

PUBLISHED BY

Department of Water Affairs
and Forestry
Private Bag X313
PRETORIA
0001
Republic of South Africa

Tel: (012) 336-7500

Copyright reserved

No part of the publication
may be reproduced in
any manner without
full acknowledgement
of the source

This report should be cited as:

Department of Water Affairs and Forestry, 2007. Best Practice Guideline H2: Pollution Prevention and Minimisation of Impacts.

Disclaimer:

Although the information contained in this document is presented in good faith and believed to be correct, the Department of Water Affairs and Forestry makes no representations or warranties as to the completeness or accuracy of the information, which is only based on actual information received, and makes no commitment to update or correct information.

Consultants:

Pulles Howard & de Lange Inc.
P O Box 861
AUCKLAND PARK
2006
Republic of South Africa

Golder Associates Africa
P O Box 6001
HALFWAY HOUSE
1685
Republic of South Africa

ISBN 978-0-9802679-6-9

Status Final July 2008

DOCUMENT INDEX

This document is the second in a series of the following Hierarchy Best Practice Guideline documents:

BPG H1: Integrated Mine Water Management

BPG H2: Pollution Prevention and Minimisation of Impacts

BPG H3: Water Reuse and Reclamation

BPG H4: Water Treatment

ACKNOWLEDGE- MENTS

AUTHORS

Mr William Pulles (Golder Associates)

SPECIALISTS

Mr Chris Waygood (Jones & Wagener)

Mr Alistair James (Metago)

Ms Riana Munnik (DWAF)

Mr Tefo Tshabidi (DWAF)

Mr Solomon Tsheko (DWAF)

Since 1999 a number of steering committee meetings and stakeholder workshops were held at various stages of the development and drafting of this series of Best Practice Guidelines for Water Resource Protection in the South African Mining Industry.

We are deeply indebted to the steering committee members, officials of the Department of Water Affairs and Forestry and stakeholders who participated in the meetings and stakeholder workshops held during the development of the series of Best Practice Guidelines for their inputs, comments and kind assistance.

The Department would like to acknowledge the authors of this document, as well as the specialists involved in the process of developing this Best Practice Guideline. Without their knowledge and expertise this guideline could not have been completed.

APPROVALS

**THIS DOCUMENT IS APPROVED BY THE DEPARTMENT OF WATER
AFFAIRS AND FORESTRY**



RIANA MUNNIK

Deputy Director: Resource Protection and Waste: Mines

Date: 1/12/2008



NNDAGANENI MUSEKENE

Director: Resource Protection and Waste

Date: 2008/12/02



DEBORAH MOCHOTLHI

Chief Director: Water Use

Date: 03/12/2008

PREFACE

Water is typically the prime environmental medium (besides air) that is affected by mining activities. Mining adversely affects water quality and poses a significant risk to South Africa's water resources. Mining operations can further substantially alter the hydrological and topographical characteristics of the mining areas and subsequently affect the surface runoff, soil moisture, evapo-transpiration and groundwater behaviour. Failure to manage impacts on water resources (surface and groundwater) in an acceptable manner throughout the life-of-mine and post-closure, on both a local and regional scale, will result in the mining industry finding it increasingly difficult to obtain community and government support for existing and future projects. Consequently, sound management practices to prevent or minimise water pollution are fundamental for mining operations to be sustainable.

Pro-active management of environmental impacts is required from the outset of mining activities. Internationally, principles of sustainable environmental management have developed rapidly in the past few years. Locally the Department of Water Affairs and Forestry (DWAF) and the mining industry have made major strides together in developing principles and approaches for the effective management of water within the industry. This has largely been achieved through the establishment of joint structures where problems have been discussed and addressed through co-operation.

The Bill of Rights in the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) enshrines the concept of sustainability; specifying rights regarding the environment, water, access to information and just administrative action. These rights and other requirements are further legislated through the National Water Act (NWA), 1998 (Act 36 of 1998). The latter is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water. Use of water for mining and related activities is also regulated through regulations that were updated after the promulgation of the NWA (Government Notice No. GN704 dated 4 June 1999).

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. Examples of resource directed actions are the formulation of resource quality objectives and the development of associated strategies to ensure ongoing attainment of these objectives; catchment management strategies and the establishment of catchment management agencies (CMAs) to implement these strategies.

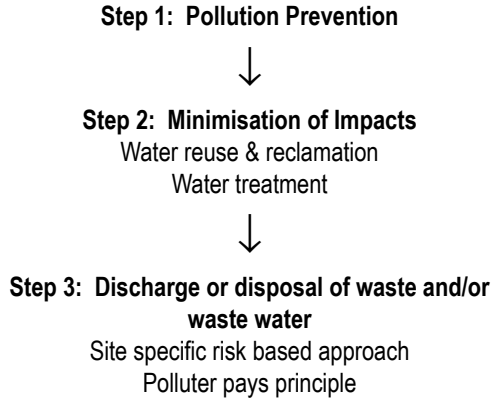
On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.

The integration of resource and source directed measures forms the basis of the **hierarchy of decision-taking** aimed at protecting the resource from waste impacts. This hierarchy is based on a *precautionary approach* and the following order of priority for mine water and waste management decisions and/or actions is applicable:

The documentation describing Water Resource Protection and Waste Management in South Africa is being developed at a number of different levels, as described and illustrated in the schematic diagram on this page.

The overall Resource Protection and Waste Management Policy sets out the interpretation of policy and legal principles as well as functional and organisational arrangements for resource protection and waste management in South Africa.

RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY

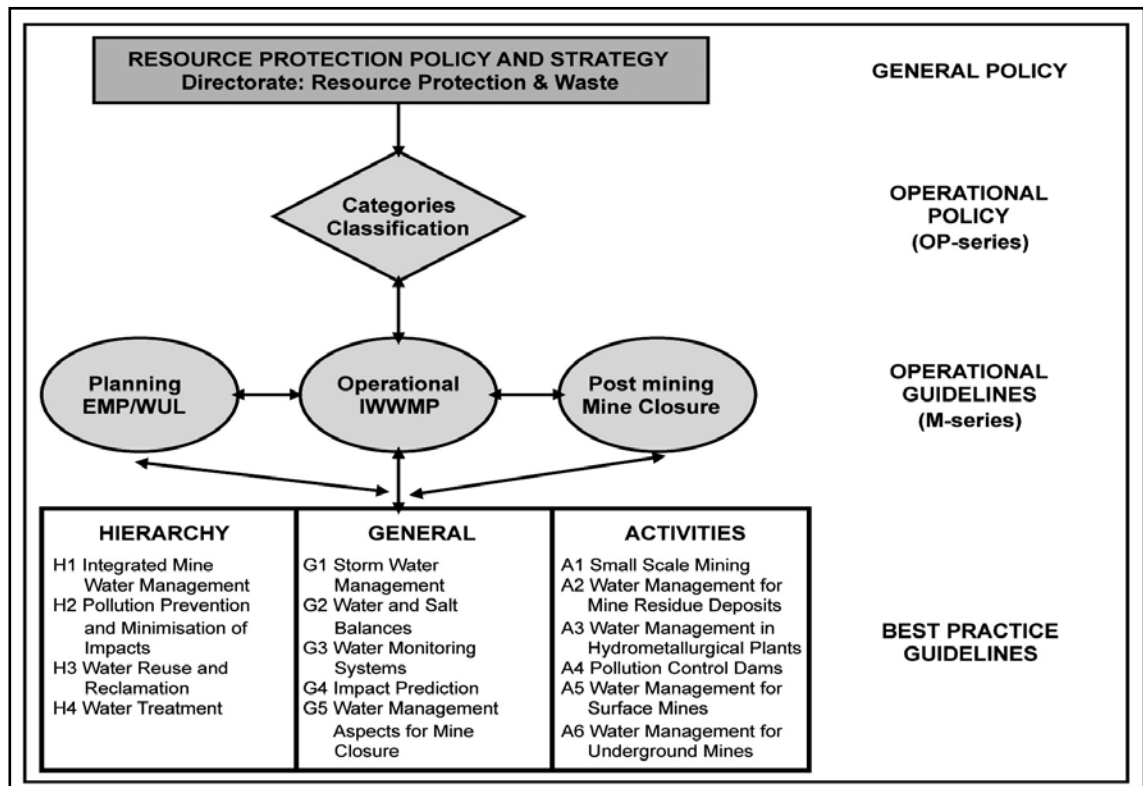


Operational policies describe the rules applicable to different categories and aspects relating to waste discharge and disposal activities. Such activities from the mining sector is categorised and classified based on their potential risks to the water environment.

Operational Guidelines contain the requirements for specific documents e.g. licence application reports.

Best Practice Guidelines (BPG's) define and document best practices for water and waste management.

Schematic Diagram of the Mining Sector Resource Protection and Waste Management Strategy



The DWAF has developed a series of **Best Practice Guidelines** (BPGs) for mines in line with International Principles and Approaches towards sustainability. The series of BPGs have been grouped as outlined below:

BEST PRACTICE GUIDELINES dealing with aspects of DWAF's water management **HIERARCHY** are prefaced with the letter **H**. The topics that are covered in these guidelines include:

- H1. Integrated Mine Water Management
- H2. Pollution Prevention and Minimisation of Impacts
- H3. Water Reuse and Reclamation
- H4. Water treatment

BEST PRACTICE GUIDELINES dealing with **GENERAL** water management strategies, techniques and tools, which could be applied cross-sectoral and always prefaced by the letter **G**. The topics that are covered in these guidelines include:

- G1. Storm Water Management
- G2. Water and Salt Balances
- G3. Water Monitoring Systems
- G4. Impact Prediction
- G5. Water Management Aspects in Mine Closure

BEST PRACTICE GUIDELINES dealing with specific mining **ACTIVITIES** or **ASPECTS** and always prefaced by the letter **A**. These guidelines address the prevention and management of impacts from:

- A1. Small-Scale Mining
- A2. Water Management for Mine Residue Deposits
- A3. Water Management in Hydrometallurgical Plants
- A4. Pollution Control Dams
- A5. Water Management for Surface Mines
- A6. Water Management for Underground Mines

The development of the guidelines is an inclusive consultative process that incorporates the input from a wide range of experts, including specialists within and outside the mining industry and government. The process of identifying which BPGs to prepare, who should participate in the preparation and consultative processes, and the approval of the BPGs was managed by a Project Steering Committee (PSC) with representation by key role-players.

