it may alter temperature regimes (Ripley et al., 1996). Depending on the origin of the discharged water (e.g. fissure water, process water, etc.), consequences for the receiving water bodies vary significantly, comprising increasing sediment loads, as well as contamination with dissolved pollutants such as sulphates and heavy metals (Coetzee, 2006). Although the spectral and spatial resolution of satellite remote sensing systems do not allow for the assessment of surface water quality parameters individually (chlorophyll, suspended sediment and dissolved organic carbon), satellite imagery can be successful in monitoring dynamics of water clarity and for example dynamics of sediment loads, related with mineral mining.

- *Changes in soil moisture and groundwater environment*: Any mining activity invariably disturbs the hydrological cycle of the region. Negative effects are produced to both ground and surface waters in both opencast and underground workings. Satellite imagery can be used to detect drainage and landforms that act as direct indicators of ground water occurrences. Both multidate VNIR, TIR and radar observations are used to monitor moisture content of the soil. Surface features are analyzed in terms of geomorphology, relative groundwater depths and vegetation patterns, not by quantitatively relating soil moisture to reflectance, which is too variable in space and time.

- *Subsidence*: Mine subsidence is the lowering or collapse of the land surface, caused by underground mining activities (Ge et al., 2007), including the extraction of mineral resources or the abstraction of fluids (Bell et al., 2000). The rocks above mine workings may not have adequate support and can collapse from their own weight either during mining, or long after mining has ceased (Bell et al., 2000). Using multiple synthetic aperture radar observations, differential radar interferometry can measure surface deformation and subsidence to high degree of accuracy over large spatial extents.

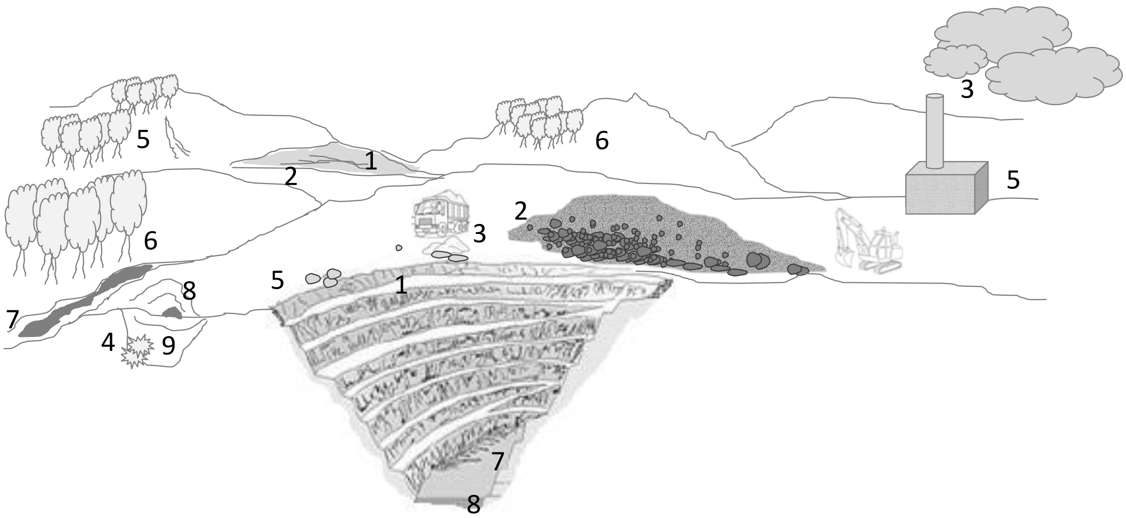


Figure 1-2 Direct and indirect variables associated with mining activities: 1. Minerals, 2. Acid mine drainage and ferruginous materials, 3. Atmospheric pollution and windblown particles, 4. Temperature increment due to (underground coal fires), 5. Land use and land cover change, 6. Vegetation stress, 7. Contaminated surface waters: sediment load and metal contamination, 8. Changes in soil moisture and groundwater environment, 9. Subsidence (from D4.1)

In Table 1-1, the relevance of the direct and indirect environmental variables related to mining activities as defined and described in D4.1 for the different ImpactMin demo-sites is summarized. In all demo-sites, it is interesting to look at minerals at the surface, including minerals related to acid mine drainage and ferruginous materials. Atmospheric pollution and windblown particles is also an issue for three out of four demo-sites, although atmospheric pollution is particularly severe in Karabash and Mednogorsk, and of only minor importance for Mostar. Only at the Mostar demo-site, there is an issue of underground coal seam burning. Furthermore, all four demo-sites suffer from land use and land cover change and contaminated surface waters (sediment load and metal contamination) connected to mineral mining. Vegetation stress is an issue for Rosia Montana, Karabash and Mednogorsk. The Mostar demo-site is reported to suffer from changes in soil moisture and groundwater environment, and subsidence and other surface deformations. These impacts however have limited spatial extent, and it is not clear if they are observable with relatively low spatial resolution satellite imagery.

Table 1-1 Environmental variables associated with mining activities as defined and described in D4.1 and the relevance for the different IMPACTMIN demo-sites

	Vihovici Mostar	Rosia Montana	Karabash	Mednogorsk
Direct variables				
Minerals	x	x	x	x
Acid mine drainage and ferruginous materials	x	x	x	x
Atmospheric pollution and windblown particles	x		x	x
Temperature increment due to (underground) coal fires	x			
Indirect variables				
Land use and land cover change	x	x	x	x
Vegetation stress		x	x	x
Contaminated surface waters: sediment load and metal contamination	x	x	x	x
Changes in soil moisture and groundwater environment	x			
Subsidence or other surface deformations	x			

This report is structured as follows: Chapter 2 gives a short overview of the requirements for a satellite mission planning at this stage of the project. The core of this document is Chapter 3, where for each demo-site under consideration, the preparatory work for demo-site implementation is described. For each demo-site, the description contains: an overview of the demonstration site, data availability, data collection, data processing and the analysis flow-sheet, and finally a discussion and recommendations. General conclusions are drawn in Chapter 4. The appendices of this report contain more detailed information about the demonstration sites and the metadata of the geographical data that is available. This is the product of two questionnaires that were sent out to the demo-site representatives.

This report was compiled by VITO (Flemish Institute for Technological Research, Belgium). VITO is a leading independent European research and consulting centre developing sustainable technologies in the area of energy, environment, materials and remote sensing. One of the main contributors to this report was Geosense (The Netherlands). Geosense is an internationally established remote sensing consultancy for the mining and oil and gas industry, with experience in the application of remote sensing and infrared spectroscopy technology for geologic mapping and mineral exploration. Also ULRMC (Ukrainian Land and Resource Management Center) contributed. ULRMC is one of the first non-profit, non-governmental scientific and technical organizations in Ukraine. ULRMC implements projects in environmental management, nature resources preservation, disaster mitigation and response, etc.

The demo-site representatives greatly contributed to this report. For Mostar, this was GFMO (University of Mostar, Faculty of Civil Engineering, Bosnia & Herzegovina) and Photon (Split, Croatia). The civil engineering faculty at the University of Mostar is the leading institution in the region actively participating in research activities in the area of civil structures, water resources, mining and environmental management. Photon is a hyperspectral survey company that delivers integrated hyperspectral and geospatial data products in a variety of applications. For Rosia Montana, this was the UBB (Babes-Bolyai University, Faculty of Environmental Sciences, Romania). The Faculty of Environmental Sciences of the UBB started its activities in 2003, putting together the skills of experienced academic staff in chemistry, physics, biology, geology and geography. For the Ural demo-sites, this was IMIN (Institute of Mineralogy, Russian Academy of Sciences) and CSM (Camborne School of Mines, University of Exeter, UK). IMIN is the largest scientific centre of the Russian Academy of Sciences in the Southern Ural, with research directed on studying the mineralogy of the major types of ore deposits, experimental modeling of magmatic and hydrothermal processes, and the decision of environmental problems which arise in mineral extraction and processing. The CSM has been training mining professionals and working with mines since 1888, and has a unique combination of research expertise in mining, geology, minerals processing, environmental mineralogy and geochemistry and applied remote sensing technologies.

2 REQUIREMENTS OF THE MISSION PLANNING

The requirements of this satellite mission planning are the following:

1. Description of each demo-site, with a clear view on environmental impacts and processes
2. Description of geo-data available at the demo-site representative, including metadata
3. Description of addition data to be collected, both satellite imagery and ancillary information, e.g. digital elevation models, ground data etc.
4. Description of the objectives of data processing, the analysis flow-sheet and products
5. Recommendations for data processing and analysis for each demo-site

The satellite mission planning contains an in depth description of each demo-site that is considered in the ImpactMin project, and where satellite data will be processed and analyzed. The basis for site description was a questionnaire sent out in February/2010 to all the demo-site representatives. The outcomes of this questionnaire can be found in **Appendix 1.1** (Mostar), **Appendix 2.1** (Rosia Montana) and **Appendix 3.1a** and **Appendix 3.2b** (Karabash and Mednogorsk, respectively). The relevant parameters related to mining impact were identified. All available information was gathered in order to quantify the impacts. In many cases, however, the direct or indirect impacts of mineral mining were not quantitatively investigated, and previous research only give an indication of the seriousness of the ongoing processes. Nevertheless, for each demo-site several core topics for satellite image processing were identified.

Moreover, ancillary geographical information was gathered. A second questionnaire was sent out to the demo-site representatives in May/2010. The idea of this questionnaire was to obtain more detailed information of the spatial data that is available for each demo-site. The outcomes of this questionnaire can be found in **Appendix 1.2** (Mostar), **Appendix 2.2** (Rosia Montana) and **Appendix 3.2a** and **Appendix 3.2b** (Karabash and Mednogorsk, respectively).

Additionally, for each demo-site the availability of satellite earth observation information was investigated, and the need for additional information to be collected was described. In D4.1, the applicability of different satellite imaging systems for monitoring mining impacts was explored (see D4.1, Table 3-7). Our search for available satellite images was focused on: SPOT-Vegetation, NOAA-AVHRR, Landsat MSS/TM/ETM+, ASTER, ALI, CHRIS and Hyperion. Existing archives of historical satellite imagery were searched, in order to obtain interesting time series of satellite imagery and to be able to analyze the dynamics of mining impacts. Unfortunately, no Hyperion, ALI or CHRIS images were available for either of the demo-sites. For new data acquisition, ImpactMin will mainly focus on the new WorldView-2 sensor, because this sensor provides imagery with very high spatial resolution and a considerable number of spectral bands.

Finally, an analysis flow sheet was prepared, which summarizes data acquisition, data processing and derived products:

The analysis flow sheets are the ‘core’ of this satellite mission planning, and will provide a general guideline for image acquisition, processing and analysis in WP6. For each demo-site, the flow-sheet is described in detail. However, general procedures for data (pre)processing are described in **Appendix 4.1** and **Appendix 4.2**, respectively.

The main links with other work packages are:

- Run parallel to WP5. There is a strong link with D5.3, ‘Aerial mission planning for the demo-sites’, where preparatory work for aerial remote sensing is done. The combination of satellite remote sensing with airborne hyperspectral data at certain demo-sites will provide important opportunities for developing new methodologies.

- Provide input to WP6, mainly for WP6.2 ‘Acquisition, processing and analysis of satellite data’. Also the deliverables D4.1 and D4.2 will provide input to WP6.
- Provide input to WP7, where tools and methods will be demonstrated on different demo-sites and the demo-site implementation plans will be provided.

3 DEMO-SITE IMPLEMENTATION PLANS

3.1 Mostar Valley, Bosnia and Herzegovina

3.1.1 Site overview and environmental impacts

The "Vihovici Coal Mine" is located in the Mostar Valley, Bosnia and Herzegovina. The mine was exploited by "Rudnici mrkog uglja" (Brown coal mines of Mostar), a state-owned company, but is inactive since 1991. The mine had entered production in 1901, first as an underground operation, but from 1963 on, open pit mining was performed. In total, 11 million tons of brown coal (lignite) were extracted from the mine. 3.5 million tons were produced by surface exploitation (open pitting). The total area of the mine site is 76 ha, with 43.2 ha surface operations and an open pit of 7 ha. The production of coal was stopped when the war broke out in 1992. All technical equipment was destroyed. From 1992 – 1995, the mine was used as public solid waste dump. Illegal waste dumping continued until 2007, when a remediation program was started and in 95% of the mine area some of the surface waste was removed. Underground coal fires were (apparently) extinguished by water and fly-ash pumping.

Figure 3-1 Pictures of the Mostar demo-site

The mine is located in a karst landscape, with associated typical structures (e.g. caverns, sinkholes, dolines). Geomorphology of the region is also dominated by alluvial formations along the Neretva River. The climate is a semi-arid, Mediterranean climate. Surface cover is sparse and consists of low-lying Mediterranean shrubs (wild pomegranate mainly). There are five general zones of Neogene layers: sandstone, breccia, sand-gravel clays, sand marls and limestone. The main carbon-coal seam is composed of direct bottom and roof layers and a carbon layer with interlayer and refills of muck. The geology of the area consists of Perm-Triassic strata, ranging from plaster-anhydrites, unconsolidated limestone, clay and mudstones, which are compressed during folding episodes and exposed on the surface and thrusted upon Mesozoic rocks. Lower Triassic is comprised of various mudstones, marls and plinth limestone.

Figure 3-2 Coal fire at the Vihovici mine site, Mostar (Harbourdom GmbH, www.coalfire.org)

The most important mining-related processes which affected the environment are:

- Surface disturbance
- Underground tunnels linking the mine with the riverine ecosystem, especially during floods. The mine area is connected with the Neretva river through natural underground connections (related with karst landscape) and through ditches that were built during mine exploration. The main purpose of these ditches was to take overflow waters from the lake and the mine to the Neretva river. During high water levels of the Neretva river, the reverse situation occurs, and water flows into the lake. According to field investigations, significant bacterial contamination in the lake water is due to inflow of sewage through the Neretva channel in times of high water of the Neretva river (Fichtner et al., 2007). The water in the lake is exchanged roughly two times a year by refilling from natural inflow from surrounding hills and mountains and outflow to the Neretva.
- Windblown dust and atmospheric emissions an temperature increment from underground burning of coal/organics (Figure 3-2)
- Waste dumping (industrial, residential) in the mine area

The situation is thought to be semi-stabilized or stationary, although the condition of underground portions is at present unknown.

See **Appendix 1.1** for complete input on the first general demo-site questionnaire.

Several previous studies were performed on the Vihovici coal mine:

- **Regular reporting by the Universities and/or Mining Institutes of the former Yugoslavia (1963-1991)**

  The reports from this period mention in detail the number of tons of coal excavated from the pit, the annual norms, surplus or deficit in the operating costs of the mine and operating expenditures and challenges. The reports show the overall decline of the amount of resource produced resulting from the decreased need for coal and rising operating costs of the mine.

Even though significant apparent reserves have been left in the mine, it was considered to be uneconomic to continue the exploitation.

- **"Study of sanation, exploitation and recultivation of Vihovici mine and restructuration of Mostar mine", BOOK 1: "Sanation, exploitation and recultivation of Vihovici mine" (1996), investor: EU-administration of Mostar, project leader: Faculty of Mining, Geology and Oil-Exploration, University of Zagreb**

Mostar's coalfield, where in the central part the mineral extraction was developed, contains considerable supplies of brown coal. Thick layers and good quality coal at relatively shallow depths lead to the development of coal mining, at first in excavating and later in open pit mines. Excavating works were limited by hydrogeological circumstances of the deposit, market conditions and mine business economics and only open pit mine has continued to exist lately. The mine shaft "Cim" had been opened next to the pit, but works have been stopped and rooms were overflowed. The mine fields have been degrading by continuous working of the "Vihovici" open pit mine and the stop of production during the war, since direct combat actions brought them into adverse and extremely unstable condition. Working levels about the waste dump have not been properly formed and connected, while the crater part was found in original condition, without convenient, functional form and acceptable final outlines. Large quantities of water accumulated on the bottom of the crater and they are directly connected to Neretva by a previously formed ditch on the same level as the water level of the river. From the beginning of the war, city waste was constantly brought to the mine field and its uncontrolled and unplanned dumping in the lake, on the edge of the crater and in other places, had turned the whole mine field into a waste deposit. Sanation and technical recultivation of the field required thrusting-over or stretching of bigger quantities of dirt masses, so that the coal mining comes to be an imperative for realization of such interventions. In order to provide for quality participation in costs of sanation, exploitation had to include the best part of remaining coal reserves. The plans also included an urgent sanitation of waste deposit by means of dislocation of deposited waste out of the mine field or by its depositing in the convenient place on site. Technically recultivated areas of waste dump in the new form and shape of crater with lake will provide for and adequate biological recultivation of regional interest for recreation.

All treated conceptual plans will be followed by required capital investments and economic effects with the selection of optional variant. According to project assignment basic guidelines a preliminary analysis of possible solutions of the pit in Vihovici was set up:

- Important contents and possible solutions of project are bound up together; they cause and condition each other and they should be treated as a whole (sanation, exploitation, recultivation and restructuring).
- The solution of the set task should be considered in the context of big mine field (70 ha) which has been degraded to a great extent by "Vihovici" pit (3,2 ha) situated in the large city of Mostar, up the river Neretva in relatively small Mostar's basin.
- Existing waste deposit in the crater and on the pit is to be treated in two ways:
    - to dislocate all refuse from mine fields (from lake, crater interned waste dump)
    - to collect the waste all over waste dump and from pit crater to deposit it all on the site, i.e. on active position of depositing
    - compare the variants by their price and reliability of realization and make proposal
- To use the pit crater as a possible future waste deposit of Mostar has to be absolutely excluded from consideration.
- Sanation of the waste deposit on site and technical recultivation of degraded field cannot be carried out without big quantities of dirt, so it is advisable to include the coal mining as a main source of such masses.

- Basic function of coal mining is to form and give another assignment to final pit crater "Vihovici". The exploitation stands for psychological support and economic alimony for the costs of sanation, i.e. initial and basic source of funds. An adequate sanation cannot be effected without exploitation.
- Elaboration of the study has to confirm the initial concepts or supplement, i.e. modify them, if it would be necessary.

- **"Study of sanation, exploitation and recultivation of Vihovici mine and restructuration of Mostar mine", BOOK 2: "Restructuration of the Mostar mine" (1996), investor: EU-administration of Mostar, project leader: Faculty of Mining, Geology and Oil-Exploration, University of Zagreb**

  At the beginning of the Mostar mine had stopped its longtime continued work on coal mining. Part of the mine facilities was completely destroyed by direct combat actions during the war, whereas other parts were devastated, and now, they are out of order. All movable property of the mine was ruined and alienated as well as installation in immovable mine facilities. Manpower from the mine has been directly or indirectly included in the war and partly left the town. A main consumer of coal, Aluminium Plant Mostar, has also stopped the production and it is the question if it would be started again and to which extent. End of the war and postwar reconstruction imply reactivation of industrial and other facilities. By number of employees and line of activities, coal mine had a dominating position in the town. New circumstances which were also obvious before the war do not contribute to continuity of coal mining. Works taken on opening of the pit "Cim" have been stopped and the mining on open pit mine "Vihovici" will be put in the action only for the purpose of sanation of devastated fields. In this context, the restructuration of the coal mine is to be carried out which will include new programmes and facilities with realisation during sanation of mine field or afterwards. Sanation and recultivation of "Vihovici" pit will provide for the new possibilities of economic and recreation activities (orchards, vineyards, plantations, lake). New-built rooms of the "Cim" pit will be put in action for the production of button mushrooms. Former explosive yard "Orlac" is being brought up to its original purpose and includes employment of a certain number of miners for purchase, care and use of explosives. The production shaft with the tower will remain as a symbol of profession and mining tradition of Mostar. According to the plans framework of shaft tower, pit bottom and approachable part of underground rooms will be used for cultural purposes and building-in of mini-brewery with restaurant. The remaining mine fields will be left over for the town-planning purposes which will mostly correspond to the needs of near and wider town locality and fit into plans mentioned in the study.

- **Water and Soil sampling (2003)**

  In 2003, before the rehabilitation project was initiated, water and soil samples were taken at five locations in the mine area and analyzed for various parameters (pH, electro-conductivity, chlorides, ammonia, nitrites, nitrates, sulphates, copper, zinc, chrome, nickel, lead, manganese, cadmium). Water analysis showed that the critical parameters are present in all five sampling localities with elevated concentration of ammonia and nitrates. Significant concentrations of ammonia are noted (5.2 ppm – 6.1 ppm, allowed release is 0.1 ppm). The elevated values indicate a continuous process of waste decomposition which may have been deposited in the lake and its surroundings. Also, significant concentrations of Fe are noted (23.2 ppm – 26.2 ppm). Soil sample analyses showed that the critical parameters exist in all five locations with concentrations of Cd (1.7 ppm – 3.2 ppm), Ni (41.0 ppm – 58.3 ppm, max limit value is 35 ppm) while Pb concentrations are within the allowed limits except for one sampling location (62.2 ppm).

- **Study for the rehabilitation of the mine site by Fichtner/dplan/HarbourDom, financed by KfW Bankengruppe and the City of Mostar: Preparatory Stage Report (Fichtner et al., 2006) and Feasibility Report (Fichtner et al., 2007)**

Upon request by the City of Mostar, KfW Bankengruppe commissioned the consortium of JV Fichtner/dplan/HarbourDom in March 2006 with a 'Feasibility Study' investigating the presence and extent of soil and groundwater contamination and elaborating rehabilitation options on the Vihovici former coal mine. A broad-based chemical analysis program and special sampling techniques were needed, because previous studies were insufficient to assess the risks of hazardous waste. The consortium intended to generate a reliable database on: (i) the degree of waste hazard and amount of waste disposed in the lake and on the rest of the mine site, (ii) investigations on the degree of hazard for the environment in the lake water, in the Neretva river water, and in ground water, and (iii) burning coal seams. The results of the risk assessment of the Preparatory Stage can be summarized as follows:

- The organoleptic investigations and lab analyses detected no significant chemical contamination of the overburden area, open-cast pit lake and Neretva river. No significant concentrations of poisonous and hazardous chemical substances above detection limits were measured in the soil, water and soil air.
- However, a potential danger was seen in the openly accessible domestic, industrial and hospital waste. Around 85,000 m^3 of waste was spread over the area.
- The investigations of smouldering coal seams revealed the existence of at least one medium scale coal fire in a coal seam about 80 m below the surface. There was no significant concentration of toxic gases at the moment of field investigations, but the direction and intensity of coal fires could change rapidly.
- The lake in the open-cast pit is bordered by steep slopes and cliffs, which are cracked and faulted and of poor geotechnical stability, as well as the area of smouldering coal seams.

According to the results of all investigations, dangers to the environment in the Vihovici complex and its surroundings are fortunately substantially less than originally assumed. As a result of hazards assessment, possible safety measures or remediation solutions were recommended. Table 6-1 in **Appendix 1.3** summarizes the assumed dangers and the investigation programme executed at Vihovici Site and the results, as well as giving a brief description of recommended remediation measures.

The remediation measures included:

- The extinction of smouldering coal fires
- The prevention of further pollution of the lake water by inflow from sewage in times of high water of the Neretva river
- Prevention of access to waste deposited in the area and the development of a concept for future use and public access to the mine site, waste coverage and fences

- **ADRICOSM-NERES project: "NEretva river Delta Environmental Requalification and Sustainable Development", Research project co-funded by the Italian ministry of environment and territory. (2007)**

Task 4.1 of this project included: Guidelines for Surface Water Quality Management. According to the *Decree on water classification (OJ 77/98)*, waters are assigned to five classes depending on their quality and consequent possible use. Water classes and their respective description is reported in the following table (Table 3-1)

Table 3-1 Classification of Waters According to the Decree on Water Classification

Class	Description
Class I	Underground and surface water that in their natural state or after disinfection can be used as drinking water or for the food industry, and surface water that can be used for the production of precious fish species (trout)
Class II	Water that in their natural state can be used for bathing and recreation, for aquatic sports, for the production of other fish species (cyprinids) or that after adequate treatment can be used for drinking purposes and other industrial uses

Class III	Water that can be used in industries that have no specific requirement on water quality, and in agriculture. These are waters that need pre-treatment before use for determined purposes
Class IV	Water that can be used after appropriate treatment only in areas with severe water shortage
Class V	Water that cannot be used for any purpose, because they do not comply with the requirements of this law

The Decree indicates two groups of **parameters** which define the classification of waters:

- The first group includes the parameters which are obligatorily tested and evaluated to define the main the main ecological functions of the basin, namely: A. physico-chemical, B. oxygen regime, C. nutrients, D. microbiological, E. biological
- The second group of parameters is evaluated only in case of specific investigations and includes: F. metals, G. organic pollutants, H. radioactive elements

The Neretva Delta area is located in the southern part of the Dalmatian coastal region at the borders of the countries of Croatia and Bosnia and Herzegovina (BiH). The River extends inland for approximately 220 km long, of which only about 20 km lies within Croatia from the mouth of Neretva on the Adriatic Sea to the border boundary between Croatia and BiH at the city of Metkovic. The Neretva River Basin covers an area of approximately 10,000 km², mostly comprised in the mountain region of B&H. In its upper course, the Neretva flows from its headwaters in Central Bosnia through canyons and cliffs. Due to its canyon character, the river's middle course is used for hydro-energy. Five hydropower plants with the reservoirs are present in BiH part of the river (Jablanica, Rama, Grabovica, Salakovac, Mostar and Čapljina). The lower course begins downstream of the mouths of the Neretva's main tributaries, Trebizat and Bregava, and spreads into an alluvial fan, called the Delta area, with an area of 20,000 ha. The upper part of the Delta area is called Hutovo Blato and is in BiH, while the lower part is situated in Croatia where the Neretva River branches into multiple courses creating a large delta covering approximately 12,000 hectares. The Croatian part of the river course forms the so-called Lower Neretva Valley. The Neretva estuary continues in the Malostonski Bay, which has long been recognized as a rare marine reserve due to the rich and specific wildlife in the sea (mollusks, etc.). The estuarine area extends for approximately 8 kilometers along the sea coastline from the city of Ploce to the north of the river mouth. In the upper and middle parts of the River the climate is continental with snow-pluvial conditions, while in the lower part there is a Mediterranean climate.

The system of surface waters of the Neretva Delta includes:

- rivers – Neretva River with its affluents: Bregova, Trebizat, Krupa, Buna, Bunica, Norin, Crna rika, Mislina, Prunjak and other, smaller rivers and creeks;
- springs – that are situated on the karst rim can be permanent or periodical, depending on the inflow and precipitation;
- ponds – are situated within the Delta and on the karst rim. Most of them disappeared during the meliorations, but some of them are still important sources of drinking water.

Hydro-geologically, the Neretva River basin aquifer is characterized by a porous karst structure covered with sediment. The aquifer, shared by B&H and Croatia, has an extension of approximately 280 km^2. The aquifer is characterized by a complete inflow from B&H to Croatia, with a predominant direction to south. With regard to groundwater recharge, there are few existing estimates available of groundwater recharge on a regional basis.

The Neretva Delta Area is an important agricultural area for Croatian coastline and has its impact on several key economic industries in the region. The strategically important port of Ploče with its cargo transport for both countries is directly affected by environmental conditions in the river Neretva. Further south, along the Croatian coastline, there is a Mali Ston Bay well known for its seashell production and exploitation is directly linked to Neretva watershed through numerous karstic springs discharging into the Adriatic Sea. The river is primarily used for transport, recreation and irrigation, the latter being the predominant water use, since agriculture is one of the primary activities of many people. About 5,376 ha of the wetlands and lagoons in the Neretva's delta were meliorated and transformed into plantations, mostly mandarine plantations. Currently, the arable lands are approximately 30% of the delta area, of which the irrigated lands are 80% (5,000 ha). Several water supply systems were built for the purpose of irrigating the farmlands, such as the Modro oko – Opuzen water supply system and the water supply system north of Metkovic, which going through the Delta up to the Mala Neretva River refreshes the water of Mala Neretva River. The coastal sea in the delta is used for transport, recreation, aquaculture and fishing. Fisheries and aquaculture are particularly developed in the seaside area, in the Mali Ston Bay, a brackish water body famous for its oysters. With regard to the karst aquifer, groundwater from natural springs and catchments is predominantly used for the water supply system.

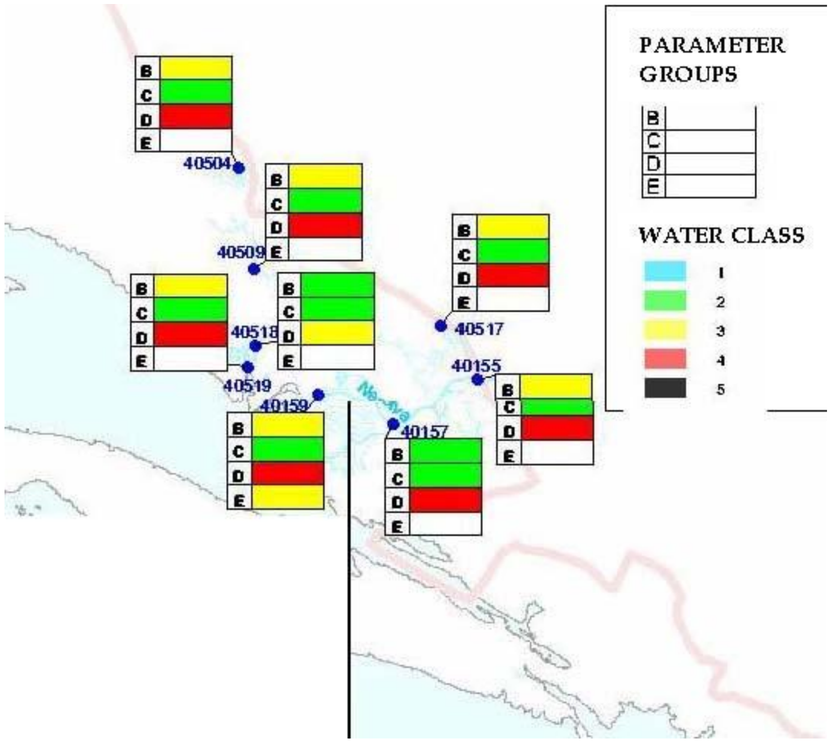
With regard to the Neretva River **water quality** monitoring, three hydrological stations have been established on Neretva River, in Ploce at the river mouth, in Opuzen downstream of the Mala Neretva, and in Metkovic, close to the state boundary with Bosnia Herzegovina. The monitoring stations work as waterlevel and water temperature record stations. Parameters monitored at the stations are: A. Physical/ chemical[1], B. Oxygen, C. Nutrients, D. Micro-biological, E. Biological, F. Heavy Metals. Water samples are taken from the top layer of the river. Measurements are taken 12 times/year for A, B, C, D groups; for E group 1 time/yr; for F group less then 12 times/year.

According to the decree on Water Classification, representative values are calculated as follows:

- in case the number of samples per year is above 12, the relevant value (except for the biological indices, P-B saprobity index and the biotic index), is calculated as the value of 90% (frequency), except for dissolved oxygen and oxygen saturation, which are calculated as the value of 10% (frequency).
- in case the number of samples per year is below 12, the relevant value of each index (including biological parameters) is calculated as the median of all results of measurements.

Figure 3-3 shows the location of monitoring stations in the area of Neretva Delta as well as classification of water quality according to the various groups of parameters. These data are published on the site of the Ministry of Agriculture, Forests and Water Resources, Directorate for Water Management.

[1] Neretva Sub-basin - International Network of Water-Environment Centres for the Balkans - http://www.inweb.gr/workshops/sub_basins/6_Neretva.html



Code		Location
Baćinska Lakes	40518	Tunel J. Podgora (inlet)
	40518	Sladinac Izlaz (outlet)
Neretva	40155	Metković
	40157	Opuzen
	40159	Rogotin
Spring of River Norin	40517	Prud

Figure 3-3 Sampling Stations and Monitoring Results in Neretva Delta, year 2000

The following table (Table 3-2) reports the water quality classification of Neretva River for the years 2000, 2001 and 2002, based on official Croatian classification for year 2000 and analytical results for years 2001 and 2002.

Table 3-2 Surface Water Classification (2000-2001-2002)

Group	Metković			Opuzen			Rogotin
Classification		II			II		II
	2000	2001	2002	2000	2001	2002	2000
A - Physical/ chemical		III	IV		V	V	
B - Oxygen	III	III	II	II	III	III	III
C - Nutrients	II	II	II	II	II	II	II
D - Microbiological parameters	IV	III	III	IV	III	III	IV
E - Biological parameters		III	-				III
F – Heavy Metals		III	II				

- **Water Quality Management, Author: Agency for Watershed of the Adriatic Sea; Continuous measurements**

Continuous water quality measurements are carried out by the Agency for watershed of the Adriatic Sea in the Neretva River and several other places. General chemical parameters, dissolved nutrients and metals were measured during the last 3 years. This is restricted information, but data should be made available for the ImpactMin project.

- **Borehole geophysical data for geothermal anomalies from burning coal seams (temperature, resistivity) in 2006**
  - The geomagnetic measurements cannot make a distinction between recent and extinct coal fire areas.
  - Different regions of significant magnetic anomalies have been found. Modeling of magnetic anomalies results in areas of higher susceptibilities (caused by heat) in greater depths (10-40 m). The extent of the anomaly areas has been estimated by looking at the analytic signal of the magnetic data and should be rather conservative.
  - The area around the abandoned borehole showed a strong magnetic anomaly (M2). It was verified that the anomaly was not caused by the casing of the well itself. So, the region G2/M2 was identified as a region with a recent coal fire beneath.
  - It is worth mentioning that the temperature anomalies in this area are very local, while the geophysical anomalies are more extensive: the true nature of all observed geophysical anomalies are yet to be determined.
- **Final report on extinction and rehabilitation works of the former Vihovici coal mine (KfW Bankengruppe, 2009)**

  The works on the extinction of burning coal and the rehabilitation of the former Vihovici coal mine started in March/2008 and finished in July/2009. During this time, in total 68 boreholes were created. The installation and activation of a cooling system, regular control of this cooling system and temperature distribution measurements were performed. This final report presents the details for all the finished boreholes (coordinates, diameter, depth, lithology, temperature and gas measurements, etc.). Burning coal extinction using fly ash and water slurry was performed in two intervals: December/2008 – March/2009 and April/2009 – July/2009.

3.1.2 Data availability

The University of Mostar (GFMO, Bosnia and Herzegovina), in cooperation with Photon (Croatia) provided various geospatial data sources, listed below:

- Topographic map, 1970, 1:25.000, 10m equidistance (scan of printed map, GeoTiff, see Figure 3-4)
- Digital Topographic Map, 1996, 1:10.000, 10m equidistance (CAD, Shapefile, see Figure 3-5)
- Digital orthophotos, 2004, 0.6m, color, optical/visible range (GeoTiff, see Figure 3-6)
- Hydrogeological map, 1995-1996, 1:10.000 (scan of printed map, GeoTiff)
- Map with electrical installations in Vihovici area, 2010 (CAD, Shapefile)
- Map with telephone installations in Vihovici area, 2010 (CAD, Shapefile)
- Map with plumbing and sewage in Vihovici area, 2010 (CAD, Shapefile)

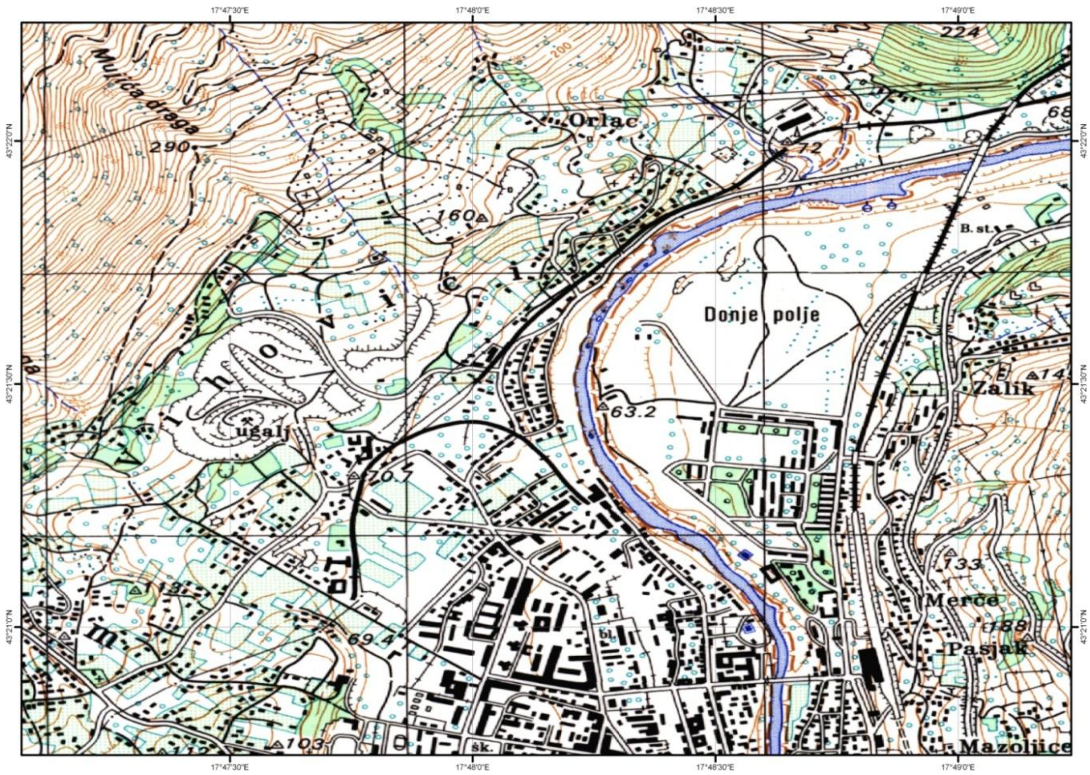


Figure 3-4 Scan of topographic map of the Vihovici mining area, Mostar (1:25000, 1970)

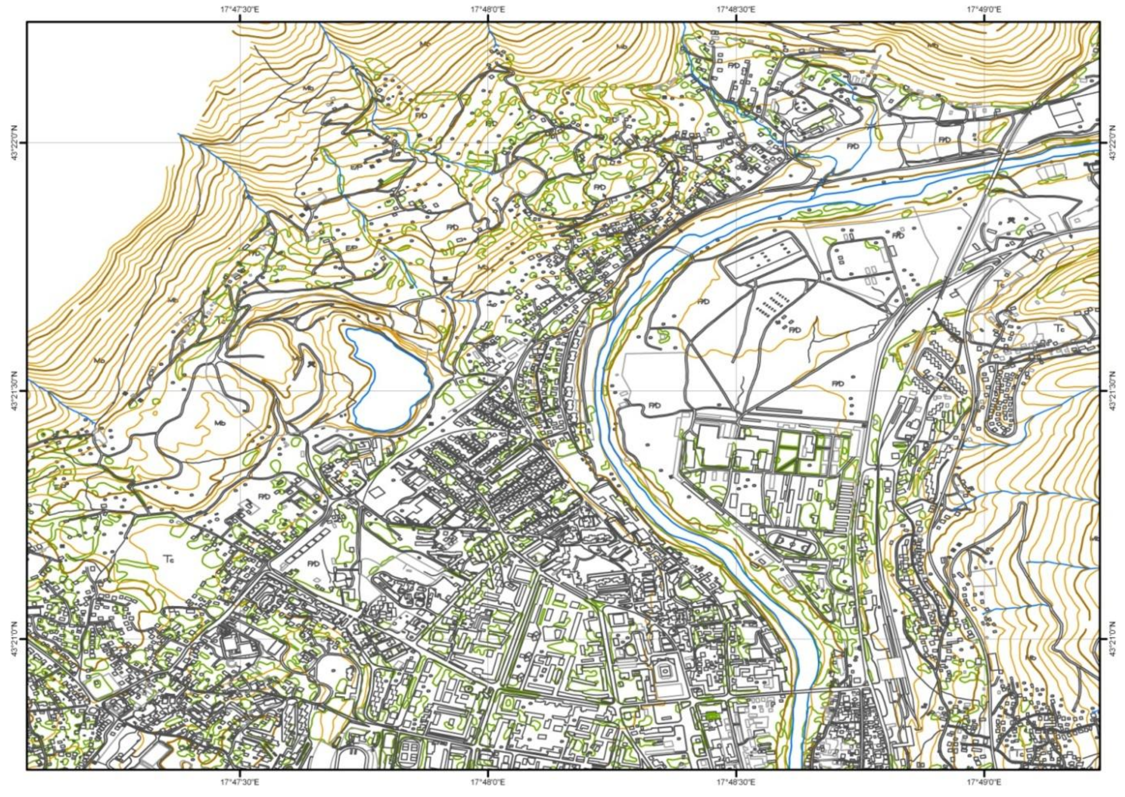


Figure 3-5 Digitized topographic map of the Vihovici mining area, Mostar (1:10000, 1996)

Figure 3-6 Mosaic of orthophoto images of the Vihovici mining area, Mostar (2004)

See **Appendix 1.2** for complete input on the second demo-site questionnaire on data availability and metadata.

3.1.3 Data collection

a. Satellite imagery

In the framework of the ImpactMin project, several types of satellite imagery were and will be acquired.

WorldView-2 imagery was ordered during the Summer of 2010, and will be ordered in Summer 2011, if possible at the same time as the airborne campaign in year 2 of the ImpactMin project. WorldView-2 was only recently launched (October/2009) and is the first satellite that offers 8 spectral bands at high spatial resolution (46 cm). For more details, see D4.1. A quicklook of the image acquired in July/2010 is displayed in Figure 3-7.

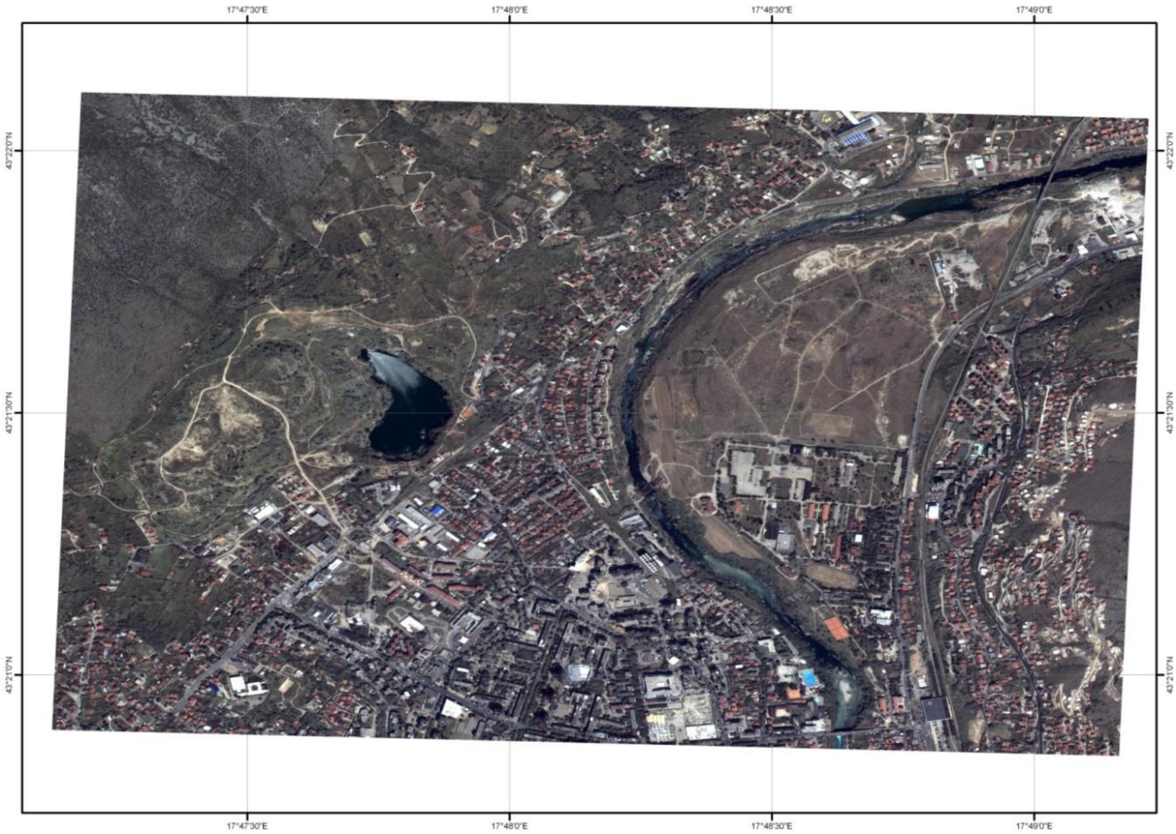


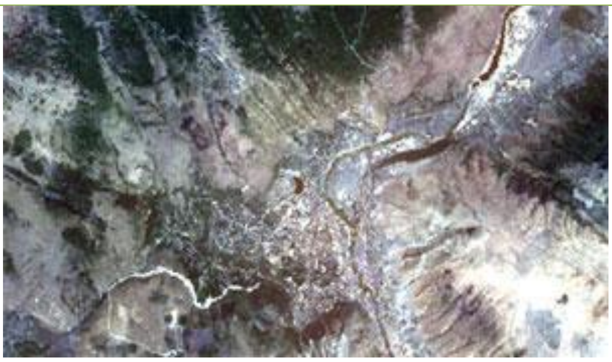
Figure 3-7 Quicklook of the WorldView-2 image of the Vihovici mining area, Mostar, acquired on 21/07/2010

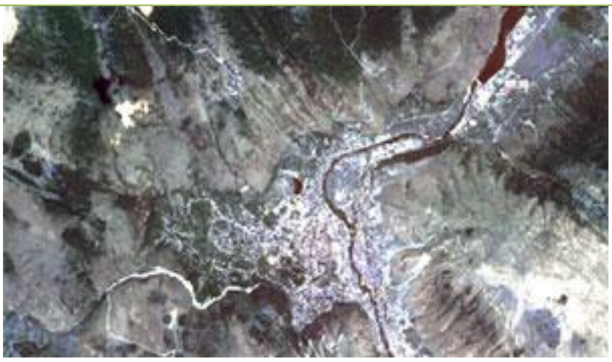
A complete time series of Landsat images could be retrieved from the Landsat image archive (Table 3-3). From July/1985 till July/2009, 15 Landsat images of reasonable quality and cloud cover are freely available. The years covered are: ’85, ’87, ’88, ’92, ’99, ’00, ’01, ’02, ’03, ‘07 and ’09. All images are acquired in late spring or summer (May – August).

