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Mine closure and reclamation – Managing mining legacies —

Part 2: Case studies and bibliography

Fermeture et remise en état des mines — Gestion des héritages miniers —

Partie 2: Études de cas et bibliographie

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Foreword

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This document was prepared by Technical Committee ISO/TC 82, *Mining*, Subcommittee SC 7, *Mine closure and reclamation management*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at https://www.iso.org/members.html

Introduction

This document includes case studies and a bibliography provided by working group members and has been separated from the standard so that development of the two documents proceeded in parallel. These resources provide supporting information and illustration of various aspects of the managing mining legacy standard. While expanding upon some of the content of the guidance of the standard, it cannot be assumed that a particular strategy that was applied in one context is directly applicable to another. Not every clause in the standard has a corresponding case study. Instead, clause activities are revealed in an integrated way as they occur in practice within these cases. In addition to descriptive case studies, there are some table-format case studies toward the end, that illustrate how inventories can be structured and developed. The bibliography expands the resources available to those applying ISO 24419-1. This bibliography is not fully comprehensive of all global regions but instead are important and relevant at the time of preparation of the standard. As management of mining legacies evolves, further resources are likely to emerge. It is up to the user to adapt and apply their understandings of the ISO 24419-1 standard and this Technical Report to local circumstances.

Mine closure and reclamation – Managing mining legacies —

Part 2: Case studies and bibliography

1 Scope

This document is a supplementary document to the International standard for managing mining legacies (ISO 24419-1) that provides illustrative case studies and resources providing further reading. The content provided in this document covers various regions of the world as a supplement to ISO 24419-1. The purpose is to provide insight into specific case studies that show how practitioners have addressed mining legacy challenges in practice. This document does not provide instructions for managing mining legacies, but instead a resource with insights from other practitioners, thereby widening knowledge of what can be required to effectively manage mining legacies.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 24419-1, *Mine closure and reclamation — Managing mining legacies — Part 1: Requirements and recommendations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24419-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Design engagement process for the Giant Mine remediation project, Yellowknife Northwest Territories, Canada

4.1 Aspect of managing mining legacies

This case study describes stakeholder engagement and consultation for management of a large mining legacy by the Canadian Government to addressing the historic legacy whilst also developing a collaborative engagement process. See Reference [32].

4.2 Recognition of a problem that needed to be resolved

In 1999, the Giant Mine went into receivership and subsequently became an abandoned mine under the responsibility of the Government of Canada. The roughly 50 years period of gold mining resulted in significant disturbance to the land and water, and severe impacts on the health and lifestyles of local people, especially Indigenous groups. The project developed an initial remediation plan for the site in 2007 that failed to receive wide spread public support and a subsequent Environmental Assessment raised significant public concerns. In 2014, the project team concluded that the remediation plan required a more meaningful engagement process with stakeholders in order to build public trust and obtain support for the management and remediation of the abandoned mine.

4.3 Steps involved and expertise/stakeholders involved

In late 2014, the project proposed a 2 year engagement process to stakeholders that involved a series of multi-day workshops. Stakeholders had a large role in developing the engagement process and ensuring the process would be meaningful to them. The series of meetings, reports and workshops addressed public education and preparation, stakeholder objectives, development of closure options, risk assessment and review, and finally the evaluation of options for the abandoned mine.

During the engagement process, the project recognized that the Indigenous and other local groups were not meaningfully engaged on what happened at Giant Mine for almost all of its operating life. More effective engagement could not address all the wrongs in a 50 year history, but it could contribute to reconciliation and a different future. Participants in the engagement process were asked to remember the past and its lessons, but to focus on how the Giant Mine could be managed in the future.

4.4 Evaluation of performance of this initiative

Since the completion of the engagement process in 2016, the stakeholder evaluation results have been used by the Government of Canada in selecting closure options for Giant Mine. Key decisions informed by the engagement included the selection of closure options for open pits, tailings areas, water management and future land use. Many of these options differed significantly from the initial closure plan and the decisions made based on engagement were communicated back to stakeholders.

A favourable outcome of the engagement process is that while the final plan could not reflect every stakeholder group's first choice for closure, there was an understanding of the many other perspectives that need to be considered in selecting closure options and the management of abandoned mines. The engagement process significantly increased stakeholder understanding of the mine and improved the project's relationship with stakeholders.

The revised Giant Mine Closure Plan was resubmitted for regulatory review and resulted in public support being voiced for the plan by stakeholders. Regulatory approval for the remediation of the Giant Mine is expected in August 2020, over 20 years since the site was abandoned by its last owner.

4.5 Key learnings for others

The Giant Mine demonstrated the importance of incorporating meaningful stakeholder input into all aspects of an abandoned mine, from planning, option selection, through to long-term care, in order to ensure stakeholder concerns are addressed. This is particularly important where there is a difficult historical legacy, that if left unaddressed, can make moving the project forward and securing regulatory and other approvals difficult.

5 Mining legacy program performance evaluation and reporting — British Columbia (BC) Canada

5.1 General

Performance reporting on a mining legacy program is part of the Crown Contaminated Sites Program (CCSP) in BC, Canada. This program was restructured following on Auditor General report that recommended improvements to accountability and transparency and overall performance of the program. This case study is largely drawn from Reference [12]. Later performance reports on the BC program indicate that about 80 % of the sites in this program are mining legacies – see References [10] and [11].

5.2 Recognition of a problem that needed to be resolved

The purpose of the Auditor General's audit was to assess whether the Province had an adequate program for managing its contaminated sites and whether it was adequately accounting for its performance. Specifically, they examined whether the provincial government had:

— established an adequate governance framework;

— gathered appropriate information to develop management plans and to support resource allocations; and

— accounted adequately for its overall performance.

5.3 Steps involved and expertise/stakeholders involved

The BC auditor general conducted an audit of the CCSP and found the program was inadequate. Following up on the audit, recommendations were made (Clause 5) and the program was restructured. A link is provided to performance reports of the CCSP to show how the recommended actions were implemented. See References [10] and [11]. Every two years a performance report like this is published. Historic reports provide further insights.

5.4 Evaluation of performance of this initiative

Key findings of the audit copied:

The Province does not have an adequate program in place for managing its contaminated sites and is not adequately accounting for its performance. Significant improvements are required in three main areas.

First, the foundation needed for a sound program is lacking. Ministries and agencies are not being guided by clear direction from government, and roles and responsibilities are not clearly defined. While some progress is being made, it varies from organization to organization. Some are well underway in incorporating a contaminated sites policy into their portfolio; others are only at the early stages of doing this.

Second, there are significant gaps in the information ministries and agencies need to develop management plans and to make resource allocation decisions. As a result, few management plans are in place and no government-wide plan exists.

Third, without a clear, coordinated program for guiding contaminated site management activities, ministries and agencies are unable to account in a meaningful way on their progress in dealing with the risks and liabilities posed by contaminated sites.

5.5 Key learnings for others

The important role of independent auditing of programs is demonstrated. The improvements made ensure that managing mining legacies is more effective at reducing liability as well as being transparent. Performance is reviewed and made public in an accessible easy to read form that improves the reputation of governments managing these sites. A research report includes more detail on this and other programs reviewed as part of a Churchill Fellowship. See Reference [6].

6 Remediation of the abandoned mines in the South Alligator uranium field, Northern Territory, Australia

6.1 Aspect of managing mining legacies

Knowledge sharing between all stakeholders.

6.2 Background

Work was carried out between 1999 and 2007 in various phases. The Commonwealth Government was responsible for getting work done with federal parks agency as lead but other agencies from Federal and Northern Territory Governments involved. Original survey work was undertaken in 1986 but consultation with Indigenous people was not organised until 1990s.

6.3 Recognition of a problem that needed to be resolved

In 1952/3, exploration for uranium commenced in the upper valley of the South Alligator River, Northern Territory, Australia. Prior to 1962 more than 50 exploration sites and 17 small mining sites and three processing sites were operated. Then, all work stopped, and sites were abandoned. In 1986 a survey took place to inventory sites. This was to gain knowledge of rehabilitation requirements prior to the area being designated stage 3 of the World Heritage Listed Kakadu National Park. Stage 3 was incorporated in 1988 and the lease from the Traditional Owners required that all mining sites be remediated by 2015 at the expense of the Commonwealth Government and to the satisfaction of the Traditional Owners.

6.4 Steps involved and expertise/stakeholders involved

In 1992 a programme of hazard reduction work was carried out to mitigate radiation and physical safety risks for tourists and other visitors to the valley. There was little consultation with the Traditional Owners. In 2000 work began to consult with Traditional Owners on what they wanted to see in terms of rehabilitation and for experts to prepare options for discussion. Consultations were extensive and had frequency that did not over stress Traditional Owners but enabled regular progress to be made on the planning for rehabilitation. Meetings were held on that incorporated site visits during the dry season; wet season meetings were less frequent and were held in a variety of locations including nearby motels and communities. The style of meeting was arranged to be less formal than usual but with a structure determined by the Traditional Owners that was in sympathy with their traditional governance mechanisms.

6.5 Evaluation of performance of this initiative

Work progress was slow in terms of obtaining data but this often related to the timing of meetings to obtain approval for studies and the delay in obtaining funds from government. Once designs had been completed there were further delays until funds to undertake civil engineering works (such as construction of the containment for all radioactive residues) could be made available. Traditional Owners were offered work and training opportunities during the construction phases as well as being employed to provide cultural advice on access to sites and issues of possible presence of sacred sites.

6.6 Key learnings for others

The involvement of Traditional Owners was essential to the long-term success of this programme. The development of a process for meetings that was sympathetic to the traditional governance mechanisms of the Traditional Owners was a vital part of the process and has been repeated elsewhere successfully. The lack of clarity in funding was a major cause of delays in implementation. Designs were completed, however these waited for four years before government finance could be found to support their implementation. Patience was essential at all stages in dealing with both the Traditional Owners and governments.

7 Valuing traditional knowledge within the Rum Jungle rehabilitation project, Northern Territory, Australia

7.1 Aspect of managing mining legacies

The former Rum Jungle Uranium Mine (Rum Jungle) is a mining legacy site located on Indigenous owned land. This case study describes the value of stakeholder input into decision making. The content is derived from two key sources. See References [1] and [2].

7.2 Recognition of a problem that needed to be resolved

The Rum Jungle ore body was discovered in 1949. Mining was undertaken between 1952 and 1963 and processing operations ceased in 1971. The sulphide rich waste mined at Rum Jungle generates substantial volumes of acid and metalliferous drainage. An aesthetic clean-up of the site was completed in 1973.