The BPGs will perform the following functions within the hierarchy of decision making:

- Utilisation by the mining sector as input for compiling water use licence applications (and other legally required documents such as EMPs, EIAs, closure plans, etc.) and for drafting licence conditions.
- Serve as a uniform basis for negotiations through the licensing process prescribed by the NWA.
- Used specifically by DWAF personnel as a basis for negotiation with the mining industry, and likewise by the mining industry as a guideline as to what the DWAF considers as best practice in resource protection and waste management.
- Inform Interested and Affected Parties on good practice at mines.

The information contained in the BPGs will be transferred through a structured knowledge transfer process, which includes the following steps:

- Workshops in key mining regions open to all interested parties, including representatives from the mining industry, government and the public.
- Provision of material to mining industry training groups for inclusion into standard employee training programmes.
- Provision of material to tertiary education institutions for inclusion into existing training programmes.
- Provision of electronic BPGs on the DWAF Internet web page.

CONTENTS

DOCUMENT INDEX	II
APPROVALS	III
PREFACE	IV
ABBREVIATIONS	VIII
GLOSSARY	IX
1 INTRODUCTION AND OBJECTIVES OF THIS BEST PRACTICE		
GUIDELINE	1
1.1 INTRODUCTION	1
1.2 OBJECTIVES OF THIS BPG	3
1.3 APPLICABILITY, STRUCTURE AND FOCUS OF THIS BPG		3
2 GENERAL PRINCIPLES OF POLLUTION PREVENTION AND IMPACT		
MINIMISATION	4
3 LEGAL FRAMEWORK FOR POLLUTION PREVENTION	...	6
4 GENERIC POLLUTION PREVENTION CONSIDERATIONS AND		
OPPORTUNITIES	8
4.1 LIFE-CYCLE RELATED POLLUTION PREVENTION		
OPPORTUNITIES	8
4.1.1 Mine exploration	8
4.1.2 Mine construction	10
4.1.3 Mining operations	11
4.1.4 Decommissioning and closure	14
4.2 PROCESS CHAIN RELATED POLLUTION PREVENTION		
OPPORTUNITIES	15
5 PROCEDURE FOR ASSESSMENT AND OPTIMIZATION OF		
POLLUTION PREVENTION	16
6 REFERENCES AND LITERATURE LIST	23



ABBREVIATIONS

ARD:	Acid Rock Drainage
BPG:	Best Practice Guideline (documents in this series)
DWAF:	Department of Water Affairs and Forestry
ECA:	Environmental Conservation Act, 1989 (Act 73 of 1989)
EIA:	Environmental Impact Assessment
EMP:	Environmental Management Plan
GN704:	Government Notice 704 promulgated in terms of NWA on 4 June 1999
IWWM:	Integrated water and waste management
IWWMP:	Integrated water and waste management plan
MPRDA:	Minerals and Petroleum Resources Development Act (Act 28 of 2002)
NEMA:	National Environmental Management Act, 1998 (Act 107 of 1998)
NWA:	National Water Act, 1998 (Act 36 of 1998)
TDF:	Tailings Disposal Facility
UNEP:	United Nations Environment Programme
WRC:	Water Research Commission

GLOSSARY

In assessing the definitions given below, it must be understood that the definitions as provided in the NWA and Government Notice 704 (GN704) are primary.

Active management system: A management system that may require external energy inputs (such as electrical power) or continuous operator attention for its continued successful operation.

Aquifer: a geological formation which has structures or textures that hold water or permit appreciable water movement through them

Audit: A systematic, documented, periodic and objective evaluation of how well management systems and equipment are performing, with the aim of facilitating management control of practices and to assess compliance with relevant policies and objectives, which include meeting regulatory requirements.

Catchment: In relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points. (National Water Act, 1998 (Act 36 of 1998)).

Category A Mines: Those mines that exploit orebodies that are associated with sulphide minerals or any other reactive minerals, either in the ore, overburden or waste material.

Clean water: Water that has not been affected by pollution.

Dirty water: Water that has contains waste.

Groundwater: Water that occurs in the voids of saturated rock and soil material beneath the ground surface is referred to as groundwater and the body within which the groundwater is found is referred to as an aquifer.

Life cycle costing: Life-cycle costing refers to the process whereby all costs associated with the system (e.g. capital cost, operational cost, maintenance costs, closure and rehabilitation cost, impact mitigation costs, etc.) as applied to the defined life cycle are considered

Life of mine: The life of mine includes all the phases of the mine's existence from the conceptual and planning phases, through design, construction, operation and decommissioning to the post-closure and aftercare phases.

Mitigation: Measures taken to reduce adverse impacts on the environment.

Passive management system: A management system that does not require external energy inputs (such as electrical power) or continuous operator attention for its continued successful operation.

Pollution: Pollution means the direct or indirect alteration of physical, chemical or biological properties of a water resource so as to make it –

- (a) less fit for any beneficial purpose for which it may reasonably be expected to be used; or
- (b) harmful or potentially harmful –
 - (aa) to the welfare, health or safety of human beings;
 - (bb) to any aquatic or non-aquatic organisms;

- (cc) to the resource quality; or
- (dd) to property.

(National Water Act, 1998 (Act 36 of 1998))

Precautionary principle: This refers to the principle that in the absence of actual data to demonstrate an alternative conclusion, the most conservative assumption will be made and precautionary management measures will need to be applied.

Prevention: Measures taken to minimize the release of wastes to the environment.

Residue: Residue includes any debris, discard, tailings, slimes, screenings, slurry, waste rock, foundry sand, beneficiation plant waste, ash and other waste product derived from or incidental to the operation of a mine or activity and which is stockpiled, stored or accumulated for potential reuse or recycling or which is disposed of. (Government Notice 704 of 4 June 1999.)

Residue deposits: Residue deposits include any dump, tailings dams, slimes dams, ash dump, waste rock dump, in-pit deposit and any other heap, pile or accumulation of residue. (Government Notice 704 of 4 June 1999.)

Resource quality: means the quality of all the aspects of a water resource including (National Water Act, 1998 (Act 36 of 1998))-

- (a) the quantity, pattern, timing, water level and assurance of instream flow;
- (b) the water quality, including the physical, chemical and biological characteristics of the water;
- (c) the character and condition of the instream and riparian habitat; and
- (d) the characteristics, condition and distribution of the aquatic biota

Risk assessment: The qualitative and quantitative evaluation performed in an effort to define the risk posed to human health or the environment by the presence or potential presence and use of specific pollutants.

Seepage: The act or process involving the slow movement of water or another fluid through a porous material like soil, slimes or discard.

Siting: The process of choosing a location for a facility.

Slope: Slope is a dimensionless number and is defined by the vertical distance (drop) divided by the horizontal distance.

Suitably qualified and experienced person: Suitably qualified means a person having a level of training and experience with the type of work to be done and recognised skills in the type of work to be done.

Surface water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.); also refers to springs, wells, or other collectors that are directly influenced by surface water.

Watercourse: Watercourse means –

- (a) a river or spring;
- (b) a natural channel in which water flows regularly or intermittently;
- (c) a wetland, lake or dam into which, or from which, water flows; and

any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its beds and banks. (National Water Act, 1998 (Act 36 of 1998)).

Water resource: Includes a watercourse, surface water, estuary, or aquifer. (National Water Act, 1998 (Act 36 of 1998))

Water system: Water system includes any dam, any other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of water. (Government Notice 704 of 4 June 1999.)

1

INTRODUCTION AND OBJECTIVES OF THIS BEST PRACTICE GUIDELINE

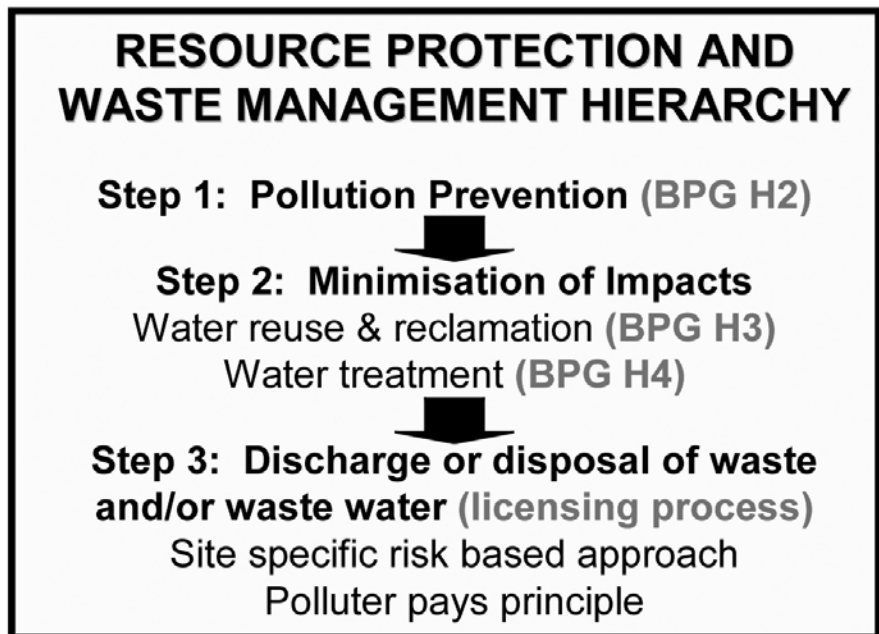
1.1 INTRODUCTION

The environmental impacts of mining can be significant, persistent and expensive to remediate or manage. It is therefore considered imperative that all reasonable efforts are made to prevent pollution and minimize impacts from mining as far as is possible. Pollution prevention strategies can be effectively planned, developed and implemented in the exploration, operational and closure phases of the mining operation. Effective pollution prevention reduces the management and financial burden associated with remediation during the operational and especially closure phases.