Table 3-3 Time series of Landsat imagery available for the Vihovici mining area, Mostar

Sensor	Date	Quicklook
Landsat 5	07/07/1985	

Sensor	Date	Quicklook
Landsat 5	15/07/1987	
Landsat 4	06/05/1988	
Landsat 7	09/08/1992	
Landsat 7	09/08/1999	

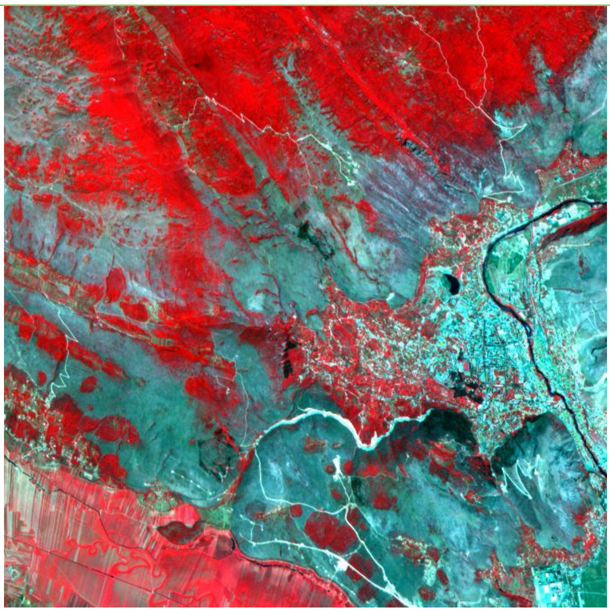
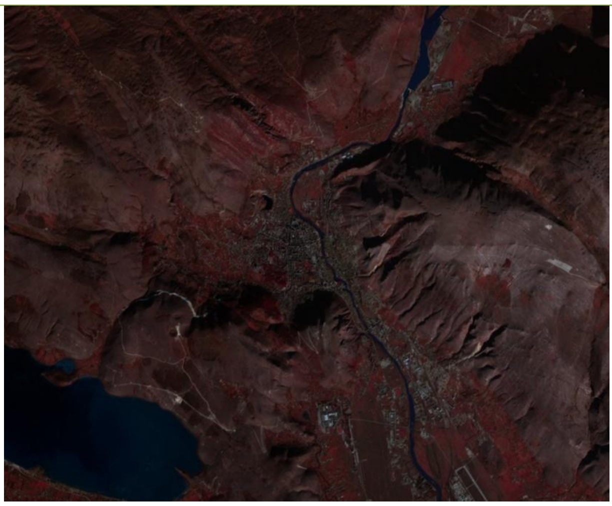
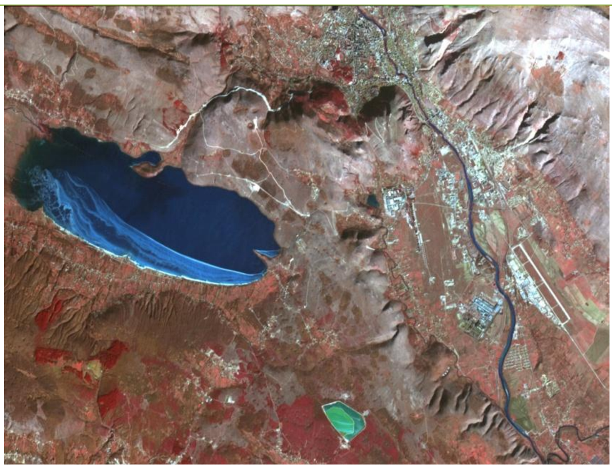
Sensor	Date	Quicklook
Landsat 7	26/09/1999	
Landsat 7	08/06/2000	
Landsat 7	20/08/2000	
Landsat 7	13/07/2001	

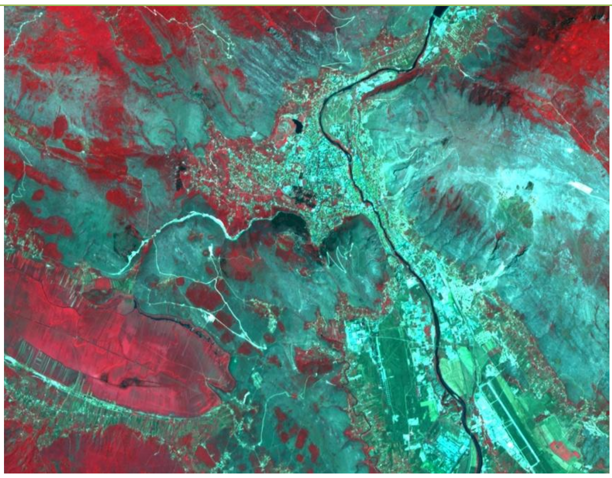
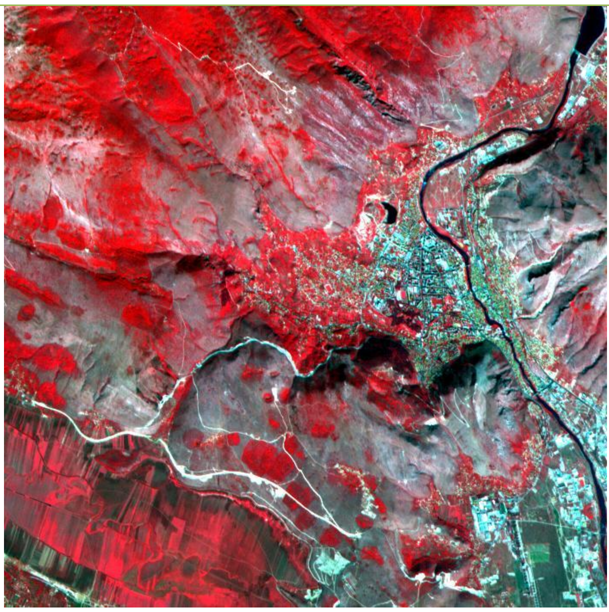
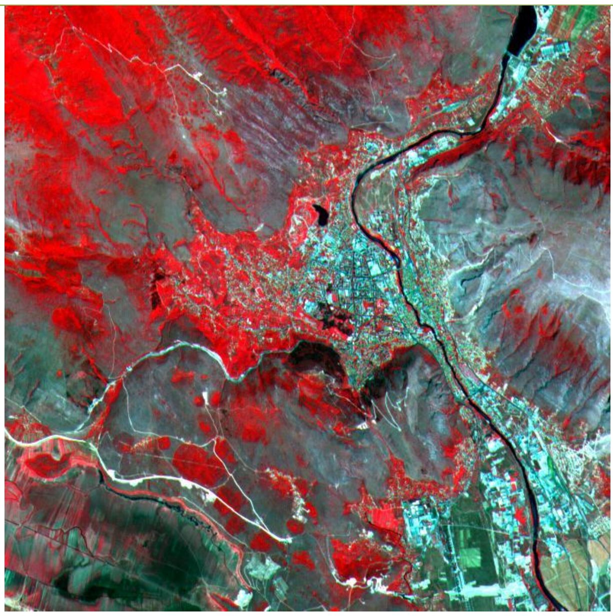
Sensor	Date	Quicklook
Landsat 5	22/06/2002	
Landsat 7	23/06/2002	
Landsat 5	27/07/2003	
Landsat 7	07/07/2007	

Sensor	Date	Quicklook
Landsat 7	16/09/2007	
Landsat 5	27/07/2009	

Six ASTER images covering the Mostar project area were acquired (Table 3-4). A few more scenes were available but of insufficient quality (cloud cover and/or low illumination angle) to be worth purchasing. The years covered are: ’01, ’03, ’06, ’09 and ‘10. The image from February/2006 only covers the Southern part of the study area. The SWIR bands of the ASTER sensor are a great benefit, allowing the identification of individual minerals, gradual changes and acid mine drainage. Due to the fact that in 2007 the SWIR system became defunct, the latter two images only comprise the VNIR and TIR bands. However, ImpactMin expects that this is not a major drawback as the analysis of satellite imagery for this area will mainly be focused on land cover analysis, vegetation monitoring, and potential acid generation caused by abundant sulphide minerals in the coal. ImpactMin will also investigate heat anomalies associated with subsurface coal fires. In WP6 ImpactMin will experiment if the spatial resolution permits the detection of thermal anomalies at this scale. For the purpose of heat anomaly detection, ImpactMin plans to purchase some night-time thermal ASTER images in April/2011 and sometime late Summer/2011.

Table 3-4 Time series of ASTER imagery available for the Vihovici mining area, Mostar

Sensor	Date	Quicklook
ASTER	06/07/2001	
ASTER	17/01/2003	
ASTER	01/02/2006	

Sensor	Date	Quicklook
ASTER	18/06/2006	
ASTER	30/09/2009	
ASTER	15/07/2010	

No Hyperion, ALI or CHRIS/PROBA imagery is available for the area.

b. Ancillary information

An ASTER, USGS and SRTM Digital Elevation Model is available. More detailed topography based on photogrammetric restitution of airborne stereopairs might become available; GFMO sent in a request at the Geodetic Institute of Bosnia and Herzegovina.

A wide range of field measurements (including field spectra) will be available from the airborne campaign. For a description, see D5.3.

3.1.4 Data processing, analysis flow-sheet and products

a. Objectives

The objectives of satellite image processing will be to monitor regional parameters of the mine: temporal change and natural succession of vegetation, urban growth, geology. Even though medium resolution Landsat MSS/TM/ETM+ imagery and ASTER is limited in spatial and spectral resolution, ImpactMin will experiment with time series analysis for the monitoring of temporal changes and settings of the mine. During the project course, ImpactMin will investigate the position of the mine and development coupled with urban growth and the natural vegetation succession and regeneration in the mining area since closure and first rehabilitation efforts (Figure 3-8). Furthermore, ImpactMin will test if the thermal bands of medium resolution imagery (including night time imagery) can be used to monitor temperature increment related to underground coal fires, although the spatial extent of the mine site is relatively small compared to pixel size of TIR images. The high resolution WorldView-2 satellite imagery can be used to map surface cover in detail, and to monitor the increased urbanization of the area in the vicinity of the mine site in the post-conflict boom (after 1995). If available, hyperspectral imagery could be used to assess the condition of the Vihovici pit lake (chlorophyll, water clarity, depth) and zones of possible interaction with the Neretva river. Also the presence of hydrocarbon waste, iron oxides, iron hydroxides and hydrophilic clays and minerals related to acid mine drainage could be investigated.

Figure 3-8 Pictures of the Mostar demo site (field visit in September/2010) showing natural regeneration of vegetation in the area

b. Data processing and analysis flow-sheet

The data processing and analysis flow-sheet (Figure 3-9, p.35) shows how satellite data will be processed and analyzed in order to reach the objectives. The flow sheet contains three parts: the data input (in blue shading), the data processing (in grey shading) and the products (in red shading). The satellite imagery that is available and that will be used to experiment with different earth observation method in order to investigate the demo-site is: Landsat and ASTER time series, including day- and nighttime imagery to be acquired in 2011, a WorldView-2 image of 2010 and one to be acquired in 2011. It might be interesting to plan the airborne campaign at the same time as the WorldView-2 image acquisition. Field data will be available through the airborne campaign in 2011 (for a detailed description see D5.3). The data processing part contains 3 components, each leading to one or more products.

The first component deals with time series analysis of medium resolution imagery. The objective is to monitor regional parameters and temporal change. Focus will be laid on the natural recovery of vegetation and the position of the mine coupled with urban growth and the monitoring of the success of clean-up and stabilization efforts in 2007-2009. In order to monitor natural recovery of vegetation, a number of vegetation indices will be calculated for the preprocessed time series. The results will be analyzed for trends. For the last topic, it might also be interesting to look at high spatial resolution airborne photographs, true color (historical) images from Google Earth and the recent WorldView-2 images (see further). For the preprocessing of the Landsat and ASTER time series respectively, it will be important to have very good spatial and spectral consistency between the images.

In the second part, thermal infrared bands will be used to monitor temperature increment related to underground coal fires. The shortcomings of borehole and geophysical methods for monitoring active coal fires (time consuming, difficult to repeat, and costly to apply over a large area) can be tackled by using remote sensing methods (Kuenzer et al., 2007). Various authors have used remote sensing techniques to detect and monitor coal fires. The background temperature, the quality of the remote sensing data, and the significance of the coal fires are the factors which determine the detectability of the coal fires (Zhang et al., 1997). All three factors might be an issue for the Mostar demo-site. However, in 2011, a request for ASTER day- and nighttime image acquisition will be carried out in order to test the applicability of ASTER TIR bands.

The third component deals with high spatial resolution imagery and the interaction with the airborne hyperspectral campaign (see also D5.3). High spatial resolution satellite imagery will be used to derive base maps, to identify polluted areas (minerals), to monitor the spatial extent of polluted areas and acid mine drainage, and to monitor water quality in the pit lake, the interaction with the Neretva river and contamination of surface waters. The output of the airborne data analysis (see D5.3) will be used to calibrate/validate the analysis of high resolution satellite imagery. An important topic will be the fusion of spatial/spectral data from different sources. Data fusion is a method that employs a combination of multi-source data with different characteristics such as spatial, spectral and radiometric resolution, to acquire a high-quality image (Vaseashta et al., 2007). The integration of spectrally and spatially complementary remote multi-sensor data will facilitate the interpretation of the imagery. Different techniques will be tested. On the basis of the information that is available so far, it can be expected that the spectral variations in this area to be subtle – both spatially and spectrally. The limited spectral and spatial resolution of the ASTER imagery are certainly going to be challenging factors in this area. Smart integration of the relatively low-resolution ASTER imagery with high resolution WorldView-2 and airborne hyperspectral data will be key to the successful use of the ASTER imagery for monitoring environmental processes in this project area. Data integration and integrated analysis will be one of the core aspects of the image analysis for this study area.

See **Appendix 4.1** for a general description of satellite image preprocessing. See **Appendix 4.2** for a general description of satellite processing.

The data processing for the Mostar demo-site will not be focused on subsidence, atmospheric pollution or changes in soil moisture and groundwater, because the spatial extent and severity of these problems will complicate successful data treatment.

c. Products

The satellite image processing will lead to various products:

- Base maps with spectral information, minerals, identification of polluted areas
- Regional parameters: temporal change, natural recovery of vegetation and urban growth
- Evaluation of the success of clean-up and stabilization (2007-2009)
- Evaluation of temperature increment due to (underground) coal fires
- Evaluation of acid mine drainage
- Evaluation of water quality in the pit lake and contamination of surface waters
- Evaluation of the interaction with the Neretva river

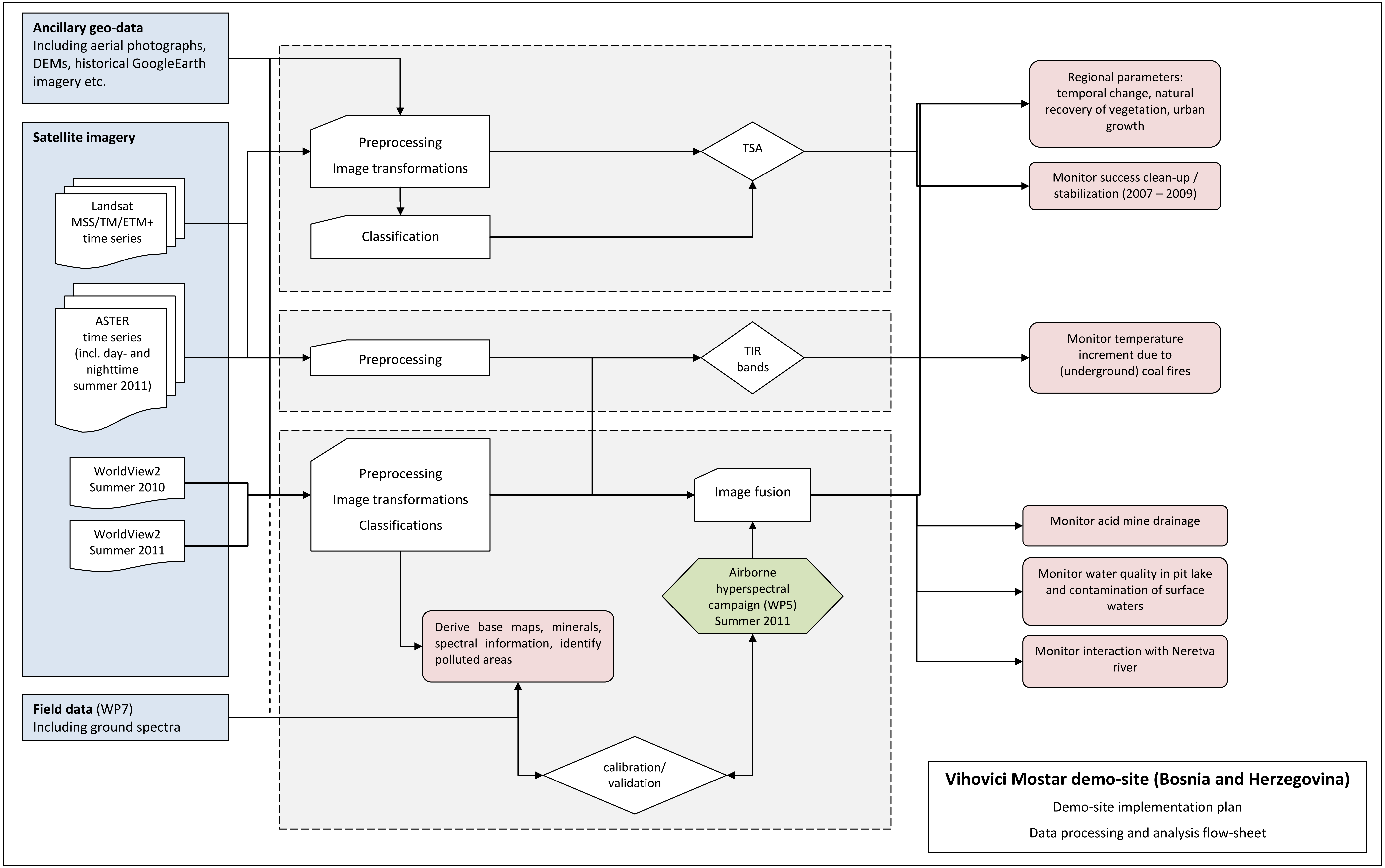


Figure 3-9 Data processing and analysis flow-sheet for the Vihovici Mostar demo-site (Bosnia and Herzegovina)

3.1.5 Discussion and recommendations

The preparatory work for demo-site implementation at the Mostar demo-site shows that there are large opportunities but also challenges for the ImpactMin project.

The big challenge of using satellite imagery for environmental monitoring of the Mostar demo-site is the limited spatial resolution of the imagery, combined with the small size of the demo-site. Also, on the basis of the information that is available so far, ImpactMin expects the spectral variations in this area to be subtle – both spatially and spectrally.

Nevertheless, the combination of satellite earth observation imagery with the images from an airborne hyperspectral campaign will allow testing different image fusion techniques. The integration of spectrally and spatially complementary remote multi-sensor data will facilitate the interpretation of the imagery. Smart integration of the relatively low-resolution ASTER imagery with high resolution WorldView-2 and airborne hyperspectral data will be key to the successful use of the ASTER imagery for monitoring environmental processes in this project area. Data integration and integrated analysis will be one of the core aspects of the image analysis for this study area. Moreover, the outcomes of the airborne campaign and the many ground measurements to be taken during the airborne campaign can be used to calibrate and validate the satellite image processing.

Another opportunity is to monitor the effect of mine closure in 1991 and rehabilitation efforts in 2007-2009. It is expected that it will be possible to monitor the natural recovery of vegetation in the area, based on time series of medium resolution satellite imagery.

Also the use of thermal infrared bands to monitor temperature increment related to underground coal seam burning is interesting. However, the background temperature, the quality of the remote sensing data, and the significance of the coal fires, will determine if it will be feasible to use satellite imagery for this purpose in this area.

3.2 Rosia Montana, Romania

3.2.1 Site overview and environmental impacts

Roşia Montană is located approximately 80 km NW of the regional capital of Alba Iulia and 85 km NNE of the City of Deva in west-central Romania, in the “Golden Quadrilateral” region of the Apuseni and Metaliferi mountain ranges in Transylvania. From 1970 till 2006, the Rosia Montana mine was owned and operated by the state. Currently, S.C. Rosia Montana Gold Corporation S.A. (R.M.G.C.) is trying to obtain the permits in order to again start operation (the so called ‘Rosia Montana Project’). Gold mining in Rosia Montana has occurred almost continuously over the last 2000 years and has influenced the social, economic, cultural and environmental conditions of Rosia Montana. Only underground mining operations were functioning before 1970. About 140 km of galleries were dug in the area in nearly 2000 years of mining. Later on, the open pit mines Cetate and Carnic were setup. The area of the open pits is 19.75 ha (Cetate) and 5.2 ha (Carnic).

Many of the impacts of this development and exploitation have been beneficial, such as the long history, the diversity of the religion and culture, economic welfare proven by the wealth of archaeological patrimony. Some of the impacts however have been negative. Environmentally, past mining has caused serious problems including pollution of soils and streams, landscape scarring, and impact on land use and biodiversity: the environment is seriously affected. The 24.95 ha open pit mining area and brown acid waters exiting the underground mining works are visible (Figure 3-10). Also, there have been no significant attempts at environmental rehabilitation and no effective environmental controls to reduce the impacts. The current situation is therefore progressive: if no remediation actions are done, continued pollution of streams and soil within the area can be expected, primarily from uncontrolled run-off and seepage from the Rosiamin operation (activity closed in May 2006, site not rehabilitated), historic mine workings, and uncontrolled waste disposal practices.

Figure 3-10 Pictures of the Rosia Montana demo-site

In terms of a general localization, the investigated area is part of the Carpathian Subprovince, district of the Trascău-Metaliferi volcanic and flysch mountains. The topography in the Rosia Montana area is typical for the mountainous landscape in the Metaliferi Mountains region, having high elongated ridges that separate deep valleys, steep slopes with peaks rising above the ridge tops at the upper end of the valleys. Ridge tops tend to be well rounded with occasional craggy outcrops in the upper part of Rosia and Corna Valleys or ridges adjacent to the site and slopes are usually steep.

Rosia Montana area has a continental temperate climate. Higher areas are characterized by a mountain microclimate with cold winters lasting 4 to 6 months, and with heavy snowfall. Spring and autumn are cold and humid, with significant rainfall. Summer is short, with gradual transitions between seasons. Climatic data – air temperature, relative humidity, nebulosity, precipitation and wind – have been recorded between 1988 and 2005 by the Rosia Montana Meteorological Station, located on the top of Rotundu Hill, in the north-eastern corner of the Project site near the upper end of the Rosia Valley.

The Rosia Montana volcanic sequence is interpreted as a maar-diatreme complex emplaced into Cretaceous sediments, predominantly black shales, with sandstone and conglomerate beds. The 3D geometry of the area is well established due to an extensive network of underground mines that have been developed since the Austro-Hungarian Empire period, and from the extensive drilling conducted from the surface and underground over the last 25 years. Environmental conditions (relief, surface lithology, climate, vegetation) determined the formation of a diverse soil cover. Its diversity is apparent at type and sub-type level, especially in the lower levels, given the soil and terrain characteristics of the respective areas and determining the rules of its distribution. Based on the data obtained from soil mapping, soil and land maps have been developed. A review of the soil map shows that 8 soil units were defined in the study area, by type and sub-type, and 19 units of soil type and sub-type associations in various proportions.

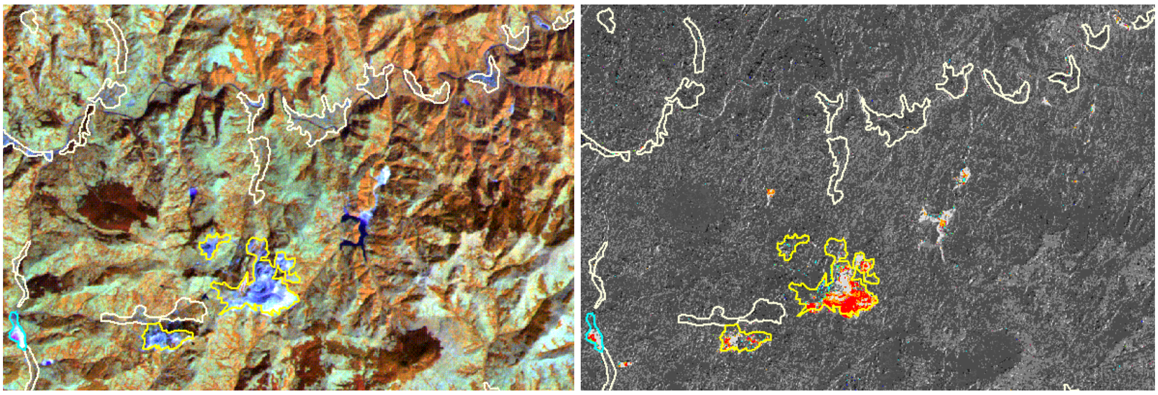


Figure 3-11 Mining area in the Apuseni Mountains analyzed in the PECOMINES project. Left: Landsat TM RGB composit (4,5,3) showing the open-pit of Rosia Montana, and neighboring opencast mine of Rosia Poieni and dump sites near Abrud. Right: the anomaly image (OH-FeOx) shows high co-occurrence of both FeOx and OH-bearing secondary minerals (Vijeda et al., 2004)

See **Appendix 2.1** for complete input on the first general demo-site questionnaire. Environmentally, past mining has caused serious problems including:

- Pollution of streams and soils: Mine waters coming from the open galleries have low pH and high contents of heavy metals. They are mainly affecting the quality of the surface waters and to some extent the groundwater. The heavy metals load includes high amount of As, Cd, Ni, Se, Pb, Cr. The pH of the dug-wells water is generally neutral to slightly acidic. The soil is not polluted with heavy metals at a relatively short distance from the mining site.
- Landscape scarring: The landscape was completely modified in the area of the opencast mine. Important amounts of rocks were excavated during the last 40 years.
- Impact on land use and biodiversity: Land use was changed in the mining operation area, including the open pit, tailings management facilities, waste heaps and industrial facilities. Vegetation was completely removed in the area.

Florea et al. (2005) studied the streams that flow radially from the mountains through the Rosia Montana mining area. Heavy metals including zinc, cadmium, lead, copper and manganese were selected for analysis. Table 3-5 shows that heavy metal concentrations are above accepted limits. Although mining activities were reduced, the solid waste rock deposited by the river side remains the main source of pollution.

Table 3-5 Element concentration in surface water in the Rosia Montana mining area (Florea et al., 2005)

Trace elements	SR[a] mg/L	Drinking water	Concentration found within this work mg/L					
			Maximum			Minimum		
			Nov. 2004	Feb. 2005	May. 2005	Nov. 2004	Feb. 2005	May. 2005
Copper	0.005	<LOD	1.328	1.347	0.575	<LOD	<LOD	<LOD
Cadmium	0.003	0.004	0.152	0.168	0.107	<LOD	<LOD	<LOD
Zinc	0.03	0.001	8.750	15.550	18.590	0.001	0.001	0.001
Lead	0.05	0.007	0.248	0.231	0.539	0.001	0.001	0.001
Manganese	0.30	0.024	141.200	223.200	320.700	0.107	0.082	0.504

[a]Romanian standard

Also Bird et al. (2005) investigated solute and sediment-bound metal pollution (Cd, Cu, Pb and Zn) along a 140 km reach of the River Abrud and River Aries and 9 mining-affected tributaries. The River Aries is a major right bank tributary of the River Mures and drains eastwards along the northern edge of the Metaliferi Mountains (Figure 3-12). Figure 3-13 shows the plot of solute Cd, Cu, Pb and Zn concentrations and values of pH and EC on a downstream basis. With the exception of Pb, metal concentrations in the River Abrud are highest immediately downstream of the EM Bucium mine. Also downstream the Rosia River, Cadmium, Cu, Zn are elevated above imperative values. The mining-affected tributaries of the River Abrud cause a local reduction in aqueous pH and elevation in solute metal concentrations. Improvement in water quality downstream results from inputs from relatively clean tributary streams and an accompanying increase in pH, which will promote the dissolution of metals through precipitation and adsorption to suspended particulates within the water column. Bird et al. (2005) show that mining activity within the Aries river catchment, particularly in the Rosia Montana region, has caused the degradation of surface water and river sediment quality. The proposed gold mine at Rosia Montana would therefore not be developed and operated within a pristine environment. However, the contrast between the level of pollution in the Rivers Abrud and Aries suggest that the hydrological link between mining activity and river systems should be minimized in order to keep levels of surface water contamination to a minimum. Potentially great environmental impacts could arise from a tailings-dam failure.

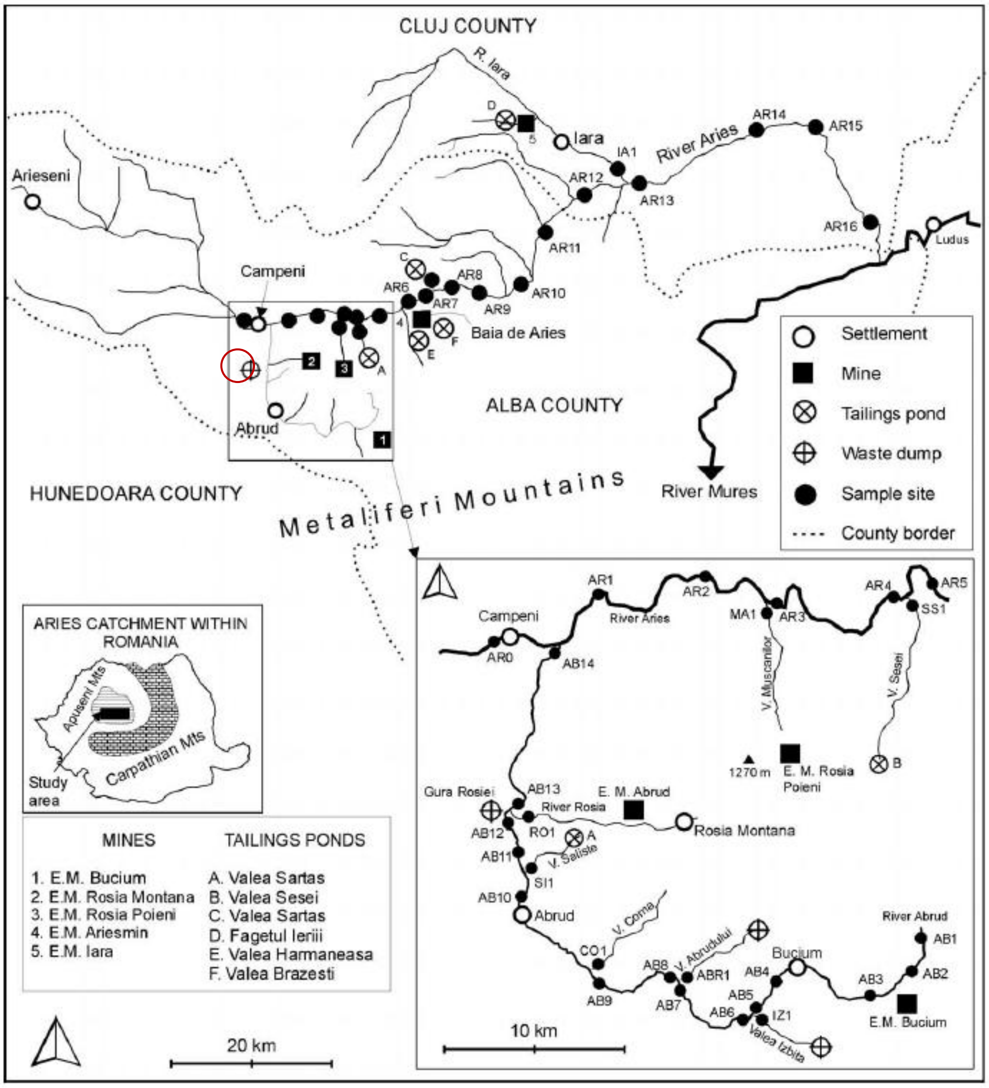


Figure 3-12 Map of the Aries River catchment showing the study rivers, mines, tailings ponds and location of sample sites (Bird et al., 2005)

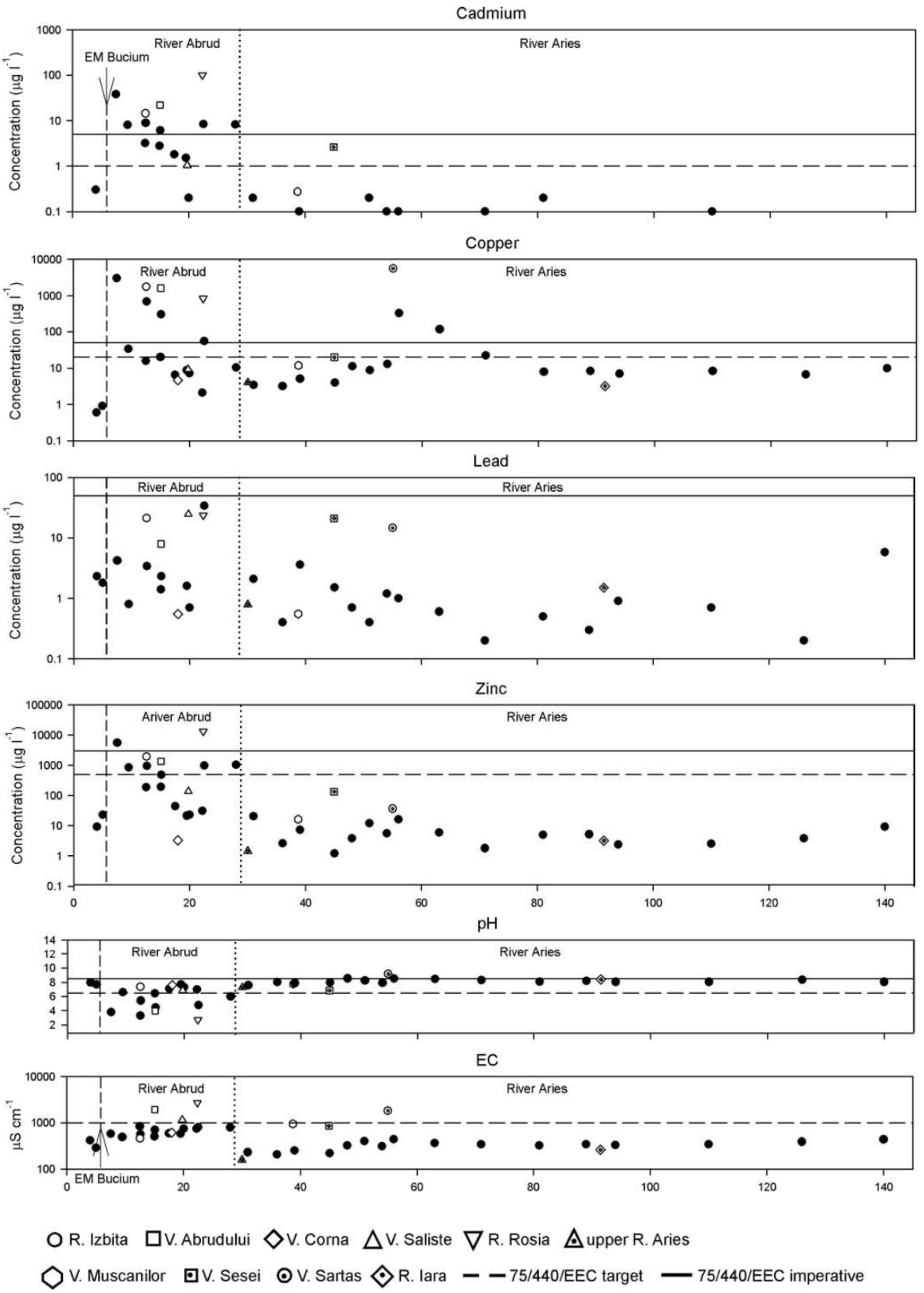


Figure 3-13 Solid metal concentrations in the Abrud River, the Aries River and major mining-affected tributaries (Bird et al., 2005). Vertical dashed and dotted lines show the location of the Bucium mine and the Abrud/Aries confluence, respectively. Samples of the River Rosia are marked with red circles

.

The area of the existing **mine waste rock dumps** is presented in the next table:

Table 3-6 Mine waste dumps in the Rosia Montana mining area

NAME	Area (m^2)	Area (ha)
23 August Dump	3479.45	0.348
Afinis Dump	1137.78	0.114
Aurora Dump	739.62	0.074
Cirnicel Adit Dump + 910m	11976.86	1.198
Dump Adit + 938m	9738.43	0.974
Gauri Dump	20796.64	2.080
Hop Dump	53683.79	5.368
Iuliana Dump	6273.84	0.627
Manesti Adit + 795 Dump	33468.07	3.347
Napoleon Dump	2677.33	0.268
Orlea Dump	43678.50	4.368
Piatra Corbului +960m Dump	1445.21	0.145
Piatra Corbului Dump	850.48	0.085
Rakosi Dump	21366.06	2.137
Valea Verde Dump	73039.24	7.304
Verkes Dump	5549.66	0.555

In the framework of a baseline conditions study conducted in 2003-2006, 153 **soil samples** were collected from the mine surrounding area and the contents of the following heavy metals were determined: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn. The returned results were compared to the reference values of MAPP Order/1997 regarding the normal contents of these chemical elements in soil (VN) and threshold values representing alert (PA) and intervention thresholds (PI) for sensitive soil use. A predominant feature of these analytical data is the fact that they have low values, generally below the alert or response thresholds (Table 3-7), except for Mn, Pb, Ni and Cr (x_{max} > PA), and Cd and Co (x_{max} > PI).

Table 3-7 Metal content in soil samples collected at Rosia Montana (2003-2005), compared to normal values (VN) and threshold values for alert (PA) and intervention (PI)

Parameter	Zn	Cu	Fe	Mn	Pb	Cd	Ni	Cr	Co
n	153	153	153	153	153	153	153	153	153
x_{min}	25.6	7.5	7.112	80	11.6	0.5	12.5	10.7	10.8
x_{max}	271.9	39	47138	**2187**	**90**	**10.1**	**114**	**79.2**	**66.6**
$x_{average}$	87.5	17.8	28794	645	35.7	1.24	49.3	29.9	29.9
VN	*100*	*20*	-	*900*	*20*	*1*	*20*	*30*	*15*
PA	*300*	*100*	-	*1500*	*50*	*3*	*75*	*100*	*30*
PI	*600*	*200*	-	*2500*	*100*	*5*	*150*	*300*	*50*

In September 2010, again 27 soil samples were collected from the area and analyzed (Lacatusu, 2007), see Figure 3-14. The results are shown in Table 3-8. Very few soil samples show metal contents above alert or intervention values. However, a large number of samples contain more heavy metals than the normal value. This shows that the background of metal content is fairly high.

Figure 3-14 Location of soil sample collection (Lacatusu, 2007)

Table 3-8 Metal content in soil samples collected at Rosia Montana (2010), compared to normal values (VN) and threshold values for alert (PA) and intervention (PI) (Lacatusu, 2007)

Parameter	Pb mg/kg	Cu mg/kg	Zn mg/kg	Cd mg/kg	Mn mg/kg	Fe %	Ni mg/kg	Co mg/kg	Cr mg/kg
n	27	27	27	27	27	27	27	25	27
x_{min}	6.7	13.4	35	0.21	155	0.91	4.6	1.4	5.9
x_{max}	56.2	300	395	1.54	2437	4.06	90.3	12.5	62.8
$x_{average}$	24.0	44.1	98.5	0.7	719.1	2.4	25.9	6.3	24.8
VN	*20*	*20*	*100*	*1*	*900*	*3.0*	*20*	*15*	*30*
PA	*50*	*100*	*300*	*3*	*1500*	*-*	*75*	*30*	*100*
PI	*100*	*200*	*600*	*5*	*2500*	*-*	*150*	*50*	*300*
n > VN and < PA	*13*	*24*	*6*	*5*	*4*	*4*	*14*	*0*	*7*
n > PA and < PI	*1*	*0*	*1*	*0*	*1*		*1*	*0*	*0*
n > PI	*0*	*1*	*0*	*0*	*0*		*0*	*0*	*0*

Currently, **air pollution** is limited in the area, since the mine is not active. During the windy periods the fine mineral fraction is mobilized from the open pit and dumps. This dust may contain different mineral components, including various amounts of Si, Al, Fe, Ti, Ca, Mg, Ni, K, Mn, Cu, Zn, Cd, Pb. However, there is no air quality monitoring system in function at this moment.

The first consistent **water monitoring** program was developed starting in 2000. At present, the water quality monitoring network operated by RMGC covers approximately 27,000 ha and includes the following types of samples: acid rock drainage and other types of wastewater, groundwater (springs, wells and boreholes), surface water (streams), water from man-made lakes, and drinking water from the supply network. Based on the described sampling for wastewater, surface and ground water, an overall evaluation of the water quality in the monitored area was carried out for each type of water sample.

The wastewater sample analysis results, mainly from the Corna and Rosia Valleys, indicated low pH and high levels of As, Cd, Ni and sulphates in the majority of the samples and occasionally elevated levels of lead and total chromium (Table 3-9), related with acid mine drainage.

Table 3-9 Results from wastewater sample analysis in the Corna and Rosia Valley. Li: lower limit, Ls: upper limit. MAC: Maximum Admissible Concentration.

Waste water		pH	As	Cd	Ni	Pb	Cr	SO_4
Corna Valley	x_{min}	**4.35**	3.1	4.56	2.6	0	3.5	10.96
	x_{max}	7.1	66.43	42.8	**536**	6.6	**2964**	**2289**
Rosia Valley	x_{min}	**2.68**	5.1	1.4	3.1	0	52	**1216**
	x_{max}	**3.03**	**1738**	**814**	**732**	**246**	**4077**	**2637**
	Li	*6.5*						
	Ls	*9.5*						
	MAC		*100*	*200*	*500*	*200*	*1000*	*600*

The contaminants found in the majority of analyzed surface and ground water samples (Table 3-10, Table 3-11 and Table 3-12) were: arsenic, cadmium, nickel, selenium and total chromium. The presence of lead and sulphates was sporadic and reflects localized sources primarily related to mining impacts. Due to the predominantly near-neutral character of the samples, total and dissolved metal concentrations (for arsenic, cadmium, nickel and lead) were largely similar.

Table 3-10 Results from groundwater sample analysis from springs in the Abruzel, Corna, Saliste and Rosia Valley. Li: lower limit, Ls: upper limit. MAC: Maximum Admissible Concentration.

Ground water (springs)		pH	As	Cd	Ni	Pb	Cr	Se	SO_4
Abruzel	x_{min}	7.32	5.2	2.3	6.5	0	0	0.9	50.0
Valley	x_{max}	7.7	9.22	**5.7**	**20.3**	4.9	12	9.43	63.9
Corna	x_{min}	**6.11**	0.4	0	0	0	0	0.55	9.7
Valley	x_{max}	7.29	**10.2**	**6.4**	**20.3**	**11.3**	31	**19.6**	**262**
Saliste	x_{min}	**6.34**	0	0	1	0	0	0.1	1.8
Valley	x_{max}	7.75	9.1	**9.2**	**42.22**	1.3	27	9.5	87.9
Rosia	x_{min}	**6.34**	0.1	0	0.3	0	0	0.24	9.5
Valley	x_{max}	7.7	**26.26**	**6.7**	8.7	3.2	15	**19**	42.8
	Li	*6.5*							
	Ls	*9.5*							
	MAC		*10*	*5*	*20*	*10*	*50*	*10*	*250*

Table 3-11 Results from groundwater sample analysis from hand dug wells in the Abruzel, Corna, Saliste and Rosia Valley. Li: lower limit, Ls: upper limit. MAC: Maximum Admissible Concentration.

Ground water (springs)		pH	As	Cd	Ni	Pb	Cr	Se	SO_4
Abruzel	x_{min}	**6.37**	0	0	3.2	0	0	0.9	32.1
Valley	x_{max}	7.35	**18.1**	**7.8**	**20.3**	**11.2**	16	**23**	234.5
Corna	x_{min}	**6.1**	0	0	0	0	0	0.5	12.2
Valley	x_{max}	7.56	**12.8**	**12.8**	12.3	**12.4**	17.2	**21**	73.7
Saliste	x_{min}	**5.94**	0	0	18.1	0	0	0.7	**422.2**
Valley	x_{max}	7.01	**12.9**	**12**	**54.31**	0	8.8	6.5	**656.5**
Rosia	x_{min}	**4.4**	0	0	0	0	0	0.07	**275.3**
Valley	x_{max}	7.6	**10.7**	**6.5**	**43.5**	**14.6**	13	**21**	**520.9**
	Li	*6.5*							
	Ls	*9.5*							
	MAC		*10*	*5*	*20*	*10*	*50*	*10*	*250*

Table 3-12 Results from groundwater sample analysis from boreholes in the Abruzel, Corna, Saliste and Rosia Valley. Li: lower limit, Ls: upper limit. MAC: Maximum Admissible Concentration.

Ground water (springs)		pH	As	Cd	Ni	Pb	Cr	Se	SO_4
Abruzel	x_{min}	**6.27**	0.6	0	1	0	0	0	199

Valley	x_{max}	7.43	**16.3**	**16**	**43.5**	**10.2**	**328.8**	2.4	**718**
Corna	x_{min}	**6.3**	0.8	0	4.6	0	1.46	0.5	17.0
Valley	x_{max}	7.8	9	**10.4**	**21**	**49.6**	**704.9**	4.1	105.3
Saliste	x_{min}	6.8	0.2	0	1.6	0	0	1.3	57.1
Valley	x_{max}	7.6	1.2	**5.7**	**31.9**	0	18	6.1	**418.1**
Rosia	x_{min}	6.68	0	0	3.3	3.2	12	0.8	44.4
Valley	x_{max}	7.23	12.3	4.4	**84**	**78.3**	**878.8**	5.3	124.1
	Li	*6.5*							
	Ls	*9.5*							
	MAC		*10*	*5*	*20*	*10*	*50*	*10*	*250*

The characteristics of the monitored surface waters were variable within the moderately acidic to neutral domain. A single exception was represented by alkaline waters collected in the Sartăş Valley and originating in the tailings pond of Baia de Arieş processing plant. The most acidic surface water samples were collected from the Abrud River – downstream of mining works belonging to Bucium area, from a tributary of Abruzel Stream and from Corna Stream – downstream of the waste rock dumps, from Roşia Stream – downstream of ARD discharge points of the Roşia Montană area, and from the Şesei Stream – downstream of the waste rock piles and of the tailings dam belonging to Roşia Poieni mine.

The general conclusion of the water quality baseline study for the Rosia Montana area is that the historical development of mine operations has resulted in the contamination of waters with specific pollutants, originating from the local mineralized bodies. Such components are leached by acidic waters generated by the exposure of sulphide-bearing ores to exogenous factors. Surface water pollution propagates at long distances from the Rosia Montana area and other mining impacted valleys, thus affecting the downstream water usage.

3.2.2 Data availability

One high resolution SPOT-5 image is available (acquired on 24/08/2004). Two ASTER images were acquired on 14/03/2002. Airborne orthophotos with spatial resolution of 0.5 m were acquired in 2005, and can be purchased from RMGC (around € 2.400 for the whole site).

The following geodata are available:

- ASTER rainbow Digital Elevation Model (15m resolution)
- Topography map (equidistance 2 m) from Spectrum Survey and Mapping
- Land use map from Spectrum Survey and Mapping
- Delineation of protected areas from Spectrum Survey and Mapping
- Location of lakes, forests and buildings from Spectrum Survey and Mapping
- Existing 20kW and 110kW power lines (including location of poles) from Spectrum Survey and Mapping

See **Appendix 2.2** for complete input on the second demo-site questionnaire on data availability and metadata.

The following orthorectified remote sensing data are available:

- Airborne Orthophotoplan - resolution 0.5m, year 2005
- SPOT-5 24/08/2004, L1A, resolution 2.5m (see Figure 3-15)
- ASTER 14/03/2002, L1A (see below)

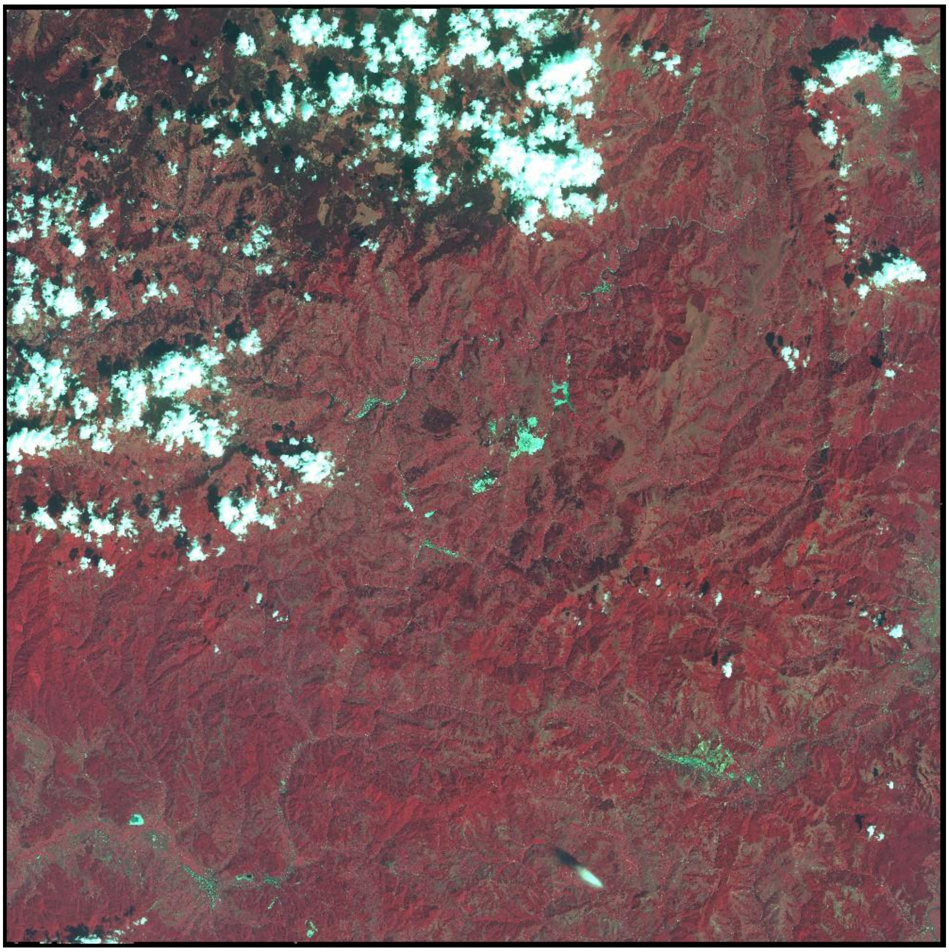


Figure 3-15 Quicklook of the SPOT-5 image acquired on 19/08/2004 for the Rosia Montana demo-site

3.2.3 Data collection

a. Satellite imagery

In the framework of the ImpactMin project, several types of satellite imagery were and will be collected and acquired.

Long time series of low resolution imagery is available. First, the Global Inventory Monitoring and Modelling System (GIMMS) monthly NDVI time series derived from NOAA-AVHRR (Tucker et al., 2005) is available from July/1981 till December/2006 at 8 km spatial resolution. Secondly, various 10-daily products derived from the SPOT-Vegetation sensor are available at 1 km resolution (Maisongrande et al., 2004). Multi-temporal analysis of NOAA-AVHRR or SPOT-Vegetation products can be used to monitor vegetation dynamics.

WorldView-2 imagery was ordered during the Summer of 2010, and will be ordered in Summer 2011, if possible at the same time as the field work campaign in year 2 of the ImpactMin project. A quicklook of the 2010 WorldView-2 image is displayed in Figure 3-16. WorldView-2 was only recently launched (October/2009) and is the first satellite that offers 8 spectral bands at high spatial resolution (46 cm). For more details, see D4.1. The image has been orthorectified using the SRTM-DEM. It would be better to use a more detailed DEM, but at this stage such a DEM is not available. ImpactMin is currently investigating the possibilities of acquiring a more detailed DEM.

