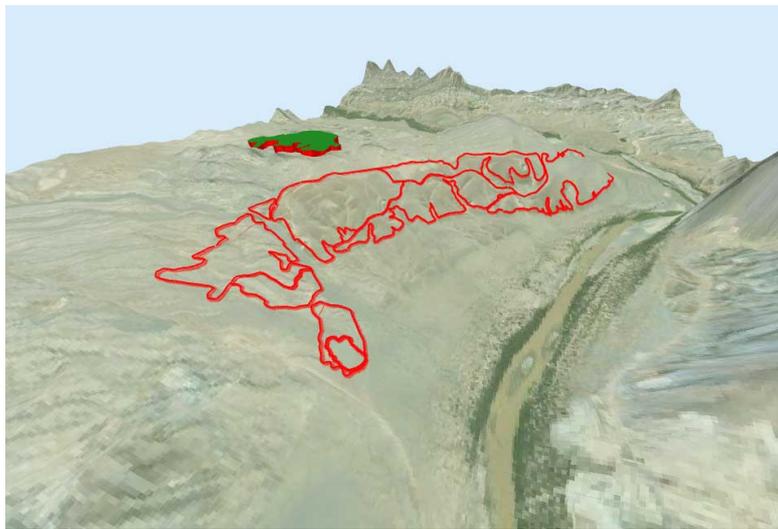


SENDELINGSDRIFT ORANGE RIVER MINES

HYDROGEOLOGICAL AND HYDROLOGICAL STUDY



Assessed by:



Assessed for:



April 2011

TABLE OF CONTENTS

1. BACKGROUND TO THE DEVELOPMENT.....	3
2. SCOPE.....	3
3. METHODOLOGY.....	3
4. LEGISLATIVE IMPLICATIONS.....	4
4.1. NAMIBIA.....	4
4.1.1. <i>The Constitution of the Republic of Namibia, 1990.....</i>	4
4.1.2. <i>Environmental Assessment Policy of Namibia, 1994.....</i>	5
4.1.3. <i>Environmental Management Act of Namibia (No. 27 of 2007).....</i>	5
4.1.4. <i>Water Resources Management Act (No. 24 of 2004).....</i>	5
4.1.5. <i>The Draft Wetland Policy, 2003.....</i>	6
4.1.6. <i>National Heritage Act of Namibia (No. 27 of 2004).....</i>	6
4.1.7. <i>The National Monuments Act of Namibia (No. 28 of 1969) as Amended until 1979.....</i>	6
4.1.8. <i>Minerals (Prospecting and Mining) Act (No. 33 of 1992).....</i>	6
4.2. SOUTH AFRICA.....	7
4.2.1. <i>National Environmental Management Act (No. 107 of 1998).....</i>	7
4.2.2. <i>National Water Act (No. 36 of 1998).....</i>	7
4.2.3. <i>Hazardous Substances Act (No. 15 of 1973).....</i>	8
4.2.4. <i>Mineral and Petroleum Resources Development Act (No. 28 of 2002).....</i>	8
4.2.5. <i>Environment Conservation Act (No.73 of 1989).....</i>	8
4.2.6. <i>National Environmental Management Biodiversity Act (No.10 of 2004).....</i>	8
5. DESKTOP REVIEW.....	9
6. RECEIVING ENVIRONMENT.....	9
6.1. LOCALITY.....	9
6.2. TOPOGRAPHY AND DRAINAGE.....	9
6.3. CLIMATE.....	10
6.4. GEOLOGY AND HYDROGEOLOGY.....	11
6.5. SURFACE WATER.....	12
6.6. SEISMIC HISTORY.....	13
7. HYDROGEOLOGICAL ASSESSMENT.....	14
7.1. CHARACTERIZATION OF THE BEDROCK.....	15
7.2. POTENTIAL FLOW PATHS.....	15
8. FLOODLINE INVESTIGATION IN THE ORANGE RIVER.....	17
8.1. HYDRAULIC STUDY – FLOODLINE CALCULATION.....	18
8.2. FLOOD HYDROLOGY FOR TRIBUTARY NEAR SENDELINGSDRIFT.....	20
9. THE MINING OPERATION.....	22
9.1. TREATMENT.....	23
9.2. TAILINGS FACILITY.....	23
9.2.1. <i>Tailings Facility Threats.....</i>	23
10. TYPICAL IMPACTS FROM MINING OPERATIONS.....	25
10.1. GROUNDWATER IMPACTS.....	25
10.2. SURFACE WATER IMPACTS.....	26
10.3. GEOLOGY IMPACTS.....	26
11. ENVIRONMENTAL RISK ASSESSMENT.....	26
11.1. DEVELOPMENT OF THE TAILINGS FACILITIES.....	27
11.2. MINING ACTIVITIES.....	28
12. MONITORING PROGRAMME.....	30
13. CONCLUSIONS.....	30
14. REFERENCES.....	30