Effective pollution prevention is particularly important for Category A mines (those where reactive minerals such as sulphides) are encountered in the orebody and/or the waste streams, and this document is especially intended for use at such mines.

While there are different ways of defining the principle of pollution prevention, the definition adopted by the federal government in Canada is a useful example: "The use of processes, practices, materials, products or energy that avoid or minimize the creation of pollutants and waste and reduce overall risk to human health and the environment." (Environmental Law Institute, 2000). In terms of the principle of pollution prevention as used in this Best Practice Guideline, the emphasis is placed on the planning and design process as the primary point where pollution prevention strategies can be identified and formulated for implementation in the exploration, operation and closure phases of any mining activity.

Pollution prevention is also the foundation of the *hierarchy of decision-taking* used by DWAF with the purpose of protecting the water resource from waste impacts. This hierarchy is based on a *precautionary approach* and the following order of priority for mine and waste water management decisions and/or actions is applicable:



This Best Practice Guideline deals with the first step, i.e. Pollution Prevention and also reiterates the key issues relating to impact minimisation, i.e. Water Reuse and Reclamation (**BPG H3**) and Water Treatment (**BPG H4**). It is worthwhile emphasizing that consideration and application of water conservation strategies will also often have a direct and significant effect on pollution prevention.

The core of integrated water management at mining sites is the mine water management hierarchy which essentially states that mines must, in the first instance seek to optimally implement pollution prevention measures. If these measures do not address all the water management issues, then the mine should secondly develop and implement appropriate water reuse and reclamation strategies. These strategies may include a greater or lesser degree of water treatment in order to render the water suitable for reuse. If there is still a residual water management problem, then the mine could evaluate and negotiate options with DWAF for the discharge of such water to the water resource.

According to the United Nations Environment Programme (UNEP) Pollution Prevention and Abatement Handbook, **early planning** and **careful design** of operations are

the key to minimizing pollution associated with mining activities. Specific responsibilities should be assigned for the implementation and monitoring of environmental measures. Before mining begins, a mining plan and a mine closure and restoration plan must be prepared and approved. These plans define the sequence and nature of extraction operations and detail the methods to be used in closure and restoration. The plans should be updated regularly (every 3 to 5 years) as mining progresses.

In terms of the precautionary approach, it is required that all mines must be able to demonstrate, within the IWWMP (see **BPG H1: Integrated Mine Water Management**) that a reasonable planning and design process has been applied to optimally prevent clean water from becoming polluted. Best practice is a planning and design process which results in an optimum physical outcome, which may vary considerably depending on individual circumstances. The process described in this document, illustrated with examples, is considered the best practice.

EXAMPLE

POLLUTION PREVENTION MEASURES

Pollution prevention can be applied in many different ways, with the following examples illustrating but a few:

- (1) Apply effective storm water management to ensure that clean runoff is maximized and diverted to the receiving water resource, while contaminated runoff is minimized and contained for reuse within the mine's operations.
- (2) Apply water management measures within the underground operations or within the pit that are aimed at minimizing the potential for water quality deterioration due to the oxidation of sulphide minerals by reducing the available contact time between water and exposed sulphide minerals.
- (3) Locate waste residue deposits in areas where there is a minimum potential for contamination of the ground and surface water resource and construct water management facilities to intercept and contain any contaminated runoff and/or seepage.
- (4) Apply appropriate hydrological, geohydrological and geochemical assessment techniques to the evaluation of design, ongoing operation and rehabilitation measures for waste residue deposits in order to identify those options that will minimize the long-term pollution risks of such facilities.
- (5) Apply appropriate hydrological, geohydrological and geochemical assessment techniques to the design of mine closure strategies for underground mines or opencast pits in order to identify those options that will minimize the long-term pollution risks of such facilities.
- (6) Apply appropriate erosion protection on slopes to protect the long-term integrity of the slopes.

The common thread throughout the pollution prevention options is to prevent or minimize pollution through the application of **appropriate assessment** techniques, the application of **appropriate design** and the **ongoing and effective management and re-evaluation** of the installed pollution prevention measures.

It is also important to emphasize that pollution prevention measures are largely based on passive management principles, i.e. the need for ongoing intervention and active management is minimal, but not zero. Examples of passive measures include Storm Water diversion berms and drains, lining of pollution control dams, finger drains under tailings disposal facilities and toe paddocks around such facilities, etc. Passive pollution prevention measures are essentially based on good planning and design to prevent a pollution problem from arising, rather than relying on active intervention to intercept and treat contaminated water. However, situations are often encountered where active impact minimisation management measures are required to supplement the passive pollution prevention measures.

Demonstration of best practice pollution prevention planning and design processes, and minimisation of impacts is considered to be essential before any water use authorization will be granted. Best Practice Guidelines **BPG G1: Storm Water Management** and **BPG G4: Impact Prediction** have particular relevance when it comes to pollution prevention, while **BPG G2: Water and Salt Balances** and **BPG G3: Water Monitoring Systems** also provide tools that can be used in pollution prevention. Pollution prevention should be the key water management strategy applied in all phases of the mine's life from planning and feasibility studies through to post closure. Pollution prevention is also strongly supported by legislation and regulations as discussed in Chapter 3 of this document.

1.2 OBJECTIVES OF THIS BPG

The primary objectives of this BPG can be stated as follows:

- (1) To ensure that pollution risks and pollution prevention opportunities have been identified, optimized and implemented during the exploration, planning, operation and closure phases of a mining project.
- (2) To ensure that measures implemented and decisions taken at any point in time, consider the effect of those decisions throughout the remaining life cycle.

- (3) To present a process to identify the pollution risks and opportunities that remain after optimization of pollution prevention measures, which are then addressed in terms of impact minimisation. To ensure that where pollution prevention fails to reduce remaining impacts to acceptable levels, that additional water reuse and reclamation and water treatment strategies will be implemented to minimize the impacts to the water environment to the level deemed acceptable in terms of consideration of resource-directed management measures.
- (4) To define procedures that can be utilized to identify and assess pollution prevention and impact minimisation management actions.
- (5) To promote the consideration of the impacts of a management action over the full life-cycle of the mining operation in order that pollution prevention is maximized over the full life-cycle.

1.3 APPLICABILITY, STRUCTURE AND FOCUS OF THIS BPG

As pollution prevention is the first step in the water management hierarchy and because pollution prevention can be and needs to be optimally applied at each phase in the mine life cycle, this BPG is applicable to all mining operations, regardless of whether they are in the exploration, planning, operational or closure phase.

This BPG is structured as follows:

- Chapter 2 covers the general principles for pollution prevention and impact minimisation.
- Chapter 3 summarises the current legal framework in South Africa within which pollution prevention and impact minimisation must be undertaken.
- Chapter 4 presents typical pollution prevention considerations and opportunities at different stages in a mine life cycle and in different stages of the process chain.
- Chapter 5 presents a practical procedure that could be used in the planning and design of optimal pollution prevention measures and minimisation of impacts.
- Chapter 6 presents a literature list that was used in compiling this document.

2

GENERAL
PRINCIPLES OF
POLLUTION PREVEN-
TION AND IMPACT
MINIMISATION

In order to support the objectives of this BPG as listed in Chapter 1, a number of key principles are identified that need to be considered when implementing pollution prevention and impact minimisation actions within mining operations.

The rationale and motivation for pollution prevention is well summarized in the following statement drawn from the Environmental Law Institute (2000): "Pollution prevention should be a strategic management principle for the mining industry. It offers the opportunity to avoid or minimize significant environmental impacts of mining while also identifying and promoting economy and efficiency in the design and operation. It enhances recovery of minerals while at the same time helping to minimize impacts on the surrounding environment and prevent the creation of long-term environmental hazards and risks."

For mining operations it is vital to plan for minimisation of impact at the earliest stages, as few changes in layout are possible once operations have commenced.

The fundamental principle of pollution prevention is to apply a **planning and design process** to **prevent, inhibit, retard** or stop the hydrological, chemical, microbiological, radioactive or thermodynamic **processes, which result in the contamination of the water environment**, at or as **close to the point where the deterioration in water quality originates** (i.e. source reduction), or to **implement physical measures to prevent or retard the transport** of the generated contaminants to the water resource (i.e. recycling, treatment and/or secure disposal).

In the context of this principle, the following key terms are defined:

Source reduction reduces or eliminates the quantity or hazardous nature of pollutants and waste at the point of generation. Source reduction includes strategies to predict the occurrence of acid-forming materials, contaminants and toxic metals likely to be mobilized by mining activities and design operations to avoid or minimize contact with these materials and/or assure their isolation. Source reduction can also include such strategies as substitution of hazardous processes by cleaner processes - such as prohibition of mercury processes for gold recovery.

Impact minimisation would first call for recycling of water and waste streams that might otherwise be released into the environment and then treating and thereafter securely disposing of hazardous substances, pollutants, and materials that could degrade the environment. Again, it is important to emphasize that source reduction should form the core of any pollution prevention strategy for the mining sector; recycling, treatment and secure disposal are not adequate substitutes for a strong source reduction program.

Recycling provides for the use or reuse of waste and waste water as a substitute for a commercial product or material. It can include strategies such as closed-loop processes for handling acids and cyanides, and maximizing the reclamation/reuse of tailings water.

Treatment is any method, technique, or process that changes the physical, chemical or biological characteristics of waste materials in a way that eliminates harmful characteristics, recovers energy or useful materials in the waste materials, leaves them capable of being reused or safely contained, or reduces their volume. It can include such strategies as decontamination of tailings.