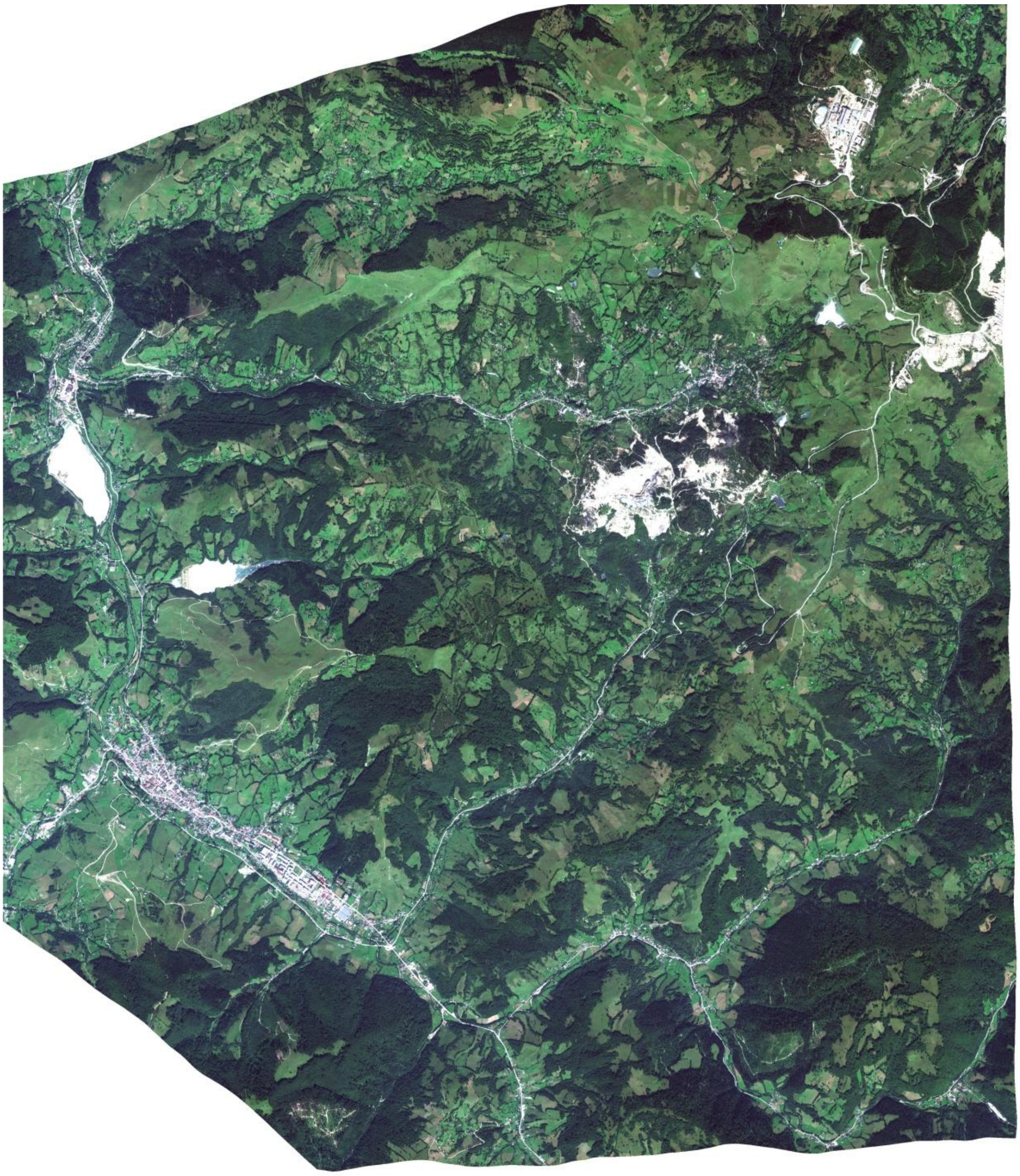
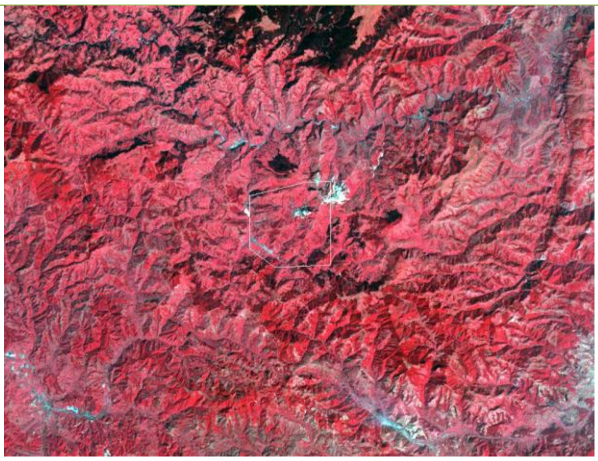
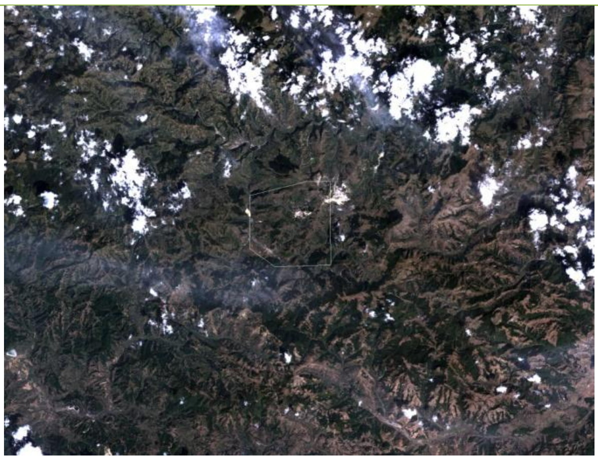
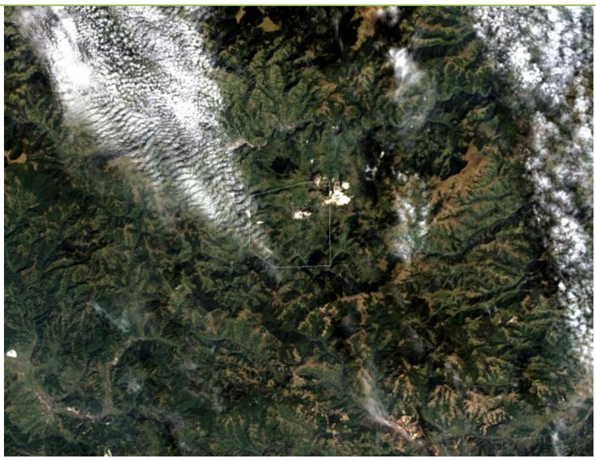


Figure 3-16 Quicklook of the orthorectified WorldView-2 image of the Rosia Montana mining area, Mostar, acquired on 15/08/2010

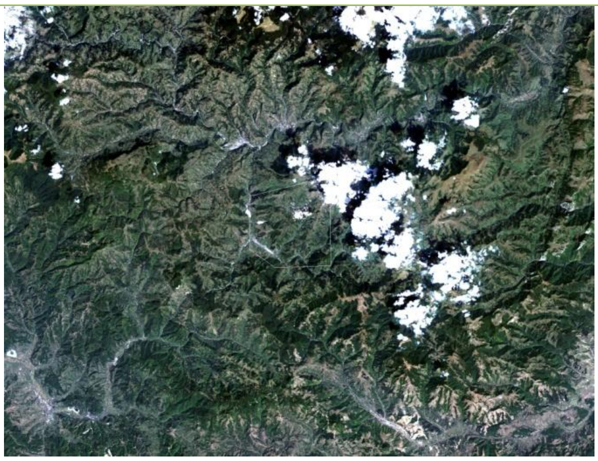
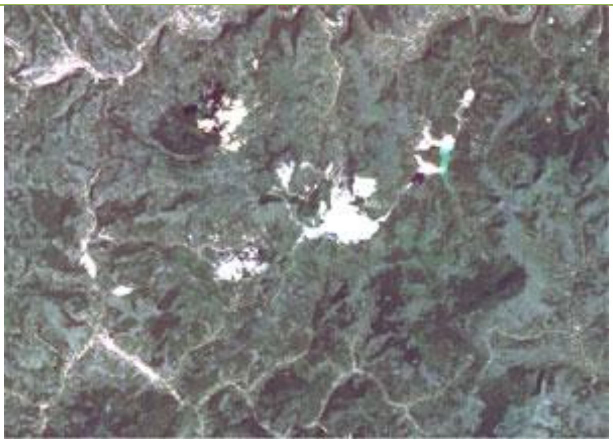
A complete time series of Landsat images could be retrieved from the Landsat image archive (Table 3-13). From September/1983 till July/2009, 13 Landsat images of reasonable quality and cloud cover are available. The years covered are: ’83, ’87, ’90, ’93, ’99, ’00, ’01, ’02, ’03, ’07 and ‘09. All images are acquired from late spring to late summer (June – September).

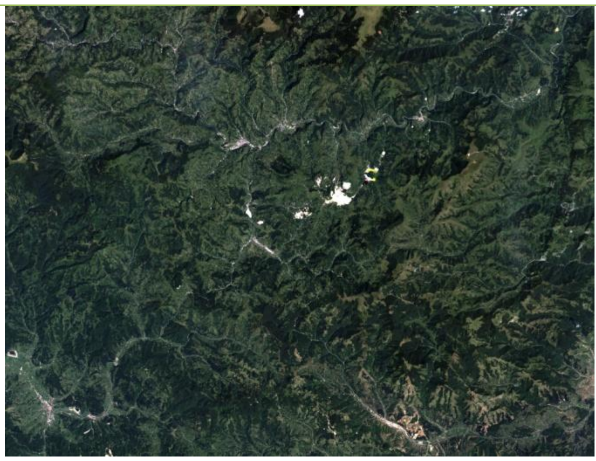
Table 3-13 Time series of Landsat imagery available for the Rosia Montana mining area

Sensor	Date	Quicklook
Landsat 4	09/09/1983	
Landsat 5	12/09/1987	
Landsat 5	02/07/1990	

Sensor	Date	Quicklook
Landsat 5	26/07/1993	
Landsat 5	27/06/1994	
Landsat 7	21/09/1999	

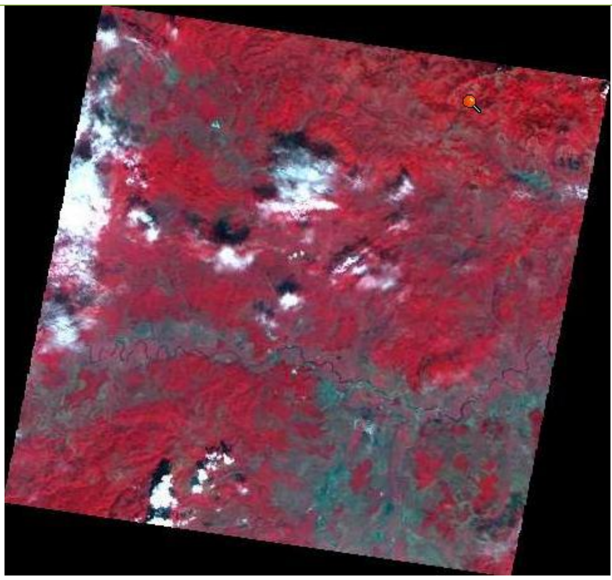
Sensor	Date	Quicklook
Landsat 7	22/08/2000	
Landsat 5	01/08/2001	
Landsat 7	28/08/2002	

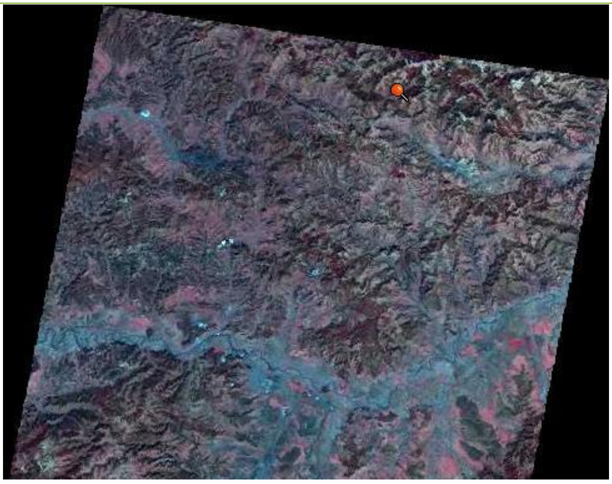
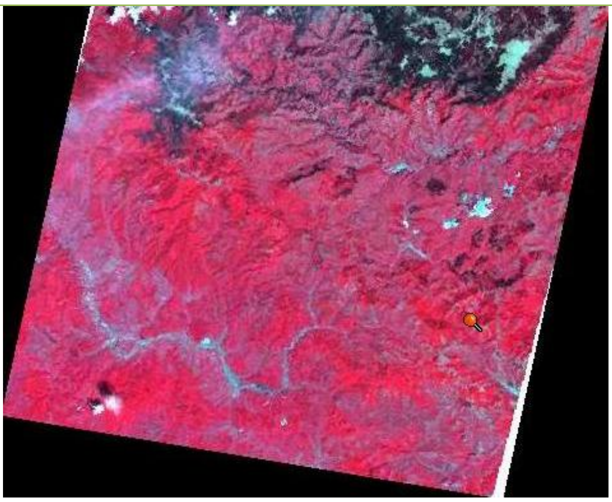
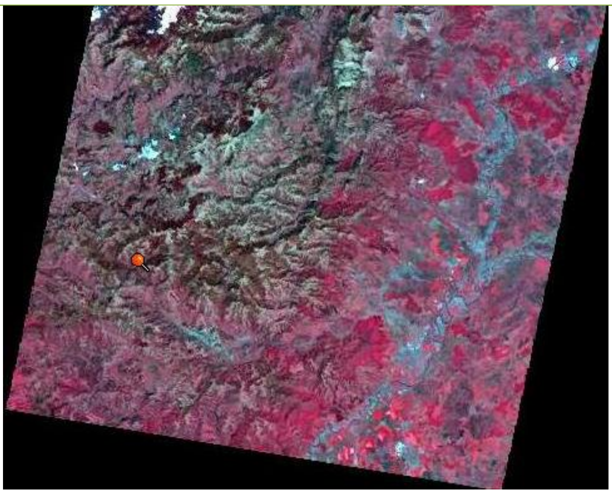
Sensor	Date	Quicklook
Landsat 5	08/09/2003	
Landsat 7	09/07/2007	
Landsat 5	17/07/2007	

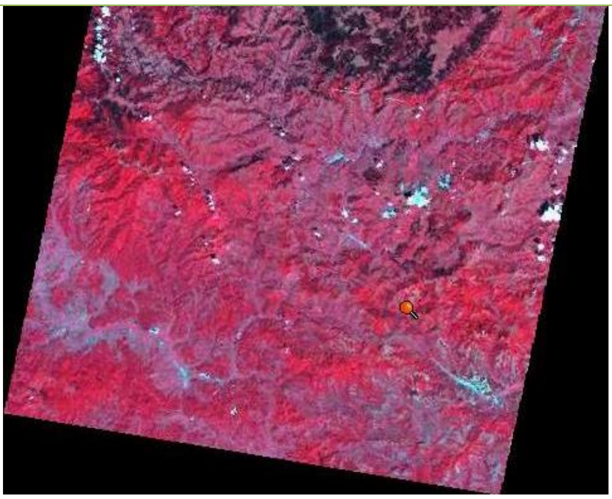
Sensor	Date	Quicklook
Landsat 5	22/07/2009	

Availability of usable ASTER scenes for this area over the last 10 year is limited. However, also a time series of ASTER images can be collected, although these images must be purchased (Table 3-14). A series of 5 ASTER images was identified. The years covered are: ’00, ’02, ’03, ’07 and ’08. Three of those scenes are acquired very early in the year at low sun-angles. Unfortunately it is our experience that at these low sun-angles the albedo so weak, that significant reduction of the spectral information content of the imagery can be expected. In WP6 it has to be determined how useful these scenes will be for spectral analysis. The SWIR bands of the ASTER sensor are a great benefit, allowing the identification of individual minerals, gradual changes and acid mine drainage. Unfortunately, since April 2008 there are no good observations in the SWIR range, because the detector saturates (ASTER Science Office, 2009). ImpactMin plans to acquire a new scene in the summer of 2011.

Table 3-14 Time series of ASTER imagery available for the Rosia Montana mining area

Sensor	Date	Quicklook
ASTER	15/08/2000	

Sensor	Date	Quicklook
ASTER	14/03/2002	
ASTER	27/05/2003	
ASTER	20/04/2007	

Sensor	Date	Quicklook
ASTER	12/08/2008	

No Hyperion, ALI or CHRIS/PROBA imagery is available for the area.

b. Ancillary information

A Digital Elevation Model was prepared based on the topography maps. The SRTM DEM and ASTER DEM (Figure 3-17) is also available.

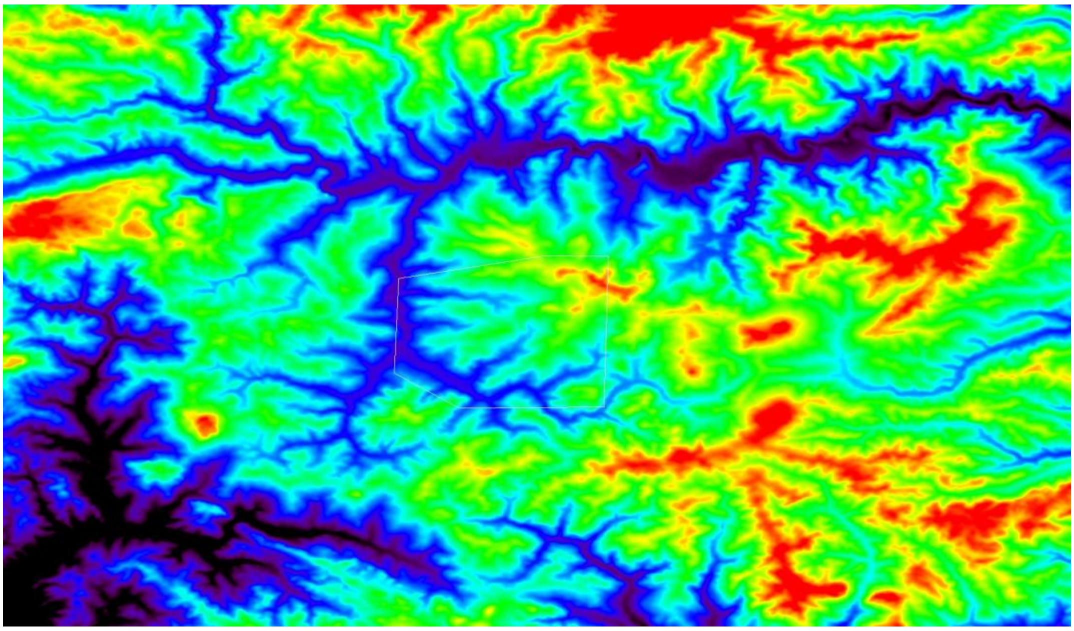


Figure 3-17 Quicklook of the ASTER DEM for the Rosia Montana demo-site

A large database of water monitoring data is available for the area (see above). Moreover, a wide range of field data will be gathered in a field campaign planned in the summer of 2011. A large number of ground spectra will be measured, including minerals, water, healthy and stressed vegetation, soils, and man-made objects. The parameters to be investigated are:

- Minerals: x-ray diffraction and ground spectra
- Acid mine drainage: water analyses in the areas with acid leaching, water analysis in streams (field multiparameter, AAS, ion chromatography), stream sediment and iron oxide precipitates analyses

- Vegetation stress: ground spectra and chemical analysis of the foliage; comparison of unaffected and affected vegetation
- Pollution of soils: XRF readings and ground spectra

Details for the ground measurements will be defined in WP7.

3.2.4 Data processing, analysis flow-sheet and products

a. Objectives

The objectives of satellite image processing at the Rosia Montana demo-site will be on the one hand to monitor regional parameters of the mine: temporal change of vegetation and land cover in general, geology, mineralogy.Even though medium resolution Landsat MSS/TM/ETM+ imagery and ASTER, and low resolution NOAA-AVHRR or SPOT-VGT products are limited in spatial and spectral resolution, the longtime series, and in case of NOAA-AVHRR or SPOT-VGT the high temporal resolution, can be interesting for the monitoring of temporal changes and settings of the mine. ImpactMin will experiment with time series analysis for the monitoring of temporal changes and settings of the mine. Special interest goes to the effect of mine closure in 2006. On the other hand, the high resolution SPOT-5 and WorldView-2 satellite imagery can be used to map surface cover in detail. Furthermore, the spectral bands of the WorldView-2 imagery will allow to monitor acid mine drainage and pollution of surface water, vegetation stress along the AMD pathways and mineralogy. Vegetation stress was never studied in the area. Although acid mine waters run through very distinct pathways, and vegetation stress due to AMD is not expected to be widespread, it is interesting to look at the vegetation on river banks along the pathways and compare it with unaffected areas, using ground spectra and WorldView-2 images. However, since WorldView-2 is just recently launched, no publications about the application of this imagery for vegetation stress monitoring have been published. It will be interesting to study the applicability of the sensor for this purpose, although the extent and severity of acid mine drainage induced vegetation stress in the area is not known thus far. The outcomes of these analysis will also provide a baseline for environmental monitoring when the mine would re-open in the future.

Analysis of satellite imagery in ImpactMin WP6/7 will be focused on:

- Acid mine drainage and pollution of surface waters
- Vegetation stress
- Mineralogy
- Temporal change

b. Data processing and analysis flow-sheet

The data processing and analysis flow-sheet (Figure 3-19, p.57) shows how satellite data will be processed and analyzed in order to reach the objectives. The flow sheet contains three parts: the data input (in blue shading), the data processing (in grey shading) and the products (in red shading). The satellite imagery that is available and that will be used to investigate the demo-site is: SPOT-VGT, NOAA-AVHRR, Landsat and ASTER time series, a SPOT-5 image acquired in 2004, a WorldView-2 image of 2010 and one to be acquired in 2011. It might be interesting to plan the airborne campaign (see D5.3) at the same time as the WorldView-2 image acquisition. The data processing part contains 2 components, each leading to one or more products.

The first component deals with time series analysis of low and medium resolution imagery. The objective is to monitor regional parameters and temporal change. Focus will be laid on temporal change of vegetation cover and land cover in general and surface geology and mineralogy. Also the effect of mine closure in 2006 will be monitored. Mining in the Rosia Montana area has been taking place almost uninterruptedly since Roman times. The open-pit mine has been active between 1970 and 2006. There has not been any serious attempts for rehabilitation, leaving the landscape scarred deeply, and uncontrolled pollution of streams and soils due to release of acid mine drainage from the waste dumps and the mine itself continues to take place. ImpactMin will investigate if the available ASTER scenes give us an opportunity to detect changes both during the late stages of the open pit mine and after closure of the mine. Integrated analysis of ASTER with Landsat imagery will allow us to monitor the variations in acid drainage from the mine and dumps, the related pollution of soils and streams, and geomorphological changes as a result of the mining activities in the period between 1983 and 2011. For the preprocessing of the Landsat and ASTER time series respectively, it will be important to have very good spatial and spectral consistency between the images.

The second component deals with high spatial resolution imagery and the interaction with the hyperspectral campaign (see also D5.3). High spatial resolution satellite imagery will be used to derive base maps, to identify polluted areas (minerals), to monitor the spatial extent of polluted areas and acid mine drainage, to monitor vegetation stress along the AMD pathways, and to monitor contamination of surface waters. WorldView-2 is the first high-resolution multispectral satellite to provide a red-edge detector (705-745 nm) for conducting vegetative analyses that can reveal plant type, age, health and diversity (DigitalGlobe, 2010). Remote sensing solutions that include the red-edge band are expected to be able to detect subtle changes in plant health. The Rosia Montana study area is characterized by very small scale land use. ImpactMin expects that the WorldView-2 data will be sufficiently detailed to allow very accurate mapping of land-use. Also, ImpactMin will investigate the use of WorldView-2 data and will confirm if the sensor has enough spectral resolution to map areas that are clearly affected by the mining activities. Figure 3-18 shows both a normal stretched true color image of one of the tailings dumps and a composite produced using a data adaptive enhancement technique, which results in the most enhancement of even the most subtle spectral features. This kind of imagery serves as an excellent basis to map land use and to design a field sampling campaign. Moreover, the output of this second component will provide a baseline for environmental monitoring when the mine would re-open in the future. The output of the foreseen hyperspectral campaign and data analysis (see D5.3) will offer the opportunity to calibrate/validate the analysis of high resolution satellite imagery. If this campaign will be carried out, an important topic will be the fusion of spatial/spectral data from different sources. Data fusion is a method that employs a combination of multi-source data with different characteristics such as spatial, spectral and radiometric resolution, to acquire a high-quality image (Vaseashta et al., 2007). The integration of spectrally and spatially complementary remote multi-sensor data will facilitate the interpretation of the imagery. Different techniques will be tested.

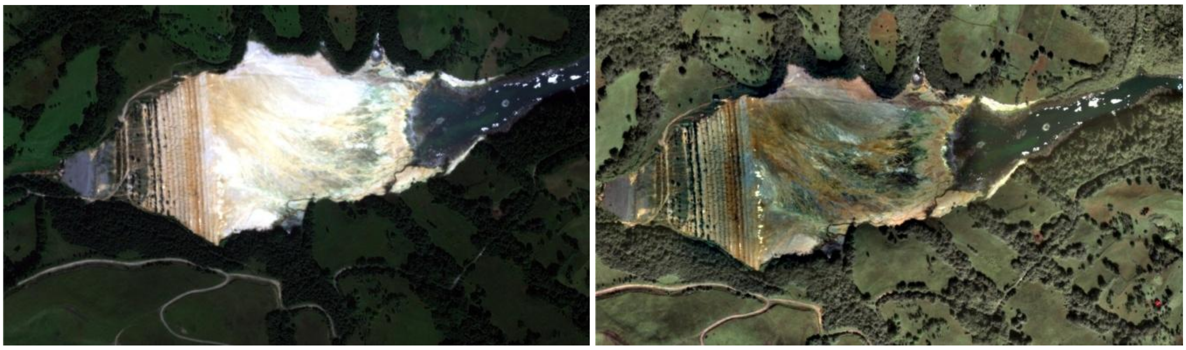


Figure 3-18 WorldView-2 color composites of a tailing dump at the Rosia Montana demo-site. Left: normal stretched color composite, right: composite produced using a data adaptive enhancement.

See **Appendix 4.1** for a general description of satellite image preprocessing. See **Appendix 4.2** for a general description of satellite processing.

The data processing for the Rosia Montana demo-site will not be focused on soil contamination, because the background values of metals in soils is rather high, and the limited spatial and spectral resolution of the available satellite imagery will not allow for detection of soil contamination.

c. Products

The satellite image processing will lead to various products:

- Base maps with spectral information, minerals, identification of polluted areas
- Regional parameters: temporal change, surface geology and mineralogy
- Evaluation of the effect of mine closure in 2006
- Evaluation of acid mine drainage and surface water pollution
- Evaluation of vegetation stress along AMD pathways
- Baseline for environmental monitoring when the mine re-opens in the future

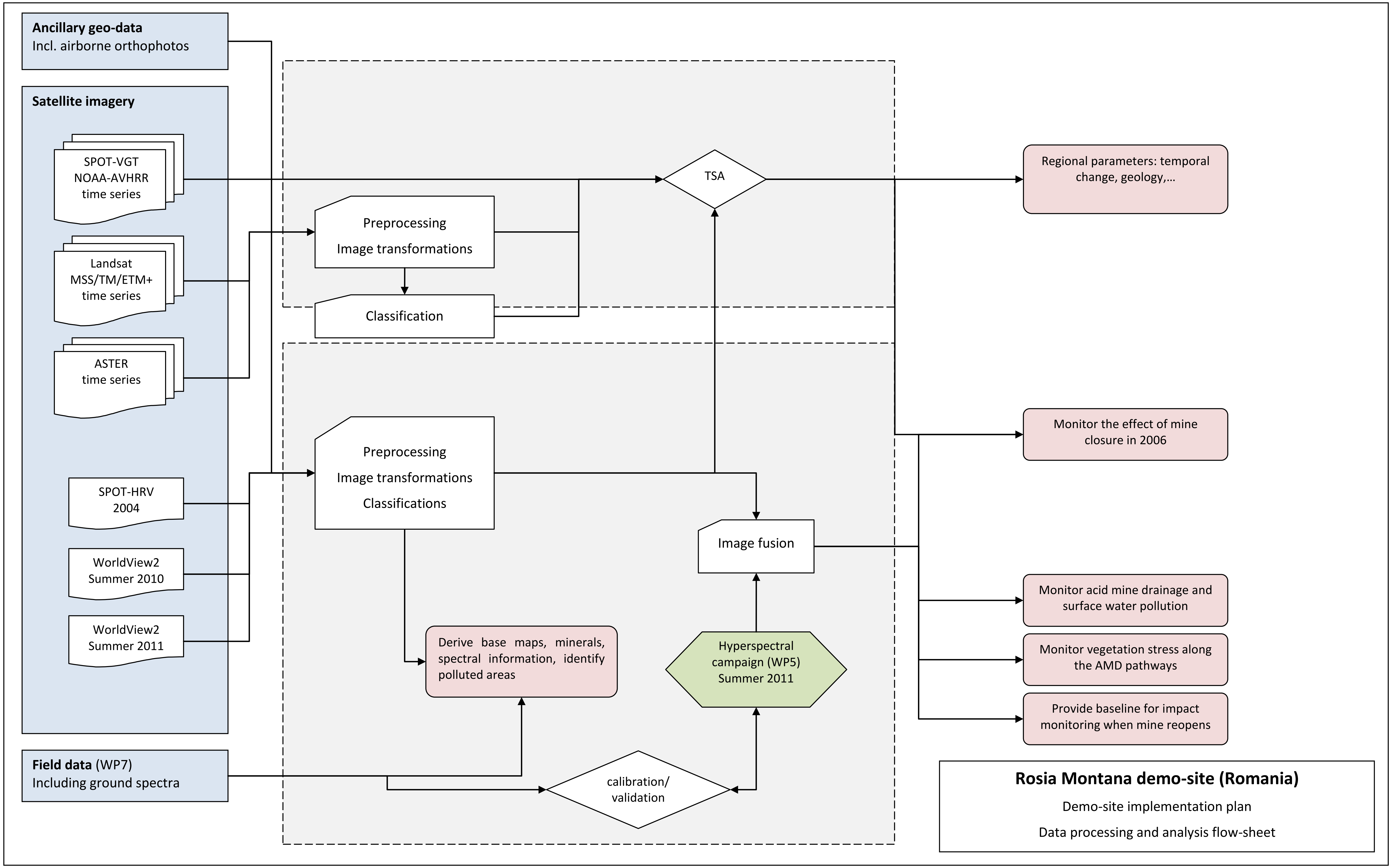


Figure 3-19 Data processing and analysis flow-sheet for the Rosia Montana demo-site (Romania)

3.2.5 Discussion and recommendations

The preparatory work for demo-site implementation at the Rosia Montana demo-site shows that there are large opportunities for demonstrating the use of satellite imagery for environmental monitoring and development of new techniques in the frame of the ImpactMin project. One of the opportunities for the Rosia Montana demo-site is the combination of hyperspectral data (see also D5.3). Different image fusion techniques can be tested, both integrating satellite imagery from different sensors, and hyperspectral images with satellite images. Also, there will be a large number of ground measurements available for calibration/validation of different analysis techniques. Furthermore, mining in the Rosia Montana area has been taking place almost uninterruptedly since Roman times. The open-pit mine has been active between 1970 and 2006. There has not been any serious attempts for rehabilitation, leaving the landscape scarred deeply, and uncontrolled pollution of streams and soils due to release of acid mine drainage from the waste dumps and the mine itself continues to take place. It will therefore be interesting to monitor both the temporal and the spatial variation of acid mine drainage. Vegetation stress due to AMD was never studied before in this area. AMD shows very distinct pathways through small mountain rivers, and ImpactMin will experiment the possibility to monitor vegetation stress along the riverbanks. Detailed ground measurements (both ground spectra and vegetation analysis, see D5.3) will be very important. The use of time series will allow for analyzing the possible effect of mine closure in 2006. Additionally, the study will allow for creating a baseline for future environmental impact studies, since the mine might be reopened in the (near) future.

3.3 *Karabash and Mednogorsk, Russia*

3.3.1 Site overview and environmental impacts

a. Karabash

The Karabash demo-site is situated within the Chelyabinsk District in the northern part of the South Ural Mountains, which has been a centre for mining and precious and base metals production for well over 3000 years. The town of Karabash lies at an altitude of ca. 200 m above sea level within a SW-NE trending flat-bottomed valley surrounded by hills with an altitude up to 610 m (Figure 3-20), has a moderate continental climate, and is situated on the border between taiga and forest-steppe. The area is extensively forested apart from small agricultural plots and the conspicuously de-vegetated western slopes of the nearby Karabash Mountain facing the smelter (Spiro et al., 2004). The geology is dominated by relatively mafic metamorphic rocks of low buffering capacity. Soil cover is generally thin and sporadic and mainly consists of Luvisols (Udachin et al., 2003). See **Appendix 3.1a** for complete input on the first general demo-site questionnaire.

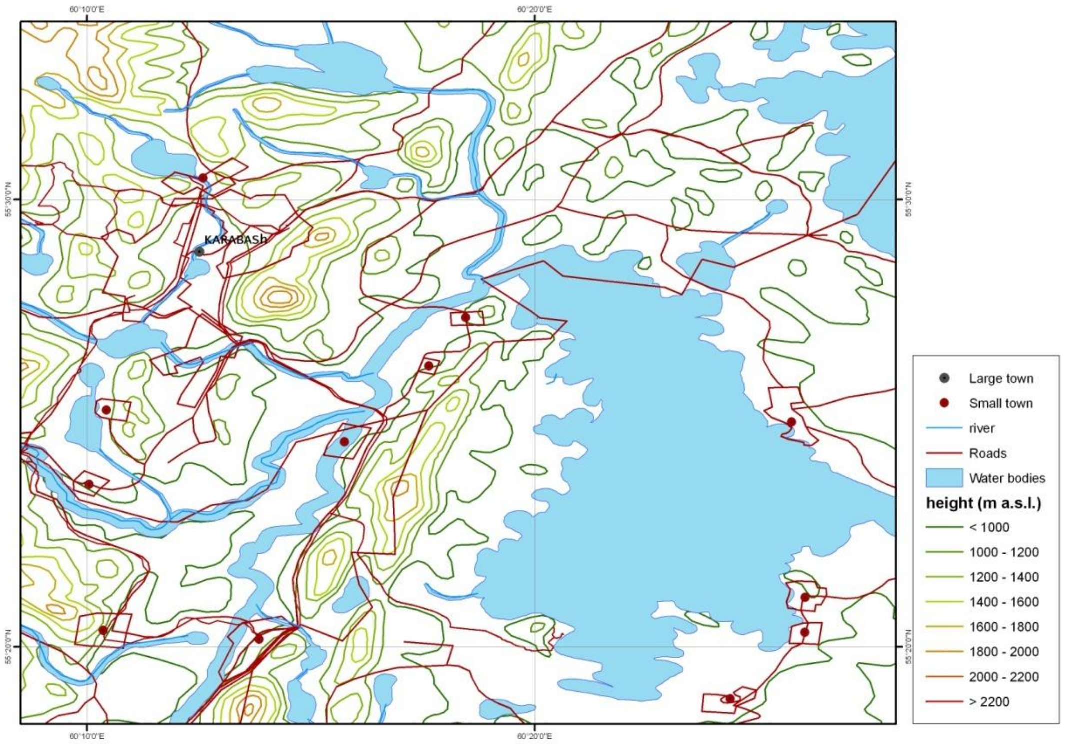


Figure 3-20 Base map of the Karabash mining area and surroundings

Karabash has a population of around 16,000, which is much less than the 50,000 in the 1960s when mining, ore beneficiation and smelting operations were at their peak (Brooks et al., 2005). The region has been a centre for mining and metal production for well over 3000 years, and these activities were greatly intensified in the early to mid-20th century (Udachin et al., 2003). In 1910, a copper smelter was built close to the centre of the town, which specializes in the production of 'blister copper'. Since the opening, the smelter has produced around 30 million tons of metallurgical slags and other wastes. In 1934, a beneficiation mill was built in the eastern part of the town. This produced copper concentrates and from 1954 also zinc and pyrite concentrates. With the closure of the last mine in 1991 also the mill was closed. The smelter began to process concentrates produced in the mining and beneficiation mill towns of Uchaly, Gay and Sibay (Udachin et al., 1998). The smelter is now reported to only take ores from Uchaly, and about 30% of the smelter's operations are now believed to be of a secondary nature, including the recycling of Pb batteries (Udachin et al., 2003). Around 1500 workers are currently employed in the smelter. Since its opening, the smelter and beneficiation plant have produced around 30 million tons of metallurgical slags and flotation wastes (Udachin et al., 1998).

Recently, the Russian Copper Company has modernized the smelter in Karabash (Yokogawa, 2008). In 2006, a new smelter was put into operation. The new smelting system processes approximately 460,000 tons per year of concentrates. Ausmet Ltd claims the smelter is now one of the most modern plants of its type in Russia and the complex is among the most up-to-date and environmentally safe copper smelters globally (AZoM News, 2007). The new Karabash smelter has won two prestigious awards from the Russian government for environmental and ecological excellence (Yokogawa, 2008).

However, environmental impact of (historical) mining in Karabash is extremely severe (Figure 3-21). The Karabash mining area contains a number of abandoned mines, waste piles from a – now closed – beneficiation mill and an active smelter. The ore processing and smelting operations have had a major impact on the local environment, especially on rivers and woodlands. Karabash was described in 1992 by the United Nations Environment Programme (UNEP) as one of the most polluted towns in the world. Nestersnko (2006) characterized the area as an ‘ecological disaster zone’, based on chemical analysis of soil samples in the area. Karabash and the surrounding areas are affected by gaseous and particulate emissions from the smelter, SO_2 emissions, fall-out of bioavailable metal-rich smelter particulates, acid drainage from old mine workings, effluents from the smelter and leachates and dusts from waste dumps, and contaminated stream sediments (Udachin et al., 2003). Massive pyrite tailings continuously fill up the Sak-Elga river valley over a length of more than 10 km and several hundred meters wide between the mine site and a freshwater reservoir. Untreated domestic wastewater is spilled into the same river. The reservoir is the main freshwater source for the city of Jekaterinenburg (1.5 million inhabitants). Several ponds and basins are filled with upwelling acid water from underground shafts. Highly acid and toxic mine waters are continuously released into the environment. The surroundings of Karabash are stripped of vegetation, probably due to the combination of logging and acid emissions and rains, resulting in massive erosion.

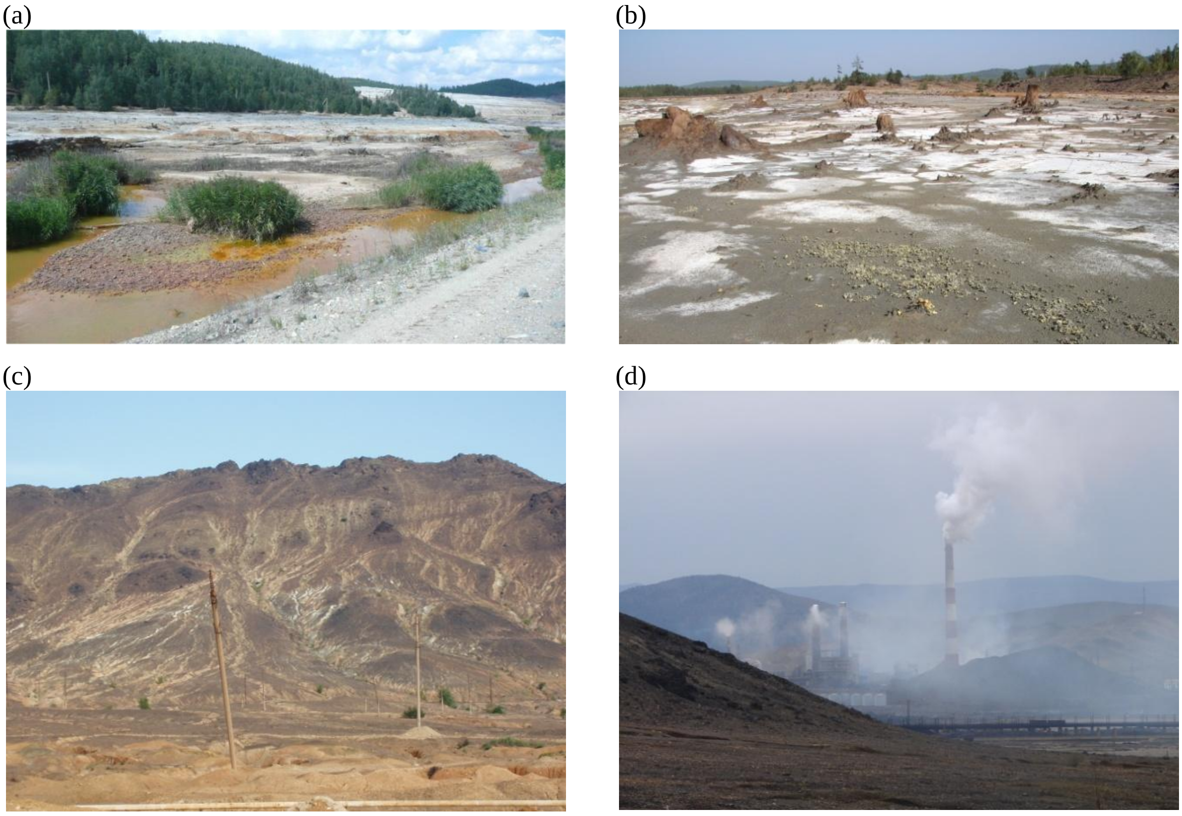


Figure 3-21 Pictures of the Karabash demo-site and surroundings: (a) mine tailings and acid drainage, (b) weathering of mine tailings in Sak-Elga river valley, (c) de-vegetated hills around Karabash subjected to erosional processes, and (d) gaseous and particulate emissions from the Karabash smelter

Several studies have looked into the effects of atmospheric pollution in Karabash. The former copper smelter of Karabash was the dominant visible source of anthropogenic airborne particulates in this area, with additional potential contributions from tailings, waste dumps, roads, and domestic burning of coal and wood (Spiro et al., 2004). The smelter was not large by international standards, but for long had no controls on gaseous or particulate emissions (Voskresensky, 2002). There are no recent or reliable data in the public domain concerning the levels of emissions from the former smelter (Williamson et al., in press), nor was evidence reported of the (positive) effects on the environmental conditions in the region of the new smelter put in operation in 2006. However, before the political changes in 1991, official SO_2 emissions estimates were in the order of 90,000 to 150,000 tons per year (Udachin et al., 1998). The close proximity of townspeople to these sources of pollution is of most immediate environmental concern (Brooks et al., 2005). The people living in the town show high rates of congenital defects, central nervous system disorders, cancer and other diseases (La Franiere, 1999). Two-thirds of the children suffer from lead, arsenic or cadmium poisoning (La Franiere, 1999) and many suffer from asthma and respiratory diseases (Ferriera-Marques, 2003). Vegetation is almost absent from the hills immediately downwind of the smelter and in the Sak-Elga River floodplain to the south of the town, where 9.2 million tons of heavy metal-rich tailings were deposited (Brooks et al., 2005). Many trees in the town have yellow leaves even in early July and show premature autumn colors (Brooks et al., 2005; Purvis et al., 2003), see also Figure 3-23. The former smelter's emissions were so hazardous that the Government shut it down in October 1991. Economic necessities caused the plant to be reopened in March 1997.

Contamination of surface and ground waters is caused by acid rock drainage from underground mines, from leachates from waste dumps and tailings and possibly from effluents from the smelter (Williamson et al., in press). To the south of Karabash are the Stalinskaya and Yuzhnaya mines which were abandoned in 1955 and 1968, respectively. There is currently no surface flow from the Yuzhnaya mine but the Stalinskaya mine discharges highly acidic waters (Figure 3-22). The Tsentralnaya underground mine in the northern part of Karabash was closed in 1991, at a final depth of 906 m. Acid mine waters were discharged from the mine until 1995 when the flow naturally ceased. The discharges produced extensive deposits of iron-rich ochres in the streams which run northeast from the mine and large amounts of metal-rich sediments in the dammed Ol'hov pond (Figure 3-22).

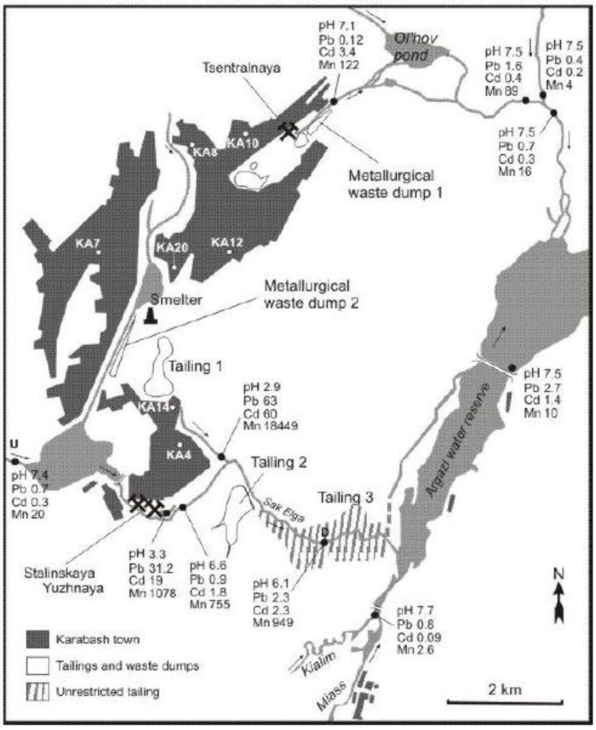


Figure 3-22 Map of Karabash showing the distribution of town buildings around the smelter, the location of abandoned mines, tailings and waste dumps, and the pH, Pb, Cd and Mn concentration of surface waters (µg/L), sampled in August 2002 (Williamson et al., in press)

MinUrals was a European Union INCO-Copernicus2 project, which encompassed a geological programme and environmental studies. An integrated multidisciplinary approach aimed at encouraging sustainable development of mining activities in the South Urals. The Karabash town was one of the three focus sites of the MinUrals project. The dominant sources of contamination were identified: (i) gaseous and particulate emissions from the smelter, (ii) wind-blown particulates from waste dumps and ore stockpiles, and (iii) effluents from the smelter and leachates from waste dumps. Williamson et al. (2004b) characterized airborne total suspended particulates (TSP), dust from smelter blast furnace and converter stacks, and filtrates of snow melt waters around the town of Karabash. TSP was collected at sites up-and downwind of the smelter and large waste and tailings dumps in October 2000 and July 2001. TSP in downwind samples has a mean equivalent spherical diameter of 0.5 µm and was found to be 100% respirable. In addition to being respirable, the particulate matter collected in downwind samples contained high levels of Pb, which was measured at 16 – 30 $\mu g\ m^{-3}$ in downwind samples (Russian maximum permitted level is 1 $\mu g\ m^{-3}$). Individual particulates mainly consisted of complex mixtures of anglesite ($PbSO_4$), Zn_2SnO_4 and poorly ordered Zn sulphates. A high proportion of contained Pb, Zn, Cd and As in this material is considered to be in a readily bioavailable form.

Brooks et al. (2005) assessed the environmental impact of the smelter on lakes in the area using chironomids. Chironomid midges are sensitive indicators of environmental change and can be related to sediment chemistry and heavy metal pollution (Ilyashuk et al., 2003). The results showed that changes in the chironomid fauna of most lakes were driven by trophic change, independent of the industrial activity. Lakes and ponds adjacent to the smelter and waste dumps, which directly receive contaminated waters, were however devoid of macro- and mesofauna and flora, probably as a direct result of metal contamination from the smelter and acid mine waters. Brooks et al. (2005) concluded that thanks to the local geology, the lakes are well-buffered to the effects of acid deposition which will limit the bioavailability of metals in the water column and sediment.

The apparently low impact on the lakes by acid rain or metal fallout from the smelter on lakes in the area is in contrast to the effect on terrestrial lichens, which have been heavily impacted for many kilometers downwind of the smelter (Purvis et al., 2003; Spiro et al., 2004; Williamson et al., 2004a). Purvis et al. (2003) investigated biogeochemical signatures in transplanted and native lichens near the Karabash smelter (Figure 3-23). Statistically significant trends in element concentrations were recorded. Fine metal particles are accumulated from pollution aerosols. Williamson et al. (2004a) assessed particulate matter on transplanted lichens stationed in the Karabash town and in a control site 30 km south. Particulate matter in the Karabash samples showed higher levels of S, Pb, Cu, Sn and Zn compared with the control samples. The lichen thallus surface of the Karabash sample revealed high levels of Cu, Zn, Fe and Pb, and a proportionate loss of K, interpreted as being due to a stress-related increase in cell membrane permeability. However, on both sample groups, mining-related particles were identified, indicating a wide spatial dispersion from the smelter.