The Finniss River Land Claim No.39 was lodged on 20 July 1979. Rum Jungle formed part of the area subject to the claim. An inquiry into the land claim identified that the Kungarakan and Warai people were the traditional Traditional Owners of Rum Jungle and other areas subject to claim.

In the years that followed Rum Jungle became iconic due to the significant impacts from ongoing oxidation of sulphide minerals releasing large concentrations of copper and other heavy metals into the downstream receiving environment. This resulted in rehabilitation works being undertaken at the site during the 1980's. The Kungarakan and Warai people were not consulted about these works and remained very unhappy with the state of the site.

To address this, in 2009, the Northern Territory and Commonwealth governments commenced rehabilitation planning at the site.

7.3 Steps involved and expertise/stakeholders involved

Work began to identify which Kungarakan and Warai people spoke for this land. This involved engaging anthropological expertise to understand all the family structures and sacred sites.

Structured meetings were organised where the outcomes and learnings of technical investigations and potential rehabilitation options discussed, and rehabilitation objectives developed. Initially this was a very confrontational environment, as there had been a long history of unfulfilled promises and not being included in decision making.

As the project developed meetings were moved from being held in town to on Indigenous country and as it became apparent that site access restrictions that had been in place over the previous 50 plus years had created a loss of connection to land. Site visits were organised to start to re-establish these connections.

Kungarakan and Warai people were also included in providing site inductions. They shared valuable cultural knowledge of the site. They were also key participants in options analysis workshops which identified a preferred rehabilitation strategy for the site.

7.4 Evaluation of performance of this initiative

At the end of stage 1 of the project in 2013, the Kungarakan and Warai people had been involved in all of the key decisions which informed the selection of a rehabilitation strategy. Their desire to see the site return, where practical to its pre-mining topography and allow for sustainable traditional land uses fitting in seamlessly with other rehabilitation objectives developed for the site.

Throughout stage 2 (2013 – 2016) the increased knowledge of the site both culturally and technically supported the development of detailed designs. More importantly as we shared information, we became more equal as stakeholders in this process.

A two-way process of honestly and transparently sharing information is the most powerful way to build respect and trust.

7.5 Key learnings for others

Stakeholder engagement is at its most effective when all parties feel like they are equals in the process. Understanding that cultural knowledge of a site is just a valuable as technical investigations allows for this to occur.

Working collaboratively creates better outcomes, with a result that is greater than the sum of all of the individual inputs.

If no one is really sharing anything of significance it is most likely not because there is nothing important to say, but rather it will be a lack of trust in either the people or the process. The development of trusting relationships takes patience, time, commitment and accountability.

8 Difficulties encountered during the closure of mines prompted improvements to legal instruments, Mali

8.1 Context of case study

From the colonial period to the present day, Mali has acquired several legal instruments to manage mining, among which, there are five (5) generations of Mining Code (1970, 1991, 1999, 2012 and 2019) and environmental protection texts. This case study illustrates the recognition of inadequate regulatory requirements in Mali and how they were addressed.

Officially, there have been no permanent closures of industrial mines to date in Mali. However, some mines have observed more or less long shutdowns. They include the Kalana, Syama and Morila Mines described here from which learnings have been gained regarding how to strengthen regulations. Further information on this case study can be accessed from *Chief of the Environmental Information Department at the Environment and Sustainable Development Agency (AEDD and Malian Agency for Standardization and Quality Promotion (AMANORM).*

8.2 The Kalana Mine

Entering production in 1985, this mine observed two shutdowns, from 1991 to 2004 and from 2018 to 2019. The causes were the low gold content, associated with the high cost of production. As difficulties arose, it was found that:

— the content of the memorandum of understanding between the Kalana Mine and the country had never been disseminated to other stakeholders;

— environmental safeguarding measures (rehabilitation of quarries, mud park management) and social measures (income-generating activities) which were provided for by the protocol, were not discussed with the other stakeholders; and

— neighbouring communities were not prepared for the two operating shutdowns.

Communities were therefore severely affected by the negative consequences, in particular by: (i) loss of jobs and financial resources; (ii) deterioration in the purchasing power and standard of living of workers and populations; (iii) the exodus of labour to urban centres and new mining sites; (iv) the intensification of social conflicts around land use and access to natural resources, at the time when the dismissed mine workers were seeking to return to agricultural production on land reduced due to their use by the mine or their assignment to it; (v) loss of hope and confidence in the administration and in mining projects.

8.3 The Syama Mine

Entering production in 1990, the Syama Mine was put on hold in 2001 following difficulties encountered by its operating company. During this shutdown period, the environmental and socio-economic impacts resulting from the extractive activity were noted. They were due to the shortcomings noted in the planning of the project, especially regarding environmental issues and community development.

Unfortunately, neither the mining company nor its minority partners, nor the Government of Mali, have undertaken any activity to rehabilitate the mining site.

8.4 The Morila Mine

The Morila Mine started operating in 2000. It is scheduled to close in 2020. To prevent difficulties that have arisen on certain mining sites, the Government of Mali has set up an inter-ministerial commission to close the mine, the members of which were appointed by a decision of the ministry responsible for mines. The role of the Commission is to examine and adopt activity reports and documents relating to the closure of the mine.

This approach aimed to fill the legal void in the Mining Code in force which did not provide for measures in terms of mine closure and Corporate Environmental and Social Responsibility.

The Commission has drawn up a plan for the gradual closure of the mine and has carried out a feasibility study for an agricultural project entitled, "Agro-industrial center of Morila" which will replace the mine in 2020.

8.5 Key learnings from these examples for others

The common point between these three (3) mines is the fact that at the time of the launching of their exploitation, the legal instruments regulating environmental and social questions did not exist or, at least, were not national requirements.

The Malian Government did not require strict compliance with environmental standards as a prerequisite for the exploitation of mineral resources.

One of the most worrying difficulties is undoubtedly the fact that populations had little access to reports and data on the state of their environment. Civil society had no effective means of measuring the extent of the problems raised by mining, preventing them, reducing them or promoting any positive change.

Henceforth, the Mining Code of Mali constitutes the Basic Law which governs mining in the country. It includes measures relating to the protection of the environment, hygiene and the health and safety of workers.

9 Government strategy for rehabilitation of abandoned asbestos mines in South Africa

9.1 Context of case study

South Africa was a major global producer of asbestos from the early 1900s. However, the demand for asbestos declined during the 1970s and numerous asbestos mines were either abandoned or closed during the 1980s in accordance with the regulated (but comparatively poor) standards of the time. Asbestos mining was banned in South Africa in 2001 and a total ban on the production, import and use of asbestos followed in 2008. Concern around the poor state of the abandoned mines and the associated health risks led to a National Asbestos Summit being conducted in November 1998. An outcome of the summit was the development of a 'Standard protocol and guidelines for the rehabilitation of derelict and/or ownerless asbestos mine residue deposits in South Africa'. This guideline directed the diverse efforts of several state departments to guide the state funded rehabilitation of asbestos mines, the replacement of asbestos roof sheeting, and other related efforts. The original guideline was later expanded into a 'National Strategy for the Management of Derelict and Ownerless Mines in South Africa'. In line with this strategy, the term 'derelict and ownerless' (D&O) mines is used to define abandoned mines as those mines for which the owners or mining rights or lease holders (a) have abandoned and are not operating nor maintaining, mitigating or managing their associated safety, health and environmental impacts and (b) can no longer be traced.

9.2 National strategy for derelict and ownerless mines

Specific objectives of the National Strategy include the compilation and maintenance of an inventory of D&O mines, the identification of priority sites, the development of an action plan to manage the risks associated with D&O mines, and ensuring that all D&O sites are rehabilitated to acceptable standards. The existence of a National Strategy is significant as it serves to not only highlight and raise awareness about D&O mines, but also allows for coordination and collaboration between different government departments and the allocation of budgets from government. At the end of May 2008, South Africa had documented 5,906 D&O mines, of which 1,730 were classified as posing a high risk to public health, safety and the environment. Many of these were asbestos mines that have subsequently been rehabilitated by government. As of 2018, there are less than 10 large (in the context of major point source of pollution), unrehabilitated, high-risk asbestos mines remaining in the country.

9.3 Progress and challenges implementing national strategy

The government funded and implemented strategy has proved to be largely effective over the past two decades at addressing D&O asbestos mines in South Africa. However, there are some identified challenges related to the lack of legal clarity, the process and requirements for undertaking government funded rehabilitation and numerous technical issues.

9.3.1 Legislative challenges

Although the term 'Derelict and Ownerless' is defined in the National Strategy, there is no legal definition and no specific legislation dealing with D&O mines. The consequence of this is that the rehabilitation project implementing agents have to comply with legislation for which processes, roles and responsibilities are not always clear, which can delay projects and/or increase costs.

9.3.2 Process challenges

As D&O mines are the responsibility of government, there are various administrative processes that complicate rehabilitation. These include the need to share responsibility and meet the requirements of different government departments, the lag associated with government budgeting cycles, onerous government procurement processes and the additional requirements of government.

9.3.3 Technical challenges

The aim of the rehabilitation of asbestos mines is to permanently eliminate the dispersion of asbestos fibres and return the disturbed area to an ecologically stable state. This needs to be achieved at sites that have been abandoned and have often deteriorated. This means there is limited prior knowledge of the mine activities and layout. Also, these sites are characterised by a lack of planning for rehabilitation, like limited stockpiling of topsoil for example, posing consequent practical challenges. Asbestos mining in South Africa also occurred in the more arid areas, where vegetation is harder to establish. As a consequence, returning the site to a productive ecological state is not always possible. For more information see Reference [85].

10 Managing biodiversity offsets and mining legacy rehabilitation and care, South Africa

10.1 Recognition of a problem that needed to be resolved

In South Africa in 2008 there were almost 6000 mining legacy sites (termed ‘derelict’ and ‘ownerless’ (abandoned)) and the estimated 2009 rehabilitation cost was approximately 447 billion US$, excluding the long-term treatment of acid mine drainage and the construction and operating fees of plants (Auditor-General South Africa, 2009; Department of Mineral Resources, 2009) (See References [88] and [89]). Under the Minerals and Petroleum Resources Development Act (MPRDA), 2002 (Act No. 28 of 2002), if a mine closure certificate has not been issued and no party can be traced to assume responsibility for the liabilities of an abandoned mine, it can be classified as derelict and ownerless. The MPRDA is significant in that it is the first legislation in South Africa to stipulate the need for mine closure certificates. As the majority of the listed mining legacy sites closed prior to the MPRDA, with no closure certificates issued and owners untraceable, many are considered ownerless. The Department of Minerals and Energy (DME) contracted the Council for Geoscience (CGS) to develop a national strategy for the management of abandoned mines in South Africa. This included a database compilation of abandoned mines, with impact risk rankings (Department of Mineral Resources, 2009). Nearly 2000 mines were classified as high-risk, with severe health and safety hazards prioritised. Where mines are deemed ownerless, government jurisdictions are responsible for funding rehabilitation. However, funding and implementation capacity is often limited, and supportive options are needed. Biodiversity offsets are an alternative mechanism for funding.