Secure disposal is any method, technique or process that prevents residual wastes from posing a threat to the environment. This includes use of designed disposal units to prevent sulphide materials from coming into contact with air and water and generating acid mine drainage. It may include placement of tailings in engineered structures with appropriate management and diversion of water to prevent mobilization and migration of pollutants.

The above-mentioned fundamental principle of pollution prevention can be elaborated upon by way of defining a number of secondary principles:

- (1) Prevention is better than cure and good planning reduces the environmental and financial liabilities. Sustainability is a key principle as it would ensure a positive legacy for future generations, not a liability.
- (2) Use and impact on as little water as is practically possible.
- (3) The closer a pollution prevention system is to the source, the more effective it is likely to be.
- (4) Pollution prevention is a planning and design process that is considered and applied for each life-cycle phase of the mine, i.e., exploration through to post-closure.
- (5) Pollution prevention measures must be considered and applied throughout the entire process chain from mining through to waste disposal.
- (6) Passive pollution prevention systems are preferred to active systems due to their generally more robust nature, often with a lower risk of failure.
- (7) If measures are properly applied during the full life cycle, post-closure risks and liabilities are reduced.
- (8) Pollution prevention is not the end point and minimisation of residual impacts through recycling, treatment and/or safe and secure disposal will most likely be required.
- (9) Apply closure pollution prevention measures during the operational phase and monitor the performance in order to validate pollution prevention performance.
- (10) Continuous improvement – pollution prevention systems should be monitored, assessed and improved on an ongoing basis.

3

LEGAL FRAMEWORK
FOR POLLUTION
PREVENTION

While there are a number of laws and regulations that relate to environmental and water management on mines (e.g. ECA and MPRDA), it is primarily the National Water Act, 1998 (Act No. 36 of 1998) and its regulations that specifically address issues relating to mine water pollution prevention. More details on the range of legislation that is applicable can be found in **BPG H1: Integrated Mine Water Management**.

Section 19 of the NWA also very specifically deals with the prevention of pollution and provides the means for DWAF to enforce pollution prevention. Section 39 (3) (d) of the MPRDA and Section 63 of the MPRDA Regulations also place a specific onus on mining companies to consider and apply pollution prevention measures.

Requirements of the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002) and its Regulations

The following regulations of the MPRDA can be considered to have a bearing on pollution prevention and impact minimisation strategies:

- Regulation 50 that sets out the contents on an environmental impact assessment report and describes a process that entails consideration of pollution prevention and impact minimisation measures.
- Regulation 51 that describes the need for an EMP that, inter alia, defines 'mitigatory measures for the prevention, management and remediation of each environmental impact...'
- Regulation 52 (2) (c) that specifies the submission of an environmental management plan that includes proposed mitigation and management measures to minimise adverse impacts and benefits.
- Regulation 60 that describes a risk assessment process that should be undertaken when applying for a mine closure certificate, and which process includes consideration of and optimisation of pollution prevention and impact minimisation measures.
- Regulation 63 that requires the mine to avoid the generation and production of pollution at source and to apply minimisation, re-use and recycling strategies where pollution cannot be completely prevented.
- Regulation 68 specifically requires that all provisions of the NWA are complied with, including the Regulations issued in terms of the NWA (see below).
- Regulation 73 that deals specifically with management of residue stockpiles and deposits and includes a risk-based approach that will also address issues relating to pollution prevention and impact minimisation.

Requirements of the National Water Act, 1998 (Act 36 of 1998) and its Regulations

Government Notice No. 704 (GN704), regulations on use of water for mining and related activities aimed at the protection of water resources, was promulgated in terms of section 26 of the NWA on 4 June 1999. While GN704 addresses a wide range of water management issues, it also places a strong focus on pollution prevention actions by way of the following regulations and sub-regulations:

- Regulation 4(a), (b), (c) and (d) - prohibition on placement of facilities in areas where high potential for pollution exists.
- Regulation 5 - prohibition on use of potentially polluting materials for construction or other purposes likely to cause pollution.

- Regulation 6(a), (b), (c), (d), (e) and (f) - relating to capacity requirements of clean and dirty water systems to ensure the prevention of pollution of clean water.
- Regulation 7(a), (b), (c), (d), (e), (f), (g) and (h) - relating to measures that must be taken to prevent pollution of the water resources.
- Regulation 8(c) and (d) - relating to the protection of pollution control measures to prevent pollution of a water resource.
- Regulation 9(1) - addresses the need to ensure the continuation of pollution control and prevention measures on cessation of mining activities.
- Regulation 10 - regarding specific additional regulations relating to the winning of sand and alluvial minerals from a watercourse or estuary.
- Regulation 12(6) - relating to the design, construction and implementation of measures to prevent pollution at residue deposits and dams containing waste.

4

**GENERIC POLLUTION
PREVENTION
CONSIDERATIONS
AND OPPORTUNITIES**

Principles 4 and 5 as described in Chapter 2 of this document highlight the issue that pollution prevention opportunities need to be optimized at different phases of the mine life, primarily exploration, operations and closure. Additionally, the principle is stipulated that pollution prevention opportunities must be sought and maximized at each step in the process chain, from the mining face through to eventual disposal of mine residues.

The type of mining that is being undertaken and the location of the mining operations are also important considerations in defining the importance of effective pollution prevention. The more sensitive the receiving environment, the greater the importance of application of effective pollution prevention and impact minimisation measures will be.

4.1 LIFE-CYCLE RELATED POLLUTION PREVENTION OPPORTUNITIES

For the purpose of this document, the following key mine life-cycle phases are addressed:

- Exploration
- Construction
- Mining operations
- Decommissioning and closure

The pollution prevention framework developed by the Environmental Law Institute (2000) is drawn on in this section and this document will provide valuable additional insights to those persons who require more detailed information. Mine sites that have been abandoned or where operations have ceased, would focus on those pollution prevention considerations that deal with the decommissioning and mine closure phase.

4.1.1 Mine exploration

Potential sources of pollution:

Exploration activities, while generally less intrusive than active mining operations, nevertheless present a number of circumstances where significant environmental impact could arise and hence present opportunities for pollution prevention, as shown in the example box below.

EXAMPLE

POTENTIAL SOURCES OF POLLUTION IN EXPLORATION PHASE

- (1) From the point of view of the water resource (ground and surface water), the exploration phase poses risks related to the importation of materials (fuel, lubricants, chemicals) to the drilling site, the generation of drilling mud, construction and use of ablation facilities and roads. These potential pollution impacts could be experienced during the exploration phase itself, and/or for some time after exploration has ceased.
- (2) Additionally, drilling of boreholes through overlying strata and aquifers into underlying orebodies could, if the boreholes are not properly sealed afterwards, generate flow conduits for the dewatering of shallow aquifers into the subsequent mine voids and can also lead to new pathways for the transport of contaminants.
- (3) Where the exploration includes sinking of adits or shafts or boxcuts to take bulk samples, additional pollution risks related to acid mine drainage with its associated contaminants, suspended solids loading, storm water contamination, accelerated

erosion and others, may manifest and appropriate pollution prevention opportunities must be identified and implemented.

- (4) In certain cases, exploration activities may require the construction of roads and other infrastructure to support the exploration and particular attention will need to be paid to Storm Water control from road runoff to prevent erosion problems and to increased suspended solids loads in runoff.
- (5) Finally, in undeveloped or underdeveloped areas, the construction of support infrastructure for the exploration activities, may attract additional development near to the exploration infrastructure and this eventuality should be considered in the planning process.

Pollution prevention opportunities:

As with all other mining phases, pollution prevention in the exploration phase is a function of detailed considered planning and design, aimed at understanding the potential impacts of alternative working methodologies

and a conscious effort to select, design and implement the alternatives that maximize the ability to prevent pollution. For the exploration phase, typical pollution prevention considerations include those shown in the example box below.

EXAMPLE

POTENTIAL POLLUTION PREVENTION IN EXPLORATION PHASE

- (1) Where contaminants are transported along exploration roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spillages occur along the transport routes.
- (2) Develop screening-level geological and geohydrological model for the exploration area and refine it continuously as additional exploration data becomes available. Use this model and understanding of the site to locate boreholes, define no-go areas and define which boreholes require special attention to sealing to prevent future pollution conduits.
- (3) Construct access roads and infrastructure in a way that sensitive ecosystems are avoided and ensure that proper designs are prepared and implemented to manage road storm runoff in a manner that minimizes sediment transport to the receiving water resource and minimizes erosion along runoff channels.
- (4) For bulk sampling activities, assess the geochemistry of the material being exposed during exploration activities and develop a management and action plan to minimize the opportunity for exposure of the high risk material to air and water. Where possible and necessary, consider segregated handling and storage for high pollution risk and low pollution risk material.
- (5) Minimise the area that is disturbed during exploration activities in order to minimize the potential for Storm Water disturbances and to reduce the sediment loads to receiving streams. Where site disturbance is significant and unavoidable, undertake proper Storm Water management planning in accordance with **BPG G2: Storm Water Management**.
- (6) Consider locating key infrastructure near to existing development nodes in order to reduce the footprint of the exploration activity and to reduce the driving force for auxiliary development adjacent to the exploration infrastructure.
- (7) Develop and implement proper environmental management and auditing systems to ensure that pollution prevention and impact minimisation plans and measures are implemented.
- (8) Plan for proper rehabilitation of all access roads and infrastructure sites to conditions that existed prior to exploration.
- (9) Make financial provisions for rehabilitation on the assumption that all exploration activities require rehabilitation and that no subsequent mining will take place. Where mining does take place and some sites are developed rather than rehabilitated, the surplus financial provisions can be transferred to the provisions for the operational mine.

4.1.2 Mine construction

environmental impacts could arise and hence present opportunities for pollution prevention, as shown in the example box below.