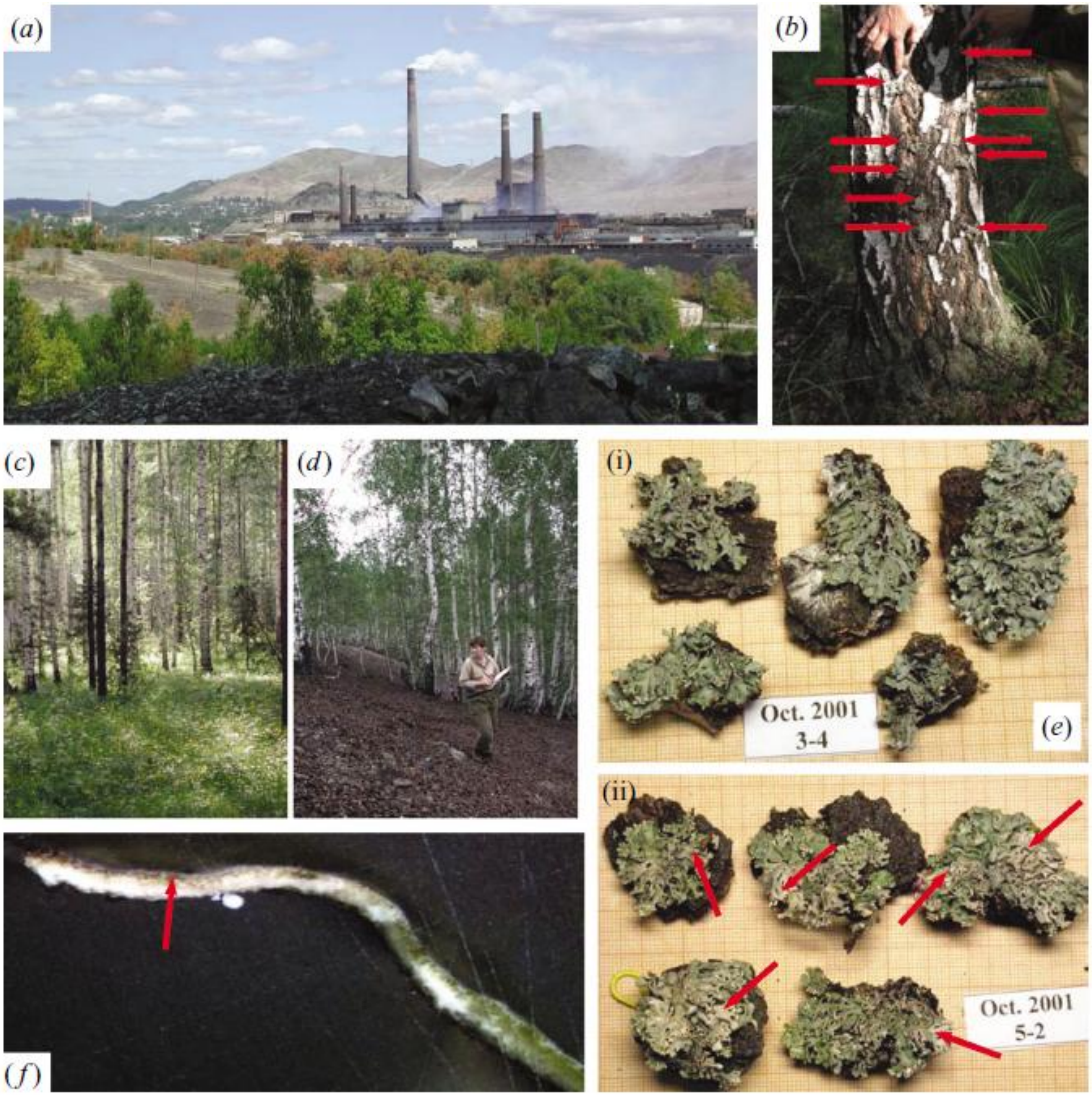


Figure 3-23 (a) View towards de-vegetated Karabash mountain with the smelter in the foreground showing premature autumn colors, 4 July 2001; (b) ten Hypogymnia lichen transplants attached to tree base at 'intermediate' impact site; (c) transplant site 30 km from Karabash with well-developed herbaceous layer; (d) 'impact zone', 2 km from Karabash where herbaceous vegetation is absent and leaf litter persists; (e) *Hypogymnia* transplants collected after three months' exposure from (i) 'background' site and (ii) 'impact zone' with highlight of damaged (bleached) areas; (f) resin-embedded section showing phaeophytinization (Purvis et al., 2003)

b. Mednogorsk

The **Mednogorsk** demo-site, the second ImpactMin demo-site in the Orenburg region in Russia, is located on the western slope of the South Ural Mountains. The topography of the area is complex and the climate is a strong continental climate. See **Appendix 3.1b** for complete input on the first general demo-site questionnaire.

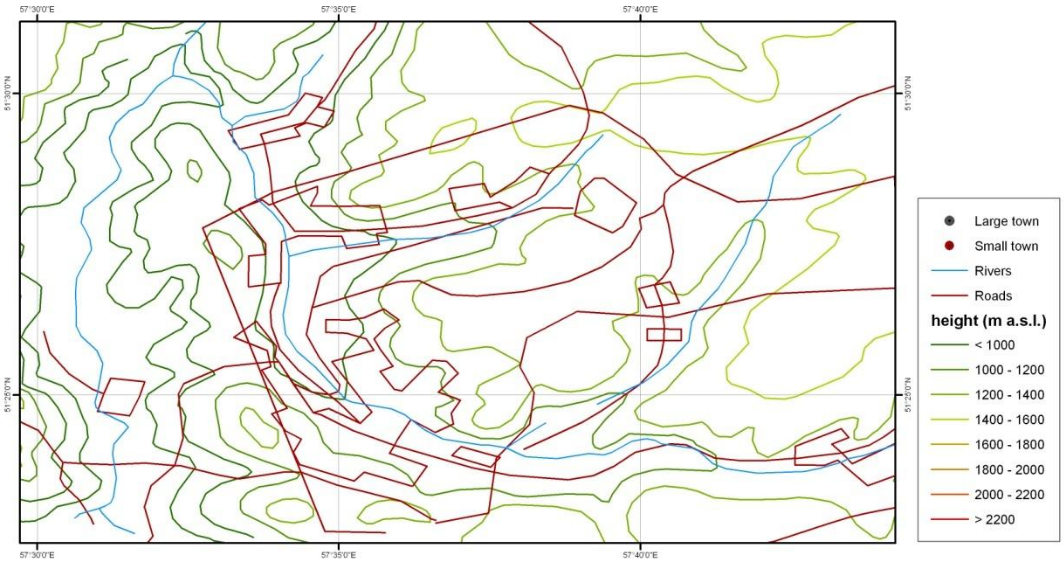


Figure 3-24 Base map of the Mednogorsk mining area and surroundings

(a)

(b)

(c)

(d)

Figure 3-25 Pictures of the Mednogorsk demo-site and surroundings: (a) Blyava open pit mine, (b)

The main sources of contamination in the Mednogorsk demo-site area are the Blyava and Yaman-Kasy open pit mines (now pit lakes), the beneficiation mill and the copper smelter, both located close to the center of the town of Mednogorsk. The Blyava VMS deposit was exploited via open pit and underground workings from the 1930s onwards, with the main period of activity between 1936 and 1972. The Yaman-Kasy VMS Cu-Zn deposit was operated between 1987 and 2002. The 'Mednogorsk copper-sulphur plant' has operated since 1937. Initially, the plant produced low quality sulphur, but after the second World War, the plant began to produce Cu concentrate (12-17%) which was transported for refinement to the Karabash smelter (Chelyabinsk district) and the Kirovgrad smelter (Sverdlovsk district). Between 1959 and 1962, following the construction of converters, the plant began to produce non-refined copper. In 1960, the plant started processing ores from the Gay deposit and from 1961 sulfuric acid (H_2SO_4) was produced. The plant is still operational and emits 68,000 ton/year of gases and dust.

The main environmental concerns of the mining operations at the Mednogorsk demo-site, and focus areas for the upcoming work in the ImpactMin project, are:

- gas and dust emissions into the atmosphere and the effects on public health (including seasonal variations),
- runoff and penetration into the ground and surface water system of acid mine waters (pH 3.4 - 5) with high concentration of metals (Cu, Zn, Al) draining from waste deposits. The acidic waters of the Zhiriclya river are being treated since 2006.
- heavy metals in soils, bioavailability and health risks, vegetation stress

3.3.2 Data availability

The IMIN provided various geospatial data sources at scale 1:200,000 for Karabash and Mednogorsk (some of them displayed in Figure 3-22 and Figure 3-24), listed below:

- Topography (‘Relif’, Shapefile)
- Roads (‘Dorogi’, Shapefile) and Routes (‘Trackname’, Shapefile)
- Administrative boundaries (‘Granica’, Shapefile)
- River (‘River’, Shapefile) and Water protective zones (‘Water’, Shapefile)
- Towns (‘Town_big’,Shapefile) and settlements (‘Town’, Shapefile)
- Nature monuments (Shapefile)
- Archaeological monuments (‘Posel_arch’, Shapefile)

Topographic maps at scale 1:100,000 might become available later on.

Metadata are available in **Appendix 3.2a** and **Appendix 3.3a** (for Karabash and Mednogorsk, respectively). No satellite data were available before the start of the ImpactMin project.

3.3.3 Data collection

a. Satellite imagery

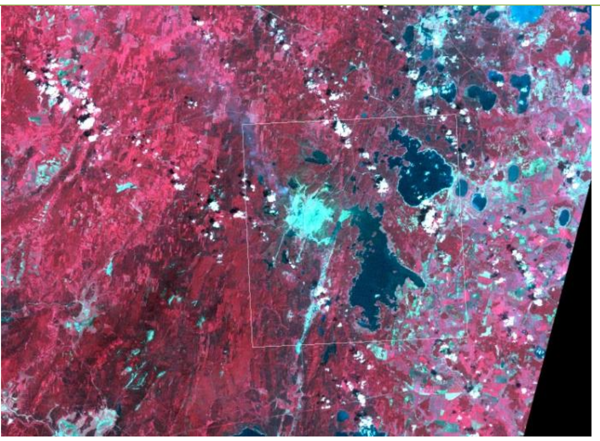
In the framework of the ImpactMin project, several types of satellite imagery were and will be collected and acquired.

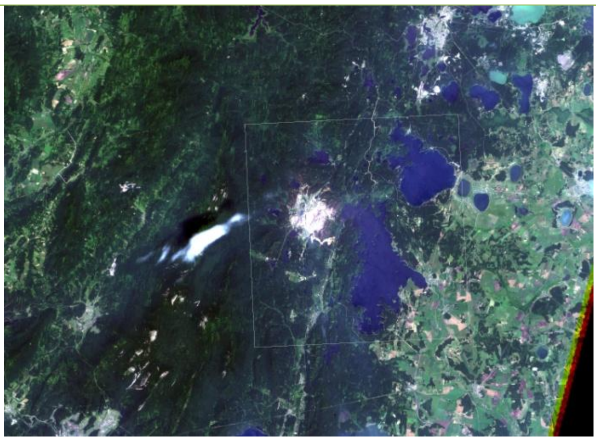
Long time series of low resolution imagery is available. First, the Global Inventory Monitoring and Modelling System (GIMMS) monthly NDVI time series derived from NOAA-AVHRR (Tucker et al., 2005) is available from July/1981 till December/2006 at 8 km spatial resolution. Secondly, various 10-daily products derived from the SPOT-Vegetation sensor are available from at 1 km resolution (Maisongrande et al., 2004): NDVI, fraction of Absorbed Photosynthetically Active Radiation (fAPAR) and dry matter productivity (DMP). Multi-temporal analysis of NOAA-AVHRR or SPOT-Vegetation products can be used to monitor vegetation dynamics.

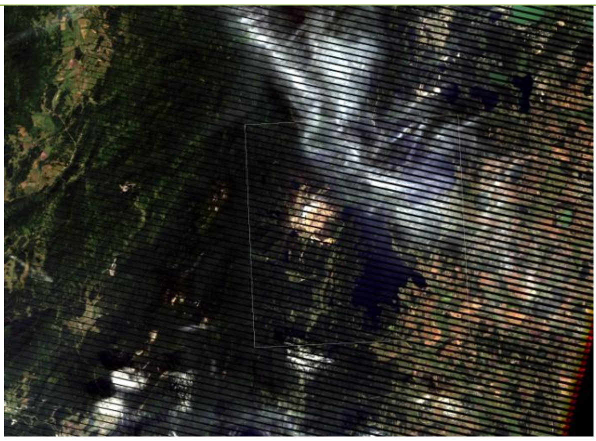
WorldView-2 imagery will be ordered during the Summer of 2011, ideally in July, which is the driest month in the Urals. In 2010, no WorldView-2 image was acquired due to cloud cover. WorldView-2 was only recently launched (October/2009) and is the first satellite that offers 8 spectral bands at high spatial resolution (46 cm). For more details, see D4.1.

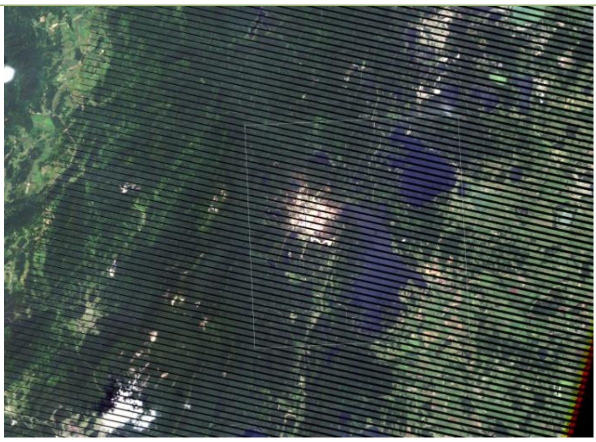
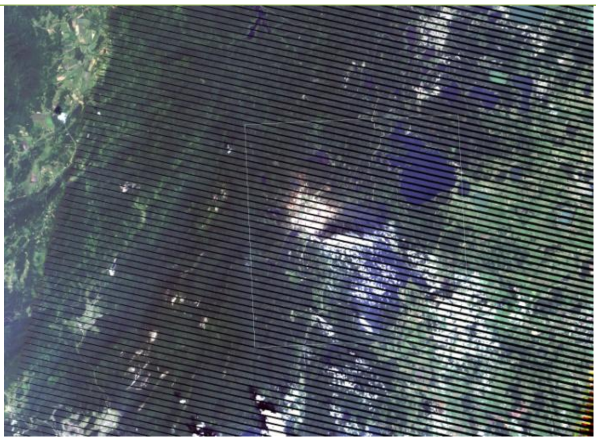
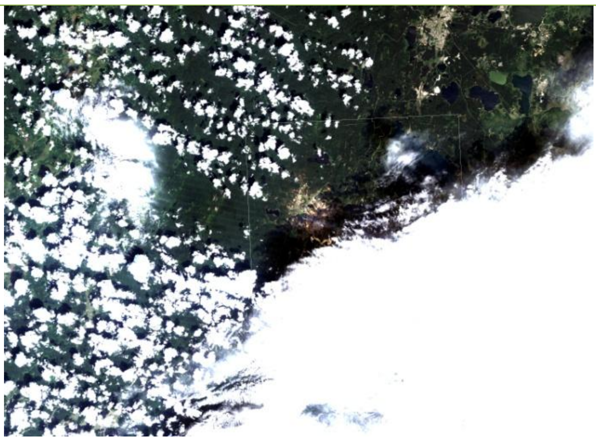
For Karabash, a complete time series of Landsat images could be retrieved from the Landsat image archive (Table 3-15). From July/1983 till August/2010, 16 Landsat images of reasonable quality and cloud cover are available. The years covered are: ’83, ’87, ’89, ’90, ’91, ’00, ’01, ’03, ’04, ’06, ’08, ’09 and ‘10. In some years up to 3 good images were acquired. There is a large gap between the 1991 image and the 2000 images. All images are acquired in late spring or summer (May – August). Note that all Landsat 7 scenes acquired since July 14, 2003 have been collected in ‘SLC-off’ mode. Without an operating Scan Line Corrector, the line of sight now traces a zig-zag pattern along the satellite ground track. As a result, imaged area is duplicated, with width that increases toward the scene edge.

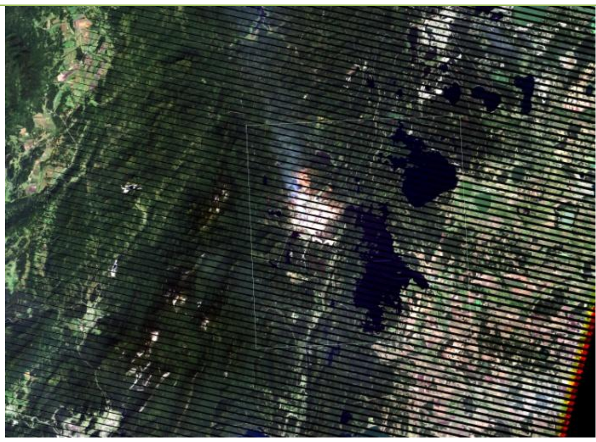
Table 3-15 Time series of Landsat imagery available for the Karabash mining area

Sensor	Date	Quicklook
Landsat 4	04/07/1983	
Landsat 5	20/05/1987	
Landsat 4	18/06/1989	

Sensor	Date	Quicklook
Landsat 5	28/07/1989	
Landsat 4	08/08/1990	
Landsat 5	02/07/1991	
Landsat 7	18/07/2000	

Sensor	Date	Quicklook
Landsat 7	11/05/2001	
Landsat 7	19/06/2001	
Landsat 7	19/07/2001	
Landsat 7	12/08/2003	

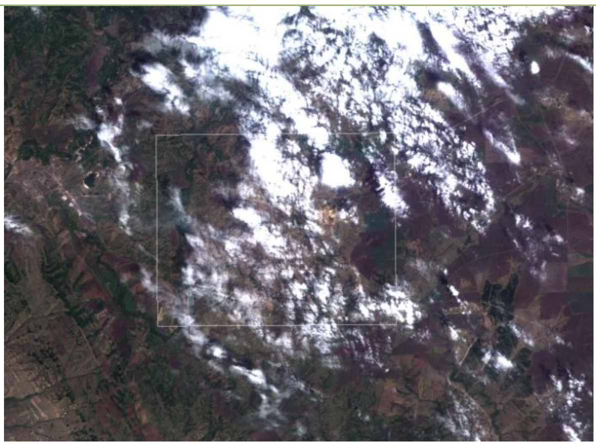
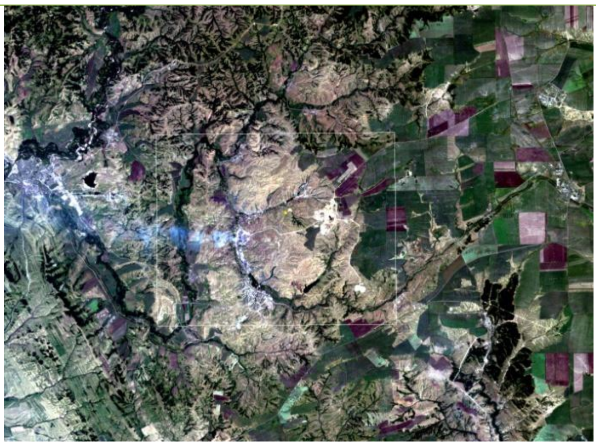
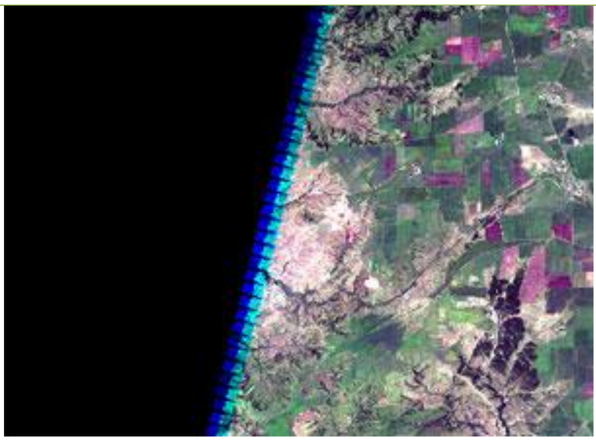
Sensor	Date	Quicklook
Landsat 7	06/07/2004	
Landsat 7	19/07/2006	
Landsat 7	24/07/2008	
Landsat 5	19/07/2009	

Sensor	Date	Quicklook
Landsat 7	30/08/2010	

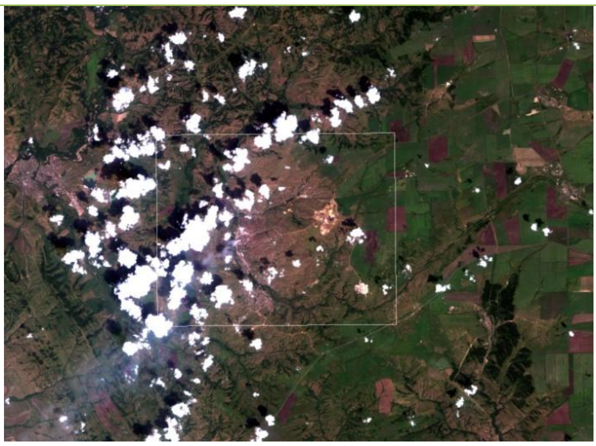
Also for Mednogorsk, a complete time series of Landsat images could be retrieved from the Landsat image archive (Table 3-16). From July/1984 till September/2009, 16 Landsat images of reasonable quality and cloud cover are available. The years covered are: ’84, ’86, ’88, ’89, ‘99, ’00, ’01, ’02, ’05, ’06, ’07 and ’09. In some years up to 4 good images were acquired. There is a large gap between the 1989 image and the 1999 images. All images are acquired in late spring or summer (May – September). Note that all Landsat 7 scenes acquired since July 14, 2003 have been collected in ‘SLC-off’ mode. Without an operating Scan Line Corrector, the line of sight now traces a zig-zag pattern along the satellite ground track. As a result, imaged area is duplicated, with width that increases toward the scene edge.

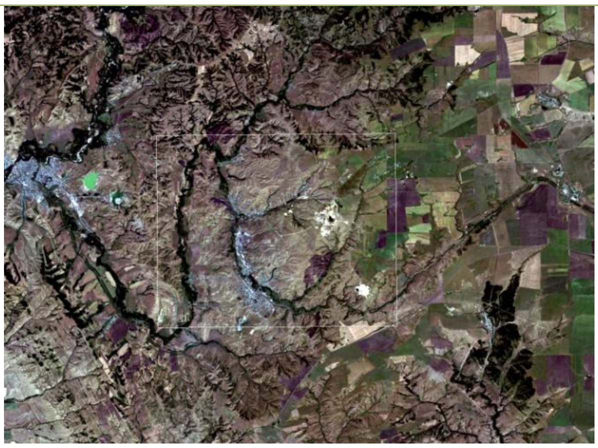
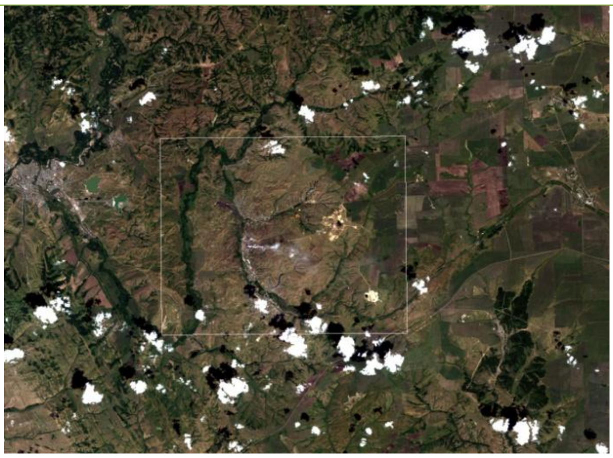
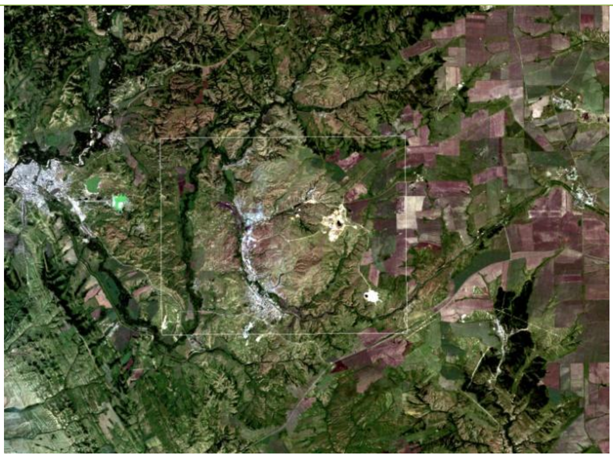
Table 3-16 Time series of Landsat imagery available for the Mednogorsk mining area (true color composite quicklooks)

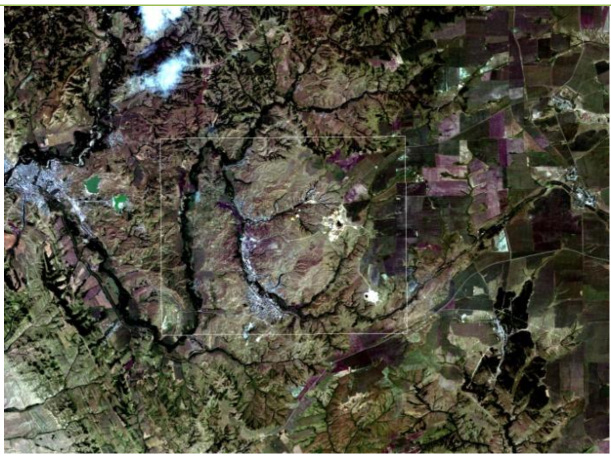
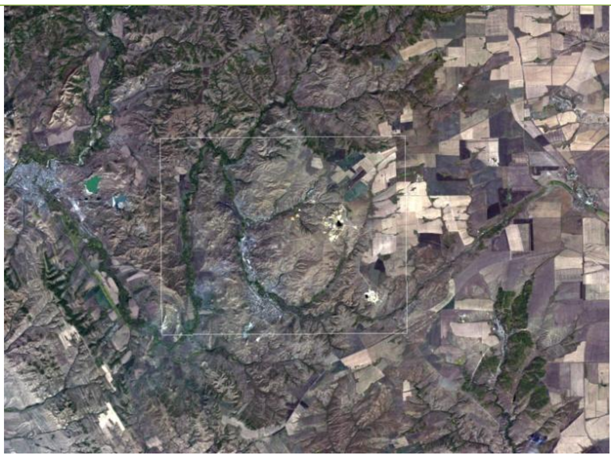
Sensor	Date	Quicklook
Landsat 5	30/07/1984	

Sensor	Date	Quicklook
Landsat 5	02/06/1986	
Landsat 4	01/07/1988	
Landsat 5	28/07/1989	
Landsat 7	09/07/1999	

Sensor	Date	Quicklook
Landsat 7	17/08/1999	
Landsat 7	27/07/2000	
Landsat 7	23/09/2001	

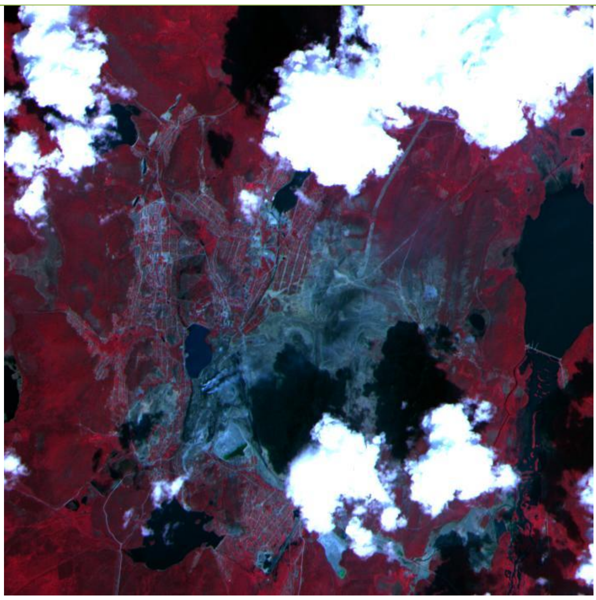
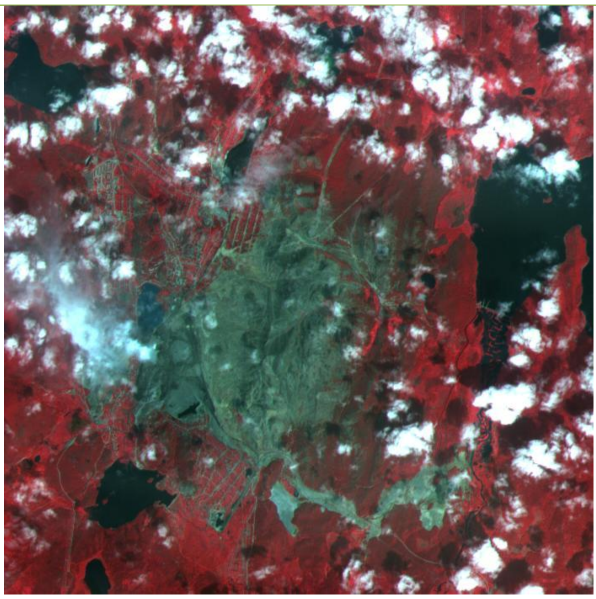
Sensor	Date	Quicklook
Landsat 7	08/07/2002	
Landsat 7	17/08/2005	
Landsat 7	01/06/2006	

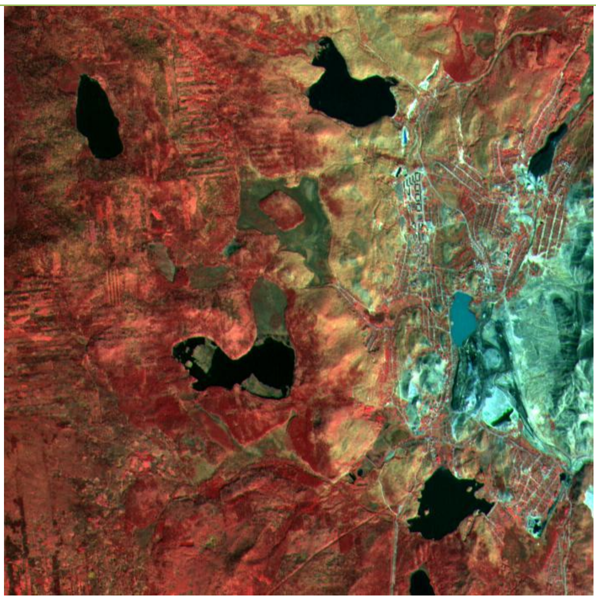
Sensor	Date	Quicklook
Landsat 5	15/08/2007	
Landsat 5	17/06/2009	
Landsat 5	03/07/2009	

Sensor	Date	Quicklook
Landsat 5	19/07/2009	
Landsat 5	21/09/2009	

Also a time series of ASTER images were collected for the Karabash mining area, although these images must be purchased (Table 3-17). A series of 3 ASTER images was identified, although the quality of the images is not optimal. The years covered are:'02 and '05. The Karabash area clearly illustrates the weak side of the ASTER programme. Over the last 10 years of the existence of the programme, only about 10 images that partly cover the area of interest have been collected. None of these images provides cloud-free coverage of the area of interest. ImpactMin purchased three scenes that could be of some interest to the project. One scene (25/09/2005) has no clouds, but covers only the western half of the area. The two other scenes (15/06/2002 and 18/08/2002) cover the entire area, but are quite clouded. A new data acquisition is planned for early summer 2011. However, new data acquisitions do not include the SWIR bands due to the fact that the SWIR sensor is faulty and has been turned off. In order to be able to study the usefulness of the Thermal Infrared to monitor air-pollution, ImpactMin also plans to acquire a night-time Thermal image from the same period.

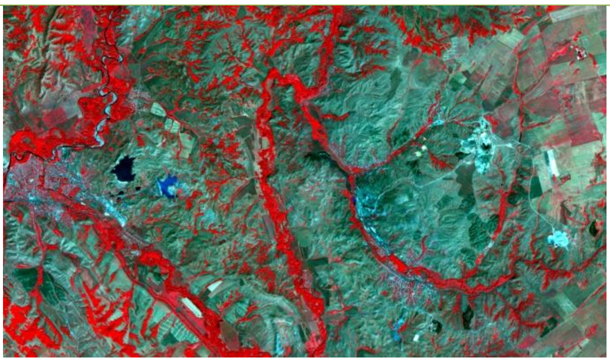
Table 3-17 Time series of ASTER imagery available for the Karabash mining area

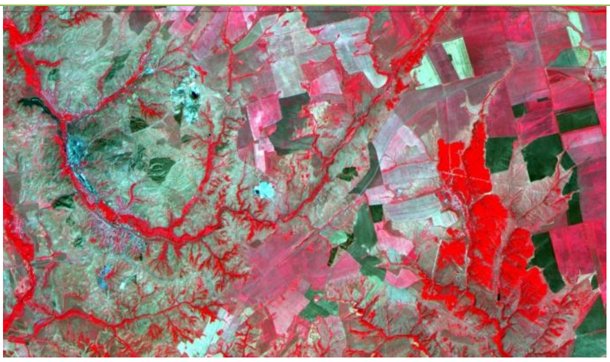
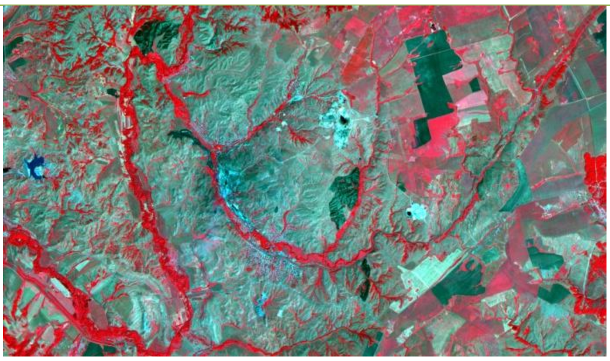
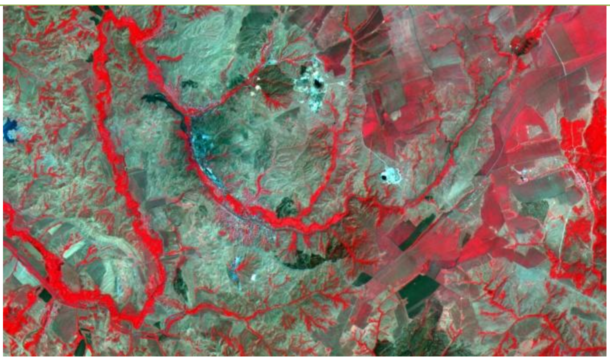
Sensor	Date	Quicklook
ASTER	15/06/2002	
ASTER	18/08/2002	

Sensor	Date	Quicklook
ASTER	25/09/2005	

Also for the Mednogorsk mining area a time series of ASTER images was collected, although these images must be purchased (Table 3-18). A series of 6 ASTER images was identified. The years covered are: ’01, ’02, ’05, ’07, ’08 and ’10. The SWIR bands of the ASTER sensor are a great benefit, allowing the identification of individual minerals, gradual changes and acid mine drainage. Unfortunately, since April 2008 there are no good observations in the SWIR range, because the detector saturates (ASTER Science Office, 2009). A new ASTER scene will be ordered to be acquired in the summer of 2011.

Table 3-18 Time series of ASTER imagery available for the Mednogorsk mining area (false color composite quicklooks)

Sensor	Date	Quicklook
ASTER	22/08/2001	
ASTER	9/08/2002	

Sensor	Date	Quicklook
ASTER	10/08/2005	
ASTER	14/08/2007	
ASTER	18/08/2008	
ASTER	6/08/2010	

No Hyperion, ALI or CHRIS/PROBA imagery is available for the area.

b. Ancillary information

ASTER DEMs are available for the Karabash and Mednogorsk areas (Figure). If good quality topographic maps become available, these can be used for digital elevation model generation.

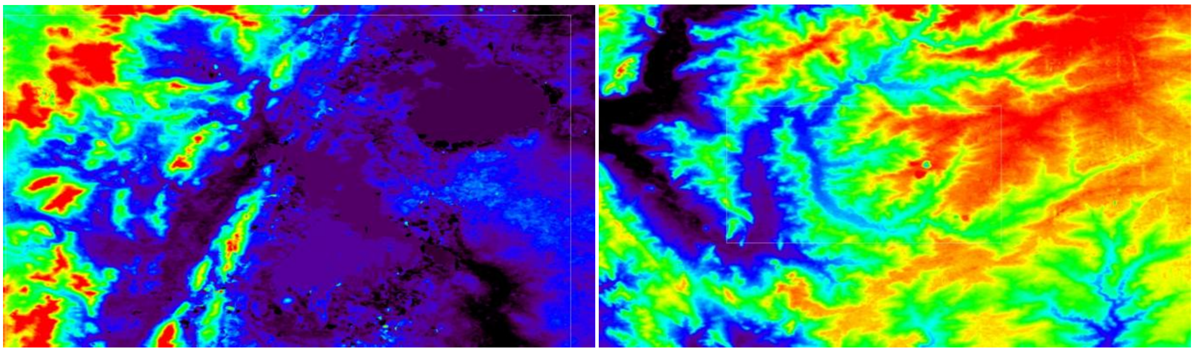


Figure 3-26 Quicklooks of the ASTER DEMs for Karabash (left) and Mednogorsk (right)

A large number of ground samples were analyzed by IMIN in the past years. IMIN has carried out extensive sampling programs for monitoring air-quality, groundwater quality, surface soil and vegetation, lake water quality and sediments. Currently, IMIN is working on assembling the database with sample locations and analytical results. The database will be available for the project before the summer of 2011. Figure 3-27 shows an overview of the sampling program.

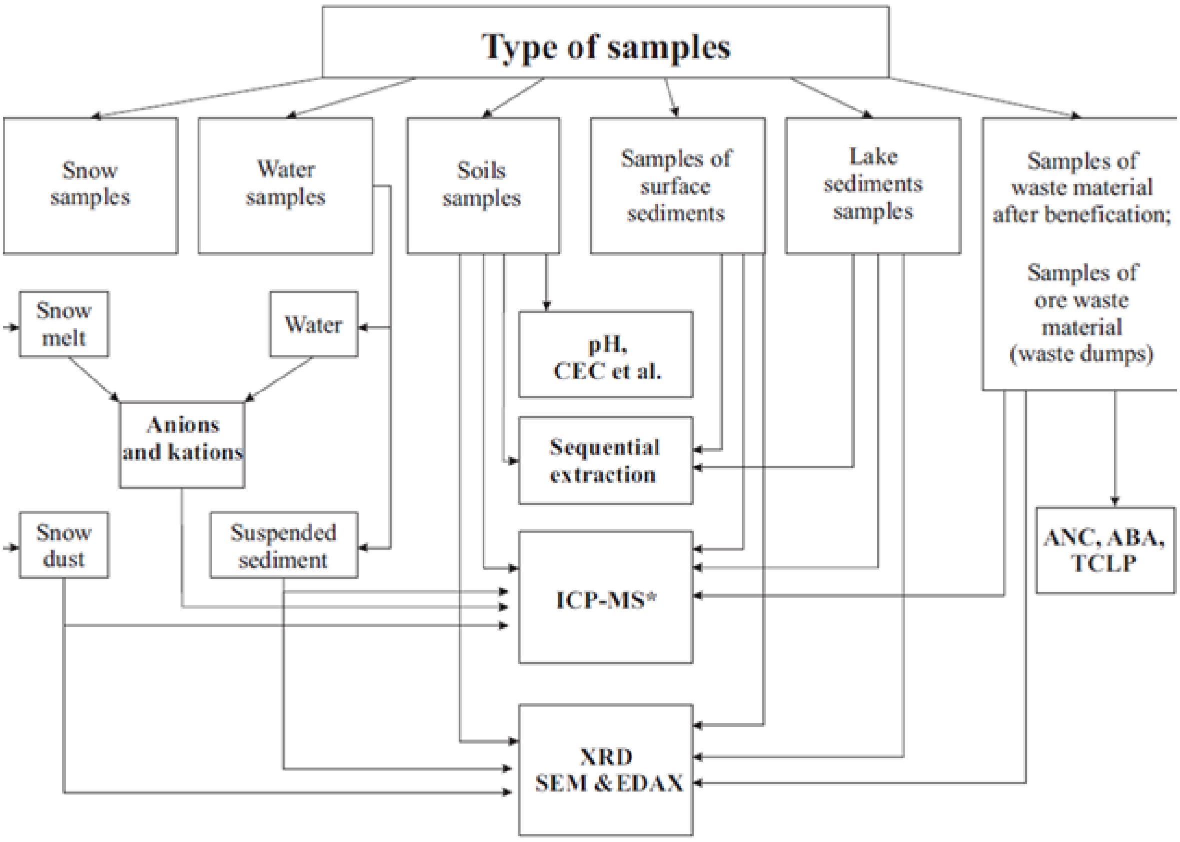


Figure 3-27 Ground sampling programs by IMIN

3.3.4 Data processing, analysis flow-sheet and products

a. Objectives

For the Karabash and Mednogorsk demo-sites, satellite imagery is our prime resource for earth observation data, primarily because the current logistic conditions make it impossible to operate sophisticated airborne sensor equipment. On the one hand, the focus of data processing for environmental impact assessment at the Russian demo-site will be focused on the analysis of time series of medium and low resolution imagery. Even though medium resolution Landsat MSS/TM/ETM+ imagery and low resolution NOAA-AVHRR or SPOT-VGT products are limited in spatial and spectral resolution, the long time series, and in case of NOAA-AVHRR or SPOT-VGT the high temporal resolution, are interesting for the monitoring of temporal changes and settings of the mine. ImpactMin will experiment with time series analysis. Focus will be laid on land cover change, de-vegetation, impact from gaseous and particulate emissions, etc. The use of these images also has the advantage that a large area can be covered and the impact of the mining and smelting operations can be monitored in an area of about 50km in each direction. The objectives are therefore not only to look at temporal evolution of vegetation, but also to investigate spatial variations in temporal evolution of vegetation. On the other hand, the acquisition of high resolution WorldView-2 imagery will allow for the detailed identification of surface cover types, individual minerals or mineral groups related to acid mine drainage, and spatial gradients of acidity. Also spatial gradients of vegetation stress related with gaseous and particulate emissions will be monitored. The Worldview-2 sensor combines both a good spatial resolution and a fair spectral resolution (9 bands, including a sub-meter resolution panchromatic band, 6 VIS bands and 2 NIR bands).

b. Data processing and analysis flow-sheet

The data processing and analysis flow-sheet (Figure 3-28, p.82) shows how satellite data will be processed and analyzed in order to reach the objectives. The flow sheet contains three parts: the data input (in blue shading), the data processing (in grey shading) and the products (in red shading). The satellite imagery that is available and that will be used to investigate the demo-site is: SPOT-VGT, NOAA-AVHRR, Landsat and ASTER time series, including day- and nighttime imagery to be acquired in 2011, and a WorldView-2 image to be acquired in 2011. The data processing part contains 3 components, each leading to one or more products.

The first component deals with time series analysis of low and medium resolution imagery. The objective is to monitor temporal change of vegetation and spatial variations of this temporal evolution. For the preprocessing of the Landsat and ASTER time series respectively, it will be important to have very good spatial and spectral consistency between the images.

In the second part, thermal infrared bands will be used to monitor air pollution. In 2011, a request for ASTER day- and nighttime image acquisition will be carried out in order to test the potential of ASTER TIR bands.

The third component deals with high spatial resolution imagery. High spatial resolution satellite imagery will be used to derive detailed base maps, to identify polluted areas (minerals), to monitor the spatial extent and spatial variation of minerals or mineral groups and acid mine drainage (iron oxides), and to monitor spatial gradients of vegetation stress. An important topic will be the fusion of spatial/spectral data from different sources. Data fusion is a method that employs a combination of multi-source data with different characteristics such as spatial, spectral and radiometric resolution, to acquire a high-quality image (Vaseashta et al., 2007). The integration of spectrally and spatially complementary remote multi-sensor data will facilitate the interpretation of the imagery. Different techniques will be tested. Given the limited number of ASTER scenes available for this area, it seems logic to integrate the analysis of the ASTER data as much as possible with that of other imagery, such as Landsat and WorldView-2. Compared to Landsat, ImpactMin expects that it will be possible to use the ASTER to make a number of improvements and additions, that may be used in order to enhance and improve our understanding of results from lower-resolution imagery such as Landsat. Firstly, ImpactMin will obtain higher spectral resolution in the VNIR. This will allow the creation of a significantly more detailed land use map and vegetation index. ImpactMin will be able to obtain a higher resolution map for iron-oxides, which in this area is an important parameter closely associated with acid drainage. Secondly, for this area the enhanced spectral resolution in the Shortwave Infrared (SWIR) is quite important, as it allows us to map the various clay minerals and some of the sulphate minerals associated with the spill of the tailings dams.

See **Appendix 4.1** for a general description of satellite image preprocessing. See **Appendix 4.2** for a general description of satellite processing.

c. Products

The satellite image processing will lead to various products:

- Evaluation of the temporal evolution of vegetation
- Evaluation of spatial variation in temporal evolution of vegetation
- Evaluation of air pollution based on thermal infrared
- Detailed base maps, including land cover maps
- Identification of minerals or mineral groups
- Evaluation of spatial gradients of acid mine drainage
- Evaluation of spatial gradients of vegetation stress

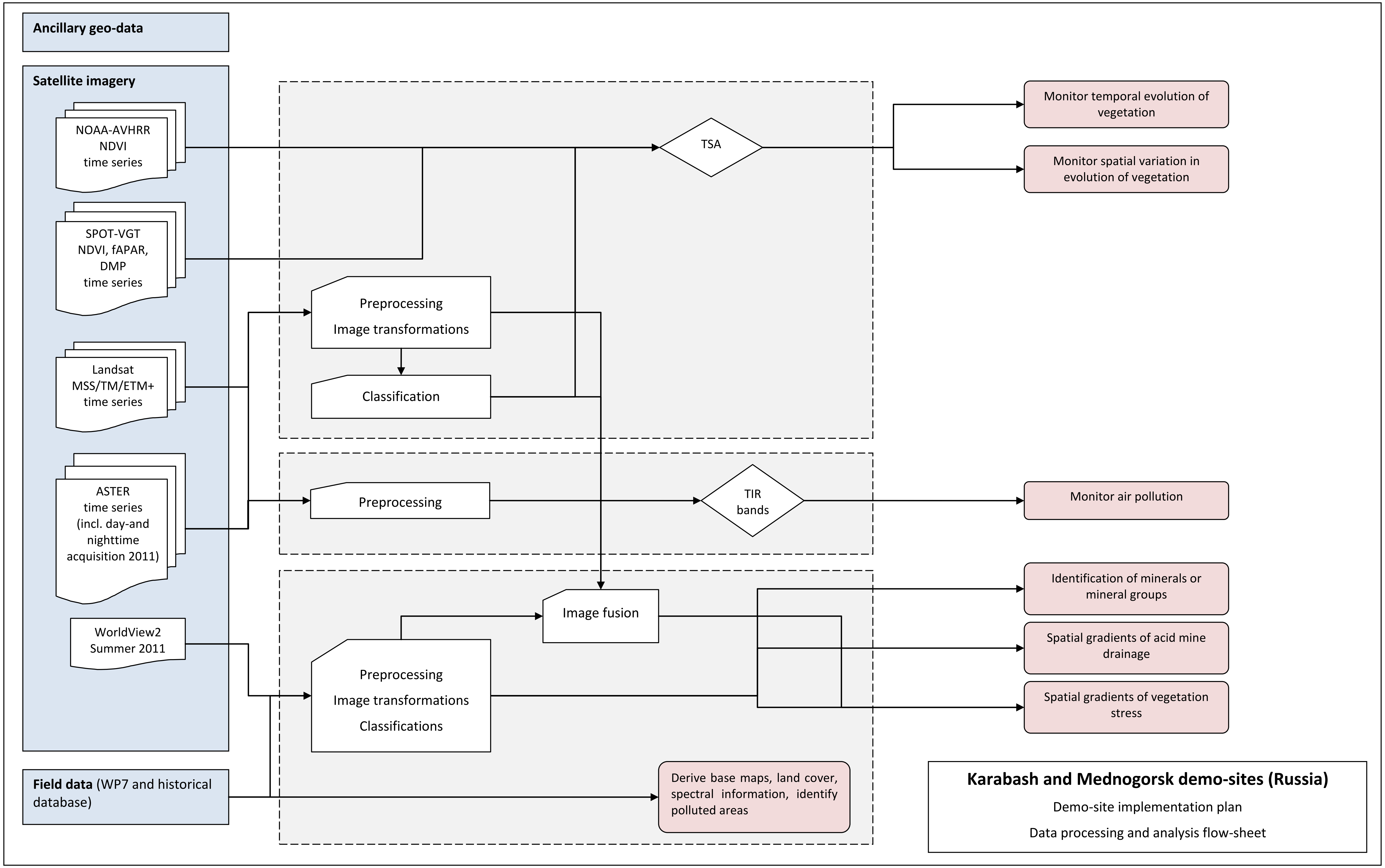


Figure 3-28 Data processing and analysis flow-sheet for the Karabash and Mednogorsk demo-sites (Russia)

3.3.5 Discussion and recommendations

The preparatory work for demo-site implementation at the Karabash and Mednogorsk demo-sites shows that there are large opportunities for demonstrating the use of satellite imagery for environmental monitoring and development of new techniques in the frame of the ImpactMin project. Firstly, environmental impacts at these demo-sites is large, both in severity as in spatial scale. Although there will be no airborne images available, the large database of ground measurements will provide opportunities for calibration/validation of image analysis techniques. It will be important to test different image fusion techniques between different satellite sensors. However, since no World-View-2 image was acquired in the summer of 2010 due to cloud cover, it will be important to obtain one in 2011. It will be interesting to monitor the evolution of vegetation in the area around the demo-sites, and also to investigate the spatial variation of this evolution. This can be done based on both low and medium resolution time series analysis. Furthermore, spatial gradients of vegetation stress, minerals, acid mine drainage etc. will be examined. Thermal infrared bands of ASTER can be used for air pollution monitoring, and different results of both satellite image processing and ground measurements might be linked to one another. It will also be interesting to look at the effect of the installation of the new smelter in Karabash. In general, the environmental impact is expected to be much larger in the Karabash area than in the Mednogorsk area. It will therefore also be interesting to compare temporal and spatial variation between both demo-sites.

4 CONCLUSIONS

The objective of the ImpactMin project is to develop new methods and a corresponding toolset for the environmental impact monitoring of mining operations using Earth Observation (EO). The basis for this development is laid by the generation of a scientific knowledge pool of methods of satellite based environmental monitoring techniques. This report (D4.3) summarizes the results of the work performed under WP4.4: Preparatory work for demo-site implementation. In the ImpactMin project, four demo-site regions are considered: Kristineberg (Sweden), the Vihovici mine in Mostar (Bosnia & Herzegovina), Rosia Montana (Romania), and two mining sites in the Orenburg region (Russia) (Figure 1-1). Since no satellite remote sensing techniques will be applied for environmental impact monitoring at the Kristineberg demo-site in Sweden, no preparatory work for demo-site implementation was performed, and this demo-site is therefore not included in this report. The preparatory work for demo-site implementation based on airborne campaigns is described in D5.3. In the Orenburg region (Russia), two demo-sites are considered in this report: Karabash and Mednogorsk.