LIST OF TABLES

Table 1. Relative heights of the water level at selected points.....	18
Table 2. Floodwater levels.....	20
Table 3. Flood Peak Results.....	22
Table 4. Potential Threats to Tailings Facilities.....	24
Table 5. Criteria for Impact Evaluation (DEAT 2006).....	27
Table 6. Impacts Evaluation – Tailings Dam.....	28
Table 7. Impacts Evaluation – Mine Operations.....	29

LIST OF FIGURES

Figure 1. Location Map	10
Figure 2. Climate Data	11
Figure 3. Hydrogeological Map	13
Figure 4. Seismic Events	14
Figure 5. Bedrock Flow Paths (No Sink Removal)	16
Figure 6. Bedrock Flow Paths (Sinks Removed)	16
Figure 7. Orange River Floodline Map	19
Figure 8. Streams and Catchment Area	21

LIST OF ABBREVIATIONS

CAD	Computer Aided Design
DWAF	Department of Water Affairs and Forestry (South Africa)
EIA	Environmental Impact Assessment
EMA	Environmental Management Act 7 of 2007 (Namibia)
EMP	Environmental Management Plan
GSN	Geological Survey Namibia
mamsl	Meters above mean sea level
mbs	Meters below surface
ML	Local Magnitude Scale
Namdeb	Namdeb Diamond Corporation (Pty) Ltd
NEMA	National Environmental Management Act 107 of 1998 (South Africa)
RMF	Regional Maximum Flood

1. BACKGROUND TO THE DEVELOPMENT

A hydrogeological and hydrological study has been commissioned by the Namdeb Diamond Corporation (Pty) Ltd for the proposed Sendelingsdrift Mine operation in the Orange River Mining license area.

According to the Draft Scoping Report (CSIR 2010), the Sendelingsdrift resource is a near-surface deposit that can be exploited with conventional open pit mining methods. Essentially, diamond-bearing material is mined with heavy earthmoving machinery, such as hydraulic excavators, Rigid Frame Trucks (RFTs), bulldozers, front-end loaders and graders. Contractors may also use Articulated Dump Trucks (ADTs). Ore retrieval will comprise of stripping; ore excavation; bedrock cleaning; drilling and blasting, stockpiling and hauling.

The assessment was conducted to evaluate the hydrogeology in the Sendelingsdrift area, and potential impacts on groundwater and surface water in the area, which could be impacted by the proposed tailings dam and mining activities. This report will therefore focus on the entire Sendelingsdrift Mine, including two tailings disposal options.

2. SCOPE

A desktop review on all available information related to ground and surface water in the area will be conducted. The client is to supply all relevant available data to the consultant.

The purpose of this study is to conduct an assessment of the groundwater sources and flow patterns in the Sendelingsdrift Mining Area. A geological map based on exploration hole drilling information and existing surface mapping of the outcrop is to be compiled. Mapping of geological structures based on remote sensing information to characterise flow in groundwater structures will also be conducted.

The study should also evaluate potential impacts on groundwater and surface water quantity and quality in the area, which could be impacted by mining, engineering and treatment activities, products and services. Impacts should be risk ranked according to high medium and low. The mitigating and monitoring measures with recommendations are to be outlined. Contingencies such as earthquakes, floods, seepage and potential fine tailings dam failure will be considered. An EMP addressing all potential surface and groundwater impacts will be drawn up to identify environmental aspects, management objectives, mitigation and management actions to be implemented in a short and long term.

Identify suitable monitoring borehole locations in the area. Draw up a borehole monitoring programme inclusive of purpose, design, frequency and type of data collection, method of reporting and analysing of data.