10.1.1 Opportunity for biodiversity offsets

Drawing upon South African legislation this case study explains how that legislation could be applied to mining legacies in that country. Biodiversity offsets are often needed and specified by regulatory approvals to compensate for residual negative development impacts on biodiversity and ecosystem services (BES). They involve equivalent gains to balance losses, either through protection (averted loss), or restoration. Offsets can deliver gains in the same biodiversity components (e.g. ecosystems, species, etc.) as those affected. Based on this South African illustration, where an area is to be used as a biodiversity offset, the biodiversity value and gains are measurable. Plans then are provided for an offset site being maintained, for as long as residual impacts persist, which may be in perpetuity. Typically, a developer from whom offsets are required would be responsible for the management and funding of offset activities for a specified period (e.g. in South Africa for a minimum of 30 years). In some jurisdictions, suitable areas for offsets are difficult to find, and there is competition for limited options to protect and/ or restore habitat. If offsets were able to target mining legacies and restore their biodiversity, it would potentially, ‘kill two birds with one stone’. The opportunities for applying mining legacies as potential offsets varies among countries, depending on what remains in the landscape and case-and context-specific options for a biodiversity offset. Any evaluation would need to consider the biodiversity offset policy framework, including the acceptable approaches for calculating offset rules, such as counterfactual based or target led approaches - relative to the rates of background loss of biodiversity. This case study explores options for considering biodiversity offsets as a mechanism to fund and implement biodiversity conservation and restoration of mining legacies, examines tools and their potential application, raises application challenges, and notes benefits.

10.2 Existing tools and concepts for biodiversity offsets for mining legacies

When offsets are specified for various development applications by jurisdictions and development companies, they are guided by legislation, internal policies, and financing requirements.

The potential for a mining legacy site to serve as an offset would depend on

— the legal context and rights to use or access the area,

- the level of disturbance, degradation, contamination, and restoration potential:
  - some mine properties can be partly disturbed, leaving the unmined or buffer portion in good ecological condition and well suited to acting as an offset;
  - an underground mine might have less surface damage, but can present contamination/pollution risks, while a surface mine can be difficult to restore;
  - the potential to restore biodiversity structure and composition decreases proportionately relative to the level of disturbance;
- the potential conservation value of the area in a wider landscape context (e.g. connectivity and linkage to priority biodiversity areas), and
- its potential to improve ecological function and delivery of priority ecosystem services (e.g. watershed restoration).

The core principles for biodiversity offsets adopted by the business and biodiversity offset program, IUCN and others (see References [82] and [83]), are considered to match the residual negative impacts of development which need to be offset, with the ecosystem type and species habitat at the mining legacy site.

10.3 Application of tools and concepts as funding mechanisms

We identified four steps for how biodiversity offset tools and concepts could be applied to mining legacies in South Africa.

Step (1), the development of a mine legacy site inventory, could include specific information relevant to biodiversity offsets. A South African database was developed by the CGS (Department of Mineral Resources, 2009). This database categorises mining legacies based on their health and safety risks, with limited biodiversity categorization. Inventory information can include details of the type of mine and its location; ecosystem/ vegetation type/s and the condition relative to a benchmark 'natural' condition; freshwater resources, known contaminants or pollution; rehabilitation and/or ecological restoration potential; and the estimated costs thereof.

Step (2), the evaluation of inventory site potential to serve as a biodiversity offset, using relevant criteria to rank their potential biodiversity value and practical complexity in achieving the required biodiversity outcomes of an offset.

Step (3), the development of an offset bank of formally registered sites. Mine legacy sites can be considered for offsets, provided core biodiversity offset principles are met. In some cases, particularly where ecological restoration is deemed feasible, and where a mine legacy site is strategically located to contribute to landscape-scale conservation targets, there could be potential to use that site. Site registration would involve documenting the ecological baseline, and proactively restoring the site, prior to selling credits to developers who can require offsets. The inventory from Step (1) can therefore list registered 'offsets bank' sites that can be traded/sold as credits.

Step (4), this step evaluates new development applications that trigger the need for biodiversity offsets to compensate for residual negative impacts.

10.4 Application challenges

Reflecting on key challenges when planning and managing biodiversity offsets the following are identified:

a) Predicting restoration outcomes is difficult, especially where there is contamination.

b) Potential implementation can fail, when there is inadequate financial provision, cost estimation, implementation capacity and ecological management.

c) Implementation and enforcement are difficult when authorisation conditions and contracts are inadequately defined.

d) Performance monitoring is difficult when there are inadequate criteria that set the standard.

e) Responsibility for offset sites after the liability ends can be contentious. Stewardship of a legacy site is difficult when there is long-term liability and land ownership uncertainty.

f) Unless clear levels of expectation have been established beforehand, it is difficult to assess performance and therefore, success of biodiversity offsets.

10.5 Industry and society benefits

From experience managing biodiversity offsets, benefits from effectively managing biodiversity offsets are illustrated:

a) Negative mine legacy impacts and the number of impacting sites may be reduced.

b) Developers have opportunities for demonstrating sustainable development practices.

c) Supplementing constrained jurisdictional mining legacy funding mechanisms.

d) Potential land and resource uses of these sites would be improved and could offer new options for local livelihoods. Those land uses could fund further ecological management.

11 Potential limitations of mechanisms used to fund mining legacy programs, Western Australia, Australia

11.1 Aspect of managing mining legacies

Government jurisdictions ensuring a funding stream is quarantined for management of mining legacies.

11.2 Background

The Western Australian *Mining Rehabilitation Fund Act 2012* (MRF Act) requires mining tenement holders to pay an annual, non-refundable levy into a central fund, known as the Mining Rehabilitation Fund (MRF), which can be utilised by the State Government to fund the rehabilitation of abandoned mine sites. Money in the principal fund can be used to rehabilitate abandoned mine sites where a tenement holder, who has contributed to the fund, fails to meet their rehabilitation obligations. Interest generated from the fund is used to administer the MRF and the rehabilitation of mining legacies that existed prior to the introduction of the MRF Act through the Abandoned Mines Program (AMP) run out of the Department of Mines, Industry Regulation and Safety.

11.3 Unanticipated low interest rates

Any changes in the interest earnings rate have a significant impact on the interest earned by the fund per year. In Western Australia, interest rates for the 2020-21 financial year are at historically low levels.

It was acknowledged that if low interest earnings rates are maintained, the amount of interest available to fund the administration of the AMP and complete rehabilitation work would be much lower than previous projections and will reduce the long-term sustainability of the AMP.

11.4 Key learnings for others

If the use of interest rates, license and/or tax revenues are used as a component of a funding stream for the management of mining legacies, authorities need to understand that changing circumstances such as a decrease in interest rates can have a detrimental effect on the ability to manage mining legacies.

Having a combination of funding mechanisms (principal/interest/bonds) can circumvent the issue of fluctuating interest rates having a potential impact on mining legacy work programs. For instance, the principal could be used to fund rehabilitation of historical abandoned mines as well as newly abandoned sites; or there could be opportunities to incentivise the private sector to remediate historical abandoned mine sites as an independent business venture, and/or mining companies could rehabilitate abandoned mines as a means to reduce their MRF liability.

12 Long term financing of the perpetual obligations resulting from hard coal mining in Germany

12.1 Historic context

In February 2007 the German government, the coal states of North Rhine-Westphalia and Saarland, RAG Aktiengesellschaft (AG) and the miners' union IGBCE agreed to shut down RAG AG's subsidized German hard coal mining operations by the end of 2018 as initiated by the EU Commission.

12.2 Origin of RAG-Stiftung (RAG Foundation)

In June 2007, the RAG-Foundation was established in Essen, with an endowment of €2,0 million under civil law with legal capacity. The foundation managed the transition process in the German coal industry on a corporate basis until the end of 2018 and safeguarded the further development of the Evonik Group (non-mining activities referred to as White Business of the former Ruhrkohle AG, today RAG AG)

In order to secure the financing of the perpetuity costs, North Rhine-Westphalia, the Saarland and the RAG-Foundation concluded the Legacy Agreement to take over the perpetual costs of the RAG AG coal industry. In December 2007, the Hard Coal Financing Act was introduced. At the same time, a controlling, profit and loss transfer agreement was enacted between the RAG-Foundation and RAG AG. In addition, the RAG-Foundation acquired Evonik Industries AG from RAG AG at a book value of approximately €1,2 billion and thus became the owner of the White Business activities of the former Ruhrkohle AG.

The first step in building up RAG-Foundation's assets was the sale of 25 % of Evonik shares to CVC Capital Partners for €2,4 billion in 2008. As of 2020, the RAG-Foundation holds an endowment capital of around €18 billion and the foundation's operations are overseen by a board of trustees made up of high-ranking representatives of the federal government, the states of North Rhine-Westphalia and Saarland, and IGBCE, among others.

12.3 The tasks of RAG-Foundation

The RAG-Foundation bears the responsibility for financing the perpetual obligations resulting from hard coal mining in Germany by RAG AG: mine water management, polder measures (to manage water ponding on subsided land) and groundwater purification. In order to safeguard the long-term financing of these activities, the foundation is building up assets through a secure but profitable program of capital investment. This program is reliably providing the foundation with the necessary returns. In addition, RAG-Foundation promotes projects in the areas of education, science and culture that are related to the hard coal mining industry in Germany.

12.4 Financing perpetual mine management obligations

Coal mining has created an extensive system of underground shafts and tunnels and together with other impacts has changed the landscape in the mining regions. Intensive underground and aboveground water management is a corollary of coal mining, because coal can only be extracted at great depths if the mine water that seeps into the galleries is continuously pumped out. The mine water still has to be continuously pumped out, if necessary after carrying out an optimization of the final mine water levels, even after coal is no longer mined. This is due to a variety of reasons, such as the need to protect drinking water. Moreover, pumping facilities have to be operated in some areas in order to prevent lakes from forming above ground as a result of mine subsidence. Last but not least, groundwater purification facilities are operated in former mining areas to protect the groundwater. This active mine water and groundwater management cannot be discontinued after coal mining has ceased; it is a task that has to be performed in perpetuity. Water requires ongoing management.

RAG AG will have to finance this management even after 2018. They will also secure the shafts and tunnels and eliminate mining-related damage— the RAG foundation will implement measures for the permanent management of mine water and groundwater that, after coal mining is discontinued, perpetual management tasks will be funded by the RAG-Foundation.