In general, there is only a limited number of satellite sensors that provide imagery for the project: NOAA-AVHRR, SPOT-Vegetation, the different Landsat sensors, ASTER, SPOT and WorldView-2. The low spatial resolution sensors (NOAA-AVHRR and SPOT-VGT) will be used to monitor general changes in vegetation in a wide area around the demo-sites where largest environmental impact is expected (mainly Karabash and Mednogorsk). Time series of medium spatial resolution sensors (Landsat and ASTER) will also be used to monitor regional parameters and temporal changes. For this time series analysis it will be extremely necessary to standardize the data. Pre-processing of images is important in order to create geometric and spectral consistency. Furthermore, the thermal bands of ASTER day- and nighttime imagery will be used to monitor temperature increment due to underground coal fires in Mostar and to monitor air pollution in Karabash and Mednogorsk. Finally, high resolution imagery (SPOT-5, WorldView-2) will be used to monitor specific environmental problems at each demo-site: detailed base maps (all demo-sites), minerals or mineral groups (Karabash and Mednogorsk), acid mine drainage and surface water pollution (Mostar, Rosia Montana, Karabash and Mednogorsk), vegetation stress (Rosia Montana, Karabash and Mednogorsk). WorldView-2 is the first satellite that offers 8 spectral bands at high spatial resolution (46 cm) and was only recently launched. For Mostar and Rosia Montana, the interaction with an hyperspectral airborne campaign will provide many possibilities for calibration and validation. ImpactMin expects that, once the field and airborne hyperspectral campaigns have been completed, ImpactMin will be able to demonstrate the great value of WorldView-2 data in areas where no other ground or airborne data are available. However, in all demo-sites, image fusion is one of the main topics to concentrate on. Where both satellite and airborne imagery will be available (Mostar, but Rosia Montana is still uncertain), image fusion of satellite and airborne imagery becomes possible. In case of the Russian demo-sites, ASTER imagery, with higher spectral resolution, will be merged with Landsat or WorldView-2 imagery. There are many possibilities to test different methodologies. To conclude, although there is a large variability in the environmental effects of mining at the different demo-sites, some general approaches for satellite data (pre)processing were defined (see Appendix 4.1 and 4.2).

This report summarizes the preparatory work and provides a basis for future work in work packages 6 (Tools and services) and 7 (Demo-site implementation). In WP6.2, the acquisition, processing and analysis of satellite data will be carried out. In WP7, the complete demo-site implementation plans will be established for the different demo-sites.

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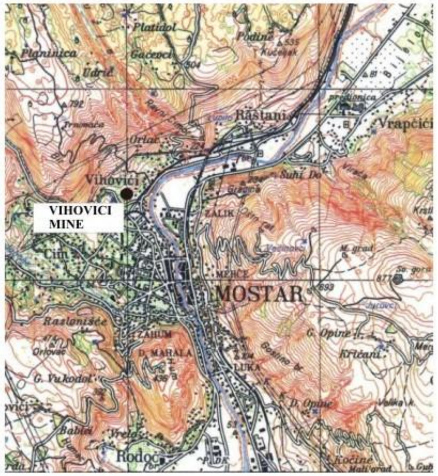
6 APPENDICES

Appendix 1.1 – Mostar demo site questionnaire

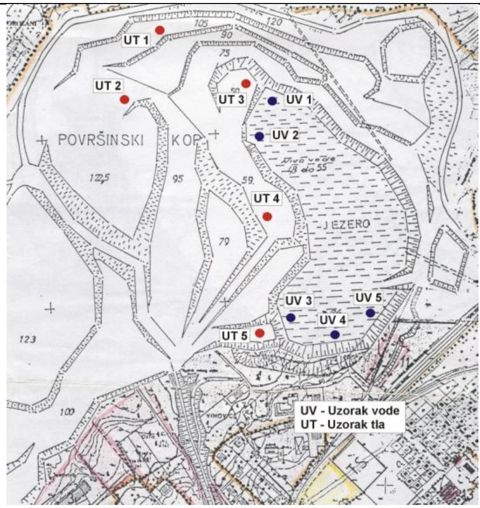
General information

Name of the IMPACTMIN demo-site?	Mostar Valley, Bosnia and Herzegovina
Name of the mine/project area	Vihovici Coal Mine
Company exploiting the mine/other type of activities?	Pre-1991: Rudnici mrkog uglja, Mostar (Brown coal mines of Mostar), a state-owned company.
Is the mine active/inactive? Since when? History of exploitation?	Mine is inactive, since 1991. The mine had entered production in 1901, first as an underground operation and in 1963 moved to surface open pitting until 1991.
Which minerals or materials are being extracted? Extraction processes? Volumes?	Brown coal (lignite), underground and open pit. Total extracted: 11 million tons, out of which 3.5 million tons were produced by surface exploitation (open pitting).
Location? Area?	Total area: 76 hectares, surface operations 43.2 Ha, open pit 7 hectares. Coordinates (LAT/LONG, WGS-84). NW corner: 43.361451, 17.791249 / SE corner: 43.355679, 17.797661.
Maps and pictures of the area?	 Geographic position of the Vihovići Mine

	  Position of the Vihovici mine relative to the Mostar urban area (left) and Distance of the excavation area from the river Neretva (300 m) (right)
Site access? Infrastructure? Hazards?	The main site is accessible via improved and unimproved surface roads, located within an urban area. Hazards: Debris and dust hazard, unstable slopes near former open pit, possible but unlikely presence of unexploded ordinance.

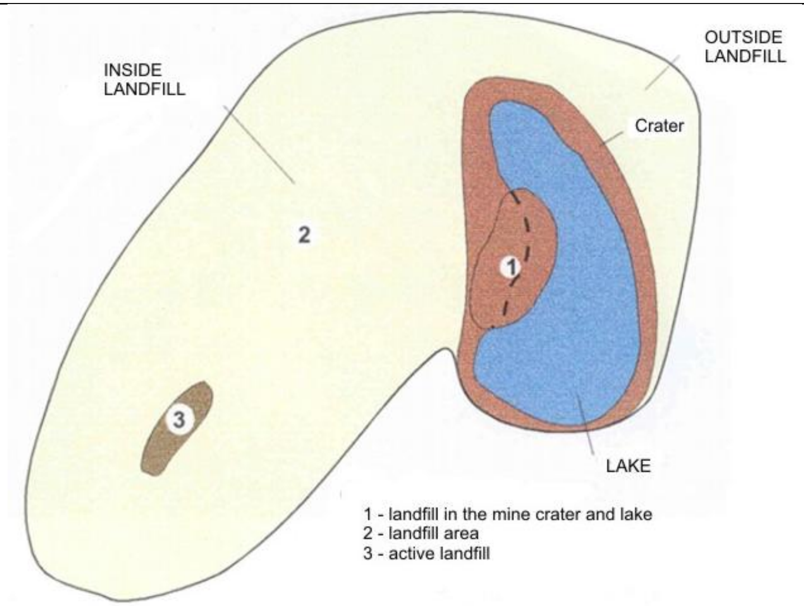
Environmental impact

General description of the physical environment?	Five general zones of Neogene layers: sandstone, breccia, sand-gravel clays, sand marls and limestone. Zone of the main carbon-coal seam is composed from layers of direct bottom and roof and carbon layer with interlayer and refills of muck. General (regional) area consists of Perm-Triassic (PT) strata, ranging from plaster-anhydrites, unconsolidated limestone, clay and mudstones, which are compressed during folding episodes and exposed on the surface and thrusted upon Mesozoic rocks. Lower Triassic (T1) is comprised from various mudstones, marls and plinth limestone Geomorphology is mainly karst landscape and associated karst structures/features (e.g. caverns, sinkholes, doline) and alluvial formations along Neretva river valley. Climate is Mediterranean, semi-arid. Surface cover is sparse and consists of low-lying Mediterranean shrubs (wild pomegranate mainly).
Maps and pictures of the mine site?	See above
Description of the mining-related processes which affect the environment? Rank in order of seriousness?	Surface disturbance, underground tunnels linking the mine with the riverine ecosystem, subsequent waste (industrial, residential) dumping in the mine area.

<table>
<tr><td></td><td>


Locations of stations for the soils (UT) and water (UV) sampling program (2003) (left) and Solid waste dumped in the pit lake (right)

Water/Soils analyses: Five water/soils sampling localities in the mine were measured for 14-27 distinct parameters in 2003 (pH, electro-conductivity, chlorides, ammonia, nitrites, nitrates, sulphates, copper, zinc, chrome, nickel, lead, manganese, cadmium). Water analysis showed that the critical parameters are present in all five sampling localities with elevated concentration of ammonia and nitrates. Significant concentrations of ammonia are noted ranging from 5.15 ppm – 6.12 ppm, while the allowed release is 0.1 ppm. The elevated values indicate continuing process of decomposing waste which may be deposited in the lake and around it. Also, significant concentrations of iron are noted ranging from 26.17 ppm and 23.16 ppm. NOTE: these samplings were carried out before the clean-up project was initiated in 2007. Soil analysis showed that the critical parameters exist in all five locations with concentrations of cadmium (2.10; 3.20; 2.20; 1.70; 2.90 ppm), nickel (58.30; 41.00; 45.30; 51.30; 49.30 ppm – max limit value 35 ppm) while lead concentrations are within allowed limits except in sampling location 4 where it goes over allowed values (62.18 ppm).
</td></tr>
<tr><td>Visible impact on the environment?</td><td>Surface disturbance of mine workings, presumed contact with the river (during flood stages), dust hazard, emission hazard (from underground burning of coal/organics)</td></tr>
<tr><td>Is the situation stationary or progressive?</td><td>Semi-stabilized, stationary, although present condition of the underground portions is at present unknown</td></tr>
<tr><td>Actions for rehabilitation already done?</td><td>Yes, clean-up in 2007-2009 removed some of the surface waste in 95% of the mine closure area and apparent extinguishing of the underground coal fires by pumping mixture of water and fly-ash. However, numerous characteristics for evaluation still remain (e.g. underground effluent).</td></tr>
</table>

	 Distribution of the solid waste caches within various locations of the Vihovići mine site.

Previous studies

Do previous studies exist?	Yes, most pertinent are: 1996 study for resuming exploitation and rehabilitation of the mine area, carried out by the Faculty of Mining, Geology and Oil exploration of the University of Zagreb. 2007 study for rehabilitation of the Coal Mining Complex Vihovici in Mostar, Bosnia and Herzegovina – feasibility report by Fichtner, financed by KfW Bankengruppe and the City of Mostar.
By which institutes/companies?	Regular reporting was carried out by the Universities and/or mining institutes of the former Yugoslavia in 1963-1991 period. Fichtner consortium in association with local institutions and personnel carried out detailed post-war compilation in preparation for burning coal-bed extinguishing operation.
Reports available? Literature? Add references?	(sorted by immediate relevance) Poslovna udruga: Geomarić – Geotehnika 94 – SIK Mostar - Završni izvještaj o radovima na gašenju i sanaciji bivšeg rudarskog kopa Vihovići, izvedeni radovi „Modula 1“ i „Modula 2“ Knjiga 1 (izrađene bušotine) Mostar, kolovoz 2009.

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Studies in comparable mine sites in the region? Add references?	ERMITE Environmental regulation of Mine waters in the European union (FP7) – 2001-2004.

Data availability

In situ data?	Water and soil sampling in five locations (described above)

	Re-cultivation study of the mine area Vihovici (2007/2008) Ecological study of the general Neretva catchment area (2004-2006) Coal quality and reserve Analyses (1996, University of Zagreb) Borehole geophysical data for geothermal anomalies from burning coal seams (temperature, resistivity) in 2006.
Remote sensing data available at your institute?	No satellite data. Digital orthophoto images, 0.6 m color, optical/visible range.
Other relevant data?	1:5,000 topographic and vectorized DEM, cadastral survey maps (parcel), 1:25,000 topography, general utility maps.
Remote sensing or other data available at (regional) providers / partners / institutes / clients / ...? Cost?	For RS data: ASTER 2000 – 2009 (30-60-90m), some available from colleagues, 150 EUR appx. Hyperion hyperspectral data (30m), if available, can be ordered on demand for around 650 EUR from EDC SPOT Multispectral (2-6m), can be ordered from SpotImages (prices vary)

Expectations

What do you think can be the added value of using satellite and/or airborne remote sensing techniques for monitoring environmental impacts of the mine?	It is important to define the Vihovici mine site in its proper geospatial context. Satellite remote sensing can be used to outline regional parameters of the mine (e.g. temporal change, urban growth, geology etc.). Even though it is limited in spatial resolution over three decades of Landsat TM/ETM data can be used to monitor the temporal changes and settings of the mine (still operational in 1972-1991 period). It would be particularly interesting to compare/contrast the position of the mine and development coupled with the urban growth. Higher resolution satellite imagery (available from the last decade) could be used to monitor the increased urbanization of the area in vicinity of the mine site in a post-conflict boom (after 1995) and success of clean-up/stabilization efforts in 2007-2009. Airborne geophysical (radiometric-magnetic data) could be used to identify possible sources of radiological contamination, presence of sub-surface targets, structures and anomalies indicative of mining, storage, effluence and collapse processes. Of particular use would be the use of airborne magnetic data which could possibly delineate subsurface voids and paths for underground fluid exchange and migration of mine waters towards Neretva River. Airborne hyperspectral (HSI) data could be used to assess the condition of Vihovici pit lake and zones of possible interaction with Neretva river, by determining indirect nutrient concentrations as a function of chlorophyll, water clarity and depth. Furthermore, the HSI data could be used to investigate for the presence of hydrocarbon waste on the surface, iron oxides and hydroxides and hydrophilic clays which could trigger possible collapse of the pit walls and earthen dams. The HSI data could also be querried to detect possible CO_2 effluent from the underground coal fires, which might have been re-started following the conclusion of the remediation campaign in 2009. Ultimately, a combination of the techniques and data outlined above would likely yield useful information for assessing the current

	and future condition of the mine-in-closure located within an urban area.

Socio-economical issues

How many people are employed by the site?	No people employed by the site. Remediation program ended after the first phase in 2009.
Is the site being used for non-mineral purposes?	Used as a solid waste dump from 1992 – 1995 (public), and illegal waste dump up to 2007. The plans are to use the site as an open-space park within the city of Mostar, if possible.
Are there other commodities (non mineral) that are being used from the site (e.g. water, power)?	None

Appendix 1.2 – Mostar metadata questionnaire

Topic

☒ Topography

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Topography Map of Mostar

Resource abstract? **Brief summary of the content of the resource.**

Topography Map of Mostar 1:25 000, Gauss-Kruger Projection, equidistance 10m

Resource type?

☐ Printed map
☐ Scanned map
☐ Raster dataset, format: ...
☐ Vector dataset, format: ...
☒ Other: Geo Tiff in Auto Cad

Resource language?

Croatian

Geographic location

Geographic bounding box
Longitude and latitude in decimal degrees

Upper left corner:
X : 6479742.4762 Y : 4803445.9469
Lower right corner:
X : 6489850.7620 Y : 4789539.1847

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

...

Date of creation

1970

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

Faculty of Civil Engineering,legal validity

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

Dimensions: 4975x6557

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): mirna.raic@gmail.com
Responsible party role
Prof.dr.sc Mladen Glibić
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
20. May 2010
Remarks
These map is old, relief is corrected but there can be a changes in the situation.

Topic

☒ Digital Elevation Model

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Digital Elevation Map of Mostar

Resource abstract? **Brief summary of the content of the resource.**

Digital Elevation Map of Mostar, UTM projection, Equidistancia 10m, 1:10000

Resource type?

☐ Printed map
☐ Scanned map
☐ Raster dataset, format: ...
☒ Vector dataset, format: Auto CAD Drawing
☐ Other: ...

Resource language?

Croatian,English

Geographic location

Geographic bounding box
Longitude and latitude in decimal degrees

Upper left corner:
X : 723124.97, Y : 480700.32
Lower right corner:
X : 730929.96 Y : 4799964.21Gauss-Kruger coordinates

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

Date of last revision of the resource, if the resource has been revised

...

Date of creation

1996

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

Faculty of Civil Engineering, Mostar, legal validity

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

In case of remote sensing data:

Level of preprocessing
☐ Radiometrically corrected
☐ Atmospherically corrected
☒ Geometrically corrected
☒ Orthorectified
☐ Other: ...

Format: ...

Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): mirna.raic@gmail.com
Responsible party role
Prof.dr.sc Mladen Glibić
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
25. May 2010.
Remarks
...

Topic
☒ Airborne imagery
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Orthophoto of Mostar
Resource abstract? **Brief summary of the content of the resource.**
Orthophoto of Mostar, Tiff Image, 4 parts,Gauss-Kruger projection
Resource type?
☒ Other: TIFF in AUTO CAD
Resource language?
...
Geographic location
Geographic bounding box **Longitude and latitude in decimal degrees**
Upper left corner: X : 6482000.0000 Y : 4803000.0000 Lower right corner: X : 6486500.0000 Y : 4797000.0000
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2004
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Faculty of Civil Engineering, Mostar, legal validity.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
Dimenzions: 4500x6000
In case of remote sensing data:
Level of preprocessing ☐ Radiometrically corrected ☐ Atmospherically corrected ☐ Geometrically corrected ☒ Orthorectified ☐ Other: ... Format: ...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access

☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): mirna.raic@gmail.com
Responsible party role
Prof.dr. sc Mladen Glibić
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mostar, legal validity Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
25.May 2010.
Remarks
...

Topic

☒ Geology

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Hydrogeological map, Vihovići-Mostar

Resource abstract? **Brief summary of the content of the resource.**

Hidrogeological map Vihovići - Mostar ,1:10000

Resource type?

☒ Printed map

Resource language?

Croatian and English

Geographic location

Geographic bounding box
Longitude and latitude in decimal degrees

Upper left corner:
X : ...°...' Y : ...°...'
Lower right corner:
X : ...°...' Y : ...°...'

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

...

Date of creation

1995-1996

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

Study of rehabilitation, exploitation and cultivation digs Vihovići, legal validaty

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

In case of remote sensing data:

Level of preprocessing
☐ Radiometrically corrected
☐ Atmospherically corrected
☒ Geometrically corrected
☐ Orthorectified
☐ Other: ...

Format: ...

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Jedinica za implementaciju projekta Vihovići, Mostar Contact (e-mail): projekt.vihovici@bih.net.ba
Responsible party role
mr.sc. Andrija Škobić
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
…
Remarks
…

Topic

☒ Other: Infrastructure

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Map with electrical installations in the Area Vihovići

Resource abstract? **Brief summary of the content of the resource.**

Map with electrical installations in the area Vihovići, Gauss-Kruger Projection

Resource type?

☒ Other: Auto Cad Drawing

Resource language?

Croatian

Geographic location

Geographic bounding box
Longitude and latitude in decimal degrees

Upper left corner:
X : 6483100.000 Y : 4802395.000
Lower right corner:
X : 6484495.000 Y : 4801000.000Gauss-Kruger coordinates

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

13. May, 2010.

Date of creation

13. May, 2010.

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

JP EP HZHB d.d Mostar, legal vaidaty

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

In case of remote sensing data:

Level of preprocessing
☐ Radiometrically corrected
☐ Atmospherically corrected
☒ Geometrically corrected
☐ Orthorectified
☐ Other: ...

Format: ...

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: JP EP HZHB d.d Mostar Contact (e-mail): darko.raspudic@ephzhb.ba
Responsible party role
...
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mosta Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
13. May 2010.
Remarks
There can be a failing

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map with Telephone installations in the Area Vihovići
Resource abstract? **Brief summary of the content of the resource.**
Map with telephone installations in the Vihovići area
Resource type?
☒ Other: Auto Cad Drawing
Resource language?
Croatian
Geographic location
Geographic bounding box **Longitude and latitude in decimal degrees**
Upper left corner: X : 6483984.5861 Y : 4801961.1375 Lower right corner: X : 6484336.8390 Y : 4801269.7571
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
25. May, 2010.
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
HT Mostar, legal validaty
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
In case of remote sensing data:
Level of preprocessing ☐ Radiometrically corrected ☐ Atmospherically corrected ☒ Geometrically corrected ☐ Orthorectified ☐ Other: ... Format: ...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
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Responsible party role
Branimir Vukojević
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Organization responsible for the creation of the metadata **Who filled this metadata record?**
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Metadata date **When was this metadata record created/updated?**
...
Remarks
...

Topic

☒ Other: Infrastructure

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Map with plumbing and sewage in the Area Vihovići

Resource abstract? **Brief summary of the content of the resource.**

Map with plumbing and sewage in the are Vihovići, Gauss-Kruger Projection

Resource type?

☒ Other: Auto Cad Drawing

Resource language?

Croatian

Geographic location

Geographic bounding box
Longitude and latitude in decimal degrees

Upper left corner:
X : 6483075.4811 Y : 4802510.9288
Lower right corner:
X : 6484242.7121 Y : 4801032.6654 Gauss-Kruger coordinates

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

...

Date of creation

18. May, 2010.

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

VODOVOD d.O.O Mosta, legal validaty

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

In case of remote sensing data:

Level of preprocessing
☐ Radiometrically corrected
☐ Atmospherically corrected
☒ Geometrically corrected
☐ Orthorectified
☐ Other: ...

Format: ...

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: VODOVOD d.O.O Mostar Contact (e-mail): 036 551 192
Responsible party role
Branimir Krvavac, d.i.g.
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Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Faculty of Civil Engineering, Mostar Contact (e-mail): danijela.p11@gmail.com
Metadata date **When was this metadata record created/updated?**
18. May 2010
Remarks

Appendix 1.3 – Rehabilitation of Vihovici in Mostar – Feasibility Report

Table 6-1 Summary of the assumed dangers and the investigation programme executed at Vihovici Site, with its results, as well as giving a brief description of recommended remediation measures (Fichtner et al., 2007)

Assumed Situation (dplan report 2003)	**Potential Contaminants**	**Investigation Measurements**	**Results**	**Endangering Situation**	**Recommended Remediation Measures**
Waste in the lake, 110,000 m³ of sanitary waste: 70% domestic waste, 18% construction waste, 10% industrial waste, 2% hospital waste, composed of 22% organic matter, 30% clinical waste, tires, batteries, butchers' waste etc.	Heavy metals, organic substances, solvents, pesticides, radioactive substances	Echo sounding (17 cross sections), topographical survey of lake bottom, 4 drillings, analysis of 4 waste samples, 2 contact water and 2 soil air samples (CO, CO_2, CH_4, H_2S) under a complex chemical program	6750 m³ waste in the lake	No significant contamination detectable, only some local pollution by PAH and mineral oil detected: *LB 2 / cumulative sample 0.0 – 0.3 m + 1.2 – 1.5 m:* eluate: PAH (0.52 µg/l) and mineral oil (1080 µg/l); solid: mineral oil (320 mg/kg) *LB 3 / 0.1 – 0.4 m:* eluate: mineral oil (430 µg/l); solid: mineral oil (1030 mg/kg) *LB 3 / 1.0 – 1.5 m:* eluate: mineral oil (4400 µg/l); solid: mineral oil (1200 mg/kg) Waste contact water: only one slightly raised mineral oil value (325 µg/l, LB 2)	No remediation measures required; just skimming of waste in lake for esthetical reasons
Waste on site, 190,000 m³ of sanitary waste, 70% domestic waste, 18% construction waste, 10% industrial waste, 2% hospital waste, composed of 22% organic matter, 30% hospital waste, tires, batteries, butchers' waste etc.	Heavy metals, organic substances, solvents, pesticides, radioactive substances	32 test pits, analysis of 7 soil samples under a complex chemical program and 30 soil air samples (CO, CO_2, CH_4)	78,000 m³ waste on-site, 10-15% domestic waste, 50-70% construction waste, 10-15% industrial waste, 5% hospital waste, no CO, CH_4, CO_2 and H_2S detected	No contamination detectable, only some local pollution by arsenic and mineral oil detected: *cumulative sample IV:* eluate: arsenic (50 µg/l); *single sample S29/4.3 m:* eluate: mineral oil (250 µg/l)	Depending on envisaged future utilisation of Site: "No Public Access": fencing "Public Access": covering waste areas or excavation of waste and its disposal in a landfill on-site

Assumed Situation (dplan report 2003)	**Potential Contaminants**	**Investigation Measurements**	**Results**	**Endangering Situation**	**Recommended Remediation Measures**
Lake water Contamination, elution of hazardous substances	Heavy metals, organic substances, solvents, pesticides, radioactive substances, bacteria	Analysis of 3 lake water samples under a complex chemical program	No significant chemical impact detected, no limit value of EU directives exceeded	No chemical contamination detectable, only bacteriological pollution (presumably from sewage)	No remediation measures required due to chemical substances form Site; if necessary to extinguish burning coal seams, possible construction of dam in *Neretvanski rov* to stop inflow of sewage
Groundwater Contamination, direct elution of hazardous substances from waste and infiltration of contaminated lake water	Heavy metals, organic substances, solvents, pesticides, radioactive substances, bacteria	Drilling of 4 boreholes, installation of 4 piezometers, analysis of 3 groundwater samples under a complex chemical program	No significant chemical impact detected, no limit value of EU directives exceeded	Mainly bacteriological pollution (presumably from sewage); some mineral oil pollution detectable. *B 1:* mineral oil (130 µg/l) *B 4:* mineral oil (700 µg/l)	No remediation measures required; situation could be improved by introduction of sewage treatment by the City of Mostar
Neretva contamination, infiltration of contaminated lake water via *Neretvanski rov* and groundwater	Heavy metals, organic substances, solvents, pesticides, radioactive substances, bacteria	Analysis of 2 water samples upstream and downstream of *Neretvanski rov* under a complex chemical program	No significant chemical impact detected, no limit value of EU directives exceeded	No chemical contamination detectable, only bacteriological pollution (presumably from sewage)	No remediation measures required; situation could be improved by introduction of sewage treatment by the City of Mostar
Smouldering coal seam, release of toxic gases, geotechnical unstable slopes	CO_2, CO, H_2S, organic compounds	Evaluation of satellite images, 39 toxic gas emission measurements and analyses, 623 surface temperature measurements, infrared measurements, 18,060 geomagnetic measurements and survey of smouldering fissures	Only CO_2, occasionally CO and combustible gases, traces of H_2S detected, temperature anomalies	Uncontrolled and unpre-dictable development of the fire; possible ignition of waste deposits and production of hazardous gases and combustion residues; subsidence damage because of volume reduction	Investigation of extent of coal fire; extinguishing of coal fires by water and mud injection

Table 1-1 Summarised table of assumed danger, executed investigation program, results and proposed measures

Appendix 2.1 – Rosia Montana demo site questionnaire

General information

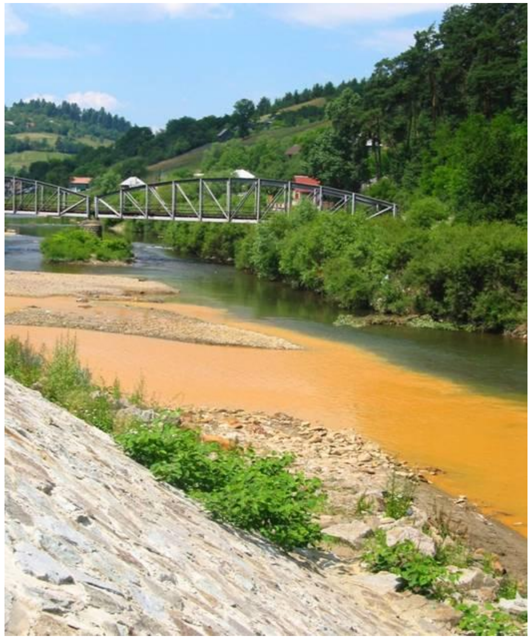
Name of the IMPACTMIN demo-site?	Rosia Montana Project
Name of the mine/project area	Rosia Montana
Company exploiting the mine/other type of activities?	S.C. Rosia Montana Gold Corporation S.A. (R.M.G.C.)
Is the mine active/inactive? Since when? History of exploitation?	Until 2006, the mine was owned and operated by the state. Currently, R.M.G.C. is trying to obtain the permits in order to start operation. Roşia Montană is a commune covering 4200 hectares with 16 villages, one of which is also called Roşia Montană. The first written record of Roşia Montană dates from 6th of February 131 AD, and comprises a wax coated tablet found in one of the Roman-era mine galleries. From its origins Roşia Montană is linked with the gold that lies in its rocks. Gold mining which has occurred almost continuously over the last 2000 years has influenced the social, economic, cultural and environmental conditions of Roşia Montană. Every governing authority, from the Romans and Austro-Hungarians to the present Government of Romania has sought to exploit the mineral of Roşia Montană (State own company closed its operation in May 2006). Only underground mining operations were functioning before 1970. Later on, the open pit mines Cetate and Carnic were setup. About 140 km of galleries were dug in the area in nearly 2000 years of mining. The area of the open pits is 19.75 ha (Cetate) and 5.2 ha (Carnic). Many of the impacts of this development and exploitation have been beneficial, such as the long history, the diversity of the religion and culture, economic welfare proven by the wealth of archaeological patrimony. Some of the impacts however have been negative. Environmentally, past mining has caused serious problems including pollution of soils and streams, landscape scarring, and impact on land use and biodiversity. Also, there have been no significant attempts at environmental rehabilitation and no effective environmental controls to reduce the impacts. Economically Roşia Montană owes its origins to mining and therefore became almost exclusively dependent on it for its income. As mining has declined in Romania and Roşia Montană since 1989 with dwindling State-funded support, so too has the quality of life in the community declined. Socially and culturally, Roşia Montană is in decline as people leave to seek a better life elsewhere. Roşia Montană remains, despite its touristic potential, an isolated location that does not attract investments capable of reinvigorating the whole commune, with the exception of the potential for mining. The RMP design includes opportunity to significantly improve the poor condition of the roads, water supply, waste water treatment, electricity supply and waste management systems. Also the RMP enables significant employment and income opportunities both to citizens and local authority. Many components of the RMP are also designed to enable the development of a local tourism industry. The existing environmental pollution will also be addressed by the RMP. Roşia Montană Gold Corporation S. A. (the "Developer") has documented in the RMP management plans that every effort will be made in cooperation with local authorities and the people of Roşia Montană to develop a range of non-mining activities which can support the social, cultural, environmental and economic welfare of the Community long after the mine has closed. From a community viewpoint this would comprise the greatest impact and

	benefit of the RMP.
Which minerals or materials are being extracted? Extraction processes? Volumes?	There are no data available about historical extraction. Currently, R.M.G.C. is trying to obtain the permits in order to start operation. Minerals to be extracted are Gold (Au) and Silver (Ag). The table below presents the ore quantities that will enter the process plant, per year and per mining pit. Ore mining will end in the 14th year, but the processing plant will continue working until the 16th year.

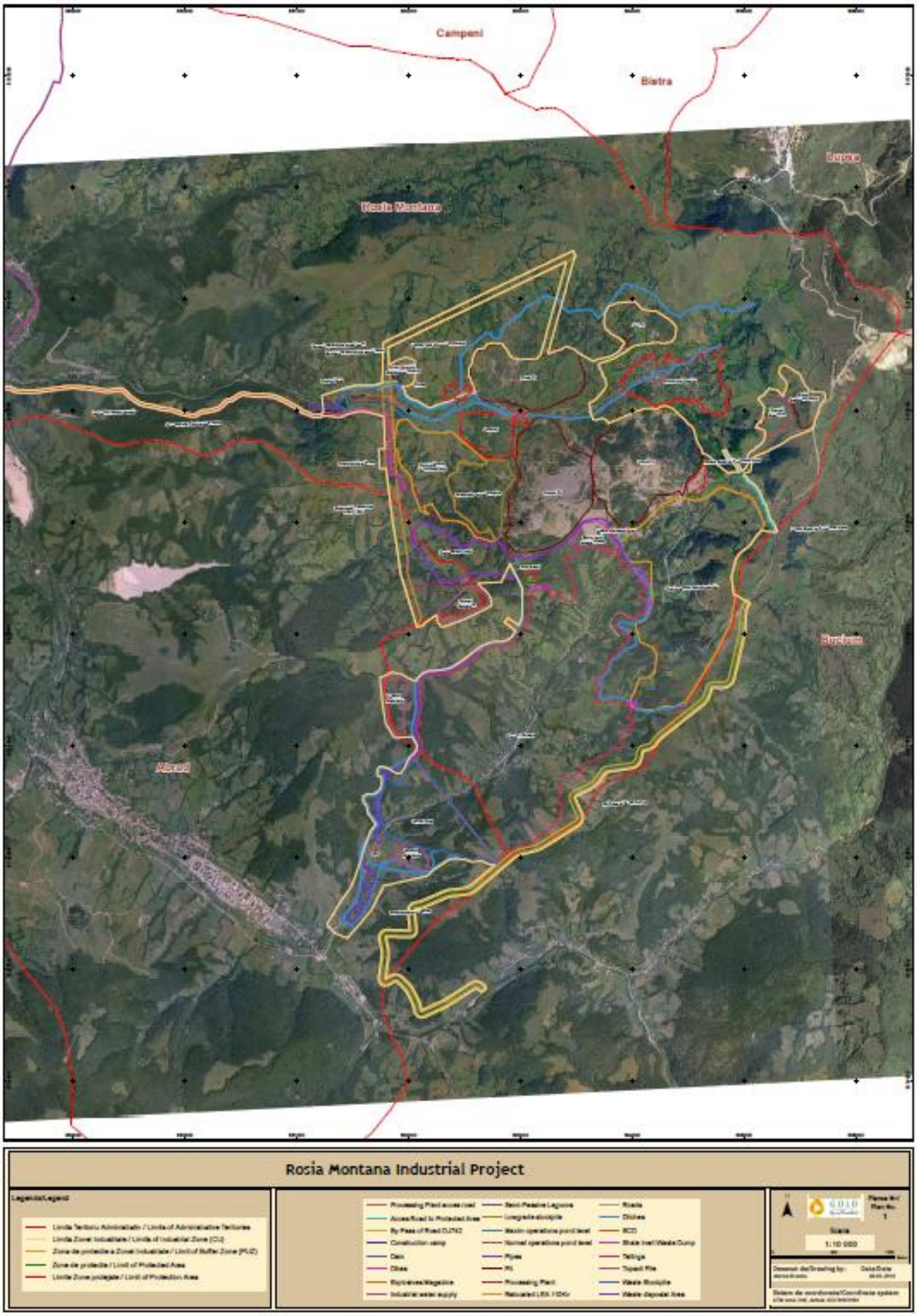
Year	Cetate Pit (mil. tons)		Cîrnic Pit (mil. tons)	Orlea Pit		Jig Pit	Total excavated ore (mil. tons)		Total ore that entered the plant (mil. tons)
	crusher	Low grade waste dump	crusher	Low grade waste dump	Crusher (mil. tons)	crusher (mil. tons)	Low grade waste dump	crusher	
0	-	-	420	312	-		312	420	-
1	693	984	10649	6822	-		7806	11342	11762
2	832	1033	12182	7528	-		8561	13014	13014
3	6883	2705	6437	1046	-		3751	13320	13320
4	8590	1505	4600	1746	-		3251	13190	13190
5	-	-	13300	4015	-		4015	13300	13300
6	-	-	13515	1538	69		1538	13515	13515
7	-	-	14179	-	3551		-	14248	14248
8	-	-	10439	-	10803	68	--	13990	13990
9	362	-	3648	-	12295	1219		14881	14881
10	1889	-	-	-	8982	4124	-	15413	15413
11	2214	-	-		4129		-	15317	15317
12	9583	-	-	-	-		-	13712	13712
13	14212	-	-	-	-		-	14212	14212
14	5796	-	-	-	-		-	5796	14250
15		-	-	-	-		-	-	13463
16		-	-	-	-		-	-	7318
17		-	-		-		-	-	-
Total 1	51064	6227	89369	23007	39829	5408			
Total	57291		112376	39829		5408	29234	185670	214905

Location? Area?	Roşia Montană is approximately 80 km north-west of the regional capital of Alba Iulia, and 85 km north north-east of the City of Deva in west-central Romania. It is in the "Golden Quadrilateral" region of the Apuseni and Metaliferi mountain ranges in Transylvania. The RMGC proposed project requires an area of 1054 ha of the administrative territory of Roşia Montană Commune, 170 ha of the administrative territory of the City of Abrud, 32 ha of the administrative territory of Bucium, and 1.6 ha of the

	administrative territory of Câmpeni.
Maps and pictures of the area?	See pictures of the current situation (open pit and acid mine drainage):    

	    For an overview of the (future) RMGC project, see next page.
Site access? Infrastructure? Hazards?	Road conditions vary greatly throughout Romania. While the major streets in larger cities and major inter-city highways are generally in fair to good condition, other roads may be in a state of disrepair, poorly lit, narrow, and often may not have marked lanes, graded shoulders, or stable facilities. Certain roads, particularly in rural areas, are also used by pedestrians, animals, bicyclists, and horse- or ox-drawn carts or wagons, which normally do not carry lights or other distinguishing safety markings. These types of transport are difficult for drivers to see, especially at night. In addition, the availability of roadside repair or medical emergency (ambulance) assistance can be quite limited, especially in mountainous rural areas. Road travel can be particularly dangerous in mountainous regions, and there are sections of major and minor roads which contain many serpentines or switchbacks. In the winter months, mountain roads can experience many weeks of wet, snow-covered, or icy conditions. Snow-clearing equipment and appropriate de-icing treatments are only just becoming a norm for local road maintenance activities. Such improvements appear to be continuing faster, and overall improvement of such issues is expected in the future. Moreover, in recent years there has been an increase in public expenditure on road maintenance, which is resulting in noticeable improvements in the overall transportation infrastructure. The development of the Transylvanian Autostrada (highway), which, when complete, will provide a high quality road from the Hungarian border to the Black Sea, is an example of such investment; and this will

	provide an important alternate road transport route for project supply both from the east and from west of the country. The Roşia Montană Project is situated in a mountainous region, and use of existing local transportation routes will be necessary to access the Project site. Because of the mountainous terrain, weather conditions are more extreme than in low-lying regions; snow pack can be significant, and it is common for icy road conditions to exist for three to four winter months. Some roads in these rural areas are in poor condition and can be narrow and have many curves. These factors make the transportation of sensitive materials and large equipment items a challenging consideration. A preliminary traffic survey was performed in 2003 on the existing road in Roşia Valley. The survey concluded that traffic to the plant site via the existing road would be excessive. As a result, a new access road along the existing (Roșiamin) narrow gauge rail haulage route will be constructed on the south side of the Roșia Valley. Because local traffic volumes and patterns are expected to change rapidly, from external economic factors as well as the onset of construction activity, RMGC will perform an additional survey prior to construction to develop a more current and accurate understanding of existing traffic conditions.


Campeni
Bistra
Lupsa
Rosia Montana
Bucium
Abrud
Rosia Montana Industrial Project
Legenda/Legend
Processing Plant
Roads
Ditches
Tailings
Scala
1:10 000

Environmental impact

General description of the physical environment?	***Geology, climate and landscape*** The Roşia Montană volcanic sequence is interpreted as a maar-diatreme complex emplaced into Cretaceous sediments, predominantly black shales, with sandstone and conglomerate beds (Exhibit 4.5.2). The three dimensional geometry of the area is well established due to an extensive network of underground mines that have been developed since the Austro-Hungarian Empire period, and from the extensive drilling conducted from the surface and underground over the last 25 years. Rock types within the **maar-diatreme complex** are dominated by breccias, including phreatomagmatic breccias, complexly re-worked and subaqueous breccias and volcaniclastics, intruded by a series of porphyritic dacitic sub-volcanic intrusions, dacitic dykes and later phreatomagmatic breccias (phreatomagmatic breccias form due to explosive eruptions of steam and other gases). The dacitic intrusions are interpreted as Neogene age and are informally named the Cetate Dacite and Cârnic Dacite. The dacite complex is interpreted to have intruded vertically into the maar breccias, sediments and volcaniclastics and to have spread laterally at shallower levels. An alternative interpretation is that only one major dacite intrusion has occurred and that this has been split into the now separate Cârnic and Cetate dacite bodies by a northeast trending strike-slip fault. The majority of the Roşia Montană volcanic deposit is made up of a lithology locally referred to as the "**vent breccia**". This is a diatreme breccia created by numerous phreatomagmatic eruptions produced as hot rising dacitic magma interacted with groundwater. It is of variable composition with clasts of dacite, Cretaceous sediments and basement schist and gneiss. The clast size, degree of rounding, and the proportion of matrix, vary widely. Texturally it exists as both massive breccia units and sub-aqueous reworked breccia indicating the breccia has erupted into a shallow lake or maar. This reworked vent breccia is fine to coarsely bedded and varies from clay-rich, to more common sandy and gravely beds, to beds containing poorly sorted, cobble sized clasts. Graded bedding is common and cross bedding and ripple marks have also been observed suggesting the presence of a lake or flow water. The vent breccia hosts the dacitic intrusives, as well as multiple later crosscutting phreatomagmatic breccia bodies. Within the vent breccia a large (1 by 1 km^2 at the surface) body of breccia has been delineated as a separate phreatomagmatic event. This is composed of generally massive (some sedimentary reworking exists in the upper levels), poorly sorted, matrix-supported breccia, with sub-angular to sub-rounded clasts of dacite, Cretaceous sediments and basement metamorphic rocks. The breccia is distinct because it is the only breccia body at Roșia Montană that still contains significant magnetite. The magnetite is coarse and interpreted to be of magmatic origin. Chlorite also occurs as an accessory mineral in altered clasts. Some sulphide is present as pyrite particles in the matrix or in scattered phyllic-argillic (clay) altered clasts of dacite. It is interpreted that this breccia was emplaced after the main period of sulphide mineralisation, which is supported by a 40Ar/39Ar date on a hornblende separated from juvenile dacite clasts (11.0 + 0.80 Ma), which is over 1 million years after the youngest date recorded for the mineralisation (12.71 + 0.13 Ma). A breccia, locally termed the **'Black Breccia'**, forms a sub-vertical pipe in the centre of the diatreme, between the Cetate and Cârnic dacites. The breccia is matrix supported, with clasts of dacite, Cretaceous sediment and basement garnet-bearing schist and gneiss in a matrix of pulverised (rock flour) Cretaceous shale, which gives the breccia its black, clay-rich character. A number of other intrusive diatreme (phreatomagmatic) breccia bodies crosscut the reworked vent breccia and also the Cârnic and Cetate dacites. Five of these have been identified in the vicinity of the Jig area, where they have a sub-vertical, pipe or lens geometry

	up to 100m in width. Within the dacites they form multiple broad (up to 100 m wide) to narrow (a few centimeters wide) dykes or breccia pipes. In both locations, the breccias are structurally controlled, with the pipes and broad dyke breccias forming at the intersection of large structures. These are composed of matrix-supported breccias with sub-rounded clasts of dacite, Cretaceous sediment and crystalline schists. The breccia bodies in the Jig area have a high proportion of metamorphic clasts, making them easily identifiable from the surrounding vent breccia and also indicating that the phreatomagmatic eruption originated in the metamorphic basement at depth. Texturally they vary from poorly sorted to moderately sorted with a matrix of fine clay (pulverised rock) in many of the dykes at Cârnic and Cetate to a more sandy matrix in the Jig area breccias. Andesitic extrusive rocks have been mapped as mantling the northern and eastern parts of the project area, forming a thin to moderately thick cover over the maar complex. The andesitic units are post mineralization in age and consist of unaltered agglomerates and flows. Roşia Montana area has a continental temperate climate. Higher areas are characterized by a mountain microclimate with cold winters lasting 4 to 6 months, and with heavy snowfall. Spring and autumn are cold and humid, with significant rainfall. Summer is short, with gradual transitions between seasons. Climatic data – air temperature, relative humidity, nebulosity, precipitation and wind – have been recorded between 1988 and 2005 by the Roşia Montană Meteorological Station, located on the top of Rotundu Hill, in the north-eastern corner of the Project site near the upper end of the Roşia Valley. No solar radiation measurements are available from Roşia Montană Meteorological Station. The station is managed by the National Administration of Meteorology, and belongs to the Romanian national meteorological network. Data presented in this paper have been provided by the National Administration of Meteorology. Sunshine daily duration data have been recorded between 2002 and 2005 by RMGC meteorological station. The Roşia Montană Project area is located within the Roşia Montană village area. The area is approximately 1645.15 ha, with the project footprint of 1050.08 ha and contains the existing and proposed mines and associated facilities, presently operated by the state-owned company and project partner Minvest. The main access way in the area is DN 74 Abrud – Câmpeni. The Roşia Montană village covers an area of approximately 42 km^2 and is located at an altitude of 700 - 800 m, N $46^0$19´0″ latitude and E $23^0$08´0″ longitude. The Roşia Montană village comprises two areas which are delineated by the streets pattern. The first area extends from the western limit of the village to an square area called Roşia Centru. The arrangement of the area is linear with the houses located in one row alongside the road that connects the Roşia village to Abrud and Cîmpeni. The second area of Roşia Montană extends from the eastern side of the first area to its north and east limits and is called Roşia Piaţă. The houses in the plaza and adjacent area are bigger than in the other areas of Roșia Montană. The Corna village is located along the Corna Valley near the Cîrnic and Cetate Mountains. The architecture of the village houses is characteristic to other localities in the Apuseni Mountain area. Settlement is generally restricted to the valley floors with only farm buildings and occasional domestic dwellings higher up the valley sides. In the Roşia Valley, smaller settlements are located west of the Roşia Montană village: Balmoşeşti and Ignăteşti, and in the Corna Valley is located the Bunţa village ***Geomorphology*** In terms of a general localization, the investigated area is part of the Carpathian Subprovince, district of the Trascău-Metaliferi volcanic and flysch mountains. The topography in the Roşia Montană Project area is typical for the mountainous landscape in the Metaliferi Mountains region, having high elongated ridges that separate deep valleys, steep slopes with peaks rising above the ridge

tops at the upper end of the valleys. Ridge tops tend to be well rounded with occasional craggy outcrops in the upper part of Roşia and Corna Valleys or ridges adjacent to the site and slopes are usually steep.

The relief immediately to the west of the Project Area is organised around the main south-north valley of the Abrud River, which receives the three following valleys of right-bank tributaries flowing from the east: Roşia, Saliste and Corna. The ridges between these valleys and the peaks to the east effectively form a natural bowl around Roşia Montană, isolating it from the wider landscape to the east, north and south. The western ridgeline of the Abrud Valley provides further isolation of the Project Area to the west.

The relief units in the area are the slopes, ridges, valleys, with the lower and middle slopes having the largest predominance. The terrain configuration is frequently undulated and it becomes uneven – rough in the valley area with fairly significant gradients. Under these rough relief conditions brittle, superficial soils (i.e. bruni eumesobazic lithic, bruni podzolic lithic) with surface skeleton and rock, exposed to erosion occurred. In terms of altitude, the area is located between 600 m and 1300 m. On the north and north east limit the following ridges are highlighted: Zănoaga (1054.8m), Rotund (1191m), Vârşii Mari (1282.9m), Ghergheleu (1156m). These peaks delineate the investigated area along the N – NW side. The terrain slope is mainly steep (between 16^0 and 30^0) and very steep (between 31^0 and 40^0) however abruptness with gradients exceeding 40^0 is also encountered.

The overall exposure of the area determined by the course of the main streams is south west and west. The rich hydrographical network that contributed to the land fragmentation determines a diverse range of exposures, from sunny to shaded and even over-shaded on the steep northern slopes or valley bottoms. The Abrud Depression encompasses a rippled area which appears like a tectonic and erosion basin (Bucium, Abrud, Roşia Montană). The Roşia Montană depression basin stretches out along the Roşia Valley as an elongated corridor framed by a number of "hills" i.e. Rotunda, Cîrnic, Dealul Cetăţii, which are in fact old volcanic cones in whose depths are encountered various non-ferrous ores.

What is noteworthy is the anthropogenic micro-relief (galleries, mine portals, waste rock dumps) which attests the historic mining in this area of the Apuseni Mountains. Geological formations with a remarkable aspect that are classified as protected areas are also present, i.e. Piatra Despicată and Piatra Corbului. Over the years, the relief in the area has suffered various changes, which are the result of the combined influences of natural and anthropogenic factors of the last 2 millenniums.

Soil cover

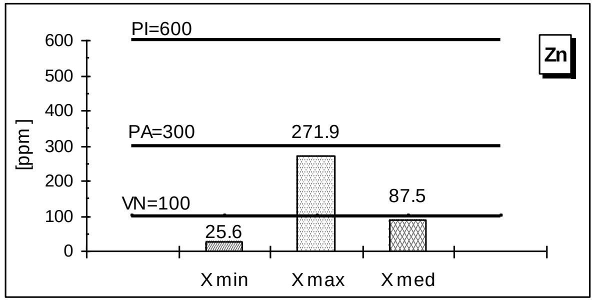
Environmental conditions (relief, surface lithology, climate, vegetation) determined the formation of a diverse soil cover. Its diversity is apparent at type and sub-type level, especially in the lower levels, given the soil and terrain characteristics of the respective areas and determining the rules of its distribution. Based on the data obtained from soil mapping, soil and land maps have been developed. A review of the soil map shows that 8 soil units were defined in the study area, by type and sub-type, and 19 units of soil type and sub-type associations in various proportions.