Potential sources of pollution:

Construction activities, while generally of a much shorter duration than the mining operations, nevertheless present a number of circumstances where significant

EXAMPLE

POTENTIAL SOURCES OF POLLUTION IN CONSTRUCTION PHASE

- (1) From the point of view of the water resource (ground and surface water), the construction phase is similar to the exploration phase in that it poses risks related to the importation of materials (fuel, lubricants, explosives, chemicals) to the construction site and the construction and use of ablution facilities and roads. These potential pollution impacts could be experienced during the construction phase itself, and/or for some time after construction has ceased.
- (2) Construction activities generally require the use of significant volumes of water for human needs and for actual construction activities (e.g. making of concrete). The manner in which this water is obtained must be considered and planned in order to minimize pollution of the water resource.
- (3) Where the construction includes sinking of adits or shafts or boxcuts, additional pollution risks related to acid mine drainage with its associated contaminants, suspended solids loading, storm water contamination, accelerated erosion and others, may manifest and appropriate pollution prevention opportunities must be identified and implemented.
- (4) Where the construction includes the erection of beneficiation plants, significant surface disturbance can be expected over a large area and over an extended time and a high potential exists for Storm Water management issues to come to the fore.
- (5) Construction activities may include the construction of starter footprints for mine residue deposits and construction of the overland transportation systems (pipelines, conveyors) over previously undisturbed land and a potential exists for a variety of pollution impacts that could be prevented at river or wetland crossings and at the disposal site.

Pollution prevention opportunities:

As with all other mining phases, pollution prevention in the construction phase is a function of detailed considered planning and design, aimed at understanding the potential impacts of alternative working methodologies and a conscious effort to select, design and implement the

alternatives that maximize the ability to prevent pollution. This pollution prevention planning process should have been fully undertaken in the mine feasibility and design stages and should be contained in an EMP that guides the construction process. For the construction phase, typical pollution prevention considerations include those shown in the example box below.

EXAMPLE

POTENTIAL POLLUTION PREVENTION IN CONSTRUCTION PHASE

- (1) Where contaminants are transported along construction roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spillages occur along the transport routes.
- (2) Store all potential sources of contamination in secure facilities with appropriate Storm Water management systems in place to ensure that contaminants are not released to the water resource through Storm Water runoff.

- (3) Construct access roads and infrastructure in a way that sensitive ecosystems are avoided and ensure that proper designs are prepared and implemented to manage road storm runoff in a manner that minimizes sediment transport to the receiving water resource and minimizes erosion along runoff channels.
- (4) For shaft sinking, adit and boxcut construction activities, assess the geochemistry of the material being exposed during construction activities and develop a management and action plan to minimize the opportunity for exposure of the high risk material to air and water. Where possible and necessary, consider segregated handling and storage for high pollution risk and low pollution risk material. Ensure that appropriate residue disposal facilities are already constructed before this high risk waste material starts being generated.
- (5) Minimise the area that is disturbed during construction activities in order to minimize the potential for Storm Water disturbances and to reduce the sediment loads to receiving streams. Where site disturbance is significant and unavoidable, undertake proper Storm Water management planning in accordance with **BPG G2: Storm Water Management**.
- (6) Develop and implement proper environmental management and auditing systems to ensure that pollution prevention and impact minimisation plans and measures developed in the design and feasibility stages are fully implemented.

4.1.3 Mining operations

Potential sources of pollution:

There are numerous facets of active mining operations that have the potential to cause significant pollution and where consideration of pollution prevention strategies

is critical. It is not possible to give an exhaustive list of potential sources of pollution for all the different types of minerals, mining methods, beneficiation methods, residue disposal methods, etc., and only a few examples are presented here to illustrate the point.

EXAMPLE

POTENTIAL SOURCES OF POLLUTION IN MINING PHASE

- (1) For Witwatersrand underground gold mines, previous research has shown that up to 60% of sulphate load in mine effluents can be ascribed to acid rock drainage that occurs in the underground stopes where water and oxygen has free access and significant contact time with freshly exposed ore.
- (2) Where liquid / gel explosives are used underground, the potential exists for excess explosives to be disposed of underground in a manner that allows these contaminants (nitrates, ammonia) to find their way into the mine water systems.
- (3) On large opencast mines, the potential exists for a significant positive water balance within the pit, thereby creating the opportunity for water to come into contact with sulphide minerals and to become contaminated. This is exacerbated in pits that have a significant rehabilitation backlog.
- (4) Large opencast mining operations have extensive haul roads and heavy vehicles traversing these roads. The potential exists for very significant Storm Water impacts and erosion from these roads. Water quality problems will also arise where such roads contain sulphide waste material.
- (5) Large heavy vehicle fleets and workshop facilities always pose a pollution potential from hydrocarbons at fuel storage depots and at maintenance workshops and vehicle cleaning facilities.
- (6) Beneficiation plants very often make use of a wide range of chemicals, some of which are extremely toxic to humans and the aquatic environment. Many risk areas exist with regard to the transport, storage, handling, usage and disposal of these materials and all these need to be thoroughly assessed with the view to identifying and optimizing pollution prevention opportunities.
- (7) Slurry or tailings pipelines from beneficiation plants have the potential to rupture and cause serious water pollution problems (especially in the case of cyanide tailings). Areas of particularly high risk are where these pipelines traverse watercourses or wetlands and these pipelines should be designed, constructed and

- operated in a manner that prevents pollution problems in the event of pipeline ruptures.
- (8) Disposal of mine residues (tailings, slurry, discard, waste rock, etc) can be undertaken in many different ways – above ground and below ground – see **BPG A2: Water Management for Mine Residue Deposits** for more details on these options and recommended assessment techniques. Decisions on which disposal method should be adopted should be based on a thorough assessment of various alternatives and their pollution potential.
 - (9) Large mining operations have very significant footprints and many potential sources of contaminated storm water. A high potential exists to minimize the storm water impacts from such sites by implementing pollution prevention principles by grouping pollution sources together into as few sub-catchments as possible, diverting clean runoff around these areas and capturing all contaminated runoff in pollution control dams for reclamation and reuse. See **BPG G1: Storm Water Management** and **BPG A4: Pollution Control Dams**.
 - (10) The water pool on top of tailings dams is often kept large for water balancing purposes or to suit a floating barge withdrawal system and to compensate for smaller return water dams. However, this results in excessive water losses through evaporation and also increases the driving head for seepage through the facility with increased pollution potential to the groundwater.
 - (11) Dust from mine residue deposits could contain significant levels of sulphide minerals that pose a risk of becoming a secondary source of pollution in the area that they are deposited.
 - (12) Product loading facilities, such as coal stockpiles, sidings, etc. are a potential source of pollution, especially in cases where the material is stored directly on the ground.

Pollution prevention opportunities:

As with all other mining phases, pollution prevention in the active mining phase is a function of detailed considered planning and design, aimed at understanding the potential impacts of alternative working methodologies and a conscious effort to select, design and implement

the alternatives that maximize the ability to prevent pollution. Many of the appropriate pollution prevention strategies are directly evident as the countermeasure to the potential pollution sources described in the preceding section. For the mining phase, typical pollution prevention considerations may include those shown in the example box below.

EXAMPLE

POTENTIAL POLLUTION PREVENTION IN MINING PHASE

- (1) Before mining begins, a mining plan that includes explicit consideration of mine closure and rehabilitation issues must be prepared and approved. These plans define the sequence and nature of extraction operations and detail the methods to be used in closure and restoration. The plans should be updated regularly (every 3 to 5 years) as mining progresses. All operational planning and activities should be undertaken with eventual mine closure in mind, such that mining operations can end in a manner that minimizes the final risks and liabilities in the post-closure phase.
- (2) During the mine planning phase, a detailed geochemical characterisation of the material to be mined should be undertaken (see **BPG G4: Impact Prediction**), differentiating between that material which will be beneficiated and report to tailings disposal facilities and the material that will report directly to waste rock dumps. Handling and placement strategies for the material should then be based on the geochemical characterization of the material, with the aim of placing the material such that the long-term pollution potential is minimized.
- (3) Consider integrating and combining waste streams in order to realize the potential synergistic effects thereof – e.g. combining an acidic and alkaline waste to produce a circumneutral waste stream.
- (4) Rationalise the layout of all infrastructure and mining aspects where contaminated storm water could be generated, such that footprint size and affected catchment areas are minimized, clean runoff volume is maximized and diverted straight to natural water bodies, contaminated runoff volume is minimized and fully

retained in appropriately sized and located pollution control dams. See **BPG G1: Storm Water Management** and **BPG A4: Pollution Control Dams**.

- (5) Construct detailed water and salt balances that take account of climatic and operational variability, as a planning tool to ensure that all pollution control dams are adequately sized and that they are integrated into a robust water reuse and reclamation strategy to ensure that captured contaminated water is effectively reused within the mining operations and that system spillages to the environment are avoided. See **BPG G2: Water and Salt Balances** and **BPG H3: Water Reuse and Reclamation**.
- (6) Evaluate alternative process plant technologies, including cleaner production techniques and closed circuit water use to reduce the pollution potential associated with the operation. See **BPG A3: Water Management in Hydrometallurgical Plants**. Such measures will need to be carefully designed and monitored to ensure that water qualities within the process circuits remain within design limits.
- (7) Evaluate options to remove sulphides from high sulphide waste prior to its disposal or separate high sulphide wastes, using thorough life cycle costing techniques that account for reductions in long-term risks, remediation requirements and liabilities.
- (8) Design and operate underground stope cleaning techniques to maximize ore recovery, including fines, from stopes where the material has been assessed as having a high pollution potential. Simultaneously, implement measures to reduce mine service water residence times in these same stopes, thereby minimizing the potential for water quality deterioration due to ARD processes.
- (9) Implement measures to prevent or minimize the ingress of water into the mining operation.
- (10) Consideration of surface uses when planning underground coal mining in order to minimize the incidence of surface subsidence (e.g. high extraction mining to be avoided in certain critical areas).
- (11) Operate and concurrently rehabilitate opencast pits to be free-draining away from the pit such that water drainage to the pit is reduced and install water collection and pumping systems within the pit that are capable of rapidly pumping the water out and thus minimizing contact time between the water and geochemically reactive materials.
- (12) Ensure that the mine plan includes contingency planning, equipment and training to enable operators to deal with common and foreseeable process upsets, leaks and releases as well as extreme climatic events.
- (13) Institute detailed monitoring systems that are capable of detecting pollution at the earliest possible stage, at all facilities where significant pollution potential exists, in order that this can lead to rapid and effective management actions to address the pollution source and minimize it to the full extent possible.
- (14) Proper storage and handling and monitoring of fuel and chemicals used on site to minimize the risk of spillages to the environment.
- (15) Reduction of dust by early revegetation and by good maintenance of roads and work areas. Specific dust suppression measures, such as minimizing drop distances and covering equipment and storage piles, may be required for ore and product handling and loading facilities. Release of dust from crushing and other ore processing and beneficiation operations should be controlled.