12.5 Building up the foundation's assets

The RAG-Foundation is greatly reducing the financial strain on the public sector by financing the perpetual mine management obligations with income from the foundation's assets (i.e. income from its capital and holdings). The foundation's assets that are available for this purpose mainly consist of assets that were generated by coal mining in the affected regions. This is because Evonik Industries AG and Vivawest GmbH have their origins in coal mining and the former RAG Group.

In the unlikely case that the RAG-Foundation's assets do not suffice to finance these tasks, the federal government and the governments of the two coal mining states have guaranteed that they will supply the required funds. The RAG-Foundation is working to make sure no shortfall occurs.

12.6 Supporting education, science and culture

In addition to funding perpetual obligations, the RAG-Foundation has the purpose of financing educational, scientific and cultural projects in the Ruhr and Saar regions, provided they are related to the coal mining industry. For example, the RAG-Foundation funds training programs for teenagers in the former Ruhr and Saar mining regions and supports scientific research regarding the consequences of Germany's coal mining activities.

In future, the foundation will also support the further development of institutions that used to be regularly funded by RAG AG and whose survival would be at stake with the cessation of coal mining. Among them are the German Mining Museum (which also conducts research), the private Georg Agricola University of Applied Sciences in Bochum, and the miners' choirs and orchestras.

12.7 The foundation's model for the future

Ever since it was founded, the RAG-Foundation has safeguarded the financing of the perpetual obligations by increasing its foundation capital. It has an ambitious goal. As of 2019, about €300 million are required per year to finance the perpetual obligations. This amount is expected to decrease in the following years. Thanks to the foundation model, this burden is lifted from the taxpayers. This concept is to everyone's benefit and can provide a funding model that can be applied elsewhere.

12.8 Extract of statutes of relevance to RAG

The statutes of the RAG-Stiftung, take into consideration the resolution of September 1, 2008. Attention is drawn to the following statutes: Article 2 Objective and Article 3 Assets. See Reference [60].

13 Organising post-mining in France

13.1 Background

France has a long experience in managing mining legacies, with a national program coordinate and founded by the state. The French Mining Code provides that at the end of the work termination carried out by the operator, the monitoring of residual risks (land movements, gas emission) and the management of "hydraulic safety installations" is transferred to the state. After this work termination, the operator stays responsible for material damage caused by his activity. When the site is orphan (operator missing or failing), this damage has to be managed and founded by the state. The mining regulator and the management of mining legacies are carried out by the regional services for the environment of the environment ministry under the authority of the regions.

This main pattern is completed by:

— GEODERIS (See Reference [47]): a public interest group formed in 2001 to provide expertise and technical assistance (includes 22 professionals with mining expertise)

— DPSM (See Reference [48]): an operational post mining department at the French Geological Survey (BRGM) that monitor, rehabilitate and carry out safety works (90 people)

— BGRM (See Reference [49]) and Ineris (See Reference [45]), public agencies, that provide additional expertise and research capacity to the French state and to GEODERIS.

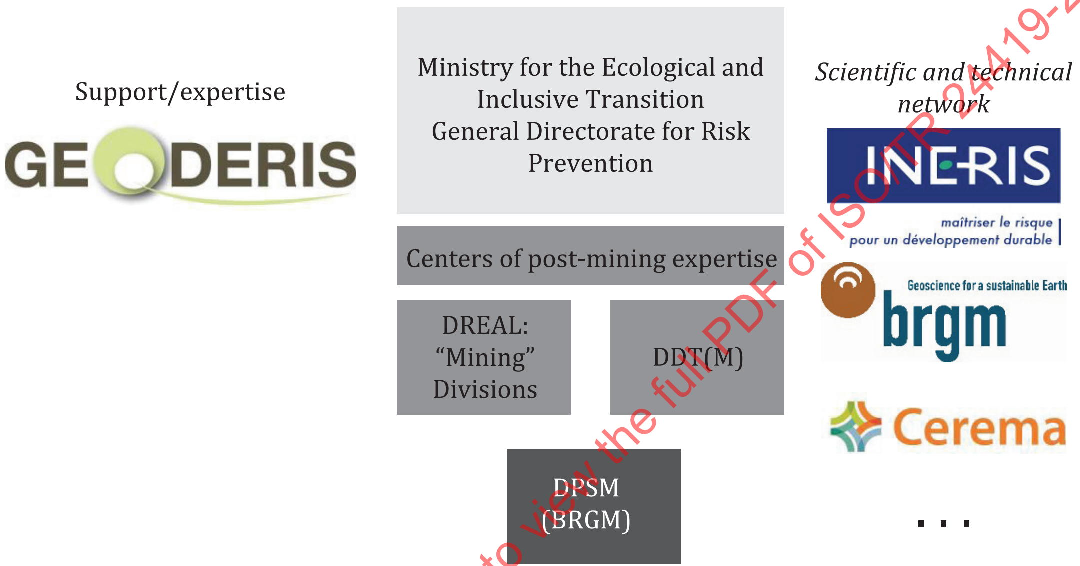

Figure 1 — Key players in mining risk management (DREAL: Regional Directorates of Environment, territory Development and Housing; DDT: Departmental Directorates of Territories)

Source: See Reference [45].

13.2 Introduction to post-mining legal arrangements

Various legislative measures (laws of 15 July 1994 and 31 March 1999) provide that the state is responsible for material damage caused by the operator’s activity when the latter is not in a position to do so or is no longer in existence and place under state care the plant and equipment required for preventive action and for ensuring safety. In addition, the state has clarified the mine decommissioning procedures and established new regulations to introduce mining risk prevention plans. This concerns the work termination process and the transfer to the state of the residual risk monitoring and the hydraulic safety installations management. However, the operator remains responsible for material damages caused by its activity even after works termination. The major responsibilities which fall on the state are the object of a post-mining action plan covering social, institutional, organisational and juridical aspects.

13.3 The French Mining Code

The code defines mines as distinct from quarries, confirms that the State retains ownership of subsurface mining resources, defines the circumstances under which mining can continue and assigns responsibility to the mining regulator. Since 1999 the French Mining Code prescribes the terms of post mining: the monitoring of residual risks, implementation of monitoring equipment for subsidence and gas, hydraulic safety installations, mining risk prevention plans and engagement with committees involving stakeholders.

13.4 Progression toward mine closure and lease relinquishment

Relinquishment transfers responsibility, equipment and information from the operator to the state and includes the following steps:

— Work termination will be declared to the regional government before the end of the validity of the mining title.

— The operator

  — outlines the measures to prevent risks, nuisances and disturbances of any kind, and

  — identifies residual risks for the safety of people and property and to maintain surveillance measures beyond the cessation of work.

— The regional government administration prescribes measures that the operator will take during the work termination.

— In the absence of implementation of the measures prescribed, the administration has the power enforce ex-officio.

— Two government declarations apply:

  — The declaration describes all the works and processes to be implemented by the operator to stop the mining activity and manage post-mining. After the analysis of the relinquishment declaration, the administration records it and prescribes complementary measures, if required.

  — The operator then sends a report to the regulator of mining describing how they completed the complementary measures (monitoring, works details and evidence of works inspection). Once this is accepted the government declaration is published and the residual risk monitoring is transferred to the State in return for the payment of 10 years of monitoring and operational costs of prevention risk facilities.

There are also specific administrative procedures for hydraulic safety systems:

— The rights and obligations related to these facilities are transferred with them.

— This transfer is approved by the administrative authority. It is accompanied by a payment by the operator of an amount equal to the estimated cost of the first ten years of operation of these facilities.

If asked, the operator will provide the community with facilities useful or necessary to sanitation, water supply, control of rainwater, runoff and groundwater.

13.5 Mining risk prevention plans

These plans are established by the administration following a public enquiry and consultation with the municipal councils involved. They include a hazard map, a risk analysis and mapping of the land use consequences.

13.6 Post mining management by the state

Regulatory functions are ensured by the appropriate central administration that is, the state agency responsible for the environment, and its decentralised office: regional services for the environment.

The budget is completely funded by the state at around 40 million euros per year for the post mining expertise and operational management:

— Expertise is assigned through an independent public interest group Geoderis. 50 % of this group includes staff provided by BRGM and 50 % by Ineris. This group has responsibility for mining hazard mapping, the assessment of safety and monitoring as well as reporting.

— Operational duties such as monitoring, hydraulic safety installations, remediation and safety works were delegated to BRGM in 2006, where the Department for Mine Safety and Risk Prevention was established and is fully funded by the state.

13.7 Conclusion

To sum up, this case study illustrates the importance of a legal clarity for responsibilities of companies and governments through all stages of closure to post-closure stability. It also highlights the importance of ensuring an ongoing funding resources to manage mining legacies. Stakeholder engagement is integral to this process of transition. Such a process would not function without the expertise and continuity of knowledge within the various entities that come together to manage closure and post-closure.

14 National review of abandoned mine land (AML) programs, United States of America

14.1 General

In the United States, federal government programs are subject to audits, reviews, and examinations, which are usually initiated on the behest of a member of the US Congress or a Congressional subcommittee. The Government Accountability Office (GAO) conducts these oversight activities. Additionally, an agency's own Office of Inspector General (OIG) can also conduct an audit on a specific program, which also can be instigated by a congressional inquiry but also through employee whistleblowing, crime reports, etc. The purpose of these audits is to review components and practices of the programs to ensure that the American public is receiving what it is paying for: that the work is done efficiently, and that the work conducted is meeting the agency-mission. Each audit will have a specific question/s that need to be addressed and the methodologies used to answer each audit request are case dependent. The reviews can result in a finding or advice for the agency. Actions from which, are monitored for progress by the auditing agency. The federal hardrock abandoned mine lands program (collectively) has directly or indirectly been a part of at least 21 audits since 1978, some of which are responsible for starting AML inventories and the development of policies and practices that have benefitted the overall program and its progression. In 2018, Senator Tom Udall requested a review of issues related to hardrock mining and the abandoned mine lands program was a focus area.

14.2 Review of hardrock AML programs

In early 2020, after an extensive review of the hardrock AML programs the GAO released a report that reconfirmed challenges listed in previous program audits. Federal AML programs that were studied for this audit include the US Department of the Interior - Bureau of Land Management, National Park Service, and the US Department of Agriculture – Forest Service, and the Environmental Protection Agency. Information was also gathered from 13 state AML program partners and community stakeholders.

These AML programs continue to be challenged by the monumental cost to complete the enormous inventory task and subsequently the corresponding effort to ensure the anticipated hazards are addressed. The 2020 report includes estimates that there are over 530,000 hardrock AML features to be located on federal public lands. At the time of the audit, the programs reported that over 140,000 AML features had been located of the estimated 530,000 features expected to be found. There are about 81,500 features that need to be characterized for the environmental or physical safety risk.