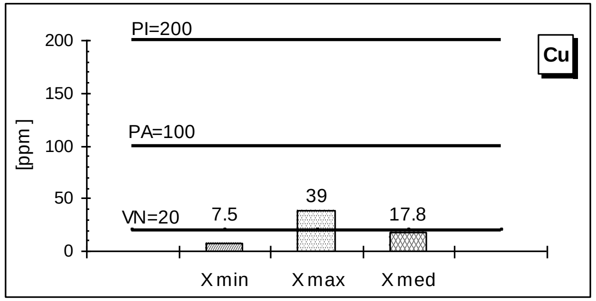
The soil types and sub-types defined as mono-type (pure) or associations include:

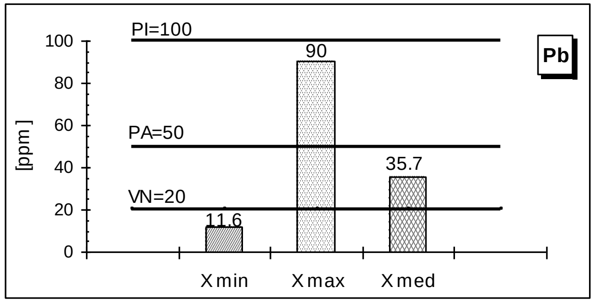
- Brown, eu-mesobasic soils with the andic, lithic and andic-lithic sub-types
- Brown, acid soils with the typical, andic, lithic and andic-lithic sub-types ;
- Typical and lithic regosols;
- Typical lithosols

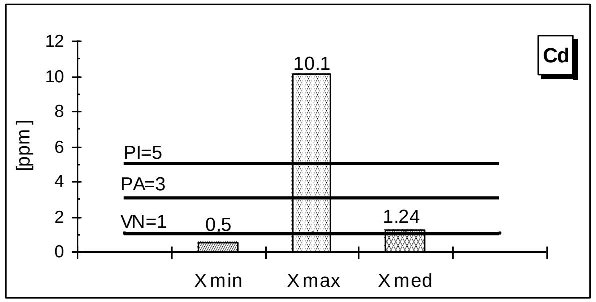
	▪ Typical colluvisols. Soils were defined according to the principles and criteria of the Romanian Soil Rating System (1980) and further correlated with the World Reference Base for Soil Resources (WRB-SR, 1998). By processing and summarizing the various soil (thickness, parental material, parental material granulometry, textural class of the soils, skeletal content by soil profile) and land characteristics (relief, main forms of relief, micro-relief, gradient, underlying rock), the land unit map was developed using the land formula including the above characteristics. A review of the land map and of the attached key suggests that 46 land units have been defined in the study area. Please see Baseline reports at www.rmgc.ro
Maps and pictures of the mine site?	See above
Description of the mining-related processes which affect the environment? Rank in order of seriousness?	Environmentally, past mining has caused serious problems including pollution of soils and streams, landscape scarring, and impact on land use and biodiversity. However, there are no criteria at hand to rank these problems in order of seriousness. In the framework of a baseline conditions study conducted in 2003-2005, 153 **soil samples** were collected from the mine surrounding area. The contents of the following heavy metals were determined: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn. The returned results were compared to the reference values of MAPP Order/1997 regarding the normal contents of these chemical elements in soil (VN) and values representing alert (PA) and response thresholds (PI) for sensitive soil use. A predominant feature of these analytical data is the fact that they have low values, generally below the alert or response thresholds (see graphs below).

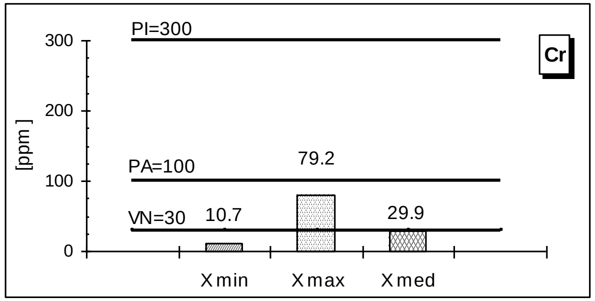
Statistic Parameter	Zn	Cu	Fe	Mn	Pb	Cd	Ni	Cr	Co
n	153	153	153	153	153	153	153	153	153
x min	25.6	7.5	7.112	80	11.6	0.5	12.5	10.7	10.8
x max	271.9	39	47138	2187	90	10.1	114	79.2	66.6
x average	87.5	17.8	28794	645	35.7	1.24	49.3	29.9	29.9
VN	100	20	-	900	20	1	20	30	15
PA	300	100	-	1500	50	3	75	100	30
PI	600	200	-	2500	100	5	150	300	50

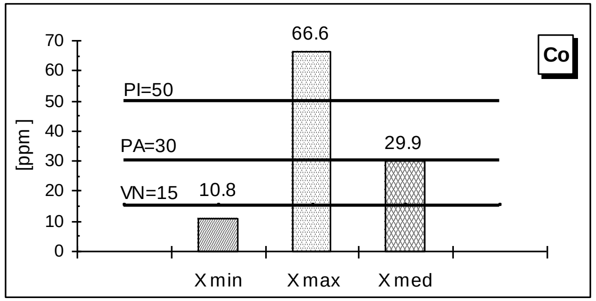












Currently, **air pollution** is limited in the area, since the mine is not active. During the windy periods the fine mineral fraction is mobilized from the open pit and dumps. This dust may contain different mineral components, including various amounts of Si, Al, Fe, Ti, Ca, Mg, Ni, K, Mn, Cu, Zn, Cd, Pb. There is no air quality monitoring system in function at this moment.

The first consistent **water monitoring** program was developed starting in 2000. At present, the water quality monitoring network operated by RMGC covers approximately 27,000 ha and has the following conventional boundaries:

- Southeast – Buciumani Valley, from Bucium to the confluence of Buciumani Valley and the Abrud River
- South and southwest – the Abrud River, from upstream of the confluence with Buciumani Valley to the city of Abrud
- West – the Abrud River, from the city of Abrud to the confluence of the Abrud River and the Arieş River
- North – the Arieş River, between the confluence of the Abrud River and the Arieş River to the confluence of the Sartăş Valley and the Arieş Valley.

The water quality monitoring network includes the following types of samples:

- Acid rock drainage and other types of wastewater
- Groundwater: springs, wells and monitoring boreholes

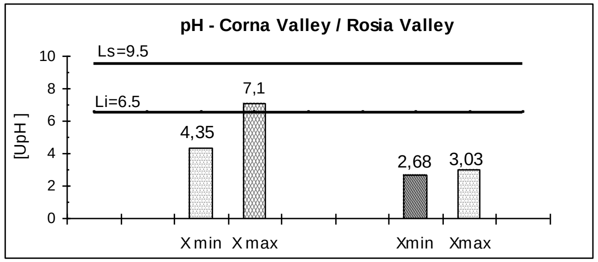
- Surface stream water
- Water from man-made lakes
- Drinking water from the supply network.

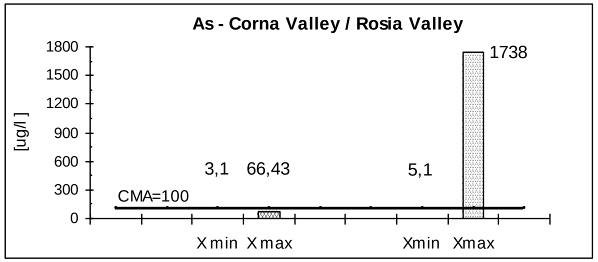
Based on the described sampling for wastewater, surface and ground water, an overall evaluation of the water quality in the monitored area was carried out for each type of water sample.

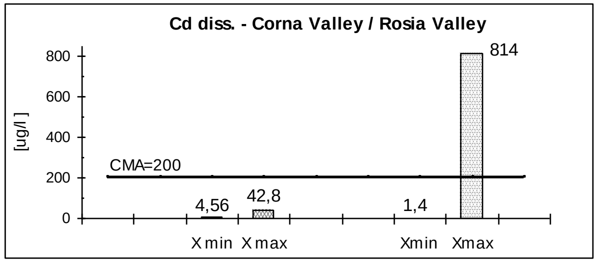
The general conclusion of the water quality baseline study for the Roşia Montană area is that the historical development of mine operations has resulted in the contamination of waters with specific pollutants, originating from the local mineralized bodies. Such components are leached by acidic waters generated by the exposure of sulphide-bearing ores to exogenous factors. Surface water pollution propagates at long distances from the Roşia Montană area and other mining impacted valleys, thus affecting the downstream water usage.

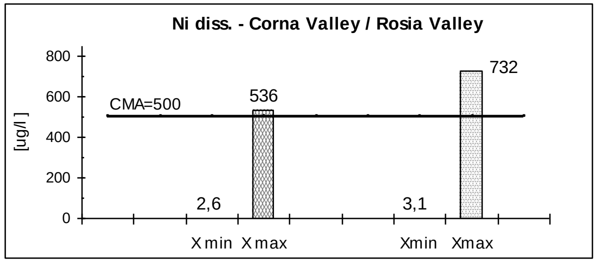
Acid Rock Drainage (ARD)

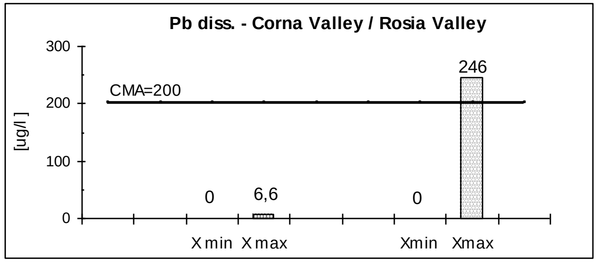
The analysis results from the four wastewater samples, mainly from the Corna and Roşia Valleys, indicated high levels of arsenic, cadmium, nickel, selenium and sulphates in the majority of the samples and occasionally elevated levels of lead and total chromium (see graphs below).

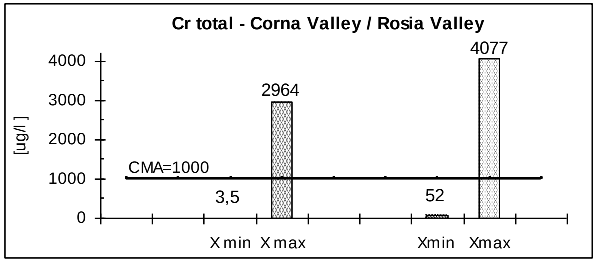


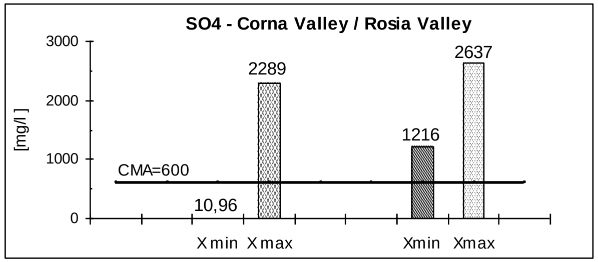










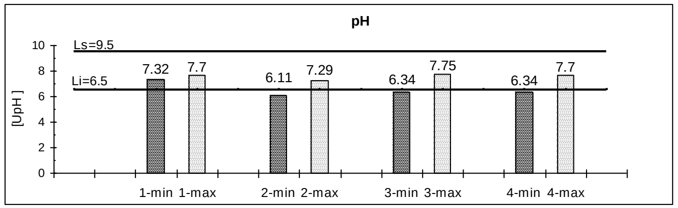


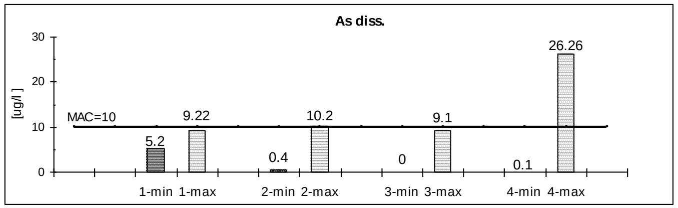
Ground water

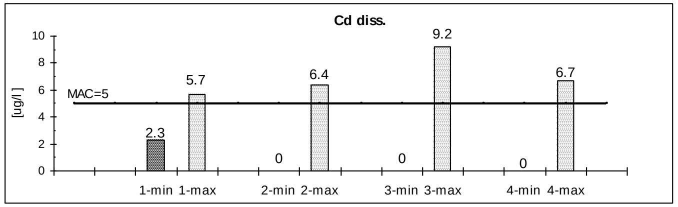
The contaminants found in the majority of analyzed surface and ground water samples were: arsenic, cadmium, nickel, selenium, total chromium; the presence of lead and sulphates was sporadic and reflects localized sources primarily related to mining impacts. Due to the predominantly near-neutral character of the samples, total and dissolved metal concentrations (for arsenic, cadmium, nickel and lead) were largely similar.

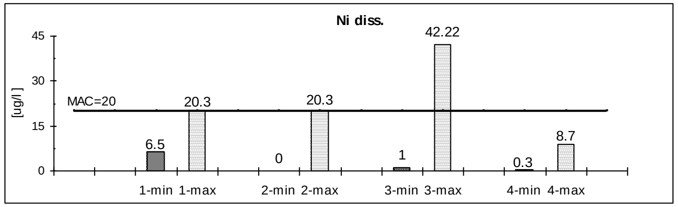
The following graphs show the result of ground water quality monitoring in: 1 – Abruzel Valley, 2 – Corna Valley, 3 – Saliste Valley, and 4 – Rosia Valley. MAC = Maximum Admissible Concentration.

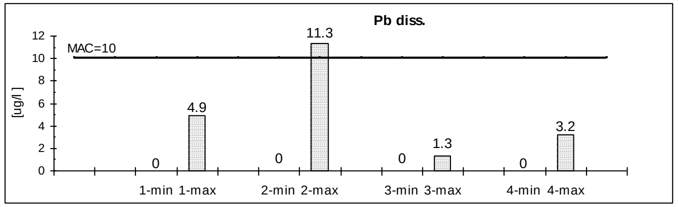
Springs:

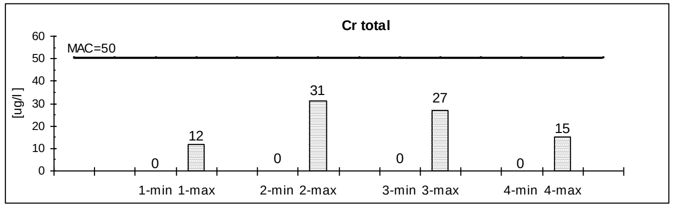


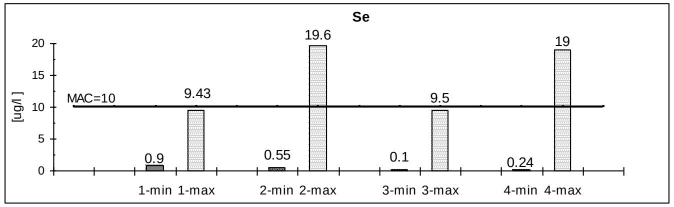


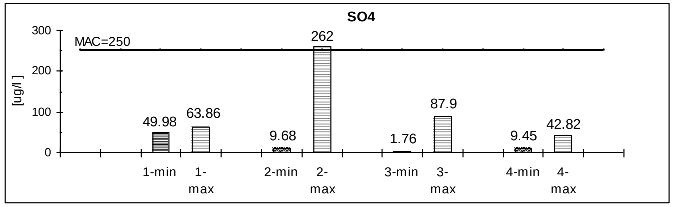




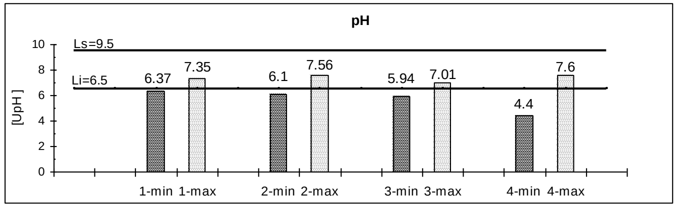


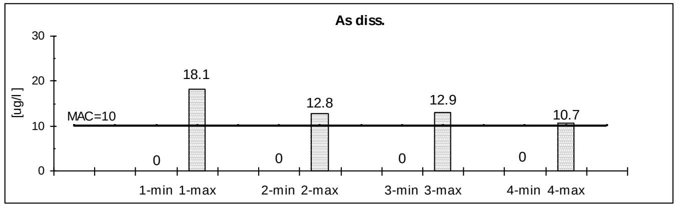


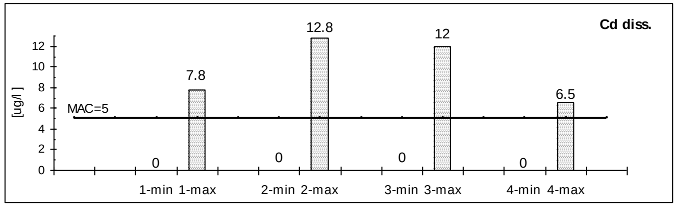


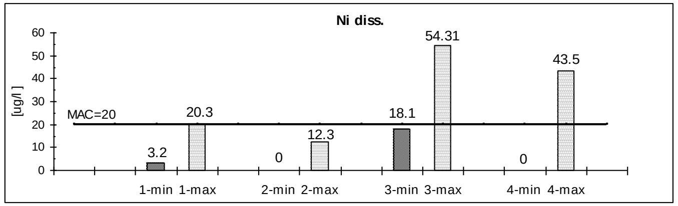


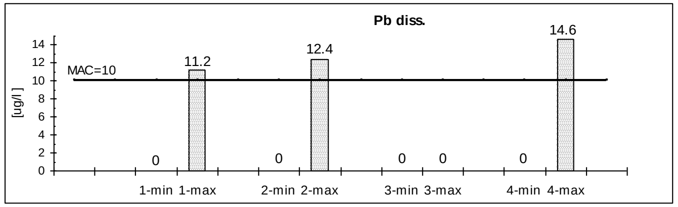
Hand dug wells:







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12.4
0
0
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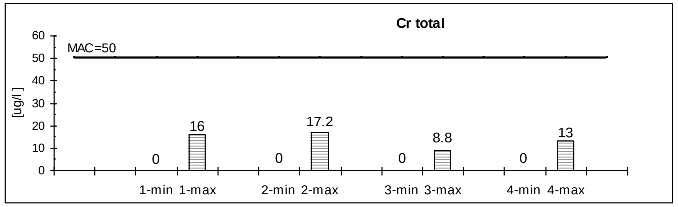
14.6
1-min 1-max 2-min 2-max 3-min 3-max 4-min 4-max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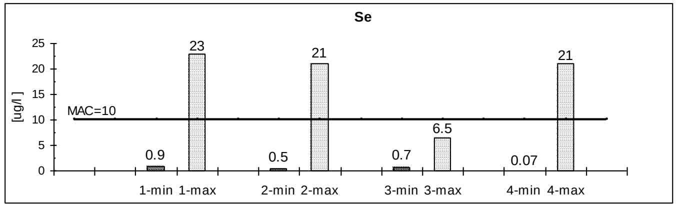
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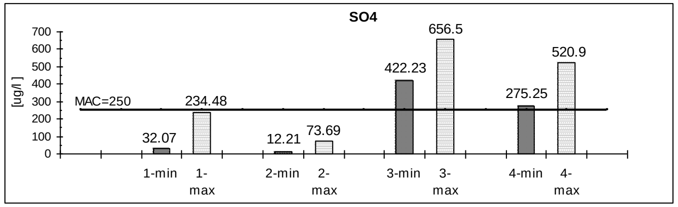
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422.23
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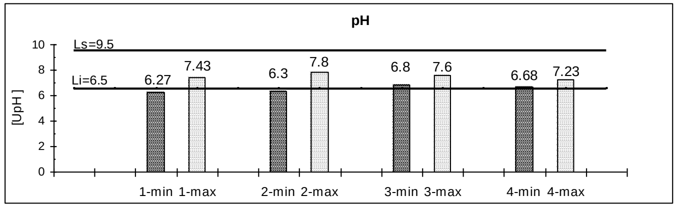
Boreholes: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Li=6.5
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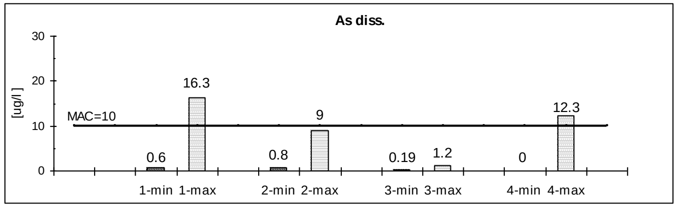
As diss.
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MAC=10
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12.3
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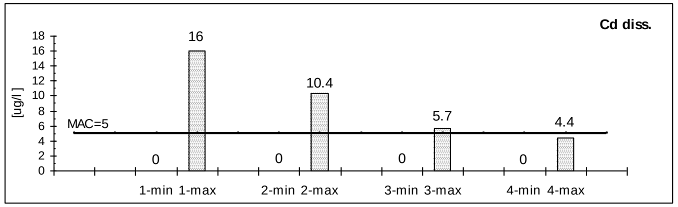
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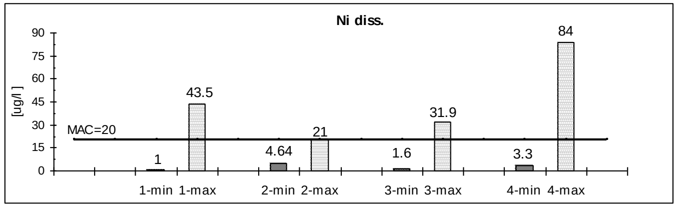
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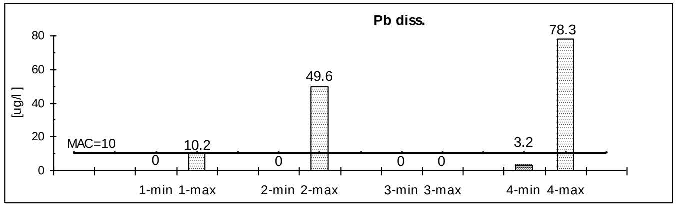
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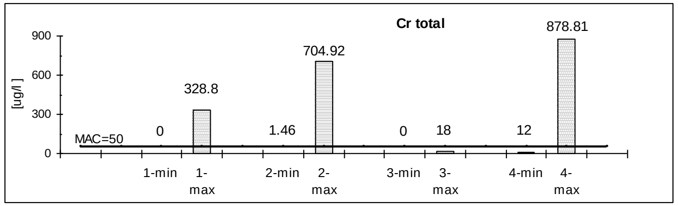
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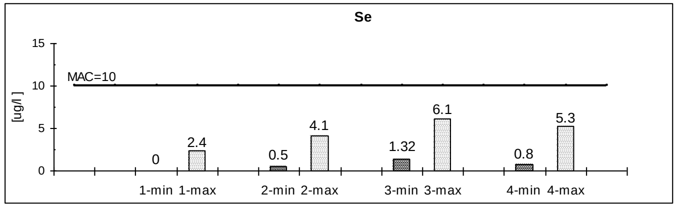
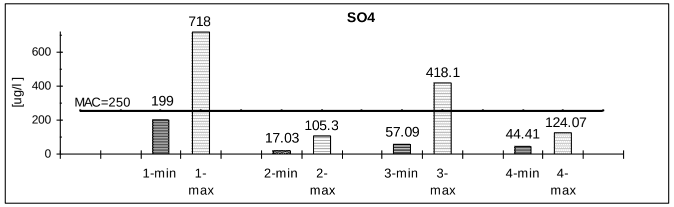




Surface Water

The characteristics of the monitored waters were variable within the moderately acidic to neutral domain. A single exception was represented by alkaline waters collected in the Sartăş Valley and originating in the tailings pond of Baia de Arieş processing plant. The most acidic surface water samples were collected from the Abrud River –downstream of mining works belonging to Bucium area, from a tributary of Abruzel Stream and from Corna Stream – downstream of the waste rock dumps, from Roşia Stream – downstream of ARD discharge points of the Roşia Montană area, and from the Şesei Stream – downstream of the waste rock piles and of the tailings dam belonging to Roşia Poieni mine.

The surfaces of the existing **mine waste rock dumps** is presented in the next table:

NAME	Area (m²)	Area (ha)
23 August Dump	3479.45	0.348
Afinis Dump	1137.78	0.114
Aurora Dump	739.62	0.074
Cirnicel Adit Dump + 910m	11976.86	1.198
Dump Adit + 938m	9738.43	0.974
Gauri Dump	20796.64	2.080
Hop Dump	53683.79	5.368
Iuliana Dump	6273.84	0.627
Manesti Adit + 795 Dump	33468.07	3.347
Napoleon Dump	2677.33	0.268
Orlea Dump	43678.50	4.368
Piatra Corbului +960m Dump	1445.21	0.145
Piatra Corbului Dump	850.48	0.085
Rakosi Dump	21366.06	2.137
Valea Verde Dump	73039.24	7.304
Verkes Dump	5549.66	0.555

Visible impact on the environment?	The environment is seriously affected. The 24.95 ha open pit mining area and brown acid waters exiting the underground mining

<table>
<tr><td></td><td>works are visible.

See pictures above</td></tr>
<tr><td>Is the situation stationary or progressive?</td><td>The current situation is progressive. If no remediation actions are done, continued pollution of streams and soil within the proposed Project boundary are expected, primarily from uncontrolled run-off and seepage from the Rosiamin operation (activity closed in May 2006, site not rehabilitated), historic mine workings, and uncontrolled waste disposal practices.

The table below summarizes the environmental of the no-action alternative compared to the project implementation.

<table>
<tr><th rowspan="2">Environmental Factor/Aspect</th><th colspan="2">Alternatives</th><th rowspan="2">Comments</th></tr>
<tr><th>Null Alternative</th><th>Project Implementation</th></tr>
<tr><td>Water flows and quality</td><td>Long term negative impacts continuing as a result of uncontrolled ARD and runoff from existing unrehabilitated mine workings and waste</td><td>Forecast significant beneficial long term impact arising as a result of the imposition of comprehensive water management and mine closure plans</td><td>The proposed Project delivers highly significant, long-term benefits compared to the no action alternative</td></tr>
<tr><td>Air quality</td><td>Existing baseline conditions would prevail long term, i.e., essentially good quality with occasional domestic heating influences and dust from unvegetated and unrestored surfaces</td><td>The impacts on air quality from site activity will be maintained below permitted limits for protection of sensitive receptors</td><td>The Project introduces significant new sources of air pollution in the short term, but these will be controlled through engineering and management measures</td></tr>
<tr><td>Noise and Vibration</td><td>Existing baseline conditions would remain long term, i.e., typical of semi-rural area</td><td>The impacts generated by noise and vibrations from site activity will be maintained below permitted limits for protection of sensitive receptors</td><td>The Project introduces significant new sources of noise and vibrations, but these will be controlled through engineering and management measures</td></tr>
<tr><td>Soil/Land Use</td><td>Roşia Valley: long term condition of land dereliction would remain with unrestored dumps and pits. Corna Valley: existing long-term conditions would remain, i.e. relatively undisturbed agricultural use of soils; some influence from emissions from unrestored mine waste dumps will continue</td><td>Roşia Valley: rehabilitation of operational areas would restore soils and growth media to support vegetation. Corna Valley: long-term impact on soils from land take for TMF and waste rock stockpile; mitigation by rehabilitation of sites using stored soils with revegetation and establishment of a productive end-use</td><td>Land take for the Project will impact soil resources, particularly in the Corna valley; however, rehabilitation will mitigate this.
The mining dereliction in Rosia Valley will be remedied.</td></tr>
<tr><td>Biodiversity</td><td>Baseline conditions will prevail long-term; loss of opportunity for</td><td>Short term impacts arising from land take. Long-term opportunity to improve or enhance existing eco-</td><td>Land take will impact significantly on existing habitats during construction and operation,</td></tr>
</table>
</td></tr>
</table>

		improvement in biodiversity	logical conditions through implementation of Biodiversity Management	however the planned rehabilitation measures will restore the habitats at closure.
	Landscape	Baseline conditions will prevail long-term: continued impact of derelict mined land in Rosia Valley	Insignificant impact al regional scale. Significant negative impact al local scale by topographical modification. Landscape rehabilitation and establishment of interesting features	The Project will have a significant impact on landscape
	Socio-economic issues	Significant impact of closure of mining in area on jobs and investment leading to acceleration of generally worsening socio-economic conditions	Significant inward investment from Project creation of jobs leading to general improvement in socio-economic conditions; long-term positive impacts	The Project brings significant and sustainable socio-economic benefits
	Cultural heritage	Impacts arising from lack of investment; long-term continued deterioration of historic monuments and buildings. Lack of access to ancient mining remains	Investment in long term preservation of historic remains, houses and other important structures as well as assuring access to sites and features of interest	Implementation of the mining project will significantly contribute to the conservation, rehabilitation and enhancement of the historical monuments and archeological sites
	Road infrastructure	Existing baseline conditions prevail long-term with poor transportation links and infrastructure	Improvement and upgrade of existing infrastructure, development of own infrastructure for transport of materials around the site	The Project will have a short-term negative impact in regard to road traffic volumes and amenity. PUZ provides the opportunity to improve the transportation infrastructure and traffic safety
	Transboundary impacts	The existing derelict mining site will remain a long-term source of heavy metal pollution that will continue to add to the pollution load carried by Mures river out of the country	The Project will deliver a long-term positive impact on water quality also in a transboundary context. In case of an accident (failure of TMF dam) the cyanide and heavy metal concentrations in the Mures River at the border will be lower than the limit values set out in the Romanian, EU and Hungarian legislation	The no-action option allows the continuation of chronic pollution that ultimately affects the quality of the Mures river flowing out of Romania
Actions for rehabilitation already	There have been no significant attempts at environmental rehabilitation and no effective environmental controls to reduce the			

done?	impacts.

Previous studies

Do previous studies exist?	Environmental Impact Assesment, 2006. See http://www.rmgc.ro/en/rosia_montana.php?page=raport Monitoring program, from 2001 onwards (water, biodiversity, climate, patrimony, etc.)
By which institutes/companies?	Organization (in alphabetical order), Team Leader, website **EIA experts registered with the Ministry of Environment** AGRARO CONSULT, Stefania Chiriac, www.agraro.ro, BUCHAREST; CEPSTRA GRUP, Mihai Zaplaic, www.cepstra.ro, BUCHAREST; ICPA- RESEARCH INSTITUTE FOR SOIL SCIENCE AND AGROCHEMISTRY, Radu Lacatusu, www.icpa.ro, BUCHAREST; CRAIM – THE REGIONAL CENTER FOR MAJOR INDUSTRIAL ACCIDENT PREVENTION, Alexandru Ozunu, www.chem.ubbcluj.ro/~aimre/craim/craim.php, CLUJ-NAPOCA; ECOIND - NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR INDUSTRIAL ECOLOGY, Margareta Nicolau, www.incdecoind.ro, BUCHAREST; EHC - ENVIRONMENTAL HEALTH CENTRE CLUJ-NAPOCA, Eugen Gurzau, www.ehc.ro, CLUJ-NAPOCA; GIE - GROUP OF INDEPENDENT EXPERTS, Adina Relicovschi, www.gieltd.com, BUCHAREST; ICAS - FOREST RESEARCH AND MANAGEMENT INSTITUTE, Iovu Biris, www.icas.ro, BRASOV; MINESA - MINING RESEARCH AND DESIGN INSTITUTE, Toma Prida, www.minesa.utcluj.ro, CLUJ-NAPOCA; USPI – UNITY OF SUPPORT FOR INTEGRATION, Sergiu Mihut, CLUJ-NAPOCA; VISAND, Violeta Visan, BUCHAREST; VMP INTEGRATED ENVIRONMENT, Marilena Patrascu (EIA Team Leader), BUCHAREST **Support consultants to the registered EIA experts** ACOUSTIC ALLIANCE CONSULTING, Bob Mantley, www.allianceacoustics.com, USA; AMEC EARTH & ENVIRON-MENTAL, Fergus Anckorn (EIA Deputy Team Leader), www.amec.com, UK and Canda; ARHEOTERRA CONSULT, Corina Bors, ALBA IULIA; CRUTA - ROMANIAN CENTER FOR REMOTE SENSING IN AGRICULTURE, Radu Mudura, BUCHAREST; CYPLUS, Stephen Gos, www.cyplus.com, GERMANY; DALEM CONSULTING, Daniela Mihai, ALBA IULIA; ERM-ENVIRONMENTAL RESOURCES MANAGEMENT, Daniel Krieger, www.erm.com, USA; GECKO EARTH AND ENVIRONMENT, Max Smith, The Netherlands; GIFFORD CONSULTING ENGINEERS, Tim Strickland, www.gifford.uk.com, UK; MNIR – ROMANIAN NATIONAL HISTORY MUSEUM, Paul Damian, www.mnir.ro, BUCHAREST; OPUS – ATELIER DE ARHITECTURA, Stefan Balici, BUCHAREST; STANTEC, Ian Callum, www.stantec.com, Canada; UNIVERSITY OF WALES - THE INSTITUTE OF GEOGRAPHY AND EARTH SCIENCES , Paul Brewer and Mark Macklin, www.fluvio.com, UK; UVVG ARAD - VASILE GOLDIS WESTERN UNIVERSITY, Corneliu Maior, www.bb.uvvg.ro/uvvg/, ARAD; UTAH – UNIVERSITY OF TOULOUSE LE MIRAIL, TOULOUSE UNIT FOR ARCHAEOLOGICAL RESEARCH, Beatrice Cauuet, FRANCE; WISUTEC, Christian Kunze, www.wisutec.de, GERMANY **Contributions from (among others):** Acad. Mircea Gomoiu, CONSTANTIA; Adina Rebeleanu, CLUJ-NAPOCA; Angela Glover, AUSTRALIA; Carry Connor, US; Gabriela Bodea, CLUJ-NAPOCA; Flavius Rovanaru, CLUJ-NAPOCA; Frederic Giovaneti, FRANCE; John Knight, UK; Mihaela

	Salanta, CLUJ-NAPOCA; Prof. Gogu Mircea, BUCHAREST
Reports available? Literature? Add references?	See http://www.rmgc.ro/en/rosia_montana.php?page=raport
Studies in comparable mine sites in the region? Add references?	None

Data availability

In situ data?	
Remote sensing data available at your institute?	Spot, sensor Spot4, resolution 2.5m, acquisition year 2004 Airborne Orthophotoplan - resolution 0.5m, year 2005
Other relevant data?	Topographic maps, related to the RMGC Project DTM - MNAT Spot, precision 4m, resolution 20m
Remote sensing or other data available at (regional) providers / partners / institutes / clients / ...? Cost?	

Expectations

What do you think can be the added value of using satellite and/or airborne remote sensing techniques for monitoring environmental impacts of the mine?	The added value of remote sensing techniques is that a reliable and cost-effective methodology for monitoring the environmental impact can be established. We expect to reduce the cost of environmental monitoring and to provide easy understandable 'state of the environment' reports to the stakeholders.

Socio-economical issues

How many people are employed by the site?	Currently, RMGC has 170 employees
Is the site being used for non-mineral purposes?	No
Are there other commodities (non mineral) that are being used from the site (e.g. water, power)?	No

Appendix 2.2 – Rosia Montana metadata questionnaire

Topic
☒ Satellite imagery
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
5 084-256/5 04/08/19 09:48:01 1 T+X
Resource abstract? **Brief summary of the content of the resource.**
SPOT-5 scene acquired in August 2004, level 1A Green, Red and Infrared band
Resource type?
☒ Raster dataset, format: Erdas Imagine by Leica Geosistems
Resource language?
English
Geographic location
Geographic bounding box **Longitude and latitude in decimal degrees**
Scene Center location X : E23°07'23" Y : N46°18'10"
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2004-08-19
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
...
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
24000x24000 pixels
In case of remote sensing data:
Level of preprocessing ☒ Geometrically corrected ☒ Orthorectified
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations

Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Spot images Cnes (Centre national d'études spatiales — the French space agency) 2002 – Distribution Spot Image Contact (e-mail): www.spotimage.com
Responsible party role
...
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Metadata date **When was this metadata record created/updated?**
...
Remarks
...

Topic
☒ Satellite imagery
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
AST_L1A_003_03142002092732_03312002153234
Resource abstract? **Brief summary of the content of the resource.**
ASTER scene acquired in March/2002 NIR (visual near infra red), SWIR (shortwave infra red), TIR (thermal infra red)
Resource type?
☒ Other: .hdf for Space Research HDF Explorer
Resource language?
English
Geographic location
Geographic bounding box **Longitude and latitude in decimal degrees**
Upper left corner: X : ...°...' Y : ...°...' Lower right corner: X : ...°...' Y : ...°...'
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
14/03/2002
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
NASA's Earth Observing System (EOS)
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
VNIR - 15 m , SWIR - 30 m, TIR - 90 m
In case of remote sensing data:
Level of preprocessing ☐ Radiometrically corrected ☐ Geometrically corrected
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A.

Contact (e-mail): ...
Responsible party role
...
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic	
☒ Satellite imagery	
Identification	
Resource title? Characteristic (unique) name by which the resource is known?	
AST_L1A_003_03142002092741_03312002153247	
Resource abstract? Brief summary of the content of the resource.	
A STER scene acquired in March/2002 VNIR(visual near infra red), SWIR(shortwave infra red),TIR(thermal infra red)	
Resource type?	
☒ Other: .hdf for Space Research HDF Explorer	
Resource language?	
English	
Geographic location	
Geographic bounding box Longitude and latitude in decimal degrees	
Upper left corner: X : ...°...' Y : ...°...' Lower right corner: X : ...°...' Y : ...°...'	
Temporal reference	
Temporal extent Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals	
...	
Date of last revision of the resource, if the resource has been revised	
...	
Date of creation	
14/03/2002	
Quality and validity	
Lineage Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.	
NASA's Earth Observing System (EOS)	
Spatial resolution Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).	
VNIR - 15 m , SWIR - 30 m, TIR - 90 m	
In case of remote sensing data:	
Level of preprocessing ☐ Radiometrically corrected ☐ Geometrically corrected	
Constraint related to access and use	
Conditions applying to access and use If applicable, provide URL of website where information is available	
☒ No conditions apply	
Limitations on public access	
☒ No limitations	
Organization responsible for spatial data set	
Responsible party For establishment, management, maintenance and distribution of the resource	
Name: Rosia Montana Gold Corporation S.A	

Contact (e-mail): ...
Responsible party role
...
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Digital Elevation Model
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
ASTER rainbow Digital Elevation Model
Resource abstract? **Brief summary of the content of the resource.**
15m resolution DEM derived from Level 1A data (WGS84 UTM 34N)
Resource type?
☒ Raster dataset, format: .ecw for ERDAS by Leica Geosystems
Resource language?
English..
Geographic location
Geographic bounding box **Longitude and latitude in UTM WGS84 (zone 34N)**
Upper left corner: X : 549632 Y : 5187360 Lower right corner: X : 704377 Y : 5045410
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
16/07/2003
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
NASA's Earth Observing System (EOS)
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
15m resolution
In case of remote sensing data:
Level of preprocessing ☒ Orthorectified
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...

Responsible party role
…
Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
…

Topic
☒ Topography
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Topography map
Resource abstract? **Brief summary of the content of the resource.** **[e.g. CORINE Land Cover Map, European Environmental Agency. 1:100000, smallest mapped unit is 25 ha, 44 classes. See [http://www.eea.europa.eu/publications/COR0-landcover/at_download/file]]**
Topography Map, equidistance 2m
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in UTM WGS84 (zone 34N)**
Upper left corner: X : 657269.10 Y : 5136976.88 Lower right corner: X : 673117.02 Y : 5124365.74
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail):
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Land use/land cover
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
utm_landuse_final_2.shp
Resource abstract? **Brief summary of the content of the resource.**
Map representing landuse , UTM projection
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS 84 UTM (zone 34N)**
Upper left corner: X : 654944.50 Y : 5136837.37 Lower right corner: X : 668748.12 Y : 5123764.12
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S. A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map of the Protection Area
Resource abstract? **Brief summary of the content of the resource.**
Map of the Protection Area , UTM projection
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS84 UTM (zone 34N)**
Upper left corner: X : 662330.41 Y : 5130531.94 Lower right corner: X : 664741.86 Y : 5128419.57
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map with lakes location
Resource abstract? **Brief summary of the content of the resource.**
Map with lakes location, UTM projection
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS84 UTM (zone 34N)**
Upper left corner: X : 661116.25 Y : 5131994.65 Lower right corner: X : 665270.92 Y : 5124805.59
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic

☒ Other: Infrastructure

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Map with forest location

Resource abstract? **Brief summary of the content of the resource.**

Map with forest location, UTM projection

Resource type?

☒ Vector dataset, format: .shp for ArcGis

Resource language?

English

Geographic location

Geographic bounding box
Coordinates in WGS84 UTM (zone 34N)

Upper left corner:
X : 658265.74 Y : 5134277.33
Lower right corner:
X : 665178.63 Y : 5124427.63

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

...

Date of creation

2001

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

Rosia Montana Gold Corporation S.A.

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set

Responsible party
For establishment, management, maintenance and distribution of the resource

Name: Rosia Montana Gold Corporation S.A.
Contact (e-mail): ...

Responsible party role

...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map with buildings location
Resource abstract? Brief summary of the content of the resource.
Map with buildings location, UTM projection
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS84 UTM (zone 34N)**
Upper left corner: X : 657233.31 Y : 5136547.20 Lower right corner: X : 668597.04 Y : 5124333.36
Temporal reference
Temporal extent Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic

☒ Other: Infrastructure

Identification

Resource title?
Characteristic (unique) name by which the resource is known?

Map with existing 20 kv powerline

Resource abstract? **Brief summary of the content of the resource.**

Map with existing 20 kv powerline, UTM projection

Resource type?

☒ Vector dataset, format: .shp for ArcGis

Resource language?

English

Geographic location

Geographic bounding box
Coordinates in WGS84 UTM (zone 34N)

Upper left corner:
X : 658198.21 Y : 5131841.28
Lower right corner:
X : 666439.15 Y : 5124116.79

Temporal reference

Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**

...

Date of last revision of the resource, if the resource has been revised

...

Date of creation

2001

Quality and validity

Lineage
Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.

Rosia Montana Gold Corporation S.A.

Spatial resolution
Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).

...

Constraint related to access and use

Conditions applying to access and use
If applicable, provide URL of website where information is available

☒ No conditions apply

Limitations on public access

☒ No limitations

Organization responsible for spatial data set

Responsible party
For establishment, management, maintenance and distribution of the resource

Name: Rosia Montana Gold Corporation S.A.
Contact (e-mail): ...

Responsible party role

...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map with existing 110 kv powerline
Resource abstract? **Brief summary of the content of the resource.**
Map with existing 110 kv powerline
Resource type?
☒ Vector dataset, format: .shp for ArcGIS
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS84 UTM (zone 34N)**
Upper left corner: X : 660946.87 Y : 5131814.97 Lower right corner: X : 663903.96 Y : 5125375.55
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@yahoo.com
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Topic
☒ Other: Infrastructure
Identification
Resource title? **Characteristic (unique) name by which the resource is known?**
Map with existing 110kv power line poles
Resource abstract? **Brief summary of the content of the resource.**
Map with existing 110kv power line poles, UTM projection
Resource type?
☒ Vector dataset, format: .shp for ArcGis
Resource language?
English
Geographic location
Geographic bounding box **Coordinates in WGS 84 UTM (zone 34N)**
Upper left corner: X : 660936.94 Y : 5131755.60 Lower right corner: X : 663828.33 Y : 5125535.61
Temporal reference
Temporal extent **Time period covered by the content of the resource: an individual date/an interval of dates (start and end date)/mix of individual dates and intervals**
...
Date of last revision of the resource, if the resource has been revised
...
Date of creation
2001
Quality and validity
Lineage **Process history and/or overall quality of the spatial data set. If appropriate, include whether the data set has been validated, whether it is the official version, and whether it has legal validity.**
Rosia Montana Gold Corporation S.A.
Spatial resolution **Level of detail? Express as resolution distances (pixel size) or equivalent scales (map scale).**
...
Constraint related to access and use
Conditions applying to access and use **If applicable, provide URL of website where information is available**
☒ No conditions apply
Limitations on public access
☒ No limitations
Organization responsible for spatial data set
Responsible party **For establishment, management, maintenance and distribution of the resource**
Name: Rosia Montana Gold Corporation S.A. Contact (e-mail): ...
Responsible party role
...

Metadata on metadata
Organization responsible for the creation of the metadata **Who filled this metadata record?**
Name: Arcalean Claudiu Contact (e-mail): claudiu.arcalean@rmgc.ro
Metadata date **When was this metadata record created/updated?**
10.08.2010
Remarks
...

Appendix 3.1a – Urals demo site questionnaire – Karabash

General information

Name of the IMPACTMIN demo-site?	Chelyabinsk demo site
Name of the mine/project area	Karabash smelting and mining area
Company exploiting the mine/other type of activities?	Joint-Stock Company “Karabash-copper”
Is the mine active/inactive? Since when? History of exploitation?	The Karabash area contains a number of abandoned mines, wastes from a now closed beneficiation mill and an active Cu smelter. The main activity in the area was the processing of copper ores and concentrates, which commenced in the early 20th century. The copper smelter began operations in 1910. The ore processing and smelting operations have had a major impact on the local environment, causing mass deforestation and acidification and intense metal contamination of local soils, streams and lakes. The town and surrounding area is also host to large areas of waste dumps and tailings, which contain high levels of pyrite, chalcopyrite, sphalerite, galena, quartz, mica, chlorite, etc., and dumps of metallurgical slags, made up of iron-silicate glass, Cu-Zn spinel, zincite, anglesite, Zn-sulphates. From 1990 the smelter specialised in the processing of nonferrous metals. Unfortunately, no data exists on the levels or types of emissions from the smelter between 1989 and 1998. In January 1998 the smelter was taken over by a Joint-Stock Company "Karabash-copper" which began to make “blister Cu” (≈97.5-98.0% pure Cu). A new system for emissions control was installed which has resulted in a 10 fold reduction in Cu and a 2 fold reduction in Zn and Pb emissions in comparison with the 1980s. The total atmospheric emissions from the smelter during its lifetime (1910-2009) is estimated at 14.3 million t (about 174 thousand t/year), including 706 104 t of dusts, containing Cu, Zn, As, Pb, Cd, Hg etc. The maximum height of the smelter chimneys is 127 m, which is the same height as the hills to the west and only slightly above the 100–120 m altitude of the hills to the east. Emissions from the smelter, especially when there is a temperature inversion, often settle into the valley in which Karabash is situated. The beneficiation mill processed ores from Karabash mines from the 1930s until 1990, when the last mine closed. In the latter part of this period, the mill also processed zinc and copper ores from other Urals deposits. The Karabash mines worked typical VMS-deposits. Ores mainly consisted of pyrite, chalcopyrite, sphalerite and bornite. Except for the main targets – Cu and Au, ores contained significant amounts of Zn (2–5 %), Ag (to 48 ppm), S (to 50 %), Fe (to 40–45 %), Ba (to 9 %), and low levels of As, Te, Se, Sb, Cd, Co, Ga, In, Ge, Tl. Until 1958, the wastes (pyritic tailings) were dumped in the river Sak-Elga. The Sak-Elga valley contains 110 ga to a depth of 0.2-0.4 to 2.0 m. From 1958 to 1989 tailings from the beneficiation mill were stored in a 350,000 m^2 constructed tailings dam. This contains around 9.2 million t of tailings. Granulated metallurgical slags from the smelter are mainly contained in a 400 000 t waste dump in the northern part of town. There are also small dumps of “non-economic ores” in and around the town. The tailings, waste dumps and abandoned underground mine workings produce acid mine drainage which flows into local streams

	and lakes.
Which minerals or materials are being extracted? Extraction processes? Volumes?	The Karabash underground mines extracted Cu-Zn ores from 4 shafts to depths ranging from 350 to 900 m. The shafts are now flooded and emitting acid mine drainage into local streams. The smelter is still operational, smelting concentrates from other mines in the Urals, and possibly also carrying out reprocessing operations. Unfortunately little information is available in the public domain on the scope of the smelter operations.
Location? Area?	See www.impactmin.ru
Maps and pictures of the area?	Topographic maps at a scale of 1:100,000 are officially accessible and may be used for the project.
Site access? Infrastructure? Hazards?	There is good road access to and within Karabash. In the summer woodland tracks can also be used. The main hazard is from gaseous and metal-rich airborne emissions from the smelter, and from contaminated sediments and waters.

Environmental impact

General description of the physical environment?	Karabash is located in the Southern Urals, in the Chelyabinsk district. To the west are large hills which rise to an altitude of 700–900 m. To the east are small-hills rising to 230–270 m. In the eastern part there is a poorly developed river network with many lakes and marshes. The largest water body is the Argazy water reserve, which covers an area of 106 кm^2 and has a maximum depth of 18 m. Smaller lakes include the Big and Small Agardyash, Alabuga, Ufimskoe, Serebry and Big Barny. The main river is the Miass which receives waters from the Big Kialim, Indashta, Atkus and the river Sak-Elga. The Miass reaches a depth of 3 m and has a flow rate from 0.3 to 1.7 m/s. The climate of the area is continental and humid. Moist winds blow in from the west, mainly from the Atlantic ocean and the Kara sea. The climate is also heavily influenced by the presence of the Ural Mountains where most precipitation occurs. The mean annual temperature in the Karabash area is +1.3 to 1.8 °C, from – 40 °C (minimum) in the winter to + 35 °C (maximum) in the summer. The average annual precipitation is 450–500 mm, 70 % of this falling in summer. The snow pack begins to form at the end of November and reaches a maximum thickness of 60–80 cm in February to March. In the mountain areas this can reach 1 m. The ridges around Karabash receive 30% more precipitation than the valley. The lowest air humidity (40–50 %) occurs in May and the highest in December (80–85 %). The wind rose is complex, 28 % of the time the wind blows towards the east, 17 % to the northeast, 15 % to the north, 5 % to the northwest, 15 % to the southeast, 9 % to the south, 7 % to the southwest and 4 % to the west. The soils around Karabash are typically grey forest soils. Their main characteristic is that they are generally very rocky and have a low gumic sub-horizon between 15 to 25 cm. The soils therefore tend to be prone to erosion. The woods are dominated by common pine and warty birch. There are also a few mountain ash trees, linden and aspen. Animals in the woods include bears, elks, wolves, lynxes, beavers, foxes, hares, marmots, minks, otters and fibers. In the woods and on boggy sites there are many kinds of birds, mushrooms, mosses and lichens. In the rivers and lakes, which are not too contaminated, there are a variety of fish. Geology of the demo site – The rocks of the Karabash area are dominated by alkaline rocks and metamorphic complexes containing quartzites and granite-migmatites. There are also large outcrops of serpentinite. Limestones and volcanic rocks are poorly

	represented and where they occur are heavily eroded. The area lies within the zone of the Main Urals fault, specifically in the northern part of the 'West Magnitogorsk deflection'. The rocks are dominated by arc-volcanics of the western part of the Ilmeno-Vishnevogorskogo metamorphic complex. The area is in the so-called "Ufa ledge" East European platform. Copper and gold deposits are connected within Paleozoic volcanic-sedimentary complexes which contain ultramafic rocks belonging to the West Magnitogorsk structural zone. To the west are rocks of the West Ural 'megazone' which are mainly gneisses and migmatites of the Uraltau.
Maps and pictures of the mine site?	
Description of the mining-related processes which affect the environment? Rank in order of seriousness?	The main sources of contamination to surface waters are waste dumps and tailings. Waters in the "Red creek" stream are characterised by low pH (2.7–2.9), high contents of heavy metals, with Cu from 20–50 mg/l, Zn from 60–80 mg/l and Al from 240–350 mg/l. Non-impacted sections of the Sak-Elga and Miass rivers have values for pH of 6.5–7.9 and low contents of metals (Cu 0.01 mg/l, Zn 0.1 mg/l, Al 0.01 mg/l). The main problem is contamination of sediments in the northern part of the Argazi water reserve (A.w.r.). This contains around 200,000 t of pyrite tailings and has been contaminated by fallout of airborne particulates from the smelter. The main source of contaminants in the terrestrial environment is the Karabash copper smelter. Accumulation of metals in the soils is most evident in the top layers (12-15 cm), irrespective of soil type. There is a sharp fall in the levels of metals with depth. Soil solutions contain abnormally high levels of metals. By carrying out biomonitoring studies (mainly using lichens) it has been possible to determine that the area surrounding Karabash has been contaminated to a distance of up to 18 km, mainly due to the fallout of atmospheric particles.
Visible impact on the environment?	
Is the situation stationary or progressive?	The chemical characteristics of surface waters changes with the season. Emissions from the smelter will vary depending on the volumes of concentrate being smelted and the climatic factors, mainly wind direction.
Actions for rehabilitation already done?	none

Previous studies

Do previous studies exist?	In 1975-1980, Makunina carried out research on the degradation of soils due to atmospheric emissions from the smelter (Makunina, 1979). They also investigated some aspects of the contamination of surface waters, climatic factors and the effects on the surrounding landscape. In the 1980s Stepanov et al. studied the influence of smelter emissions on ecosystems around Karabash, particularly on pine-birch forests (Stepanov et al., 1989). They established that the occurrence and diversity of species, and the structure of the soils is impoverished downwind from the smelter. In 1988-1989, geochemical studies were carried out in the area of Karabash by Nesterenko (2004). The aim of the work was to determine levels and types of metal in soils, stream sediments, vegetation and agricultural products. During the same period, Korablev et al. (not dated) published figures for the volumes of tailings and metallurgical slags in and around Karabash town.