Numerous additional examples exist and these will be identified by the mine through a rigorous planning and design process, undertaken in accordance with the procedures described in Chapter 5 of this document.

4.1.4 Decommissioning and closure

Potential sources of pollution:

One of the unfortunate features of mining operations is their tendency to exhibit serious long-term residual water impacts and to act as sources of pollution for decades if not centuries. The primary reason for this is that many mining activities expose geochemically active

minerals to water and oxygen, leading to chemical and microbiological oxidation processes that liberate a wide range of contaminants. The potential sources of pollution at closed mines again vary depending on the type of mineral mined, the mining method, beneficiation method and waste disposal method employed during the active mining operations phase. Typical aspects of closed mines that present potential sources of pollution include those shown in the example box below.

EXAMPLE

POTENTIAL SOURCES OF POLLUTION IN DECOMMISSIONING AND CLOSURE PHASE

- (1) Backfilled and rehabilitated opencast pits that fill up with water and discharge contaminated water at one or more decant/seepage points into the surface or ground water resource.
- (2) Underground mines that flood and discharge contaminated water from one or more shafts / adits, boreholes, geological features, etc., into the surface or ground water resource.
- (3) Waste residue deposits that produce contaminated runoff, seepage and/or dust that enters the water resource.
- (4) Footprints from reclaimed waste deposits that continue to provide a secondary source of contaminants after the primary source (the waste deposit itself) has been removed.
- (5) Groundwater contamination from areas previously contaminated by hydrocarbons from fuel depots or workshops.
- (6) Spillages or seepage from pollution control dams that remain after closure as part of the environmental management system.

Pollution prevention opportunities:

Again, as with all other mining phases, pollution prevention in the mine closure phase is a function of detailed considered planning and design, aimed at understanding the potential impacts of alternative remediation methodologies and a conscious effort to select, design and implement the alternatives that maximize the ability to prevent pollution.

The best time to plan for pollution prevention at the mine closure and post-closure phase is during the initial mine planning / infrastructure development planning phase and continuously during the active mine operations

phase. The opportunities to prevent pollution in the closure phase are generally very limited if they haven't been considered and implemented at an earlier phase in the mine life cycle. Reference to the examples of sources of pollution in the mine closure phase indicate that little can be done in terms of pollution prevention if this strategy is only considered close to or at actual cessation of mining activities. For example, design and location of waste residue deposits cannot be changed at mine closure. Location and nature of decant points cannot be readily changed after the mine has ceased operations. However, a number of pollution prevention opportunities do exist for the mine closure phase and may include those shown in the example box below.

EXAMPLE

POTENTIAL POLLUTION PREVENTION IN DECOMMISSIONING AND CLOSURE PHASE

- (1) Decommission an underground mine on the basis of a detailed model and assessment of water inputs, flow paths, discharge points and location and nature of geochemical processes that cause water quality deterioration. Plan to control ingress points and flow paths to prevent or minimize pollution by closing certain flow paths and opening and strengthening others.
- (2) Design and construct a waste deposit in a manner that ensures that geochemically active material is isolated as far as possible from water and oxygen.

- (3) Design and implement a waste deposit cover on the basis of an assessment of its long-term performance in preventing or minimizing pollution of the water resource. Once the cover performance characteristics have been specified, ensure that the cover is designed to be sustainable in terms of erosion by employing suitably qualified persons to assess cover erodability. Concurrent rehabilitation allows for the actual performance of the cover to be monitored and validated.
- (4) Minimize water ingress into mine voids or backfilled pits by designing water management measures to maximize clean water diversion directly to the water resource (see **BPG G1: Storm Water Management**).
- (5) Remove potential sources of pollution such as hydrocarbon-contaminated soils and dispose of at an authorised disposal facility.
- (6) Implement as many of the closure measures as possible during the operational phase of the mine and institute appropriate monitoring programmes in order to be able to demonstrate the actual performance of the various management actions during the life of mine, rather than after decommissioning.

4.2 PROCESS CHAIN RELATED POLLUTION PREVENTION OPPORTUNITIES

Many of the pollution prevention opportunities and strategies for identifying them are discussed in the various activity series best practice guidelines, with the following specific aspects covered in the following BPGs:

- The mine face and ore transport processes in underground mines – **BPG A6: Water Management for Underground Mines**.
- The mine face and ore transport processes in surface mines – **BPG A5: Water Management for Surface Mines**.
- The beneficiation plant – **BPG A3: Water Management in Hydrometallurgical Plants**.
- Waste disposal facilities – **BPG A2: Water Management for Mine Residue Deposits**.
- Water pollution control dams – **BPG A4: Pollution Control Dams**.

5

PROCEDURE FOR ASSESSMENT AND OPTIMIZATION OF POLLUTION PREVENTION

Chapter 4 of this document presents a number of typical and generic pollution sources and pollution prevention opportunities that could be encountered for various mining operations at different phases in their life cycle. References are also provided to a number of the other BPGs that have been prepared by DWAF, especially the activity series BPGs, which cover various components of the mining operation.

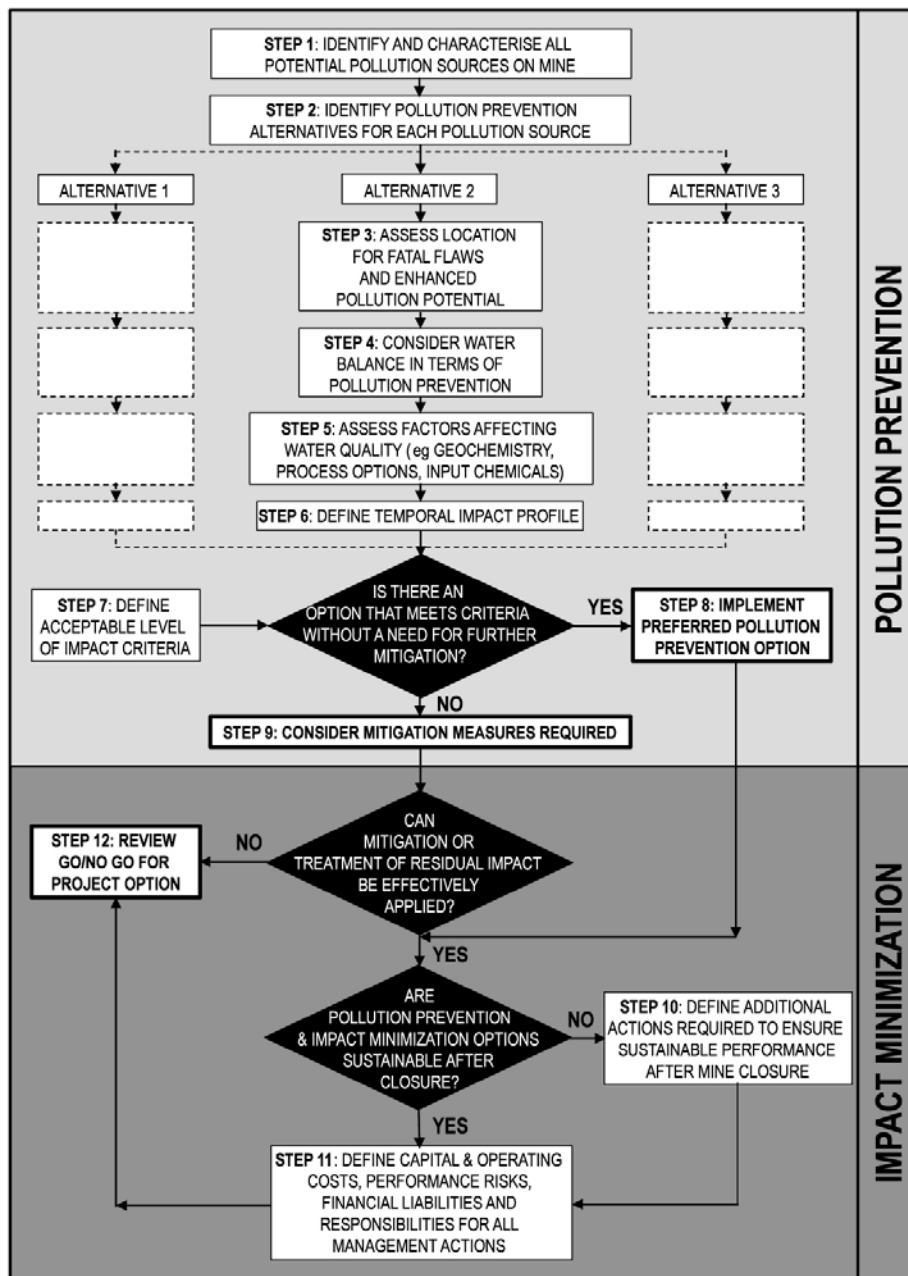
While it is clear that each mine presents unique challenges and opportunities with regard to pollution prevention, depending on the location of the mine, the type of mineral being mined, the mining method, the beneficiation process, the waste disposal philosophy and facilities, etc., there are a number of generic issues that will apply and many of these are addressed in Chapter 4. While the outcome of the process will vary from mine to mine, the methodology that should be adopted in evaluating and developing pollution prevention and impact minimisation measures is also generically applicable.