The costs to address each feature are extraordinary in terms of labour and operations. The federal AML programs have expended almost 2,9 billion dollars towards the AML issue between fiscal years 2008

– 2017. Of the estimates available from the agencies, it could cost over $650 million to complete the inventory of AML features and over $5 billion to address the physical safety hazard features. Estimated costs for addressing environmental features could be as high as 7 billion dollars. Not all agencies were able to give estimates for all components of the program. The BLM estimated it would take over 500 years to complete the workload with the current funding and labour capacity.

As indicated in earlier reviews of the AML programs, consistency in AML terminology across the programs remain a challenge when comparing programs across agencies.

14.3 Partnerships

Partnerships with state AML programs and non-governmental organizations are very important for chipping away at the large workload, especially when there is a low likelihood that a viable responsible party exists to pay for these efforts. Because of the way the applicable AML environmental laws are written, external parties that are interested in assisting with the effort are reluctant to assist because of legal liabilities, for example they become a responsible party under the Comprehensive Environmental Response, Compensation and Liability Act.

14.4 Cost challenges

The limiting factor for the AML issue for the federal government is the remarkable cost to address all the major components of the programs. The likelihood of having a viable responsible party in existence for the legacy mines is low, the American taxpayer will likely be covering the costs. Collaboration between the stakeholders for environmental features is stymied because of the liability limitations included in the environmental laws that authorize such clean-ups.

15 Funding and resourcing legacy nickel mine rehabilitation, New Caledonia

15.1 General

This case study describes the importance of strong working relationships between the government, mining legacy rehabilitation program and the active mines in the Thio valley, when managing mining legacies in New Caledonia. The Nickel Fund was instrumental to the process whereby a working relationship was established by the government of New Caledonia, together with the local government, in order to ensure community safety from flooding and impacted water courses. Together the government facilitated a process whereby the mining company took back its responsibility for managing mining legacies on its leases. The government continues to monitor the program, progress and performance and monitor and contain solid materials in transit down slope from mining areas as a legacy of past mining, the government also monitors and responds to the consequences of rainfall events associated with current mining operations.

15.2 Establishment of the Nickel Fund to rehabilitate legacy mines

New programs of mining rehabilitation of orphan mine sites were added in 2009 when the Nickel Fund was established. This fund replaced an old fund established to address mining activities in crisis periods. Funds are sourced from mining titles whereby any company that owns a title gives between 800 XPF (French Pacific Franc) per hectare (around 10 AUD) per year, to the Department of Mines, who transfers all of it to the Nickel Fund. For the larger companies (with larger titles) the price is 1 000 XPF /ha/year. It represents around 240 million XPF (3,1 million AUD). These funds transit through the government to 'Fonds Nickel'. While more funds have been expended than collected in the last five years through this process, costs have been offset by the amount held in the earlier fund. Further modifications can be required to attract additional funds for the future so the Nickel Fund is evolving.

15.3 Estimating the needs of the Nickel Fund

When assessing the total rehabilitation work required to repair all damaged land from mining, a very high level estimate indicates that the government would require about 160 billion XPF (around

2 billion AUD) if the total 20,000 ha had to be rehabilitated by the government. However, within this area of cleared and/or mined sites with impacted streams, the majority of legacy mines remain under mining tenure with operations continuing. The requirements to rehabilitate mining legacies is included in operators' mining licenses so companies are responsible for managing mining legacies within their tenure. Some areas were already being addressed by the provincial institution in charge of the environment until 2009, past research programs and using European funds, for a few sites. From 2009 the mines department took over these projects as well as the remainder to manage them under the Nickel Fund. This amounts to 10 % of the total area of mining legacies that has to be funded from the Nickel Fund. A further breakdown of this 10 % shows that some areas can't be treated as they are too steep, too rocky, and generally inaccessible. Only about one third of this remaining area, comprising multiple sites (see Reference [104]), can be rehabilitated, which indicates a total legacy liability of (4 to 5) billion XPF ((5 to 6) million AUD)). This amount is based on an average estimate and of course many variables could change the amount required.

15.4 Management of the Nickel Fund

The Nickel Fund is managed by a board of directors with a president and vice-president. This leadership team meets every year to review budget progress and forecasts. Board meetings take place two to four times a year, to deliberate upon and select those companies to work with, according to our rehabilitation strategy. For the everyday management, the director of the Nickel Fund, leads decision making processes for all the studies, choices of techniques, the selection of contracts and the details of smaller rehabilitation programs.

Supporting the director and program, are a technical crew of 3 engineers. One is a specialist on mine rehabilitation, another on revegetation, and the last one in rivers and creeks/ hydrology and watercourses management. There is also a technician who multitasks on both mines, creeks, monitoring. The budget and administrative duties are held by a shared crew of three, that work primarily for the Department for Mines, Industry, Energy, New Caledonia Government (DIMENC).

15.5 Illustrating key challenges with reference to the Thio Valley area

The rehabilitation program of the legacy mines in the Thio valley is an example referred to in this case study. The key challenges were to address the problem fast enough to offer satisfaction to the affected community while explaining that these efforts are not considered definitive, and to understand that dealing with the main river is too complex and expensive nor would it be permanent. Difficulties encountered include access to areas for rehabilitation, and ensuring the appropriate stakeholders are identified and involved. Care needs to be taken to ensure there are no conflicts within this tribal district, about a particular subject, creek, or contract. Another challenge at this site is that we had inexperienced teams for creek works, which delayed the rehabilitation works, river improvement, and extended the costs. But progress was made and now in this region, there are two well established and trained companies that can offer their services in these particular types of works.

15.6 How the Thio valley community were engaged

Communities were already involved and grouped into an association following disastrous flooding in 2013. The town, the association, the mining companies, and the Nickel Fund had several technical committees to decide the priorities, budget, and schedule the works required. The companies who did the corrective works were also part of the community.

15.7 Benefits from the program in the Thio valley

High rainfall, flooding and discoloured water are the particular environmental issues that initiated the social movement in Thio. Because all stakeholders worked together, tensions were gradually reduced between tribes within the region and with mining operators/government. It has been a shared experience, a common project with everyone involved, so that each one feels also responsible to contribute for a better living environment. Also, skills and knowledge on these topics are being shared within the population and the companies involved in the environmental solutions.

15.8 Progress so far in the Thio valley

The priorities are clearly focussed on rehabilitation on particular orphan mine sites in order to reduce the effluent entering the main river together with effort applied at the active mine. Since the commencement of work in this valley, we have also added more watercourses to our list of future rehabilitation. Mine tailings have contributed to the sediment load from erosion of slopes and by creating disturbances within creeks but there are additional land stability problems due to fire regimes (variable from year to year), and natural landslides due to steep slope within natural landscapes and the physical properties of these materials. There are natural occurrences of chromium, nickel and iron ions and so on in the runoff waters that impact stream systems and they too are influence by fire, vegetation clearing. These occurrences are detected in water quality monitoring and is the subject of research by the National Centre for Technical Research on nickel (CNRT) and its social, technical and economic environment (See Reference [105]). The CRNT undertake targeted studies of chemical reactions in groundwater as well as water catchment behaviour in response to rehabilitation works undertaking monitoring for their specific studies.

Within the Nickel Fund programs practitioners collect samples before and after their works particularly, if the water is used for human consumption around or downstream of the rehabilitation works. The focus of water quality monitoring is predominantly directed toward turbidity and water flows before and after removal of sediment and other solids.

15.9 Evaluating performance

We do not have global indicators, but monitoring data from rivers and repaired topography get us feedback on how much materials have come back, and if further improvements in water quality are needed in our target watercourses. At the orphan mines, we control the levels in sedimentation ponds, and verify water drainage from the top to the bottom of the site, and initiate maintenance operations if required. Most of all, feedback from affected communities gives the most immediate indication of our performance, reflecting their understanding of progress and overall improvement in land stability and water quality.

15.10 Maintenance of rehabilitated sites

Maintenance is critically important as rehabilitation cannot be conceived as a one-off operation. Inspections are made within the two following years (or more if sensitive). To avoid relentless maintenance, we do conceive our rehabilitation schemes with a big focus on water distribution, and revegetation that will reduce as much as possible the erosive process. By reducing sediments after a few years, maintenance is therefore limited to freshly rehabilitated sites, due to earthworks that has redisturbed and decompacted the soils. The priority is to direct water appropriately and reducing the damage from water runoff, in preference to trying to collect more sediments. In the long term, sediment ponds pose a significant risk if they were to fail whether catastrophically or leakage. Funds are set aside for previously rehabilitated sites that we are responsible for, but we also try to limit these costs. Same on revegetation: if the process of plant recolonisation does not meet our standards, we put some more efforts to achieve this goal.

16 Reopening the Otanmäki Mine, Finland

16.1 Aspect of managing mining legacies and source

Circular economy and remining, remediation at the Otanmäki Mine Oy prepared by the Geological Survey of Finland (GTK) See References [34], [35] and [36].

16.2 Recognition of a problem that needed to be resolved

The aim of the Otanmäki Mine mining project is to reopen the Otanmäki Mining Area (Fe, Ti, V), which operated from 1955 until 1985. The main product will be vanadium-pentoxide, ilmenite and iron concentrate. The main concern at the site are mine tailings and waste rock sites, which do not have proper bottom or cover structures and acidic seepage waters and dust are transported to the surrounding environment. The seepage is transported via ditches to the old settling pond which has turned into a bird wetland. The wetland discharges via River Vimepelijoki to Lake Vuottolahti. According to Tornivaara et al. (2018) the emissions are low, and the acidic waters are neutralized before entering nearby ponds and lakes. The seepage contains mainly elevated vanadium and manganese concentrations, which are restrained in lake bottom sediments. However, though it seems the emissions do not pose a risk to the environment, Tornivaara et al (2018) suggest further studies on water geochemistry and lake bottom sediment, in order to assess the potential ecological impacts at the site.

In accordance with the EU's Extractive Waste Directive (2006/21/EC), all EU member countries have surveyed their extractive waste facilities of closed and abandoned mines that can cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment. These surveys have been rather concise and do not necessarily contain enough information about the content of the mine waste sites in order to assess their potential for reprocessing or even remediation measures. Therefore, more detailed studies have been conducted according to the environmental load and impacts.

16.3 Steps involved and expertise/stakeholders involved

Prior to open pit and underground mining the Otanmäki Mine Oy tends to reprocess the old mine tailings to accelerate the development of the mining project.