	Regular studies have been carried out around Karabash by a team from the Institute of Mineralogy in Miass (Udachin et al., 1998; Udachin et al., 2003; Belogub et al., 2006). Between 2000-2004, additional works were carried out under the European Commission 5th Framework Programme INCO-Copernicus 2 contract (ICA2-CT-2000-10011). This produced publications in English, including Williamson et al. (2004), Spiro et al. (2005) and Brooks et al. (2005). Students and teachers of the South-Ural and Chelyabinsk state Universities and also employees of Hiroshima university (Prof. R.Kitagava) are also involved in works (Kitagawa et al., 2006).
By which institutes/companies?	
Reports available? Literature? Add references?	
Studies in comparable mine sites in the region? Add references?	

Data availability

In situ data?	
Remote sensing data available at your institute?	
Other relevant data?	
Remote sensing or other data available at (regional) providers / partners / institutes / clients / ...? Cost?	

Expectations

What do you think can be the added value of using satellite and/or airborne remote sensing techniques for monitoring environmental impacts of the mine?	

Socio-economical issues

How many people are employed by the site?	13,500
Is the site being used for non-mineral purposes?	No

Are there other commodities (non mineral) that are being used from the site (e.g. water, power)?	Yes, water from the Argazi water reservoir.

Appendix 3.1b – Urals demo site questionnaire – Mednogorsk

General information

Name of the IMPACTMIN demo-site?	Orenburg demo-site
Name of the mine/project area	Mednogorsk smelting and mining area
Company exploiting the mine/other type of activities?	Mednogorsky copper-sulfur plant”
Is the mine active/inactive? Since when? History of exploitation?	The main sources of contamination in the demo site area are the Blyava and Yaman-Kasy mines, the beneficiation mill and the copper smelter. The Blyava deposit was exploited from the 1930s, with the main period of activity from 1936 on 1972, via open pit and underground workings. The ore body, which is a typical VMS-deposit, lay on the western contact between large subvolcanic rhyolitic porphyries and pillow lavas of Silurian age which they intruded. The “Mednogorsk copper-sulphur plant” has operated since 1937. The plant began producing low quality sulphur, but after the Second World War began to produce Cu concentrate (Cu 12-17 %) which was transported to the Karabash smelter (Chelyabinsk district) and Kirovgrad smelter (Sverdlovsk district) plants for refining. Between 1959-1962, following the construction of converters, the plant began to produce non-refined copper. In 1960 the plant began to process ores from the Gay deposit. In 1961 it began sulfuric acid production. A large volume of waste was accumulated from these various processes between 1952 and 1972.
Which minerals or materials are being extracted? Extraction processes? Volumes?	The Blyava open pit (1952-1972) and Yaman-Kasy open pit (1987-2002) produced Cu-Zn ores. The open pits are currently flooded and contain pit lakes (the file in PDF-version "Pit lakeU" is attached). The depth of water in the pit lakes is 42 and 43 m, respectively. The “Mednogorsk copper-sulfur plant” is still operational. The plant emits 68000 t/year of gases and dusts. The plant belongs to the "Ural mining-metallurgical company", which currently owns 4 copper smelters and 9 mines in the Urals.
Location? Area?	See www.impactmin.ru
Maps and pictures of the area?	Topographic maps at a scale of 1:100,000 are officially accessible and can be used for the project.
Site access? Infrastructure? Hazards?	The demo site can be accessed via the Orenburg-Chelyabinsk railway and the Orsk-Orenburg highway. Dirt tracks in the area can only be accessed in the summer. The population of Mednogorsk is 32,000. Hazards are the same as in any other mining/industrial site.

Environmental impact

General description of the physical environment?	Mednogorsk city is located in the Southern Urals, in the Kuvandyksky administrative area of the Orenburg district. All demo sites in the Orenburg district lie within the Blyavinsky geomorphological area. This Blyavinsky area lies between the river Blyava to the south, and the river Kuragan to the northeast. The area lies on the western slopes of the Southern Urals mountains, in the Sakmarsky geological zone. The geology of the area is highly complex, lying within a zones which has been dismembered due to large scale faulting. The landscape consists of a series of extended ridges, rounded hills and shallow valleys. The main rivers of the area are the

	Kuragan and Blyava, which have their source in the western slopes of the main watershed of the Southern Urals mountains. These rivers lie within the Sakmary river basin, and have well developed, deep and wide valleys, and distinctive terraces. There are 2 main terraces, the first at 2-3 m, and the second at 7-10 m above the mean river level. The modern channels of these rivers have widths of 10 to 20 m. The climate of the area is sharply continental with hot short summers and cold long winters. The highest levels of precipitation, around 60%, occur in summer and autumn. A covering of snow begins to form between November and December. The average temperature of the warmest month (July) is +22.1ºC, with a maximum temperature of +36. The average temperature of the coldest month (January) is -20.4ºC, with a minimum of -38 ºC. The wind is mainly either from the east or west. Ground waters in the area are mainly hosted in Paleozoic volcanic and metamorphic rocks, and younger Mesozoic, Cenozoic and Holocene lithologies. However, climatic, geomorphological and geological conditions in area are not favourable to the development of underground aquifers, due to high rates of evaporation and poor water retention. The largest aquifers are in Mesozoic and Cenozoic lithologies. Holocene alluvial deposits cover ancient plains and are characterised by high water penetration rates. Soils in the Orenburg demo sites are mainly mountain chernozems. This soil type differs from typical chernozems due to a reduced gumic horizon (horizon A which exceeds 40 cm) and a high content of rock fragments in all underlying horizons. Also, mountain chernozems usually have a high content of clay in horizons B and C (to 75 %).
Maps and pictures of the mine site?	
Description of the mining-related processes which affect the environment? Rank in order of seriousness?	Leachates from the waste dumps and tailings are acid, with a pH from 3.4 to 5, and contain high concentrations of potentially toxic metals (Cu 10–70 mg/l, Zn 30–110 mg/l, Al 50–350 mg/l). Non-impacted sections of the river Blyava have high values for pH of 8.07–8.25 and low contents of metals – Cu and Zn to 0.01 mg/l.
Visible impact on the environment?	SEM-photo with EDAX-spectra for dust, chemical composition of AMD (including pit lake waters), secondary sulphates is available in small amount and in publications in Russian. Works on this will be carried out within WP7.
Is the situation stationary or progressive?	The condition of waterways depends on the season and climatic features. The levels of atmospheric emissions mainly depends on the rate of sulfuric acid production and the wind direction.
Actions for rehabilitation already done?	Acid waters entering the river Zhiriclya have been treated since 2006 using active methods. No rehabilitation of the pit lakes has been carried out.

Previous studies

Do previous studies exist?	Environmental-geochemical studies on the landscapes of the Mednogorsk area were carried out by Bodrov (1997). Three main types of landscapes were identified: illuvial (areas of higher relief), transilluvial, and nea-aquatic (basins containing deposited materials). There are also two articles about medical issues in the Mednogorsk area (Boev et al., 2002; Kuksanov et al., 2006). Two articles report the compositions of waters from pit lakes (Udachin et al., 2009) and surface waters (Aminov, 2008). Two abstracts report the geochemical compositions of soils and the forms of heavy metals, metal bioavailability and risk estimations (Udachin, 2010; Udachin, 2010a). Most of these papers are published in Russian.
By which institutes/companies?	

Reports available? Literature? Add references?	
Studies in comparable mine sites in the region? Add references?	

Data availability

In situ data?	
Remote sensing data available at your institute?	
Other relevant data?	
Remote sensing or other data available at (regional) providers / partners / institutes / clients / ...? Cost?	

Expectations

What do you think can be the added value of using satellite and/or airborne remote sensing techniques for monitoring environmental impacts of the mine?	To assess the spatial distribution of impacts from the mining-related activities in the Orenburg sites, including effects on vegetation.

Socio-economical issues

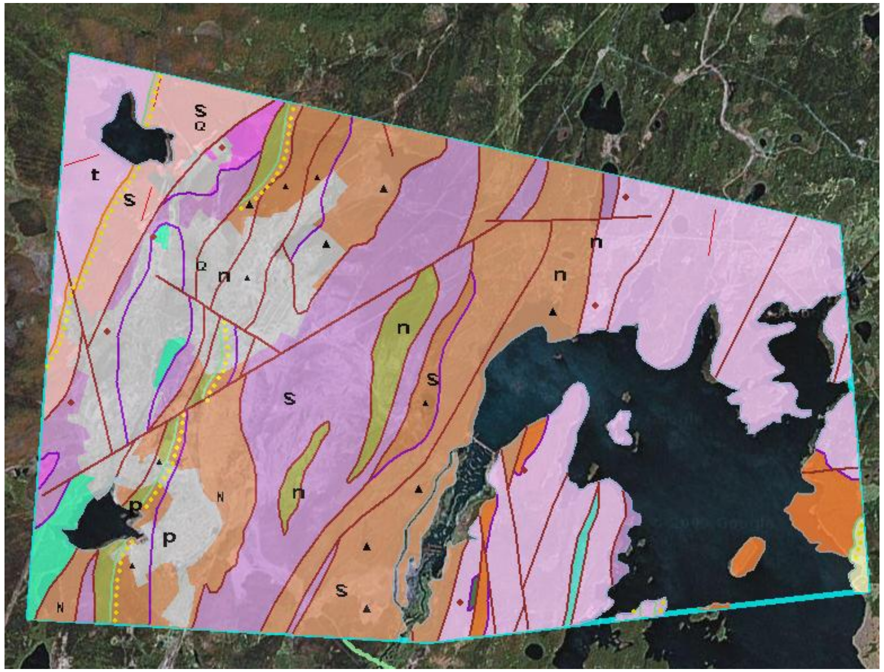
How many people are employed by the site?	32,000
Is the site being used for non-mineral purposes?	Yes
Are there other commodities (non mineral) that are being used from the site (e.g. water, power)?	In city the factory on which works electric motors make

Appendix 3.2a – Urals metadata questionnaire – Karabash

Site "Karabash" - the original map: State geological map scale 1:200000. Second edition. A series of South Urals. Sheet N-41-I (Kyshtym). Prepared for publication in 2008

General information:

Наименование	Geographical position		Satellite imagery	Onboard image	URL
	Upper left corner	Lower right corner			Language
Karabash demo site	X: 60.175641761964 Y: 55.430712596142	X: 60.4179871595251 Y: 55.5277567148089	GoogleMapsLayer	отсутствуют	http://impactmin.ru/Default.asp?IdM=Worksru/en



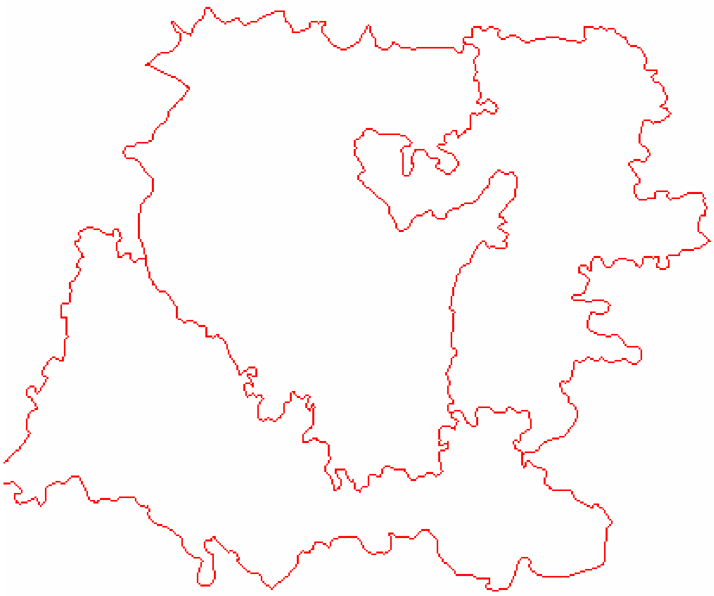
Description of the resource data

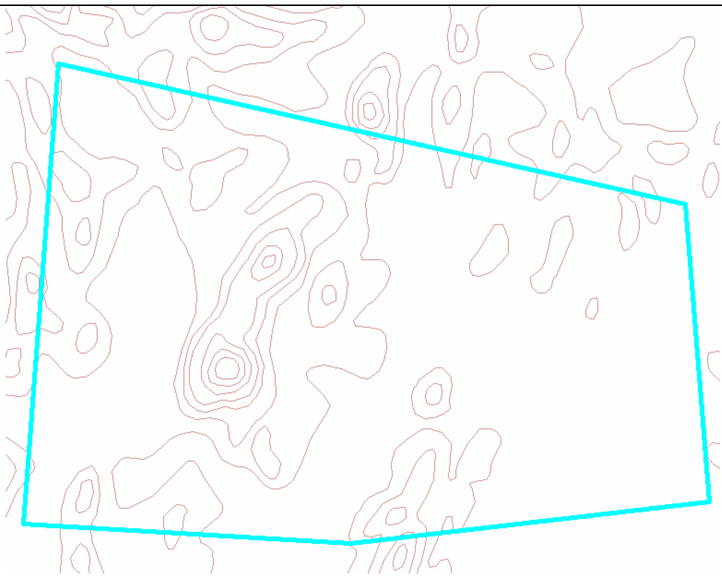
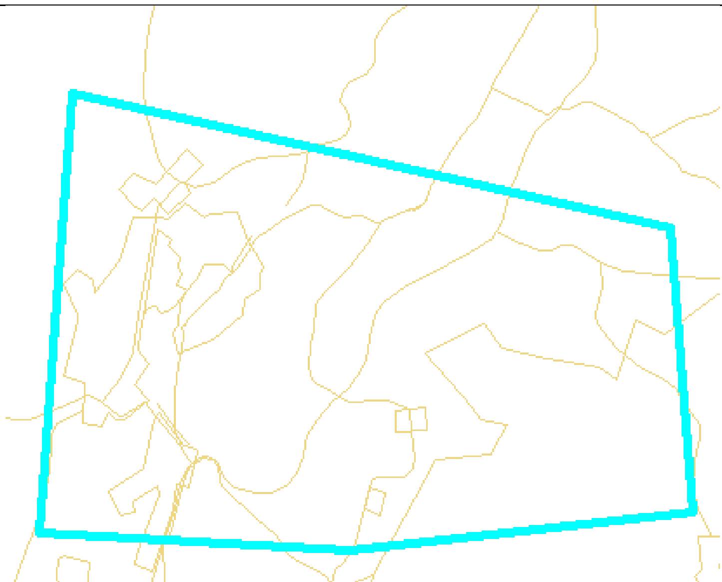
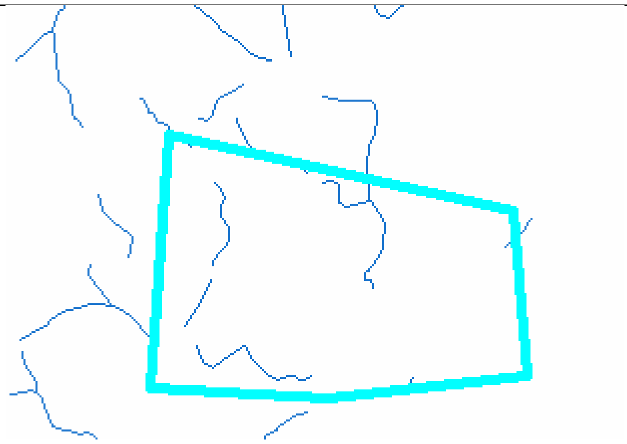
Identification	Name	Characteristic and Brief description	Type (1- vector, format - shp 2- vector, database, mdb)	Date Range (year)	Last Modified Date (year)	Date Created (year)	Quality	History	Scale	limitations related to access and use	Condi-tions for applying to access and use
1. **Topology and other data** The company supplies data – open source											
1.1.world.shp	Country	Country 1000000	1	2006-2010	2008	2006, samples		2006, samples	1:100000000	no	no
1.2. Capitals.shp	Capitals	Capitals 1000000	1	2006-2010	2008	2006, samples	average	2006, samples	1:100000000	no	no
1.3.s_447.shp	Border of the regions	Border of the regions (Chelyabinsk,Orenburg Regions)	1	2006-2010	2009	2009	average	2009	1:100000	no	no
1.4.121.shp	Topological basis	Topological basis Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009		2009	1:100000	no	no
1.5.123.shp	Roads	Roads Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009	average	2009	1:100000	no	no
1.6.122.shp	River	River Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009	average	2009	1:100000	no	no
1.7.town- Point From Database	Towns	Towns Chelyabinsk, Orenburg Regions	2	2008-2010	2009	2009	average	2009	1:100000	no	no
1.8. Settlements - point - FromDatabase	Settlements	Settlements Chelyabinsk, Orenburg Regions	2	2008-2010	2009	2009	average	2009	1:100000	no	no

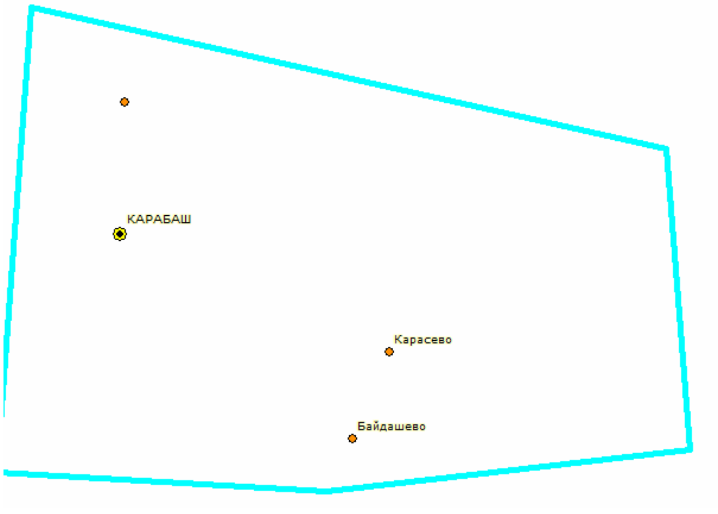
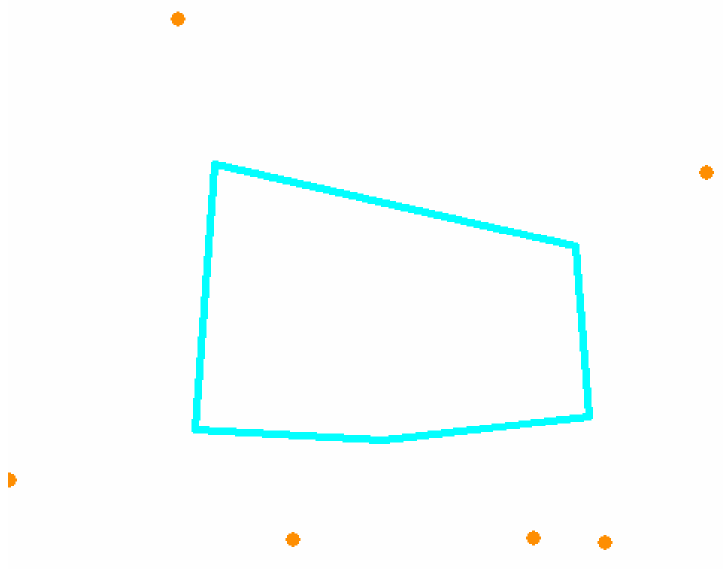
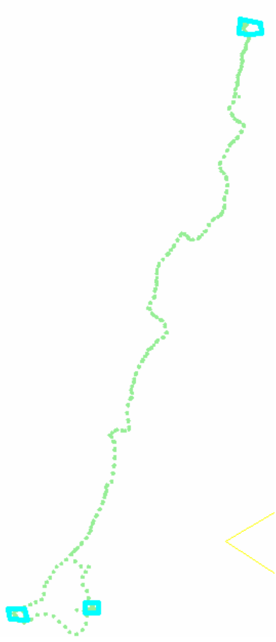
1.9. Nature monuments - Point From Database	Nature monuments	Nature monuments Chelyabinsk Regions	2	2008-2010	2010	2008	good	2010	1:2000	no	no
1.10.impaktmin201007.shp	Route impaktmin	Route impaktmin-work in Chelyabinsk, Orenburg Regions	1	2010	2010	2008	good	2010	1:2000	no	no
1.11.s_432.shp	Mineral deposits	Chelyabinsk Regions	1	2008-2010	2010	2008	good	2008	1:100000	ImpactMin	authorization
1.12.s_314.shp	Water protective zone	Water protective zone Chelyabinsk Regions	1	2008-2010	2010	2008	average	2008	1:100000	ImpactMin	authorization
1.13. Sites.shp	Sites	Sites impaktmin-work in Chelyabinsk, Orenburg Regions	1	2008-2010	2010	2010	good	2010	1:100000	ImpactMin	authorization
2. **Geology.** The company supplies data - Limited Liability scientific and technical production company (LLC NTPP) "Geopoisk"											
2.1.base_p7ecolog.shp	Ecological point	Ecological point	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.2.baseaecolog.shp	Ecological area	Ecological area	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.3.basealecolg.shp	Ecological	Ecological	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.4.baselecolog.shp	Ecological lines	Ecological lines	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.5.elem_zaleg_p01.shp	Elements of the bedding	Elements of the bedding	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.6.elem_zaleg_p02.shp	Elements of the bedding	Elements of the bedding	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization

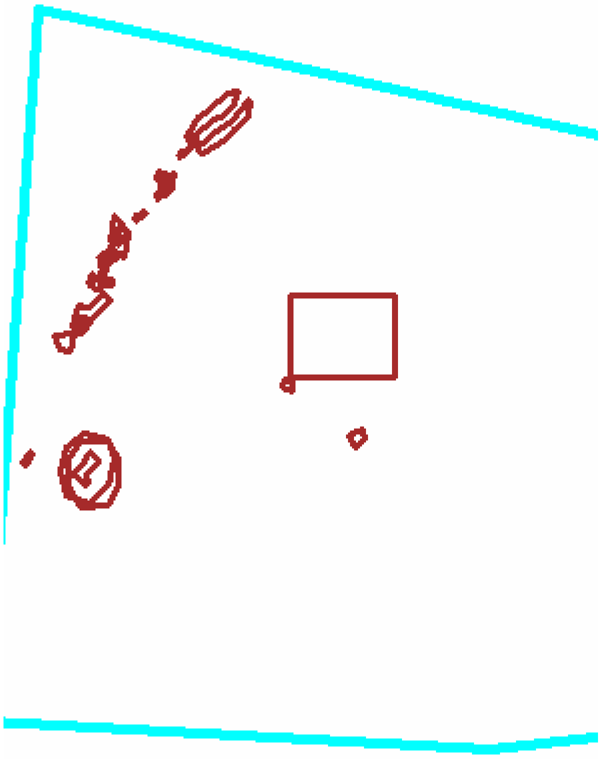
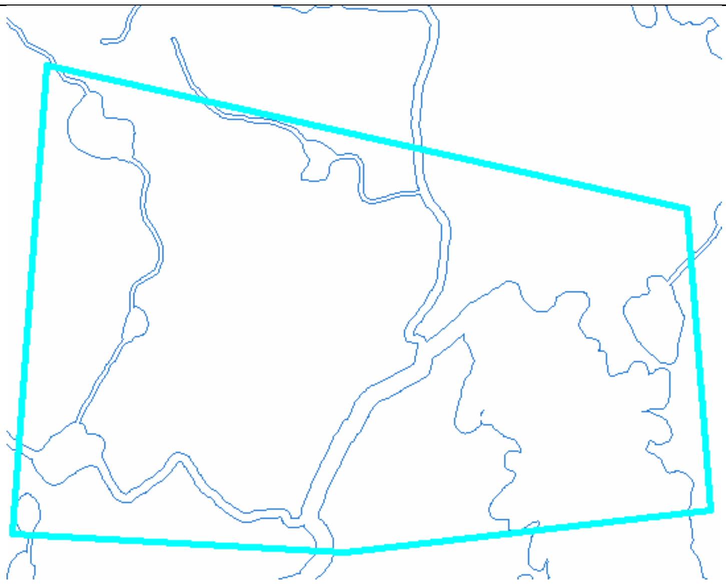
2.7.krap_p1ecolog.shp	Ecological Specks	Ecological Specks	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.8. Polygon From Database	Dumps and quarries	Dumps and quarries	2	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.9.ppaecolog.shp	Ecological dirty	Ecological dirty	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.10.tectlecolog_l02.shp	Tectonic Line	Tectonic Line	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.11.tectlecolog_p02.shp	Tectonics	Tectonics	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.12. polygons.shp	minerals area	minerals area	1	2010	2010	2010	average	2010	1: 200000	ImpactMin	authorization

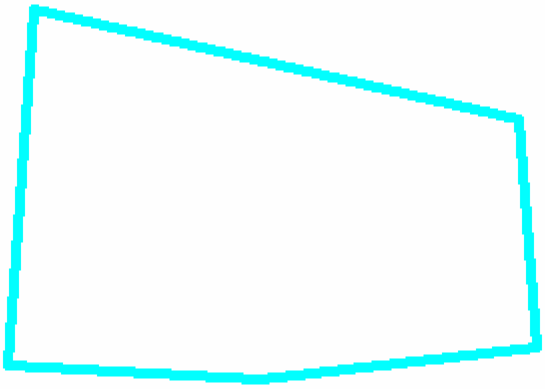
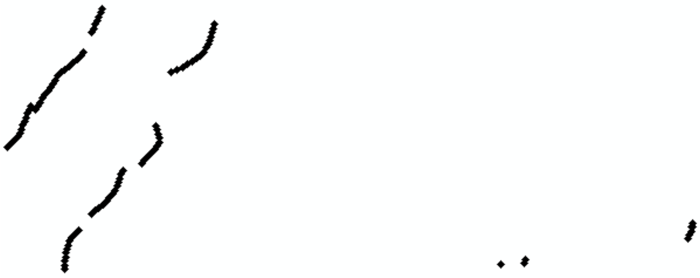
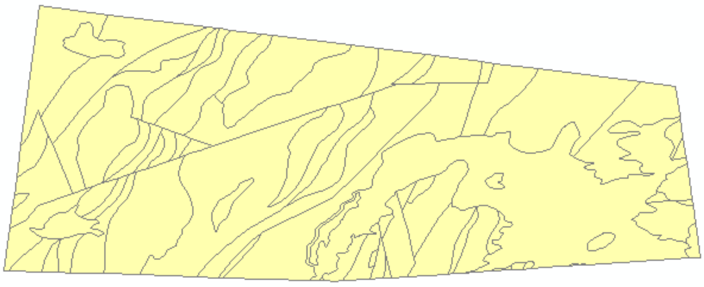
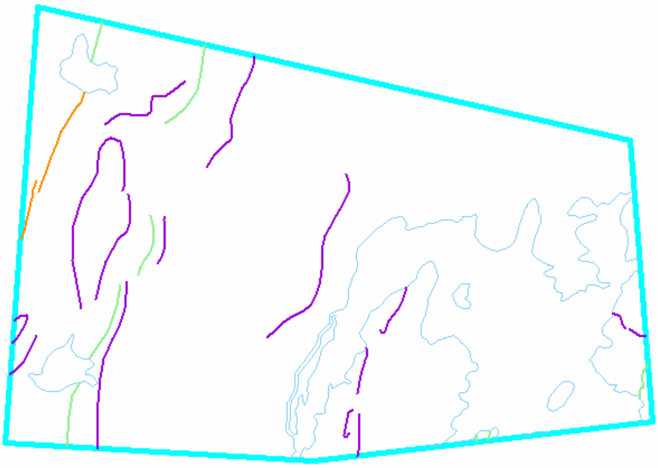
View source map

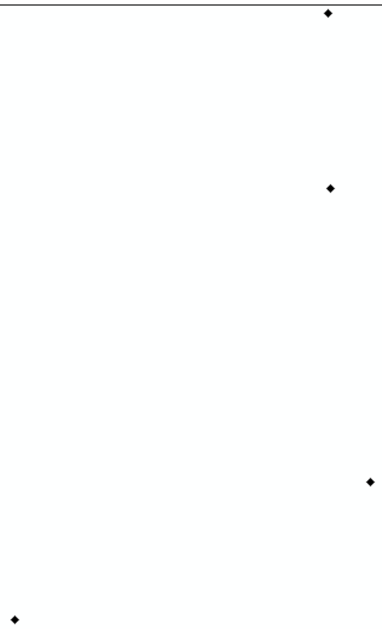
Identification	Name	Layer
1.1.world.shp	Country	
1.2. Capitals.shp	Capitals	
1.3.s_447.shp	Border of the regions	

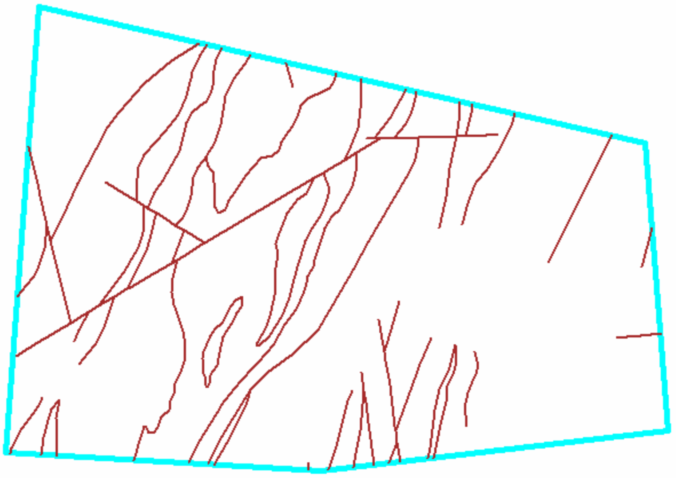
1.4.121.shp	Topological basis	
1.5.123.shp	Roads	
1.6.122.shp	River	

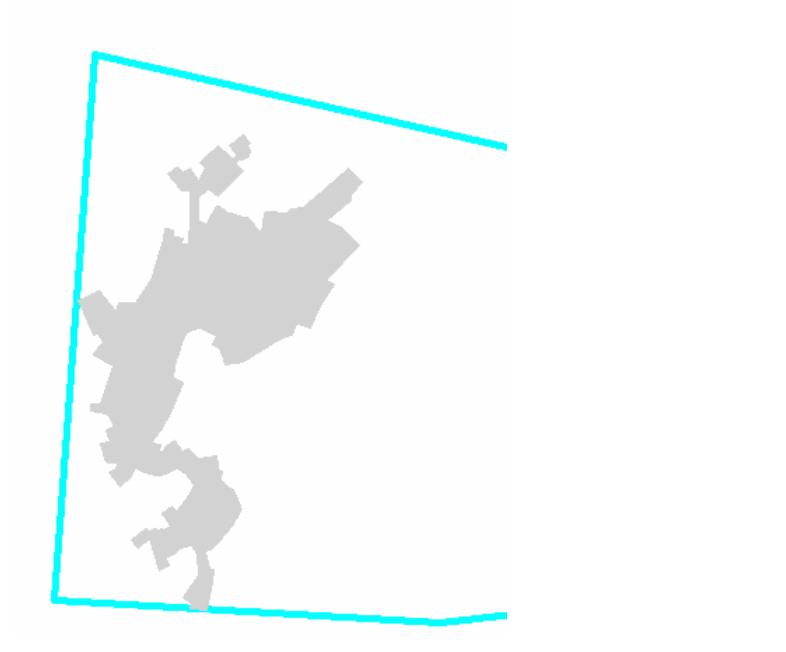
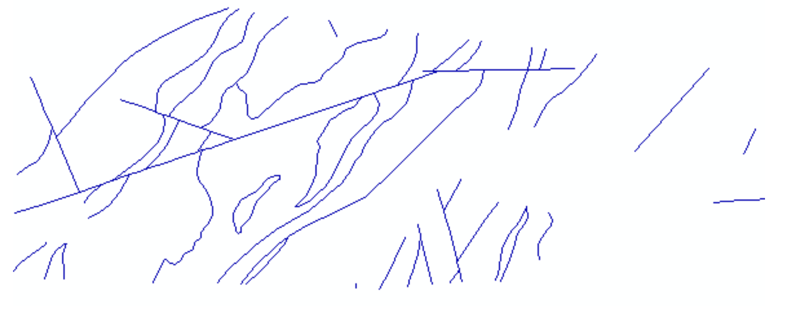
1.7.town- Point From Database	Towns	
1.8. Settlements -point - FromDatabase	Settlements	
1.9. Nature monuments - Point From Database	Nature monuments	
1.10.impaktmin201007.shp	Route impaktmin	

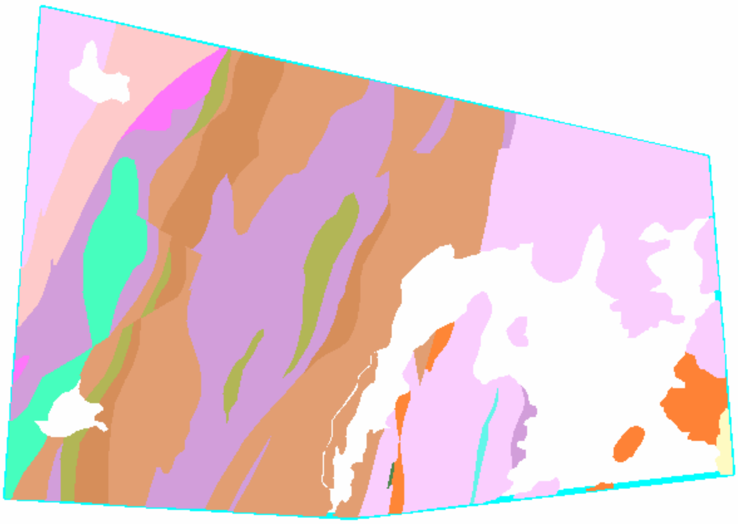
1.11.s_432.shp	Mineral deposits	
1.12.s_314.shp	Water protective zone	

1.13. Sites.shp	Sites	
2.1.base_p7ecolog.shp	Ecological point	
2.2.baseaecolog.shp	Ecological area	
2.3.basealecolg.shp	Ecological	

2.4.baselecolog.shp	Ecological lines	
2.5.elem_zaleg_p01.shp	Elements of the bedding	
2.6.elem_zaleg_p02.shp	Elements of the bedding	

2.7.krap_p1ecolog.shp	Ecological Specks	
2.8. Polygon From Database	Dumps and quarries	

2.9.ppaecolog.shp	Ecological dirty	
2.10.tectlecolog_l02.shp	Tectonic Line	
2.11.tectlecolog_p02.shp	Tectonics	

2.12. polygons.shp	minerals area	

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Responsible party role – the software part of the project

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Author of metadata records – Grebennikova Luidmila (gln@ilmeny.ac.ru)

Date of metadata creation -December/2010.

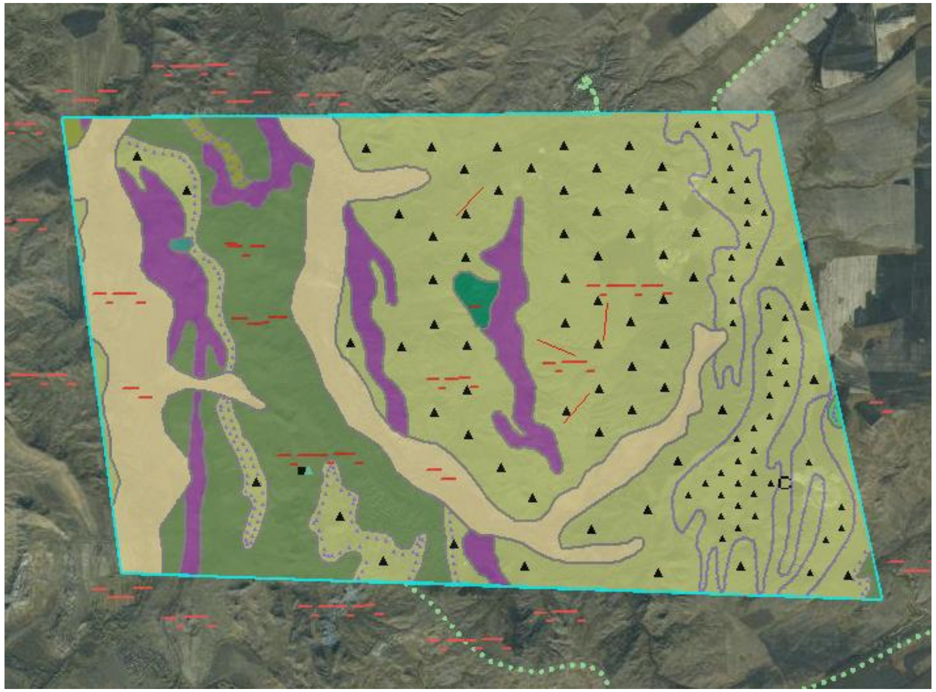
Appendix 3.2b – Urals metadata questionnaire – Mednogorsk

Site "Mednogorsk" - the original map: State geological map scale 1:200000. A series of South Urals. Sheet M-40-IV (Mednogorsk), 1956 Published in 1957

Go to the site "Mednogorsk"and "Gay" used URAL LEGEND SERIES SHEETS Gosgeolkarta-1000 / 3. VSEGEI, 2005

General information:

Наименование	Geographical position				URL
	Upper left corner	Lower right corner	Satellite imagery	Onboard image	Language
Mednogorsk demo site	X: 57.5005848568374 Y: 51.3891525439969	X: 57.6858501017362 Y: 51.4669934719632	GoogleMapsLayer	no	http://impactmin.ru/Default.asp?IdM=Worksru/en



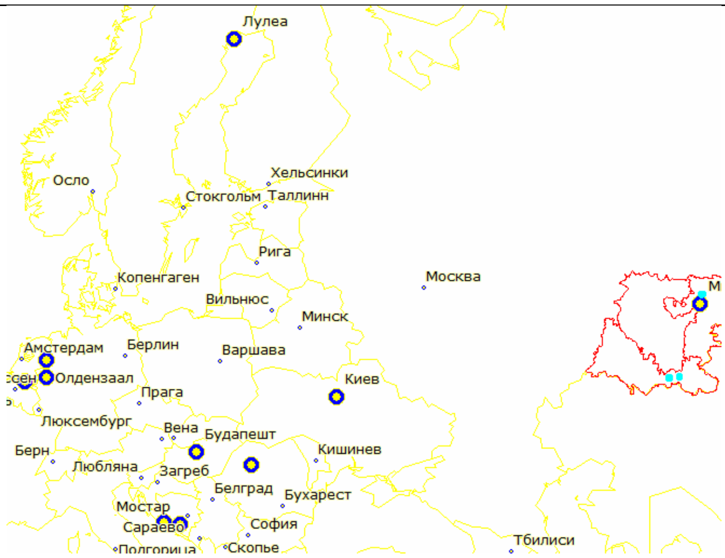
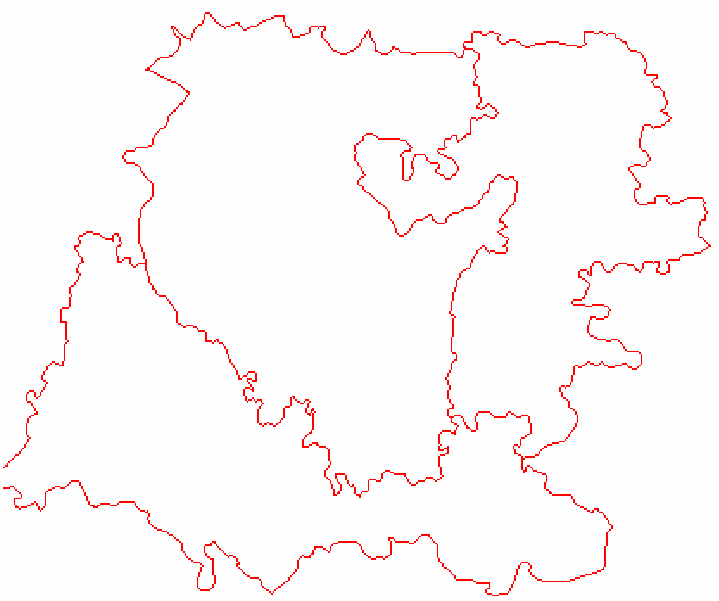
Description of the resource data

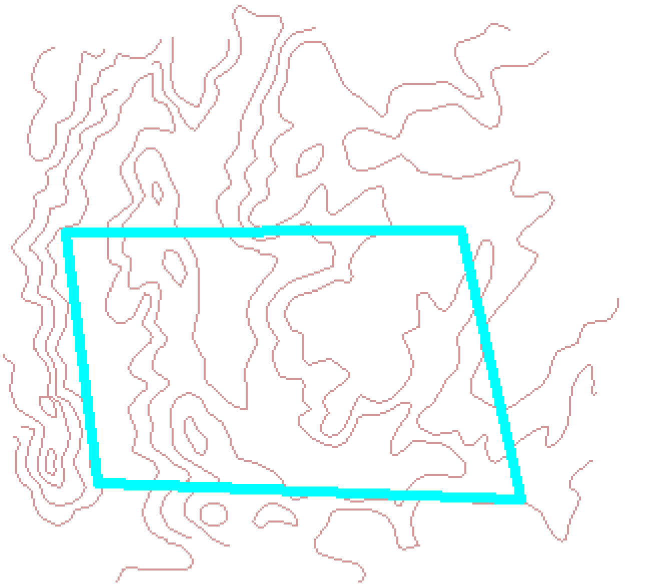
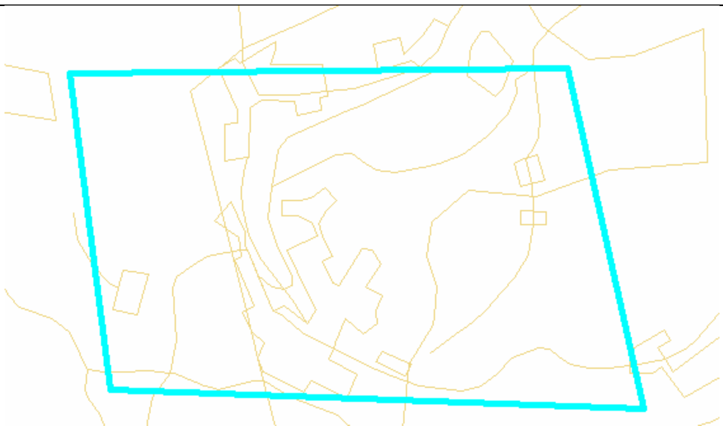
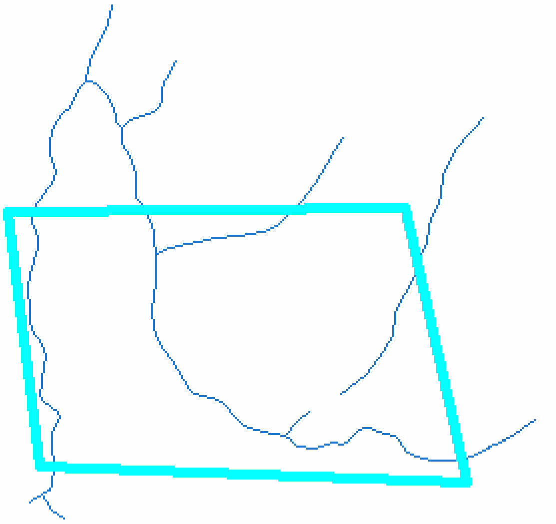
Identification	Name	Characteristic and Brief description	Type (1- vector, format - shp 2- vector, database, mdb)	Date Range	Last Modified Date	Date Created	Quality	History	Scale	limitations related to access and use	Condi-tions for applying to access and use
3. Topology and other data The company supplies data – open source											
1.1.world.shp	Country	Country 1000000	1	2006-2010	2008	2006, samples		2006, samples	1:100000000	no	no
1.2. Capitals.shp	Capitals	Capitals 1000000	1	2006-2010	2008	2006, samples	average	2006, samples	1:100000000	no	no
1.3.s_447.shp	Border of the regions	Border of the regions (Chelyabinsk,Orenburg Regions)	1	2008-2010	2009	2009	average	2009	1:100000	no	no
1.4.121.shp	Topological basis	Topological basis Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009		2009	1:100000	no	no
1.5.123.shp	Roads	Roads Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009	average	2009	1:100000	no	no
1.6.122.shp	River	River Chelyabinsk, Orenburg Regions	1	2008-2010	2009	2009	average	2009	1:100000	no	no
1.7.town- Point From Database	Towns	Towns Chelyabinsk, Orenburg Regions	2	2008-2010	2009	2009	average	2009	1:100000	no	no
1.8. Settlements - point - FromDatabase	Settlements	Settlements Chelyabinsk, Orenburg Regions	2	2008-2010	2009	2009	average	2009	1:100000	no	no

1.9. Nature monuments - Point From Database	Nature monuments	Nature monuments Chelyabinsk Regions	2	2008-2010	2010	2010	good	2010	1:2000	no	no
1.10.impaktmin201007.shp	Route impaktmin	Route impaktmin-work in Chelyabinsk, Orenburg Regions	1	2010	2010	2010	good	2010	1:2000	no	no
1.11.s_432.shp	Mineral deposits	Chelyabinsk Regions	1	2008-2010	2010	2010	good	2010	1:100000	ImpactMin	authorization
1.12.s_314.shp	Water protective zone	Water protective zone Chelyabinsk Regions	1	2008-2010	2008	2008	average	2008	1:100000	ImpactMin	authorization
1.13. Sites.shp	Sites	Sites impaktmin-work in Chelyabinsk, Orenburg Regions	1	2008-2010	2010	2010	good	2010	1:100000	ImpactMin	authorization
4. **Geology.** The company supplies data - Limited Liability scientific and technical production company (LLC NTPP) "Geopoisk"											
2.1.daiki.shp	Daiki	Daiki	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.2.elem_zaleg.shp	Elements of the bedding	Elements of the bedding	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.3.index.shp	Index	Index	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.4.krap.shp	specks	specks	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.5. Polygon From Database	Dumps and quarries	Dumps and quarries	2	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.6.geol_border_l.shp	Geology border	Geology border	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization

2.7.geol_border_p.shp	Geology border-polygon	Geology border-polygon	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.8.quartzite.shp	Quartzite	Quartzite	1	2008-2010	2010	2008	good	2008	1: 200000	ImpactMin	authorization
2.9.fauna.shp	Fauna	Fauna	1	2008-2010	2010	2008	average	2008	1: 200000	ImpactMin	authorization
2.12. polygons.shp	minerals area	minerals area	2	2010	2010	2010	average	2010	1: 200000	ImpactMin	authorization

View source map

Identification	Name	Layer
1.1.world.shp	Country	
1.2. Capitals.shp	Capitals	
1.3.s_447.shp	Border of the regions	