Although there may be different ways of arriving at the same conclusions with regard to the identification of most appropriate pollution prevention and impact minimisation measures, a logical and practical procedure is presented in Figure 5.1 below and discussed in this chapter. While this figure shows the procedure in a stepwise sequential fashion, it must be emphasized that the process is in fact, highly iterative. The process followed and the outcome thereof should be documented in the existing environmental documentation prepared by the mine, i.e. EMP, IWWMP and Integrated Water Use Licence Application. While many of the steps described in Figure 5.1 may already form part of the mine and environmental planning process, the purpose of this chapter and the defined procedure is to ensure that optimization of pollution prevention strategies is undertaken as a specific process during mine planning and design. (Note that whereas Figure 5.1 only shows the stepwise procedure for Alternative 1, the same process is applied to all alternatives)

Although it has been raised many times in the preceding chapters, It is restated that pollution prevention is essentially a rational planning and design process where alternative options are considered with the aim of identifying those that offer the optimal degree of pollution prevention and require the least amount of active long-term interventions. In cases where the potential pollution impact or risk is considered significant or where it may persist after mine closure, then the best (in terms of performance and sustainability) pollution prevention option must be implemented, unless a very strong motivation and appropriate mitigation measures with appropriate financial resources can be presented. In cases where the potential pollution impact is less significant, is of a shorter duration and does not persist after mine closure, cost benefit analyses can be used to motivate implementing a less than optimal pollution prevention option, provided it is coupled with appropriate impact minimisation measures and that financial resources are clearly available to ensure that these minimisation measures are sustainably implemented.

Suitably qualified and experienced persons must be utilized in undertaking the pollution prevention assessments in order that there can be confidence in the outcome of the assessment process.

Figure 5.1: Pollution prevention assessment procedure



The individual steps incorporated in the pollution prevention assessment procedure are discussed in this chapter.

Step 1: Identify and characterize all potential pollution sources on mine

The initial step in identifying pollution prevention options is to first understand where all the potential sources of

pollution on the mine are. A rigorous EIA process as is already required on all mines should identify these sources and the information provided in Chapter 4 of this document will also assist in this step. Once these sources have been defined, it is necessary to qualitatively characterize the sources in terms of understanding the potential modes and pathways of pollution that may arise from each and the receptors that may be impacted on by the pollution. Traditional screening- level impact

and/or risk assessment techniques can be applied to do this as is shown in Figure 5.2. As a more quantitative approach and assessment will be undertaken in Steps 3, 4, 5 and 6, it is only necessary to undertake a qualitative

assessment at this first step in order that potential pollution prevention options can be identified. A tabular or other suitable format to document the results of step 1 can be used as illustrated in Table 5.1 below.

Figure 5.2: Risk assessment methodology

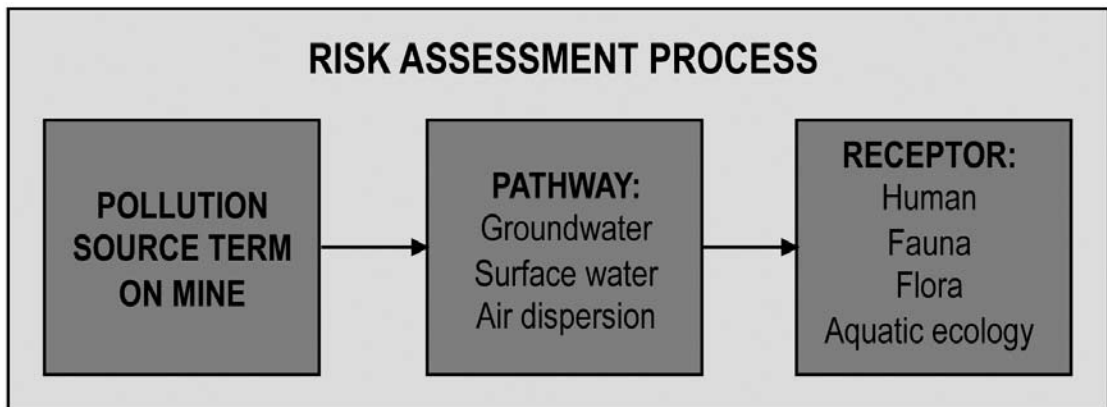


Table 5.1: Characterisation of potential pollution sources, pathways and receptors

Potential pollution source	Nature / type of potential pollution	Potential water pollution pathways	Potential water pollution receptors	Potential pollution prevention options
Tailings Disposal Facility	Seepage from base of facility	Contaminate aquifer Move through aquifer to receiving stream	Stock watering from boreholes Aquatic ecology Downstream crop irrigation	
	Seepage from toe	Surface runoff to receiving stream	Aquatic ecology Downstream crop irrigation	
	Surface runoff from side slopes	Surface runoff to receiving stream	Aquatic ecology Downstream crop irrigation	
	Dust dispersion to surrounding land	Surface runoff to receiving stream	Aquatic ecology Downstream crop irrigation	
Underground stope	ARD from contact between water and ore	Into mine service water circuit, pumped to surface & discharged to receiving stream	Aquatic ecology Downstream rural community potable use	
Etc. for all other potential pollution sources				

The last column in the above Table would be filled in as part of Step 2 below.

Step 2: Identify pollution prevention alternatives for each pollution source

Step 2 flows logically from Step 1 and there are normally a number of alternative options that could be considered to prevent pollution from any pollution source. These options

would ultimately influence either the water balance or the factors affecting water quality, or both. In most cases, a suitably qualified person with reasonable experience will be capable of identifying and specifying an appropriate set of alternative pollution prevention options that should be considered, particularly as these are most often quite

logical countermeasures that derive from knowledge of the potential pollution sources, materials and their mode of pollution.

Some typical pollution prevention options are given in Chapter 4 of this document. In many cases, the pollution prevention options are described as standard best practice in the various activity BPGS (A1 – A6) published by DWAF – see Preface to this document.

Pollution prevention options may cover a very wide range of alternatives. For example, for a tailings disposal facility (TDF), options that may be considered to have a pollution prevention character include those shown in the example box below (a number of these are today considered as minimum practice).

EXAMPLE

POLLUTION PREVENTION OPTIONS FOR TAILINGS DISPOSAL FACILITY

- (1) Using paste technology instead of conventional hydraulic placement as the reduction in water content gives rise to a reduction in water usage and a reduction in seepage motive forces.
- (2) Using a conventional penstock decanting system instead of a floating barge as this allows a smaller pool to be maintained, allowing for less water consumption through evaporation and a reduced driving force for seepage.
- (3) Constructing a larger return water dam in order that water can be taken off the TDF during high precipitation events, thereby maintaining the smallest possible pool size. A large return water dam will also reduce the spillage risk of the return water dam.
- (4) Placement of a liner with all its seepage interception and monitoring systems under the complete TDF footprint to catch all seepage and cut off pollution pathways to the aquifer.
- (5) Construction of long finger drains around the TDF perimeter to intercept all toe seepage and horizontal seepage from the TDF.
- (6) Construction of toe drains around the TDF perimeter to intercept any seepage into drains from where it can be routed to appropriate treatment systems.
- (7) Construction of properly sized toe paddocks around the TDF perimeter to capture all side slope runoff and transported sediments.
- (8) Correct shaping of side slopes and top, with properly designed drainage systems to ensure a stable and sustainable landform after closure, where erosion is minimized.
- (9) Placement of an appropriate cover aimed at manipulating the water and oxygen flux into the TDF in order to achieve a particular reduction in long-term ARD risk.

The outcome of the exercise to identify a range of pollution prevention alternatives could be added into the last column of Table 5.1 above, to provide an easy summary of the identified pollution sources and potential pollution prevention alternatives to be considered.

Step 3: Assess location for fatal flaws and enhanced pollution potential

Correct location of components of a mining operation is often one of the most important pollution prevention decisions that can be made. Detailed knowledge of the existing environment in terms of geology, hydrogeology, hydrology and receptors of potential pollution is required in undertaking this step. This is particularly true for the

placement of waste disposal facilities that generally have a perpetual footprint. These considerations are addressed in **BPG A2: Water Management for Mine Residue Deposits**.

Location of facilities is also very important from a storm water management perspective (see **BPG G1: Storm Water Management**) where a conscious effort needs to be made to minimize the size of the area that produces dirty runoff while maximizing the size of the area that produces clean runoff. This will require conscious assessment and design intervention to group facilities that cause dirty runoff together into a restricted number and size of catchments. This consideration will also ensure that waste material that has a pollution potential,

is not used for activities such as road building which will then result in a much bigger contaminated runoff and seepage footprint.

Step 4: Consider water balance in terms of pollution prevention

As has been mentioned previously, pollution prevention most often entails applying measures that modify the water balance and/or factors that affect water quality. Relevant BPGs that do address these issues are all the activity series BPGs (see Preface), **BPG G1: Storm Water Management**, **BPG G2: Water and Salt Balances**, **BPG G4: Impact Prediction** and **BPG H3: Water Reuse and Reclamation**.

In general terms, it can be stated that successful pollution prevention alternatives will typically reduce the volumes of water that come into contact with sources of pollution while impact minimisation alternatives will typically reduce the volumes of contaminated water that can migrate along transport pathways to potential receptors.