The old mine has been filled with water since closure, and the mine tailings pond contains 10 million tonnes of diverse waste, the composition of which was not precisely known. The company set up a tailings pond research project to pave the way for the actual mining project. Based on GTK's mineral resource estimate, it was known that the average ilmenite content of the tailings was 16 %. The goal of the beneficiation process was set at 50 % yield. GTK Mintec's pilot plant and laboratories in city of Outokumpu serve as a platform for testing and research of the enrichment process. Based on pilot and actual testing, the most optimal, gravity-based separation method was selected for the tailings to achieve the target yield and high quality product. In addition to reprocessing the ilmenite in tailings, most of the material can be used in various infrastructure construction sites and as a raw material for concrete production.

The initial project of the tailings will last for a maximum of 8 years. The initial project will yield a reasonable return, lowering the threshold for launching the actual mining project. The water that has filled the mine is pumped into the processes of the tailings project and at the same time the mine can be emptied. The circular economy solutions in the old mining area will pay off, pave the way for market confidence and hopefully strengthen regional social licensing.

16.4 Evaluation of performance of this initiative

As the liability of the mining waste and their impact on the environment has been transformed to the Otanmäki Oy, it is assumed the potential environmental impact will decrease at the site. Furthermore, as the old mine tailing will be reprocessed also the amount of the mining waste will be diminished. The environmental, mining and water permits or authorisations also require proper bottom and cover structures for the new waste sites. The estimated lifetime of the project is 15 years and the mine and the factory would employ approx. 350-400 persons, which will naturally bring income to the region.

16.5 Key learnings for others

The SME-sized mining companies do not have similar access to research infrastructure than multinational mining companies. It is costly to conduct feasibility studies for the ore, let alone mining waste, and without active cooperation with public research institutes, like GTK, these kinds of reprocessing projects are not very likely.

Mining waste is one of the largest waste streams in EU and there are thousands of old, abandoned waste sites which still contain valuables that could be reprocessed. While drawing attention to the important potential value of this resource, the composition of the tailings is usually not known and therefore more studies are necessary before it is possible to commercialize the sites.

17 Online monitoring and early alert system for tailings storage facilities (TSF), Chile

17.1 Background

In recent history, mining has driven Chile's development and has thus become one of its main economic activities. Nowadays, the challenges imposed by national and international circumstances have caused the industry to consider its operational standards and practices; thus, a number of initiatives have been put in place to take actions designed to promote a sustainable mining development.

After the disaster in Brumadinho, the whole world has centred its attention on the mining industry. The accident, beyond its technical considerations, impacts mining from different angles, deepening a reputational crisis that, without drastic measures, can end in serious consequences for the sector if material actions are not taken fast enough. The spill of 13 million cubic meters of sludge, at a rate of about 80 kilometres per hour, destroyed homes and took the lives of 270 people, of whom 259 were officially confirmed dead, in January 2019, and 11 others reported as missing, whose bodies had not been found. In addition, it has affected forests, putting at risk the rivers around it, causing environmental and social damage that the community is no longer willing to accept. Brumadinho is just the last of a series of failures every year all over the world. The previous disasters of Samarco and Mount Polley underscored the issue of TSF on international level and in Chile. TSFs pose challenges for sustainable development during as well as after mining.

Bearing in mind that Chile is a country with the third largest number of TSFs globally and that these deposits are of key importance for the industry, there is no question that solutions are essential to enhance TSF management to better control their performance and relationship with their environments. Based on the catastrophic events that recently occurred in the world, both environmental issues governed by different regulations and the social aspects that grant the social license to operate has to be addressed. Additionally, mining is facing the challenge of keeping the confidence of investors who provide the industry with the financial license to maintain its development.

17.2 Transparent tailings initiative

The Chilean mining sector, with both private and public organizations, is working since 2016 on the safety aspect of TSF, developing the 'Transparent Tailings Initiative, aimed to develop a standardized monitoring and early-warning system applicable to TSFs. Through an information management platform, this system will provide the parties involved (authorities, mining companies, and communities) with quality, reliable, and timely information regarding TSF performance, in aspects of physical stability and surrounding water monitoring. This initiative, under the auspices of the Alta Ley program, has been co-designed and implemented by Fundación Chile, CORFO, Ministry of Mining, National Service of Geology and Mining (SERNAGEOMIN), National Emergency Office (ONEMI), Superintendence of the Environment (SMA), General Water Department (DGA), Antofagasta Minerals (AMSA), BHP, CODELCO, Anglo American, National Mining Society (SONAMI), Advanced Mining Technology Center of the University of Chile (AMTC), and Valor Compartido.

The commitment is to contribute to the continuous improvement of the safe and reliable operation of TSF, by providing quality and timely information to authorities, mining companies, and communities, thus enhancing the communication between the parties and the response to emergency situations. With a greater focus on TSF safety, this initiative will also help to provide stable TSFs in the long term, preventing negative legacies.

17.3 Purpose of initiative

The initiative pursues the development of a standardized monitoring and early-alert system applicable to TSF such that, by means of an information management platform, can provide the involved parties (authorities, mining companies and communities) with quality, reliable and online information about the dams' behaviour in terms of physical (geotechnical) and chemical (environmental) stability. The ultimate goal is to strengthen the preventive operational management, improve communications and response among the parties when faced to unexpected emergency situations.

Starting as a voluntary program, in 2018, it was included in the Chilean National Policy for Tailings, considering its potential application for all the 119 active mine tailings. Chile's Mining Minister Baldo Prokurica highlighted "The Transparent Tailings Initiative will position Chile as leader in the management of information on the performance of these tailings deposits, through online monitoring and accident prevention. All this through the delivery of timely information through the creation of the national observatory of tailings deposits, administered and operated by Sernageomin".

17.4 System design

The system is designed to raise and process information with different degrees of complexity and frequency in different types and life of cycle state of deposits. These tools make up a system for monitoring and analysing the performance of the deposit, where the general process integrates a set of heterogeneous data such as visual inspection or instrument data, which are often massive, in models that can generate clear results to help decision-making, remote control and to achieve a progressive knowledge of the behaviour of the structure that, as a final purpose, allows a clear and timely communication to different users

The aforementioned system exhibits two interrelated components: (1) the monitoring system including the data capturing methods and technologies, their collection and storage, post processing and the differentiated visualization of the data collected for the TSF performance definition; and (2) the early-warning system notifying events and alerts to the main actors involved: public entities, mining companies, and communities, in case of eventual emergencies.

The monitoring system is based on a standard that defines several technical criteria especially designed to monitor and evaluate the physical stability of TSF and its influence on surrounding waterbodies. This standard has been agreed upon by all the parties comprising this public-private alliance. To evaluate the physical stability of TSF, a tool capable of assessing a TSF condition has been developed based on three main failure mechanisms (overtopping, piping, and slope instability) that can compromise the physical stability of such facilities. These mechanisms contain two sequential assessment modules differentiated by the frequency, volume, and complexity of the information required. This physical stability assessment tool has been mainly conceived to learn and notify how deposits behave in front of factors such as location, selected design, and the operation, to have a comprehensive panorama that helps enhance the TSF preventive management. The standard consists of two interrelated modules that are assessed in sequence, as shown in Figure 1, and described below:

— M1: Module 1 Qualitative assessment: Qualitative verification tool that periodically assesses the physical vulnerability of the TSF and verifies the occurrence of aggravating factors, such as deviations from the design and events that can facilitate the triggering of a failure mechanism.

— M2: Module 2 Verification of 30 critical parameters and 12 failure scenarios: Monitoring tool that verifies the physical condition of the TSF by analysing the monitoring values of the critical parameters and their trends compared to threshold values. Exceedance of regulatory and site-specific threshold values can activate alert signals or alarms depending on the severity of the situation. This tool also verifies the combined occurrence of anomalous critical parameters values and trigger events that can configure a failure scenario, whose definition depends on the analysis of the most common types of historical failures.

The results of the assessments of these two modules M1 and M2 are used to issue an external communication to the stakeholders about the physical stability of the TSF, considering following alert types:

— Early preventive alert: This alert represents a normal functioning of the TSF, which is permanently monitoring the critical parameters.

— Yellow alert: This alert corresponds to an abnormal condition of the TSF that requires an intensification of monitoring, inspection and control from both mining company and authority.

— Red alert: This alert is associated with a critical physical condition of the TSF that requires the implementation of the emergency plan to evacuate the facility and the downstream communities.

Mine companies will operate and maintain the local system until TSF has been closed and closure certificate has been received that certifies the full and timely compliance of the obligations established in the mine closure law.

Further information can be found at Reference [106].

18 Public private partnership funding mode of legacy Green Golden Lake coal mining rehabilitation program, China

18.1 Introduction of China managing mine legacy

Since 2000, Chinese Government has successively released a series of policies, which aimed at improving mine geological environmental conditions, including “Mine Geological Environment Protection Regulations” and “Land Reclamation Regulations”. Management of mining legacies is charged by the municipal and county departments and funded by the special government funds. Besides, Chinese Government carried out special treatment program and mine greening action for mine geological environment restoration, for example, National Mine Parks program and a financial bond system. An economic mechanism for development compensation and protection has been built gradually.

To improve the rehabilitation of mining legacies, the appropriate administration issued a document about encouraging social capital to enter the mine ecological restoration in 2019. Under this document, the resolving of mine geological environment problems left by the historical mines was incorporated into the local government's objectives and tasks, social capital participation was encouraged to accompany the local capital investment, and the property right incentive policy was implemented.

Under the new policy framework, the management of legacy mining was combined with the construction of new countryside, the relocation of ecological immigrants, geological disaster treatment, land remediation, and the increase or decrease of urban and rural construction land. And many successful and typical cases were explored, such as Shimao Quarry Intercontinental Hotel (selected as one of the world's top ten architectural wonders), Zhejiang Suichang Gold Mine National Mine Park, Tangshan Nanhu Park, Kailuan Coal Mine National Mine Park, Sichuan Jiayang Coal Mine National Mine Park, and the Huaibei Green Golden Lake, and so on.

18.2 Green Golden Lake coal mining rehabilitation program

18.2.1 Background

The Green Golden Lake is a successful case of rehabilitation of subsided land due to coal mining in Huaibei, Anhui province. It was a serious damaged region with the sinking depth varying from 1,5 meters to 7 meters, which resulted in serious ecological system damages such as farmland damage, houses collapsed, roads and bridges broken, water pollution. More than 10 000 households in 11 surrounding communities were impacted. After the rehabilitation program, this area became an ecological area characterized by water, forest, leisure and residence with high vegetation coverage, by integrating ecological restoration, resource protection, scientific research, cultural creativity, tourism and leisure. And the living conditions also got improved significantly. The area thus got a new beautiful name “Green Golden Lake”.