1.4.121.shp	Topological basis	
1.5.123.shp	Roads	
1.6.122.shp	River	

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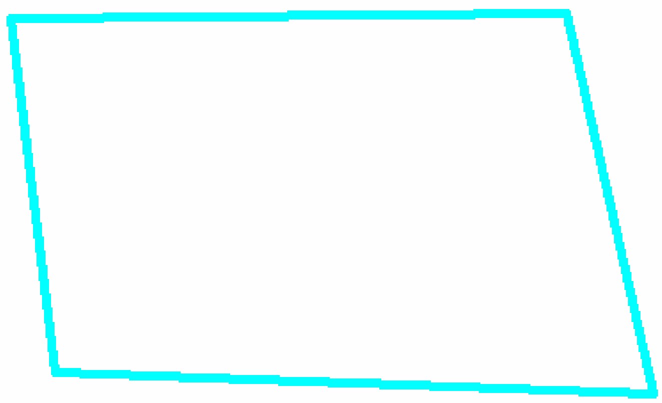
</td></tr>
<tr><td>1.8.Settlements - point - FromDatabase</td><td>Settlements</td></tr>
<tr><td>1.10.impaktmin201007.shp</td><td>Route impaktmin</td><td></td></tr>
<tr><td>1.13.Sites.shp</td><td>Sites</td><td></td></tr>
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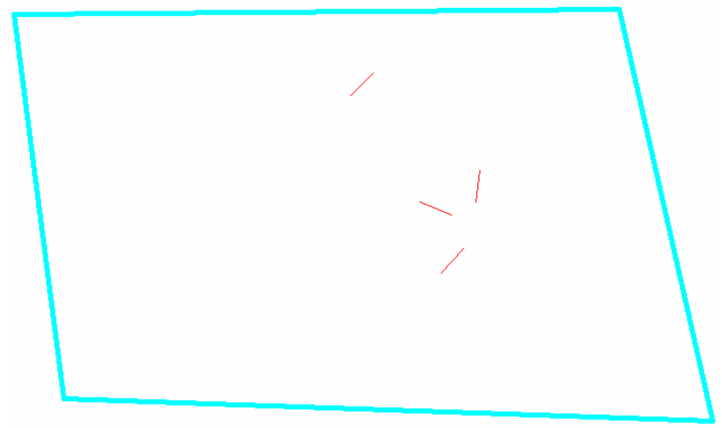
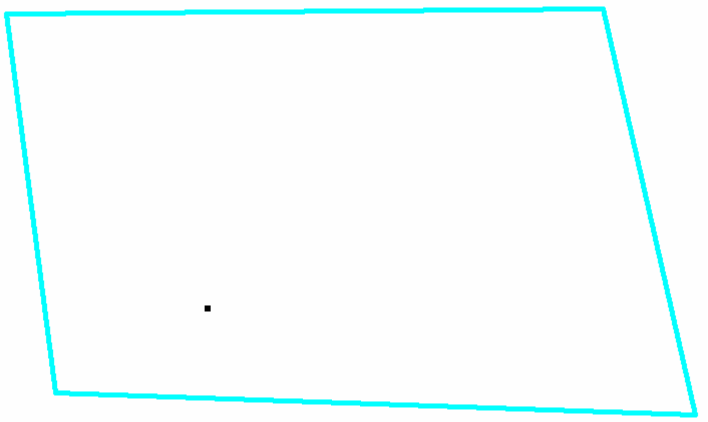
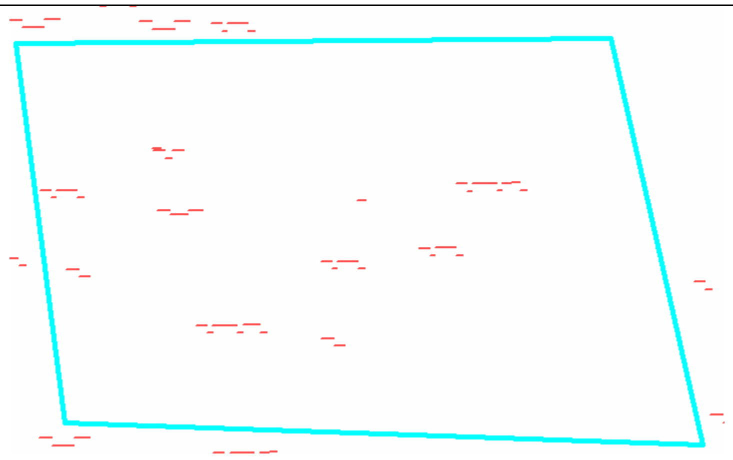
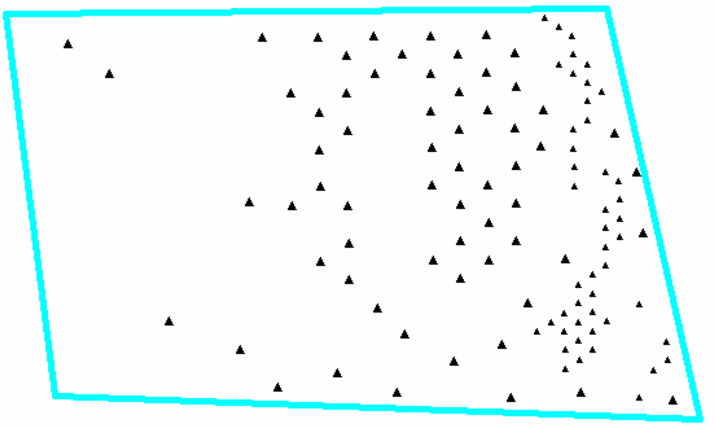
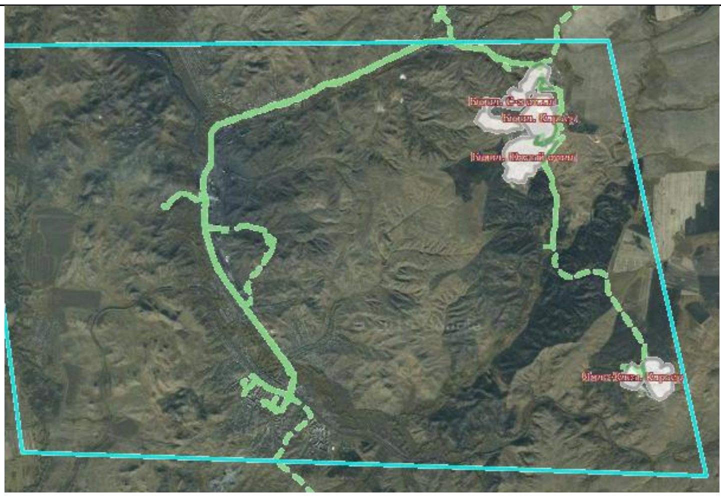
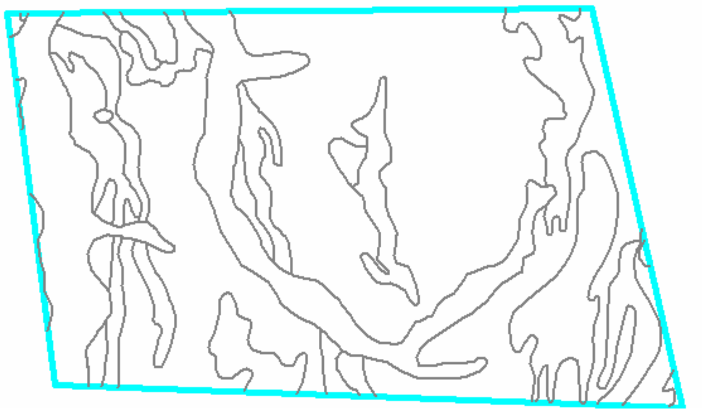
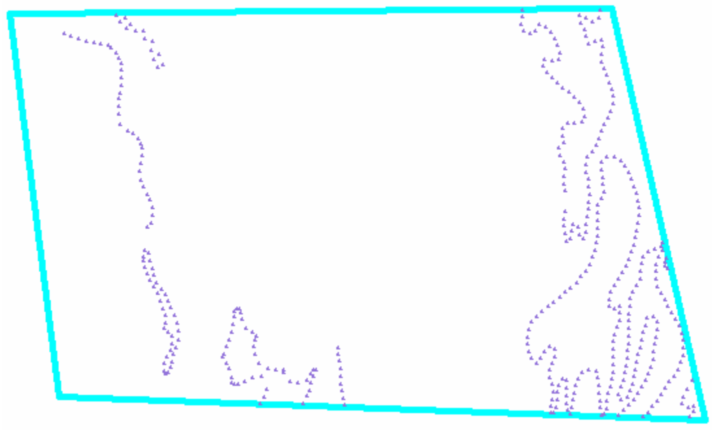
2.1.daiki.shp	Daiki	
2.2.elem_zaleg.shp	Elements of the bedding	
2.3.index.shp	Index	

2.4.krap.shp	specks	
2.5. Polygon From Database	Dumps and quarries	
2.6.геол_гран_l.shp	Geology border	

2.7.геол_гран_р.shp	Geology border-polygon	
2.9.фауна.shp	Fauna	
2.10. polygons.shp	minerals area	

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Date of metadata creation - December/2010.

Appendix 4.1 – General satellite data preprocessing

Landsat preprocessing

Modified from Bruce and Hilbert (2006)

Geometric correction

The preprocessing of the Landsat time series will consist in the first place of geometric correction and orthorectification. Ground control points will be taken from topographic maps, and the best quality DEM will be used for orthocorrection. When applying the geometric correction and relief displacement correction procedures, the Nearest Neighbour (NN) resampling algorithm can be employed so as to maintain spectral integrity. It will also be important to maintain geometric consistency between the images of the time series, thus image co-registration or relative geometric correction might be necessary.

Radiometric correction

Following the geometric correction, radiometric corrections must be considered. The brightness value measured for any given object is influenced by factors such as changes in scene illumination, atmospheric conditions, instrument response characteristics and viewing geometry. Because a multi-temporal data set will be used, it is necessary to correct radiometry across time. Both absolute correction methods that attempt to completely remove the varying radiometric errors and produce an output absolute reflectance value for each pixel, and relative correction methods that attempt not to remove the radiometric errors, but rather to account for them by empirically correcting the radiometry of all scenes to the radiometric conditions of a reference scene can be considered. Because the time-series is a multi-sensor series, it will be necessary to radiometrically match the values from each of the detectors to a chosen reference detector. The next process in radiometric correction involves the conversion of the measured multispectral brightness values to top of atmosphere (TOA) reflectance units. This normalization procedure is crucial when creating multitemporal and/or multisensory mosaics as it largely removes variations between these images due to sensor differences, Earth-sun distance and solar zenith angle (caused by different scene dates, overpass time and latitude differences). The first step involves conversion of measured DN to radiance using inflight sensor calibration parameters. These parameters are supplied with the imagery and are determined from comparison of inflight calibration sources with pre-flight absolute radiance values. The second step involves calculating top of atmosphere (TOA) reflectance for each band, corrected for illumination variations (sun angle and Earth-sun distance) within and between scenes (Chander and Markham, 2003). The correction can be applied on a pixel by pixel basis for each scene. Some of the parameters for the conversion are available in the image header files, while the exoatmospheric irradiance values for Landsat 5 are available from Markham and Barker (1986) and for Landsat 7 from NASA's Landsat 7 Science Data Users Handbook (NASA, 2009). This conversion from DN to TOA reflectance is an important step in the production of accurate ratio indices, like NDVI or other vegetation indices.

Atmospheric correction

Whereas the conversion from DN to TOA reflectance corrects for sensor gains and offsets, solar irradiance and solar zenith angle, it makes no attempt to account for atmospheric influence. A combination of both absolute and relative correction methods can be applied to account for atmospheric influence. Absolute atmospheric correction methods aim to physically account for one or more of the distorting effects of the atmosphere and thereby convert the brightness values of each pixel to actual reflectances as they would have been measured on the ground. Radiative transfer models and derivatives (e.g. Modtran, FLAASH) are complex and require in-situ measurements or estimations of detailed atmospheric parameters and/or ground-based multispectral irradiance measurements to provide accurate results. These measurements will not be available in the project. Simpler absolute correction methods derive parameters directly from the image data. The Dark Object Subtraction (DOS) 1% method has been successfully applied in a number of Landsat studies to remove additive path radiance. This method assumes that the lowest reflectance value across a scene will be 1% for dark objects such as deep water and shadow (one or both of which occur in each image used in this project) and therefore the difference between this value and the actual DN measured for these dark objects can be attributed to the additive effects of haze. Subtraction of this value for each band will remove this error. A subsequent relative correction method normalizes the reflectance of all images in the time series and attempts to account for any remaining atmospheric differences between images. This correction is applied after topographic normalization (see below).

Topographic normalization

This correction procedure attempts to account for the brightness distortion caused by differences in illumination as a result of the changing angle of the sun relative to the angle of the terrain. This correction is particularly important in study areas with varied topography, where the differential effect of solar irradiance on the terrain significantly varies the radiometry (Pons and Solé-Sugrañes, 1994). Slope and aspect values can be derived from a Digital Elevation Model. The DEM is processed so that each pixel value represents the amount of illumination it should receive from the sun. This information is then modeled using an algorithm to enhance or subdue the original brightness values of the image data. However, the DEM should have the same planimetric resolution as the imagery, and precise geometric correction of the DEM to the imagery is essential, otherwise illumination corrections can cause more spectral variation than is corrected.

Relative radiometric correction

Relative radiometric correction methods calibrate image reflectance to a chosen reference image. Such relative methods are of particular importance when comparing images to detect change, and allows the direct quantitative comparison across time, as long as times of year and seasonal conditions are similar. Two broad strategies for relative data calibration between imagery of different dates are described in the literature, based on either data distributions or pairwise observations of pixel values. Although less sensitive to errors in geometric matching between images of different dates, the distribution-based methods such as histogram matching often rely on unreasonable data assumptions such as invariant histogram minima and maxima between image pairs (Furby and Campbell, 2001). If the geometric consistency of the time series is high, the pairwise methods can be used. The Pseudo-Invariant Feature (PIF) technique involves collection of targets that exhibit minimal spectral change through time, which are then used to derive a relationship. This relationship is used to calibrate multitemporal images to a reference image, normalizing for sun angle, sensor radiometry and atmospheric degradation. The pseudo-invariant targets are generally spectrally invariant man-made targets such as bitumen, concrete and other urban features, though dark vegetation and various other bright and dark features have also been used. A number of methods have been proposed for the collection of invariant PIFs, ranging from manual selection, use of iterative thresholding of bands 3 and 4 and the extraction of pixels that reside at the non-vegetated extremes of the Kauth-Thomas greenness-brightness scattergram (Hall et al., 1991).

Cloud detection

Before image classification or time series comparison, it is important to filter out the clouds in each scene. Irish (2007) proposes an automatic cloud cover assessment algorithm for Landsat ETM+ imagery, that employs two passes. In pass one, the reflective and thermal properties of scene features are used to establish the presence of absence of clouds in a scene. If present, a scene-specific thermal profile for clouds is established. In pass two, a unique thermal signature for clouds is developed and used to identify the remaining clouds in a scene.

Gap filling of SLC-off images

An instrument malfunction of Landsat 7 occurred on May 31, 2003, with the result that all Landsat 7 scenes acquired since July 14, 2003 have been collected in ‘SLC-off’ mode. Without an operating Scan Line Corrector, the line of sight now traces a zig-zag pattern along the satellite ground track. As a result, imaged area is duplicated, with width that increases toward the scene edge. All Landsat 7 ETM+ SLC-off imagery processed on or after December 11, 2008, will include gap mask files. (Please note the difference between acquisition date and processing date.) The gap mask files are bit mask files showing the locations of the image gaps (areas that fall between ETM+ scans). One tarred and gzip-compressed gap mask file is provided for each band in GeoTIFF format. The file naming convention for gap mask files is identical to that described above for LPGS-processed GeoTIFF data, with the third character (data format) set as 'G'.

For example, a gap mask of the Rosia Montana demo-site image acquired on 09/07/2007 (and processed in 2009) is presented in Figure 6-1. ULRMC received the image from Maryland university archive. The Rosia Montana area is without strips and/or very small (one pixel).

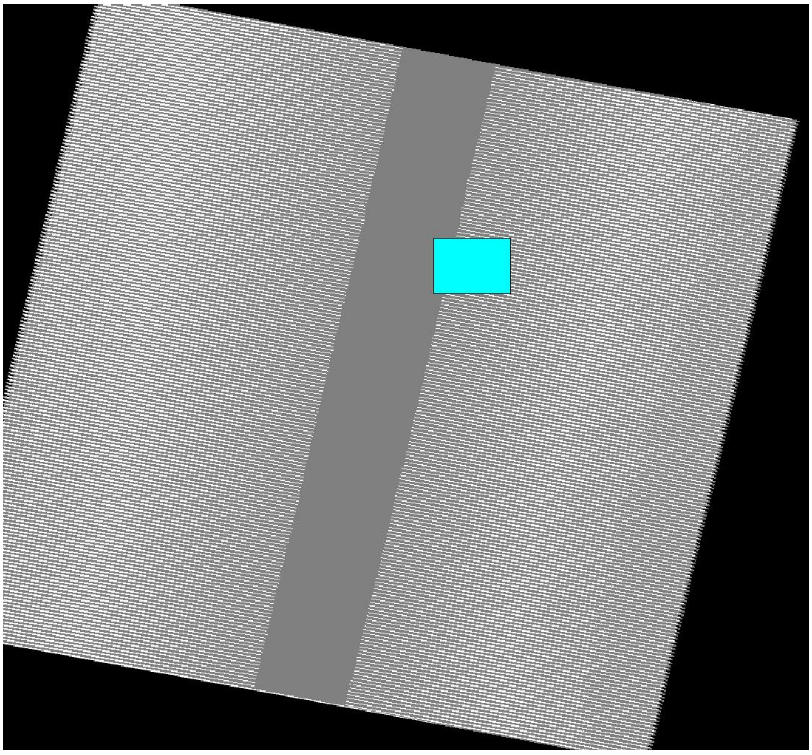

Figure 6-1 Landsat SLC-off gap mask for Rosia Montana (acquired on 09/07/2007, processed in 2009)

If a gap mask is not provided, it can easily be created. A tutorial for creating them can be found on the USGS Landsat missions website[2].

These gaps due to the failing Scan Line Corrector of Landsat 7 might be filled through mosaicking with other images from the same area, as long as they are acquired in the same time frame and cloud cover is not an issue. In any case, it is important to obtain adequate data co-registration, good cloud and cloud shadow detection, and atmospheric correction, before mosaicking of different images.

ASTER preprocessing

Geometric correction

The preprocessing of the ASTER time series will consist in the first place of geometric correction and orthorectification. Ground control points will be taken from topographic maps, and the best quality DEM (in most cases SRTM DEM) will be used as vertical reference for orthocorrection. When applying the geometric correction and relief displacement correction procedures, the Nearest Neighbour (NN) resampling algorithm can be employed so as to maintain spectral integrity. It will also be important to maintain geometric consistency between the images of the time series, thus image co-registration or relative geometric correction might be necessary. Usually the geometric accuracy of ASTER is not good, even after orthorectification. This means that it will be necessary to adjust the position of ASTER scene in order to co-register with other spatial data. In particular when integrating multiple remote sensing datasets into time-series, accurate co-registration is an important requirement.

Radiometric correction

The advantages of radiometric correction, i.e. convert DN values in physical quantities, is that a spectral signature with meaningful units can be compared from one image to another. Also, spectral

[2] See http://landsat.usgs.gov/gap_mask_files_are_not_provided_can_I_create_my_own.php

libraries could be used. Thirdly, when using spectral information, it becomes possible to use band ratios in image analysis (see also Appendix 4.2).

Atmospheric correction

The atmospheric correction of ASTER images is not straightforward, as the existing techniques do not seem to work very well on ASTER. Geosense normally uses an in-house developed method based on an empirical approach.

Other preprocessing steps include: topographic normalization, relative radiometric correction, cloud detection, generation of color composites, etc. See above for comparable preprocessing steps on Landsat.

WorldView2 preprocessing

Geometric correction

The WorldView-2 images are orthorectified using the SRTM-DEM, or a more detailed DEM, if available. ImpactMin is currently investigating the possibilities of acquiring a more detailed DEM.

Atmospheric correction and topographic normalization

Several methodologies exist for atmospheric correction, both model-based using software such as ATCOR, FLAASH and ACORN, and empirical methods, such as Empirical Line Correction. Advantage of model-based software is that it allows us to perform a radiometric correction for rugged areas. For the Empirical Line Method, and for verification of the Model-based methods, ImpactMin plans to collect field samples for spectral analysis.

Appendix 4.2 – General satellite data processing

Low resolution time series

Comparing with the bi-temporal change detection, the temporal trajectory analysis emphasize more on discovering the trend of change by constructing the ‘curves’ or ‘profiles’ of multitemporal data (Jianya et al., 2008). The so-called long time-series analysis method can be employed for temporal trajectory analysis. For example, Long term series of NDVI data, generated from coarse spatial resolution sensors like NOAA-AVHRR or SPOT-Vegetation, are valuable tools for the detection of both temporally discrete changes, like forest clearing, as well as gradual changes such as long term precipitation decline (Hansen and De Fries, 2004). The AVHRR sensors, on board of the NOAA satellites, have provided one of the most extended time series of remotely-sensed data and continues producing daily information of surface and atmospheric conditions (Baldi et al., 2008). Other long time series of NDVI now available are Terra MODIS (March 2000 – now) and SPOT-Vegetation (April 1998 – now). Numerous studies of temporal analysis of changes in vegetation functionality based on long NDVI time series analysis were published (see also D4.1). Using time-series of satellite data it is shown, for instance, that the length of the growing season is increasing at the northern hemisphere, which may be caused by global warming. Although seasonal variations in atmospheric water vapor, atmospheric aerosol content and large areas of bare soil in arid and semiarid areas may cause significant variations in NDVI not associated with actual vegetation cover (Huete and Tucker, 1991), this index has been shown to be a good indicator of various vegetation parameters, including green leaf area index (LAI), biomass, percent green cover, green biomass production and the fraction of absorbed photosynthetically active radiation (Sellers, 1985; Tucker, 1979). In many cases, cloud contamination, atmospheric perturbations and variable illumination and viewing geometry affect the sensor data, leading to NDVI-values which are far lower than what would have been observed under perfect measurement conditions (Sellers, 1985). To eliminate the strongest perturbations, the atmospherically corrected daily imageries are combined to 10-days maximum value composite (MVC) imageries. Even after this correction, noise is still biasing the data (Pettorelli et al., 2005) in the case of cloud or snow cover persisting longer than 10 days or a malfunctioning of the sensor. Therefore, a smoothing operation like the one proposed by Swets et al. (1999) can be performed. If not all perturbations are eliminated, 10-daily smoothed images can be combined to monthly maximum value composites (Figure 6-2).

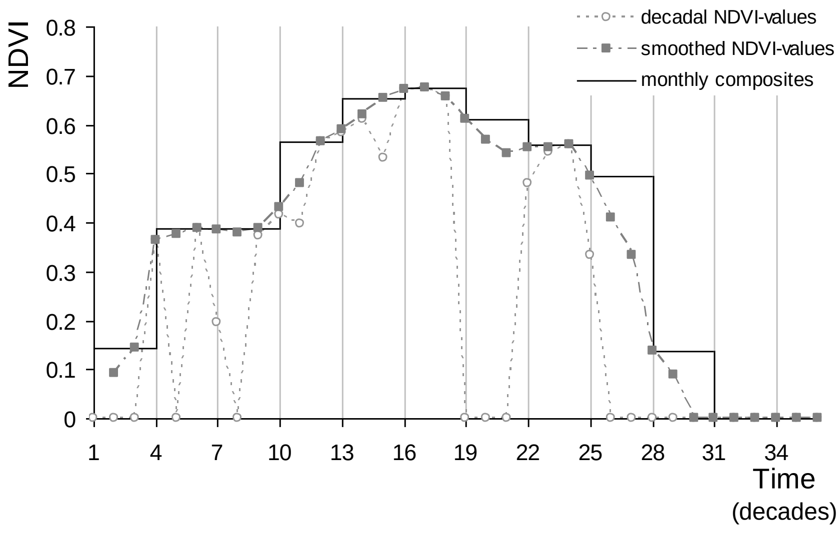

Figure 6-2 Comparison of the dekadal NDVI from the GIMMS NOAA-AVHRR dataset (grey circles, dotted line), the smoothed dekadal NDVI, (grey squares, interrupted line) and the monthly maximum value composites (black triangles, solid line), for one year for a region in Eastern Europe. Vertical lines indicate different months. Due to snow cover, most of the NDVI-values in the winter period are missing.

Various variables can be calculated to characterize changes in the amount and seasonality of the photosynthetic activity: average annual NDVI, integrated NDVI, maximum annual NDVI, minimum annual NDVI, NDVI intra-annual coefficient of variation, difference indexes with the long term average, phenology measures like the rate of increase and decrease of the NDVI, dates of beginning, end and peak(s) of the growing season, length of the growing season, etc. (Anyamba and Tucker, 2005; Baldi et al., 2008; Peters et al., 2002; Pettorelli et al., 2005) sometimes corrected for relations with precipitation (Anyamba and Tucker, 2005; Fensholt et al., 2009).

There are no known examples of the use of NDVI time series for the monitoring of environmental impact of mineral mining. There are some examples of time series analysis for environmental monitoring in general, for example landscape greening in Central and Eastern Europe (Van Dessel, 2010), see Figure 6-3. Additionally, many different types of analysis can be done at pixel level, in order to investigate spatial variation of historical trends of vegetation.

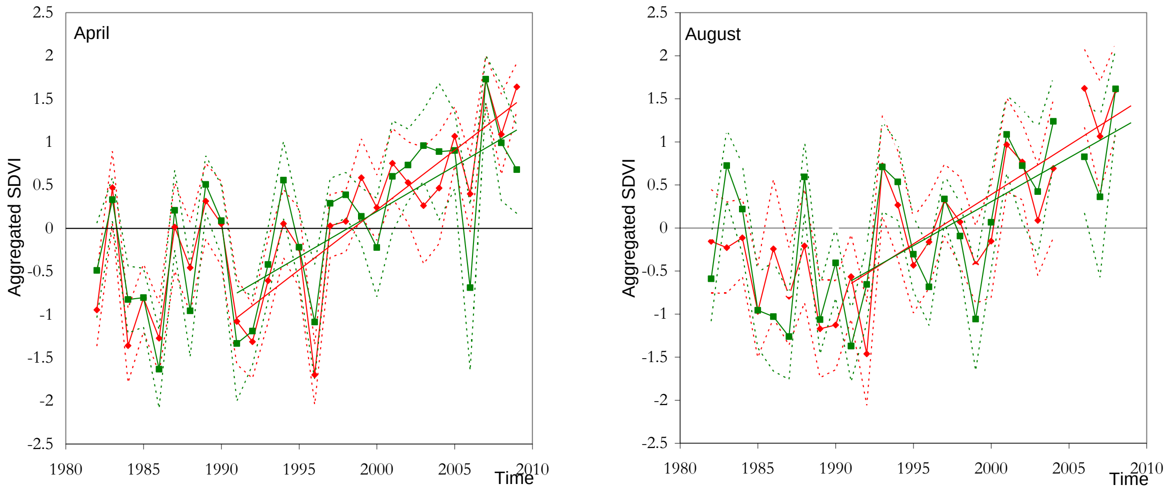

Figure 6-3 Standardized Difference Vegetation Index (SDVI) values for April and August for a national park area in Germany (green) and an agricultural area subjected to land abandonment in Bohemia (red) (Van Dessel, 2010)

The software that will be used for low resolution time series analysis is a software developed in-house at VITO: GLIMPSE (Global Image Processing Software). If necessary, additional tools will be programmed in ENVI/IDL. Furthermore, the IDRISI Taiga Earth Trends Modeler can be used to model and analyze ecosystem dynamics, since it provides a variety of techniques and methods for detection and measurement of trends, change and impacts.

Landsat processing

Image transformations

An important aspect of data processing and data interpretation is the creation of band ratios. Ratioing is an enhancement process in which the value of one band is divided by that of any other band in the sensor array. If both values are similar, the resulting quotient is a number close to 1. If the numerator number is low and denominator high, the quotient approaches zero. If this is reversed (high numerator; low denominator) the number is well above 1. These new numbers can be stretched or expanded to produce images with considerable contrast variation in a black and white rendition. Certain features or materials can produce distinctive gray tones in certain ratios. Band ratios are particularly suited to those data sets where the numerator band is chosen to monitor a little-varying standard, whereas the denominator band maps the variability of a specific spectral feature (Fraser and Green, 1987). For example, the ratio between red/near infrared provides good distinction between bare rock and vegetation-covered areas. The ratio mid IR/blue is successful in distinguishing between limonitic and nonlimonitic rocks. The ratio red/blue tends to emphasize red- or orange-colored features or materials, such as natural hydrated iron oxide, as light tones. Three band ratio images can be combined as color composites which highlight certain features in distinctive colors.

There are many distinct vegetation indices. Vegetation indices are defined as dimensionless, radiation based measurements computed from the combination of spectral characteristics (Asner et al., 2003). They define some transformation of the data in order to maximize sensitivity to the parameter of interest whilst minimizing sensitivity to other terms. As such, they are able to overcome the limitations of multivariate statistical single band applications by minimizing external factors (e.g. illumination and atmosphere conditions) and internal factors (e.g. underlying soil and leaf angle distribution), and therefore correlating more closely with vegetative biochemical constituents. The NDVI is one of the most widely used vegetation index, but other vegetation indices attempt to adjust for soil or atmospheric influences. Other transformations are principal component analysis, tasseled cap (Crist and Cicone, 1984) or canonical transformations. See also D4.1.

Image classification

In digital image classification, image pixels are assigned to information classes or feature categories. Image classification methods use digital algorithms to compare pixels to each other and/or to pixels of known identity in order to assemble groups of similar pixels into classes with like characteristics. See also D4.1 for a detailed description on different image classification algorithms, including supervised, unsupervised, object-based and sub-pixel classification techniques.

Change detection and time series analysis

After preprocessing of Landsat imagery, where it is very important to obtain geographical and spectral consistency between all the images of the time series (see also Appendix 4.1), different transformations can be applied on the images before calculating differences in brightness. For example, a tasseled cap transformation can be applied before image differencing (Figure 6-4). Based on this analysis, the research area can be classified according to different types of changes.

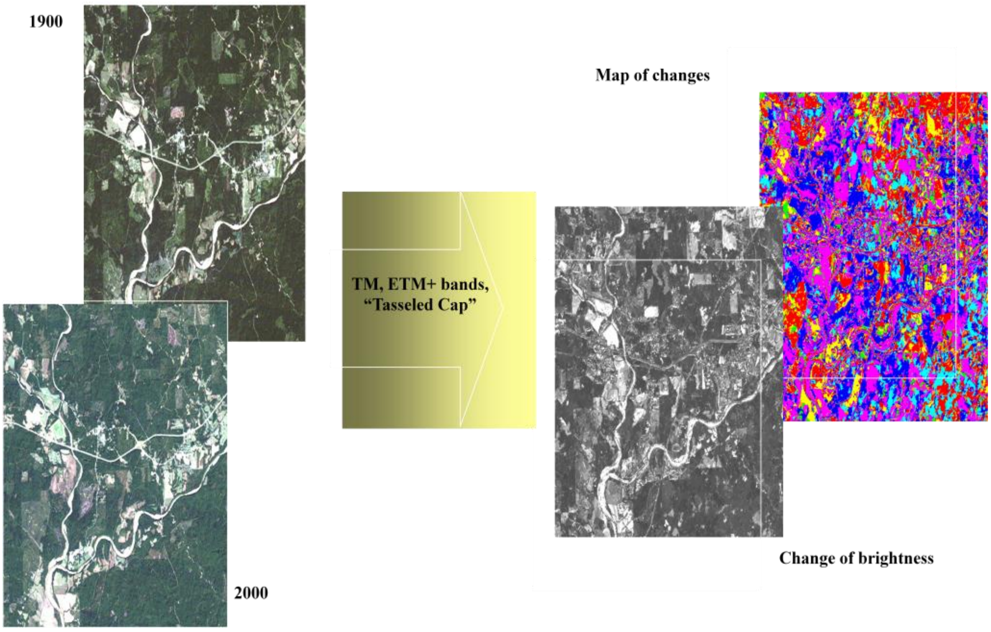

Figure 6-4 Change detection based on Tasseled Cap transformed images

Change detection can also be applied on classified images (see above) through cross-comparison of pixel values and analysis of cross matrices.

Furthermore, the IDRISI Taiga Earth Trends Modeler tool can be used to model and analyze ecosystem dynamics, since it provides a variety of techniques and methods for detection and measurement of trends, change and impacts.

ASTER processing

Image transformations and the generation of color composites

ASTER VNIR, RGB=VNIR321

This is the standard 15m-resolution color composite. In this image, vegetation will be red, and iron oxides will – depending on the species – be yellowish-greenish to cyan. In Figure 6-5 an example is shown of such a color composite.

One of the problems with standard color composites is that when very bright and very dark areas occur in the same image, the detail in those areas becomes very poor. For that reason ImpactMin applies a data adaptive enhancement method that allows us to remove those strong differences in brightness, thus enhancing local contrasts. This method is particularly useful to enhance subtle spectral variations at local scale.

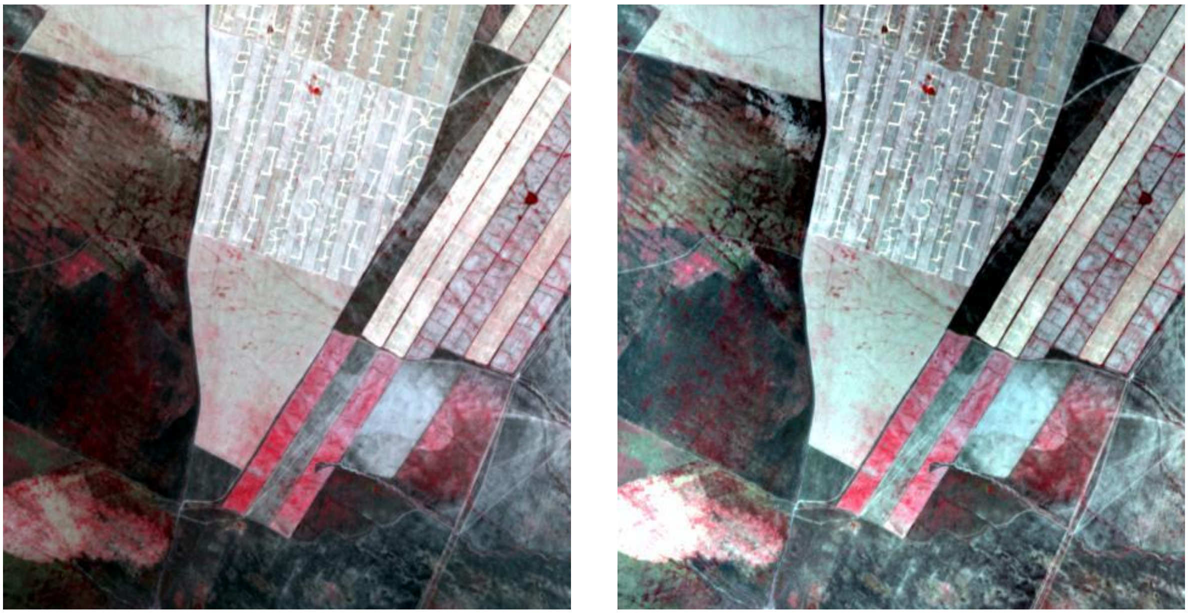

Figure 6-5 Standard ASTER VNIR color composite. Left: normal enhancement; Right: Data adaptive enhancement

Synthetic Truecolor

ASTER has no blue band. Therefore it is not possible to generate real Natural Color images, such as for example is the case with Landsat. However, a fairly powerful method to synthesize the blue band on the basis of information in the other ASTER bands was developed. Using this method ImpactMin can produce a so called “Synthetic True-color Image”. Colors in this image are usually very realistic (see Figure 6-6).

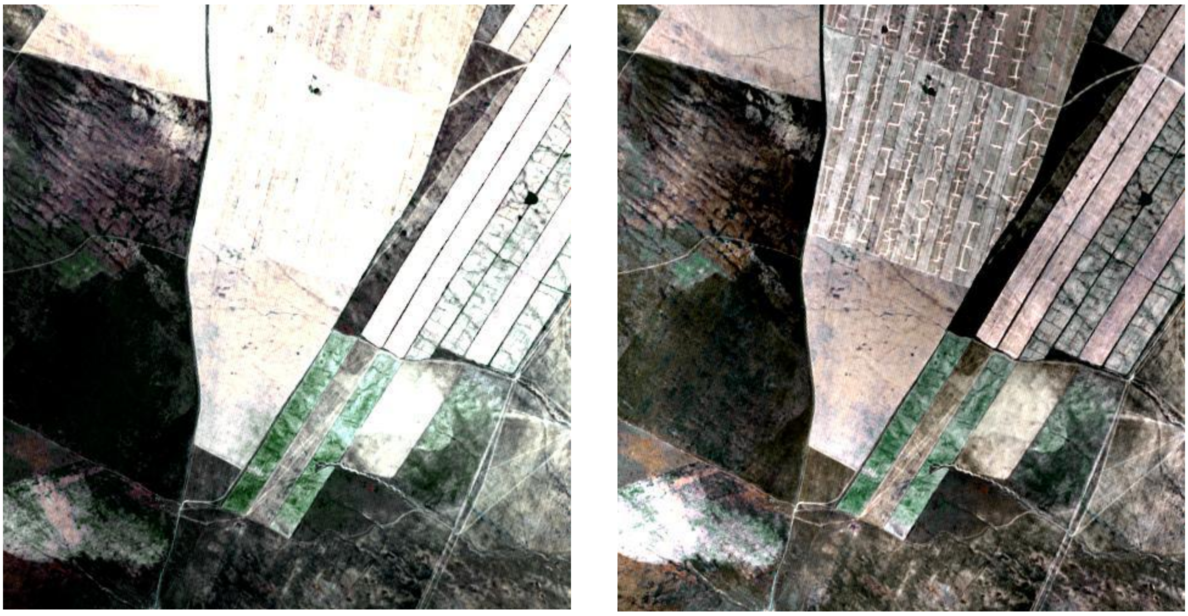

Figure 6-6 Synthetic truecolour image for same area as Figure 2. Left normal enhancement, right special enhancement

SWIR 468

This SWIR image (see Figure 6-7) is very useful for identification of clay minerals (usually reddish-pinkish), propyllitic minerals (greenish-bluish) and carbonate minerals (yellow-green).

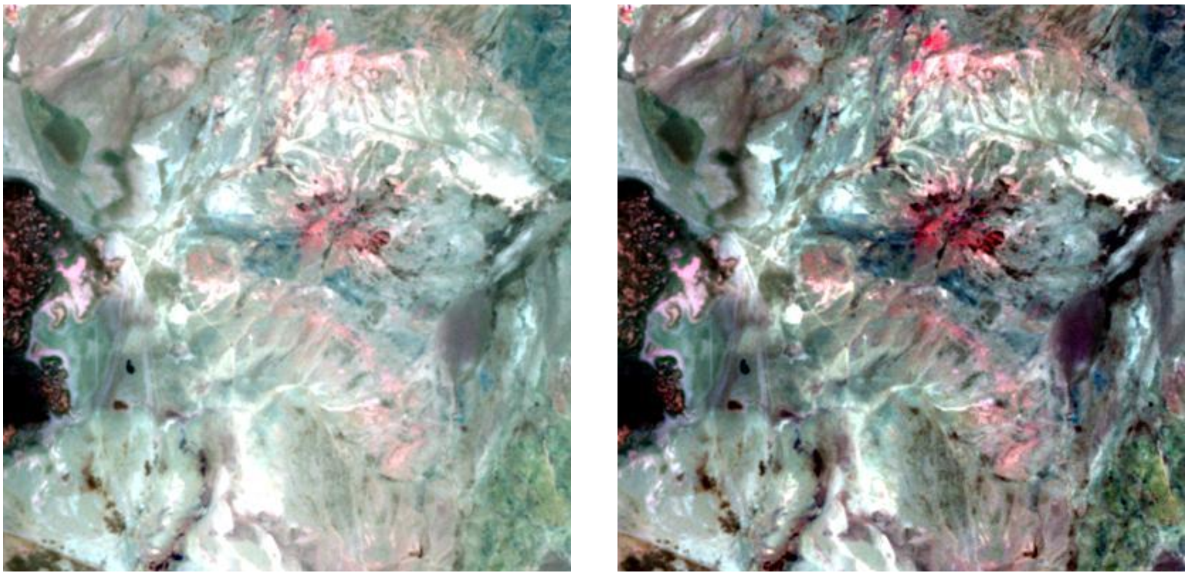

Figure 6-7 Example of SWIR468-colour composite, showing clay-minerals in pink and propyllitic minerals in green and bluish. Left image is normal enhancement, Right image is data-adaptive enhancement.

SWIR456

This SWIR image (see Figure 6-8) is very useful to discriminate between different types of clay, such as montmorillonite (brownish-yellowish) illite (orange), kaolinite (pinkish-orange), alunite (pink) and pyrophyllite (reddish-pink)

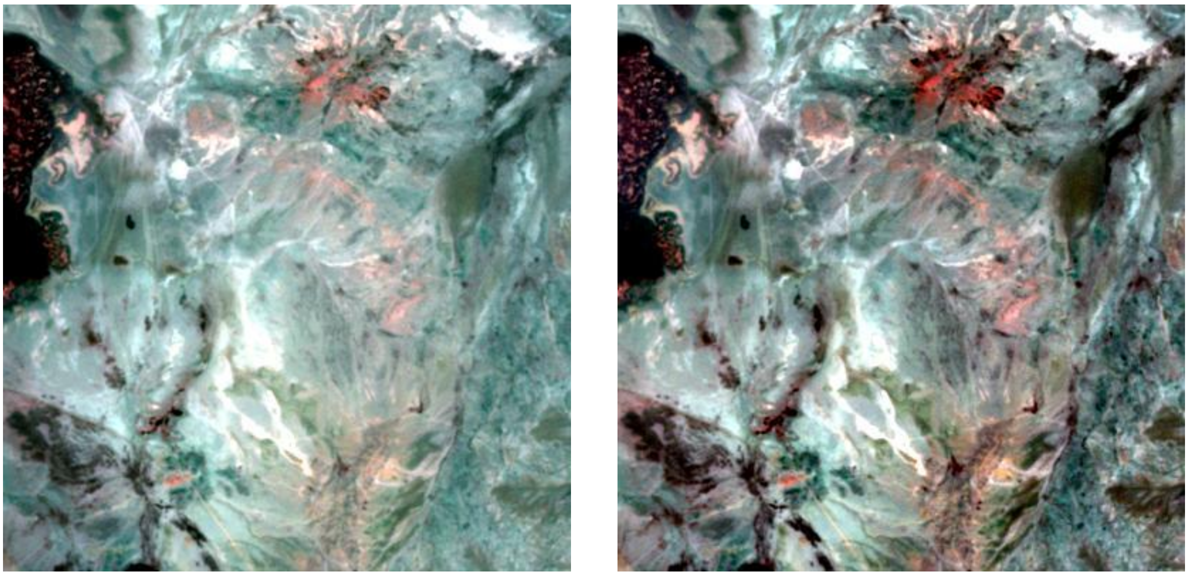

Figure 6-8 Example of SWIR456-colour composite, showing different clay minerals in different shades of yellow-orange-pink-red. Left image is normal enhancement, Right image is special enhancement. Note the significant enhancement of the clay minerals.

TIR531

The thermal imagery is very useful in the first place to map minerals such as Silica and carbonates and Gypsum. Silica is very clearly visible in the TIR531-colour composite, characterized by reddish colours (see Figure 6-9). Also, the Thermal provides very useful structural information, especially when properly combined with digital elevation data.

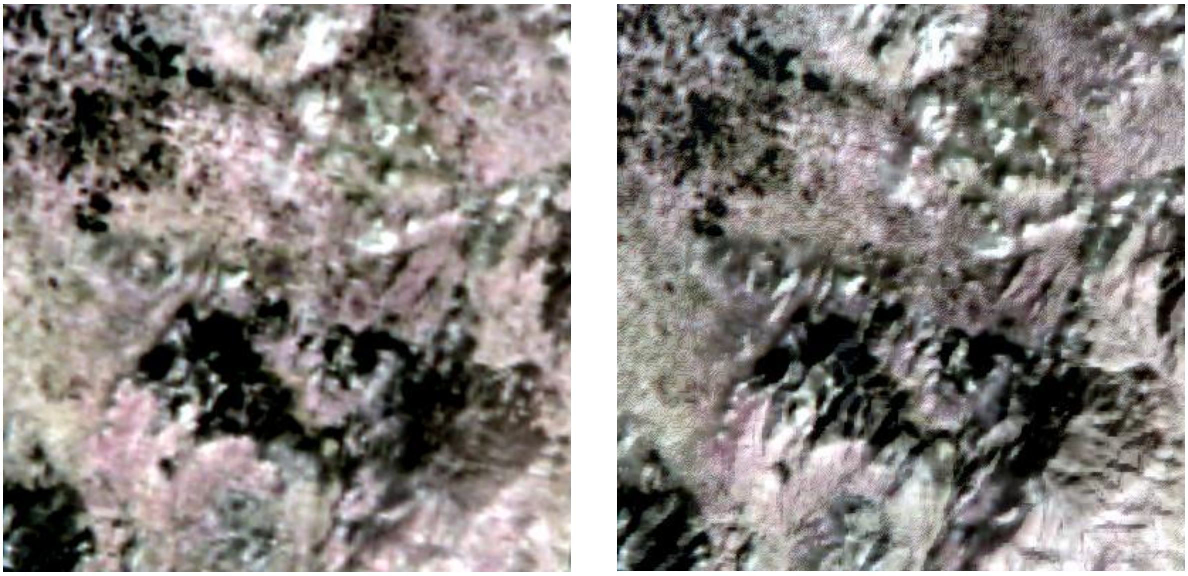

Figure 6-9 Example of TIR531 colour composite showing more siliceous surface materials in pinkish-reddish. Left image is normal TIR531 composite. Right image is a TIR531 combined with a DEM in order to enhance structures.

Spatial and spectral analysis and integration with other spatial data

As can be seen in the description of the project areas, each project area has its own characteristics and problems, and it will be clear that each area requires its own specific approach when it comes to the interpretation of ASTER data and the integration with other types of spatial data. Nevertheless, some general procedures can be outlined that in some form apply to most of the situations encountered in this project.

WorldView-2 processing

Analysis and interpretation

No publications or case studies have been found that document the use of WorldView-2 for environmental monitoring. The positions of the spectral bands, in combination with the very high spatial resolution, are very promising with respect to monitoring of water quality, vegetation monitoring, land-use monitoring, urban development and detection of minerals such as Iron oxides and certain sulphate minerals, which are all important parameters in the Mostar area. ImpactMin expects that, once the field and airborne hyperspectral campaigns have been completed (for Mostar and Rosia Montana), ImpactMin will be able to demonstrate the great value of WorldView-2 data in areas where no other ground or airborne data are available. Also, ImpactMin sees interesting possibilities to use the high-resolution of WorldView-2 for the sharpening of other lower-resolution data, such as ASTER (see Fig below) or Airborne Hyperspectral imagery.

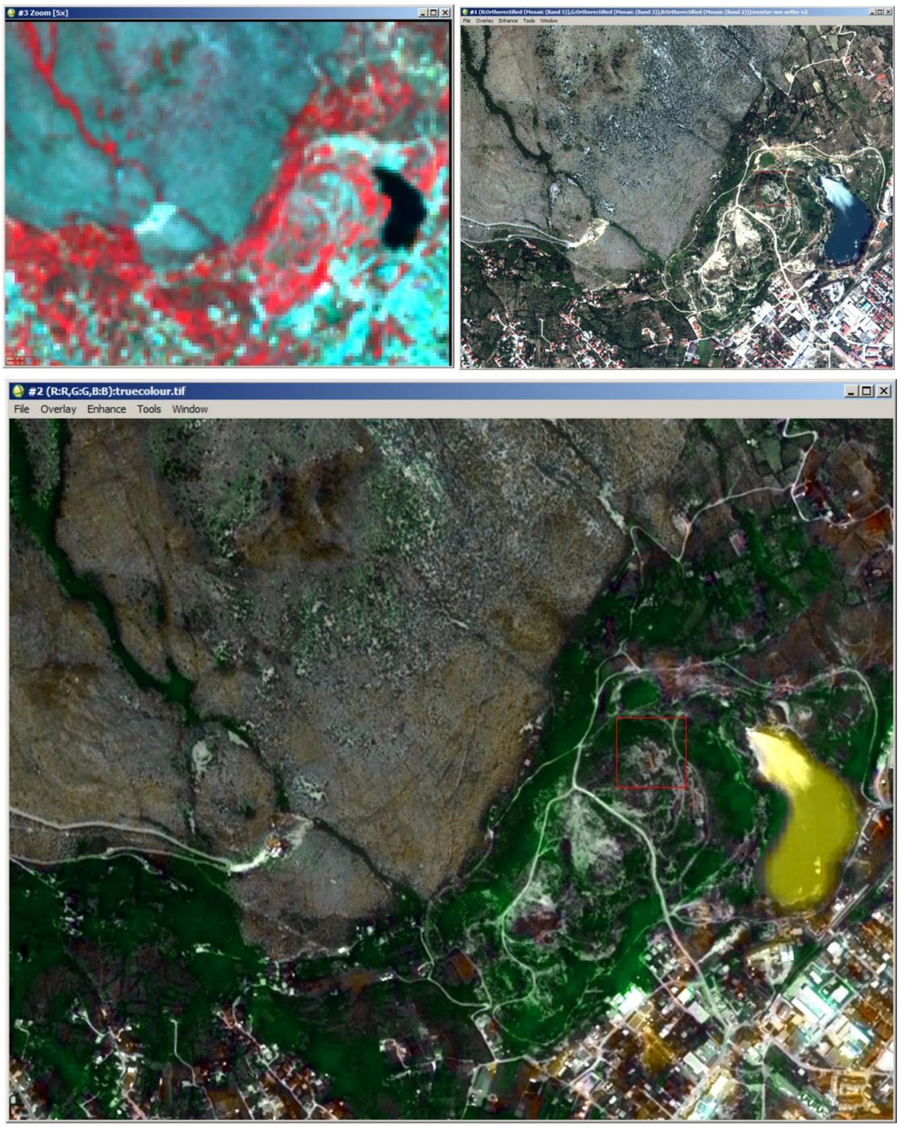

Figure 6-10 Top-Left: ASTER VNIR321; Top-Right: WorldView-2 532; Bottom ASTER synthetic truecolour image, sharpened with 2m-WorldView-2 (multispectral) band 2