Each of the pollution prevention alternatives identified in Step 2, should be assessed and characterized in terms of the effect that that strategy would have on the system water balance and how this effect serves to prevent or minimize pollution. This assessment should be undertaken in a quantitative manner, so that alternatives can be properly compared against each other. It must be emphasized, however, that the alternative that has the biggest positive impact on water balance is not always the alternative that should be implemented. This could be for reasons of practicality, cost-benefit or because of water quality considerations.

It is also important to emphasize that the water balance calculations will be subject to uncertainty due to a number of factors such as natural variability in model input parameters, model simplifications, unpredictability of future hydrological and climatic conditions. This uncertainty is a natural feature of predictive modelling and does not invalidate the modelling, it simply requires that the extent and effect of the uncertainty be understood, quantified and stated.

Step 5: Assess factors affecting water quality

Factors affecting water quality are typically more complex and difficult to determine and quantify because the chemical and microbiological factors that affect water quality are inherently more complex than those that

affect water balance. Nevertheless, tools are available to assess these potential water quality effects and those that relate to geochemistry are addressed in **BPG G4: Impact Prediction**. It is also important to emphasize that the geochemical and water quality calculations will be subject to uncertainty due to a number of factors as described previously. This uncertainty is a natural feature of predictive modelling and does not invalidate the modelling, it simply requires that the extent and effect of the uncertainty be understood, quantified and stated.

For mines still in the planning phase, it is important that the exploration programme make provision for taking samples of material that would find its way into the mine residue deposits and that this material undergoes the necessary geochemical characterization to support the water quality evaluations covered in this Step 5. Where it is necessary to assess the water quality impacts of facilities that have a very long-term presence, such as waste residue deposits, it is necessary to evaluate the water quality implications of alternative pollution prevention options in a quantitative and not just qualitative manner, using appropriate assessment techniques described in **BPG G4: Impact Prediction**.

Additionally, with regard to ore beneficiation, options could be considered to utilize different process chemicals with a lower water quality risk. A number of these considerations are addressed in **BPG A3: Water Management in Hydrometallurgical Plants**.

Step 6: Define temporal impacts profile

For those facilities that have an intended life span equivalent to the mine life or longer (e.g. opencast pits, underground mines, mine residue deposits), it is necessary to evaluate the potential pollution impacts over the same life span as the mine and for at least 100 years (or such other time as is agreed with the relevant authorities) after mine closure for those facilities that will persist after mine closure. These time-based or temporal impact profiles should be prepared for all alternatives being considered. This is to ensure that a pollution prevention option with a best short-term benefit but poor long-term benefit is not inadvertently selected.

Step 7: Define acceptable level of impact criteria

In order to assess which pollution prevention options are appropriate, it is necessary to establish an understanding of what level of impact is considered acceptable, using a

risk assessment process and to agree this with DWAF and interested and affected parties. The criteria that denote an acceptable level of impact will differ from mine to mine and from catchment to catchment, with new mines generally being required to comply with more stringent criteria, primarily because it is possible to optimize pollution prevention strategies at the planning phase and to design these mining operations to have minimum impacts. The criteria for acceptable level of impact can also change over the life of the mine due to other changes such as land use patterns, values, population and demographic changes, more stringent environmental standards, etc. This requirement is also often driven by the fact that water is in short supply and there is a higher need for water reuse and reclamation.

Optimal pollution prevention makes water reuse, reclamation and treatment easier and cheaper.

It is again important, when considering the criteria for acceptable level of impact to take account of the temporal variation in impact for those mining facilities that have very long lifetimes. The level of uncertainty in the impact predictions must also be considered in order that error margins can be applied to account for this uncertainty.

Decision point 1: Is there an option that meets criteria without a need for further mitigation?

Once all the pollution prevention alternatives have been fully evaluated in Steps 4, 5 and 6 and the criteria for defining the level of acceptable impact have been set and agreed (Step 7), it is possible to review all the pollution prevention options and to establish whether any options are able to ensure that the pollution impact meets the acceptable criteria without the need for further impact minimisation or mitigation measures. In answering this question, it will also be necessary to consider the uncertainties in the predictions and the possibility of the criteria for acceptable levels of impact changing in future for reasons as described above. If there are such pollution prevention measures that meet the criteria set in Step 7, then the best option can be implemented in Step 8. If not, then additional assessments will need to be undertaken in order to define the additional impact minimisation measures that will be required to meet the criteria.

Step 8: Implement preferred pollution prevention option

Where a preferred pollution prevention option can be identified and agreed upon that fully addresses the pollution risks associated with that facility, without the need for additional impact minimisation measures, and provided it is a practical and affordable option, this option should be defined and documented in the mine EMP, IWWMP and Integrated Water Use Licence and closure plan. It must be remembered that the implementation of such a pollution prevention option must be accompanied by an appropriate monitoring and auditing programme to ensure that the desired pollution prevention objectives are actually being met and to identify the need for any additional impact minimisation measures – see **BPG G3: Water Monitoring Systems**.

impact, the best option that partially addresses the pollution risks associated with that facility should be defined and documented in the mine EMP, IWWMP, Integrated Water Use License and mine closure plan. It must be remembered that the implementation of such a pollution prevention option must be accompanied by an appropriate monitoring and auditing programme to ensure that the desired pollution prevention objectives are actually being met and to identify the need for any additional impact minimisation measures – see **BPG G3: Water Monitoring Systems**. As the identified pollution prevention option only partially addresses the pollution impact, additional impact mitigation measures will need to be identified and implemented to minimize the impact further until the criteria for acceptable impact (Step 7) are met.

Step 9: Consider mitigation measures required

Where no pollution prevention option can be identified that fully meets the criteria for acceptable levels of

The additional impact minimisation and mitigation measures are likely to entail some degree of interception and collection of contaminated water and the subsequent reuse or reclamation / treatment and it will probably be necessary to utilize **BPG H3: Water Reuse and Reclamation** and **BPG H4: Water Treatment** to develop

the necessary strategies. These BPGs give these topics extensive coverage and this information is not repeated here.

Decision Point 2: Can mitigation or treatment of residual impact be effectively applied?

If it is not possible to identify water reuse, reclamation or treatment options to reduce the impact to the acceptable limit, then it will be necessary to review whether or not the mining project should go ahead (see Step 12).

Decision Point 3: Are the pollution prevention and impact minimisation options sustainable after closure?

For those aspects of the mining operation that will continue to produce a potential environmental impact after mine closure (e.g. mine residue deposits, rehabilitated pits, underground mine workings, etc.), it is necessary to determine whether the identified pollution prevention and impact minimisation options will continue to perform adequately in the post-closure period. In undertaking this assessment, particular consideration must be given to the risks of environmental standards becoming stricter during the life of mine, and to the fact that active maintenance measures will be more difficult to guarantee after closure.

As has been described and discussed previously, it is preferred that pollution prevention and impact minimisation options are able to operate passively, i.e. without active intervention and management. If the identified systems are passive, it is important to emphasize that appropriate maintenance measures are still required for passive management systems.

Step 10: Define additional actions required to ensure sustainable performance after mine closure

It is necessary to determine what additional actions may need to be implemented to ensure that the applied management measures continue to provide the required environmental performance after mine closure, taking all the abovementioned uncertainties into account. It is possible that the identified additional actions only need implementation at or near mine decommissioning and then these measures must be planned and budgeted for.

This step should also define a clear ongoing monitoring, auditing and review process that should be implemented to assess the compliance of the applied management actions with agreed performance objectives and to identify additional measures that may be required.

Step 11: Define costs, risks, liabilities, etc.

Regardless of whether or not the management measures being implemented are passive or active, there is a clear need to define the costs (capital, operating, decommissioning, maintenance and post-closure) associated with each option that is to be implemented, together with uncertainties in the cost estimations.

Additionally, as the assessment process described above is largely based on predictions, there is also a need to define the risks and liabilities associated with the options in terms of non-compliance with the agreed acceptable level of impact (Step 7), which may itself change over the mine life, and to define how these risks and liabilities will be covered – possibly by way of the mine's rehabilitation fund. A clear statement is also required in terms of who will be responsible for the implementation and maintenance of the various applied management actions.

Step 12: Review GO / NO GO for project option

Where it is not possible to identify and agree on pollution prevention and impact minimisation options that are capable of ensuring, with acceptable risk, that the agreed acceptable level of impact is achieved, it may be necessary to review the desirability of the project. This is a decision that will need to be made at a high level and is subject to negotiation and not to best practice. During these negotiations, the possibility for discharge to the water resource could also be addressed.

6

REFERENCES AND LITERATURE LIST

REFERENCES

Environmental Law Institute, 2000, Pollution Prevention and Mining – A Proposed Framework for the Americas.

UNEP, 1998, Pollution Prevention and Abatement Handbook – Toward Cleaner Production, ISBN 0-8213-3638-X.

Younger, P.L. and Sapsford, D.J. 2006, Acid Drainage Prevention Guidelines for Scottish Opencast Coal Mining: The Primacy of the Conceptual Model, Poster paper presented at the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis MO. R.I. Barnhisel (ed.) Published by the American Society of Mining and Reclamation (ASMR), 3134 Montavesta Road, Lexington, KY 40502

RTR Resource Management, 2006, Niblack Lookout Unit Initial Construction /Exploration Project Storm Water Pollution Prevention Plan (SWPPP)

LITERATURE LIST

Barnard, D. (1999) Environmental Law for All. A Practical Guide for Business, Community, the Planning Professions, Environmentalists and Lawyers, Impact Books CC, Pretoria.

Drever, J.E. (1982) The Geochemistry of Natural Waters, Prentice-Hall, Eaglewood Cliffs.

Evangelou, V. P. (1998) Environmental Soil and Water Chemistry – Principles and Applications, John Wiley and Sons, Inc.

Hemmond, H. F. (2000) Chemical Fate and Transport in the Environment, 2nd edition, Academic Press.

Zhu, C. (2002) Environmental Applications of Geochemical Modelling, Cambridge University Press.