18.2.2 Recognition of a financial problem that needed to be resolved

The Green Golden Lake coal subsidence rehabilitation program (from March, 2016 to the end of 2017) is a national key project of mine geological environment treatment. The total budget was ¥ 2,2 billion. However, the government's special fund for the rehabilitation of Green Golden Lake was only about

¥ 0,2 billion. Compared with the total budget, there was a huge fund gap as high as ¥ 2 billion. So the implementation of the program faced tough finance shortage problem.

To solve the large fund shortage, the program used the Public Private Partnership (PPP) financing mode in 2015, and adopted the integrated government procurement service mode of "investment-construction-maintenance-transfer". In August, the program was bidding publicly on the government bidding website. The local government, as the purchaser, selected two social investors through bidding under the law. Then both sides signed the PPP agreement setting an investment return rate and maintenance fee. Under the agreement, the investors were responsible for completing the project investment, financing, construction and maintenance, while the government would pay the service fees in 10 years, being responsible for the project design, supervision, land acquisition and relocation compensation and coordination, included in the annual financial budget. At last, the government would own the development right, use right and income of water areas, lakes and available land formed.

18.2.3 Evaluation of performance of this initiative

Since the final acceptance of construction at the end of 2018, Huaibei City has paid the government service purchase fee on schedule under the agreement for three years, and the PPP model has entered a benign development stage. In the PPP program, the advantages of the government in planning, policy and management, the social capital in construction, operation and maintenance were exploited fully. Both sides shared benefits and risks to achieve win-win cooperation.

18.2.4 Key learning for others

This case study illustrates the importance of the social funding in the mining legacy program. It also highlights the importance of the cooperation of government policy and social funds in the program. Without the social investment, it would be hard to maximize the effectiveness and the chance of the mine legacy restoration.

19 Structured case studies

The case studies in Tables 1 to 5 follow an alternative structured format. While giving insights on particular case studies, they also indicate how a mining legacy inventory can be structured. This format allows for the basic information to be included, and added to, over time.

Table 1 — Montjean sur Loire mines, France

Mining legacies - abandoned mine description	
Location: *In the west of France, Maine et Loire department, between Angers and Caen cities, very close to the town of Montjean-sur-Loire*	***Surroundings:*** ☐ cities /urban ☒ village ☒ agricultural / natural Description: former mining sites are closed to individual dwellings in the village of Montjean, vineyards and the Loire river
Context(s)	
Main metal(s) / mineral(s) exploited: *Coal (poor quality, used for local forges and not for the steel industry)* *Ore mineralogy, Rock host mineralogy: no pyrite within the mineralization* ***Mineral deposit:*** ☐ alluvial ☒ stratiform / layers (☒ subvertical or ☐ subhorizontal) ☐ Veins ☐ Placer ☐ Others:.. ***Geology / hydrogeology / hydrology / climate description:*** Some 12 seams identified, oriented N120°, [0,5 m to 5 m] of thickness, [45° to 90°] of dip. Mineral deposit partially covered by Loire river and alluvium. Oceanic climate, with fairly mild and rainy winters / dry and fairly hot summers, Precipitation totals 695 mm per year (40 mm to 70 mm, average per month).	
Mining works	
Mining activities: ☐ Open pit exploitation ☒ Underground work ☐ Treatment facility ☒ Mining waste storage facilities ☐ Others: .... ***Activity period(s):*** *Coal mined since the 15th century. Main exploitation between 1806 and 1892 (a strong inflow of water invades underground works stopping mining extraction).* ***Production:*** 500 000 t between 1750 and 1892 ***Exploitation methods / characteristics (extension, depth, dips, openings...):*** *1/ Many small isolated shafts linked with former artisanal extraction on outcrops (< 20 m of depth). More than 40 shafts 2/ Wall mining methods, with short walls, "reverse benches shape" and backfilled upwards, [15 – 300 m] of depth and 10 levels, extension: 1 500 m E-W and 500 m N-S.* ***Ore treatment methods (residues granulometry, chemical used...):*** None (on site here) ***Waste storage facilities (type [tailings, heap leach, waste rocks...] size, slopes, type of cover, basement, etc.):*** *Three flat waste-rocks heaps.* ***Available mining data:*** ☒ "Old" ones (exploitation period) ☐ "New" one (post-exploitation) ☒ GIS ones Description: 4 main mining plans of the old underground works and many Mining Engineer reports. The plans are georeferenced in a dedicated GIS.	
Other(s) comment(s):	
There is no document (plans) locating the old isolated shafts of the older exploitation period.	

Post-exploitation impacts			
Impacts observed or identified			
Nature of impacts: ☒ Geotechnical ☐ Hydro(geo)logical ☐ Environmental ☐ Health safety ☐ Cultural / social ☐ Others: .... Description:			
Impact	*Year / period*	*Description*	
1	*1941*	*Local sinkhole, 2 x 6,7 m in surface (width x length), above underground mining voids*	
2	*2007*	*Local sinkhole on the head of a shaft partially backfilled. This event occurred after a long rainly event.*	
3	*2013*	*Main sinkhole, 8 m × 14 m in surface (width x length) and 5 m of depth. The roof of "supposed" underground works suddenly broke up. Three houses evacuated and one barn destroyed (fortunately no victims).*	
Post-exploitation management			
Kind and step implemented: ☒ Hazard / risk studies ☒ Specific on-site investigations / Monitoring ☒ Safety works ☐Others:.. Description:			
Impact	*Year / period*	*Description*	*Costs*
1, 2 et 3	*2009-2010*	*A wide hazard study on the Layon coal Bassin (16 former licenses, including Montjean-sur-Loire one). Local sinkhole is mostly mapped (with 3 levels; weak, medium and strong)*	*~120 k€*
1, 2 et 3	*2012-2013*	*Drilling campaign to precise risk level under houses located in hazard area (strong and medium levels).*	*~150 k€*
3	*2014-2015*	*Design study of a treatment solution. Implementation and supervision of the backfilling of the collapse and construction of a concrete slab*	*~220 k€*
Other(s) comment(s):			
None			

Table 2 — South Alligator Valley uranium mines, Australia

<table>
<tr><th colspan="2">Mining legacies - Abandoned mine description</th></tr>
<tr><td>Location: Northern Territory, Australia 250 km SE of Darwin</td><td>Surroundings: ☐ cities /urban ☐ village ☒ agricultural / natural

Description: Seasonal river valley in Sandstone escarpment country; located in stage 3 of Kakadu National Park - World Heritage listed</td></tr>
<tr><th colspan="2">Context(s)</th></tr>
<tr><td colspan="2">Main metal(s) / mineral(s) exploited: Uranium…

Ore mineralogy, Rock host mineralogy: Sub-unconformity epimetamorphic uranium deposits in metasediments of lower Proterozoic age. Deposits are strata and structure controlled

Mineral deposit: ☐ alluvial ☐ stratiform / layers (☒ subvertical or ☐ subhorizontal) ☒ Veins ☐ Placer

☐ Others………

Geology / hydrogeology / hydrology / climate description: Wet dry tropics; rainfall 1 200 mm September to April; dry sclerophyll forest</td></tr>
<tr><th colspan="2">Mining works</th></tr>
<tr><td colspan="2">Mining activities: ☒ Open pit exploitation ☒ Underground work ☒ Treatment facility ☒ Mining waste storage facilities

☒ Others: …Mining camps

Activity period(s): 1955-64 52 exploration sites and 17 mines; three processing sites

Production: overall production ~975 t U3O8 also 312,5 kg Gold

Exploitation methods / characteristics (extension, depth, dips, openings…): aerial radiometric survey, drilling. many small explorations pads and roadways.

Ore treatment methods (residues granulometry, chemical used…): Three sites. Simple battery and hand sorting; battery and gravity flotation plant; small solvent extraction mill

Waste storage facilities (type [tailings, heap leach, waste rocks…] size, slopes, type of cover, basement, etc.): tailings at mill deposited alongside river, waste rock piles throughout the valley

Available mining data: ☒ “Old” ones (exploitation period) ☒ “New” one (post-exploitation) ☐ Geographical ones

Description: Mining Reports with NT Government Mines Department, reports on remediation and hazard reduction programmes; Papers and presentations from NT and Commonwealth government agencies on remediation programmes and monitoring post-remediation</td></tr>
<tr><th colspan="2">Other(s) comment(s):</th></tr>
<tr><td colspan="2">High level of consultation and involvement with Indigenous Traditional Owners over many years. Hazard reduction works for physical and radiological safety 1992; Full remediation 2006-7; monitoring ongoing post 2007</td></tr>
</table>

Post-exploitation impacts		
Impacts observed or identified		
Nature of impacts: ☒ Geotechnical ☒ Hydro(geo)logical ☒ Environmental ☒ Health safety ☒ Cultural / social ☐ Others:... Description:		
Impact	*Year / period*	*Description*
1	*1955-1995*	*Physical safety from open shafts and adits; unstable pit walls*
2	*1962-0ngoing*	*AMD flow from some underground workings*
3	*1955-2006*	*Exposure of cultural sites including stone arrangements and rock art*

Post-exploitation management			
Kind and step implemented: ☒ Hazard / risk studies ☒ Specific on-site investigations /Monitoring ☒ Safety works ☐ Others:... Description: Ground water chemistry monitoring and inspection of vegetation, fencing, surface stability and radiation levels at containment annually			
Impact	*Year / period*	*Description*	*Costs*
1	*1992*	*Hazard reduction programme to seal shafts and adits, restrict access; signage; collection and burial of radioactive waste at separate sites; demolition of mill site*	*AUD 300 K*
2	*2006-7*	*Remediation of all sites; relocation of tailings and consolidation of waste to one engineered containment*	*AUD 7,6 M*
3	*2007-ongoing*	*Monitoring of groundwater and stability of containment*	
Other(s) comment(s):			
None			

Table 3 — Tybo tailings, USA

Mining legacy - Abandoned tailings impoundment description	
Location: *Tybo Mine Tailings Impoundment, Tonopah, Nevada, USA*	***Surroundings:*** ☐ cities /urban ☐ village ☒ agricultural / natural Description: *Located 58 miles of Tonopah (population 2,478, 2010)*
Context(s)	
Main metal(s) / mineral(s) exploited: *silver, gold, lead, zinc, and copper* *Ore mineralogy, Rock host mineralogy: Rhyodacite- shattered porphyry along faultines.* ***Mineral deposit:*** ☐ alluvial ☐ stratiform / layers (☐ subvertical or ☐ subhorizontal) ☒ Veins ☐ Placer ☐ Others......... ***Geology / hydrogeology / hydrology / climate description:*** *The site is located in the Basin and Range geologic province, characterized by repetitive north to northeast trending mountain ranges and broad intermontane alluvial valleys. The mountain ranges consist mostly of Tertiary volcanic rocks, with some Paleozoic limestone and other sedimentary rocks outcropping near Tybo. The area is dry and arid, receiving only 11 inches of precipitation per year. The Tybo tailings lay within the Tybo Creek drainage east of the canyon where the canyon terminates into the valley.*	
Mining works	
Mining activities: ☐ Open pit exploitation ☐ Underground work ☐ Treatment facility ☒ Mining waste storage facilities ☐ Others: .... ***Activity period(s):*** *1866-1945* ***Production:*** *$6,8 million* ***Exploitation methods / characteristics (extension, depth, dips, openings...):*** *Several underground shafts located in Tybo Canyon mined oxidized ore for silver along fault lines to depths of 450 feet* ***Ore treatment methods (residues granulometry, chemical used...):*** *Cyanide leaching* ***Waste storage facilities (type [tailings, heap leach, waste rocks...] size, slopes, type of cover, basement, etc.):*** *sulfide ore tailings* ***Available mining data:*** ☒ "Old" ones (exploitation period) ☐ "New" one (post-exploitation) ☐ Geographical ones Description:	
Other(s) comment(s):	
Other sources: Nash, J.T. 1994. Geological signatures of silver and gold deposits, Tonopah 1degreex2degree quadrangle, Nevada-description and applications to exploration. United States Geological Survey Bulletin 2077.Available online at: https://pubs.usgs.gov/bul/2077/report.pdf	

Post-exploitation impacts

Impacts observed or identified

Nature of impacts: ☐ Geotechnical ☒ Hydro(geo)logical ☒ Environmental ☐ Health safety ☐ Cultural / social

☐ Others:..

Description:

Impact	*Year / period*	*Description*
1	*Ongoing*	*Inter-braided drainage channels transect the tailings impoundment. During storm events and snowmelt, red acidic sulfur-odored water flows from the impoundment into the drainages and nearby pond areas. Due to the volume and age of the tailings, gradient of the inclined alluvial fan, propensity for flash flooding within the watershed and lack of effective waste source containment the tailings are subject to extensive off-site migration via the surface water pathway. Tailings impoundment measuring approximately length 1,000 feet x width 600 feet; surface area of (10 to 12) acres. Depth at dam is estimated to be 20 feet thick and tapering to the west. Substantial tailings deposition along Tybo Creek has been observed for several miles downgradient of the site.*

Post-exploitation management

Kind and step implemented: ☒ Hazard / risk studies ☐ Specific on-site investigations /Monitoring ☒ *Safety works*

☐Others:..

Description:

Impact	*Year / period*	*Description*	*Costs*
1	*2014*	An HHRA was completed in 2014 and elevated arsenic risks for recreational visitors were detected for adult and child in the upper areas and acceptable risk in the lower areas. Ecological risks identified, though in an unlikely scenario, were arsenic and lead.	

Other(s) comment(s):

Local management felt that the site 'looked bad' (coloration, odours) and encouraged the Abandoned Mine Lands program prioritize the site for funding. The program asked the AML team to conduct an HHRA to determine risk at the site. The results of the HHRA indicated that as much as the site appears to be in poor condition, it does not pose an immediate human or ecological risk. Reducing access to the site was recommended. With the expanded knowledge of the risks at the site, the national AML program continues to focus efforts on sites that pose a higher risk. This site is under the jurisdiction of the US Department of Interior, Bureau of Land Management, Battle Mountain District, Nevada

Table 4 — Remediation Klaraschacht, Germany

Abandoned mine description	
Location: Southwest Germany, Saarland, Sulzbach	***Surroundings:*** ☐ cities /urban ☒ village ☒ agricultural / natural Description: Residential area next to a forest area and a highway
Context(s)	
Main metal(s) / mineral(s) exploited: Hard coal ***Mineral deposit:*** ☐ alluvial ☒ stratiform / layers (☒ subvertical or ☐ subhorizontal) ☐ Veins ☐ Placer ☐ Others:... ***Geology / hydrogeology / hydrology / climate description:*** ground surface level: +315,75 mNN, backfill level: +311,75 mNN, friable mudstone up to +308,75 mNN, carbonate rock formation below +308,75 mNN	
Mining works	
Mining activities: ☐ Open pit exploitation ☒ Underground work ☐ Treatment facility ☐ Mining waste storage facilities ☐ Others: .... ***Activity period(s):*** Construction of the shaft: 1885, commissioning: 1890, decommissioning: 1937, backfill: 1940 ***Production:*** 1890 - 1937 ***Exploitation methods / characteristics (extension, depth, dips, openings...):*** longwall mining ***Ore treatment methods (residues granulometry, chemical used...):*** None ***Waste storage facilities (type [tailings, heap leach, waste rocks...] size, slopes, type of cover, basement, etc.):*** nearby mining heap ***Available mining data:*** ☒ “Old” ones (exploitation period) ☐ “New” one (post-exploitation) ☒ GIS ones Description: georeferenced mine plans, drilling data, as-built plans after backfill	
Other(s) comment(s):	

<table>
<tr><th colspan="4">Post-exploitation impacts</th></tr>
<tr><th colspan="4">Impacts observed or identified</th></tr>
<tr><td colspan="4">Nature of impacts: ☒ Geotechnical ☐ Hydro(geo)logical ☐ Environmental ☒ Health safety ☐ Cultural / social
☐ Others:...
Description:</td></tr>
<tr><td>Impact</td><td>Year / period</td><td colspan="2">Description</td></tr>
<tr><td>1</td><td>1940</td><td colspan="2">Backfill with loose material and fencing</td></tr>
<tr><th colspan="4">Post-exploitation management</th></tr>
<tr><td colspan="4">Kind and step implemented: ☒ Hazard / risk studies ☒ Specific on-site investigations / Monitoring ☒ Safety works
Description:</td></tr>
<tr><td>Impact</td><td>Year / period</td><td>Description</td><td>Costs</td></tr>
<tr><td>1</td><td>2016 - 2019</td><td>Risk management based on mine plans and drilling data, remediation concept</td><td>~115 k€</td></tr>
<tr><td>2</td><td>2020</td><td>Removal of 22,25 m backfill material, installation of a degassing unit, backfill with 500 m^3 concrete, remediation of the surface</td><td>~330 k€</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="4">Other(s) comment(s):</th></tr>
<tr><td colspan="4">None</td></tr>
</table>

Table 5 — Remediation of the near-surface mining area at ‘Braut in Küpperswiese, Germany

<table>
<tr><th colspan="2">Abandoned mine description</th></tr>
<tr><td>Location: Germany, North Rhine-Westphalia, Essen</td><td>Surroundings: ☒ cities / urban ☐ village ☐ agricultural / natural

Description: Residential area with main road, roughly 800 m distance to the river Ruhr</td></tr>
<tr><th colspan="2">Context(s)</th></tr>
<tr><td colspan="2">Main mineral exploited: Hard Coal

Mineral deposit: ☐ alluvial ☒ stratiform / layers (☐ subvertical or ☒ subhorizontal) ☐ Veins ☐ Placer

☐ Others:...

Geology:

Sandstone and shale bed rock including several hard coal seams with varying thickness and a 40 gon dip to south-east</td></tr>
<tr><th colspan="2">Mining works</th></tr>
<tr><td colspan="2">Mining activities: ☐ Open pit exploitation ☒ Underground work ☐ Treatment facility ☐ Mining waste storage facilities

☐ Others: ....

Activity period(s): Near-surface hard coal mining

Production: 1825 - 1916

Exploitation methods / characteristics (extension, depth, dips, openings...): Near-surface longwall mining

Ore treatment methods (residues granulometry, chemical used...): None

Waste storage facilities (type [tailings, heap leach, waste rocks...] size, slopes, type of cover, basement, etc.): None

Available mining data: ☒ “Old” ones (exploitation period) ☐ “New” one (post-exploitation) ☒ GIS ones

Description: mining plans of the mines “Braut in Küpperswiese”, “Pauline” and “Vereinigte Braut Kreftenscheer 2“</td></tr>
<tr><th colspan="2">Other(s) comment(s):</th></tr>
<tr><td colspan="2">-</td></tr>
</table>

Post-exploitation impacts			
Impacts observed or identified			
Nature of impacts: ☒ Geotechnical ☐ Hydro(geo)logical ☐ Environmental ☒ Health safety ☐ Cultural / social ☐ Others:.. Description:			
Impact	*Year / period*	*Description*	
1	1916	Sealing of the mine entrances	
Post-exploitation management			
Kind and step implemented: ☒ Hazard / risk studies ☒ Specific on-site investigations / Monitoring ☒ Safety works ☐ Others:.. .... Description:			
Impact	*Year / period*	*Description*	*Costs*
1	2015	Risk assessment regarding the structural integrity of the topographical surface based on drilling results (~350 m) Additional drilling (~2 100 m) and back filling of the open cavities with position stable material (~490 t)	~110 k€
Other(s) comment(s):			
None			

Table 6 — Multiple mining legacies near Pontgibaud – Auvergne, France

Mining legacy description – abandoned mine	
Location: Centre of France, 20 km west from Clermont-Ferrand	***Surroundings:*** Village Description: Mining sites close to villages, 4 main mining wastes dumps next to river and one next to Pontgibaud village
Context(s)	
Main metal(s) / mineral(s) exploited: Lead, zinc, silver, antimony *Ore mineralogy, Rock host mineralogy:* Pyrite and marcasite associated to FeAsS, PbS (main mineral exploited) and ZnS and a few FeCuS2. Rock host is gneiss and basalt, quartz and barytine. ***Mineral deposit:*** Veins Others: No data ***Geology / hydrogeology / hydrology / climate description:*** Basalts and gneiss, small montains (between 500-1 200 m asl), groundwater in basalt layers, continental weather	
Mining works	
Mining activities: Open pit exploitation: no / Underground work: 68 km of galleries, 60 shafts / Treatment facility: 4 / Mining waste storage facilities: 4 Others: / Description: ***Activity period(s):*** 1838-1897. ***Production:*** Pb : 50 000 t, Ag : 100 t, Sn : 4 000 t ***Exploitation methods / characteristics (extension, depth, dips, openings...):*** Underground extraction between 35-250 m deep ***Ore treatment methods (residues granulometry, chemical used...):*** crushing, hand and mechanical sorting, gravimetric separation (washing, decantation,...) and roasting. ***Waste storage facilities (type [tailings, heap leach, waste rocks...] size, slopes, type of cover, basement, etc.):*** Four main TSF (total of 200 000 m3), no cover, no basement sealing ***Available mining data:*** “Old” ones (exploitation period): yes / “New” one (post-exploitation): yes / Geographical ones: yes. Description: Many mining plans. Data in dedicated GIS	
Other(s) comment(s):	
No	