This specialist study will therefore ensure that informed decision-making and responsible mining operation and fine tailings disposal practices are achieved along the international Orange River, in regard to hydrogeological matters. This study will be included in the Orange River Life of Mine Extension Project and forms part of the EIA process.

3. METHODOLOGY

The following methods were used to investigate the hydrogeological situation of the area; and to evaluate the potential environmental impacts of the proposed tailings storage facility and the mining activities at the mine:

1. Baseline information about the mine and its surroundings was obtained from existing secondary information as well as from a reconnaissance site visit conducted in the past.
2. Hydrogeological and geological data were analysed to compile a geological map outlining various geological units, locations of any existing water boreholes in the area, exploration boreholes, springs and pits.

3. Groundwater levels and flow paths in the Sendelingsdrift area were evaluated by using groundwater levels and strikes obtained from a recent drilling programme (June 2010) conducted in Zone 6 and 7, see Figure 3.

4. LEGISLATIVE IMPLICATIONS

The Orange River (a perennial river) is located less than 400m from the proposed mine outline, at places. The river is a shared watercourse system that forms part of the international border between Namibia and South Africa. The river's northern high-water mark is considered the boundary separating the two sovereign states. The environmental integrity of the river is thus of utmost importance to both countries, especially South Africa, as the river falls within its boundaries.

In order to avoid possible international disputes, expensive environmental penalties or remediation due to the proposed development/operation, it is important to investigate and identify, as thoroughly and as early as possible, the legal implications that may arise as a result of the construction and operations of the development.

It is therefore imperative that the development complies with all relevant Namibian, South African and international legal requirements to avoid any potential impacts on the environment. Impact on the environment and/or the nearby-shared water system can be perceived as threatening the well-being and security of the neighbouring country, which may stimulate hostile responses and/or transboundary disputes.

In order to protect and achieve sustainable management of the environment and the use of natural resources, all developments deemed to have adverse impacts on the environment, are governed by the Environmental Management Act 7 of 2007 (EMA) in Namibia and the National Environmental Management Act 107 of 1998 (NEMA) in South Africa. These two Acts governs all environmental related legislations in the respective countries. The following subsections are presenting some of the legal requirements from Namibia and from South Africa that is deemed to be directly related to the project.

4.1. Namibia

The Environmental Management Act of Namibia states that a person who causes damage to the environment must pay the costs associated with rehabilitation of damage to the environment and to human health caused by pollution, including costs for measures as are reasonably required to be implemented to prevent further environmental damage. The Act further states that any person who, without good reason, fails or refuses to comply with a compliance order commits an offence and is liable on conviction to a fine not exceeding N\$500,000 or to imprisonment for a period not exceeding 25 years or to both such fine and such imprisonment.

In addition to the EMA, a number of other laws are applicable for environmental protection. A summary of the legislation most pertinent to the proposed development is provided below.

4.1.1. The Constitution of the Republic of Namibia, 1990

Article 95 of Namibia's constitution provides that:

“The State shall actively promote and maintain the welfare of the people by adopting, inter alia, policies aimed at the following:

(l) management of ecosystems, essential ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future; in particular the Government shall provide measures against the dumping or recycling of foreign nuclear and toxic waste on Namibian territory.”

This article recommends that a relatively high level of environmental protection is called for in respect of pollution control and waste management.

4.1.2. Environmental Assessment Policy of Namibia, 1994

This policy places high priority on maintaining ecosystems and related ecological processes, in particular those important for water supply, food production, health, tourism and sustainable development.

The policy also states that all projects, policies, programmes, and plans that have detrimental effects on the environment, be accompanied by an EIA. It further provides a guideline list of all activities requiring an impact assessment. The proposed development of the tailings dam and mine is listed as a project requiring an impact assessment.

The policy further requires all major industries and mines to prepare waste management plans and present these to the local authorities for approval.

Apart from the requirements of the Environmental Assessment Policy, the following sustainability principles need to be taken into consideration, particularly to achieve proper waste management and pollution control:

4.1.2.1. Cradle to Grave Responsibility

This principle provides that those who initiate potentially polluting activities to the environment and its resources, should be liable for the protection, rehabilitation and restoration of the environment and its resources.

4.1.2.2. Precautionary Principle

There are numerous versions of the precautionary principle. At its simplest it provides that if there is any doubt about the effects of a potentially polluting activity, a cautious approach should be adopted.

4.1.2.3. The Polluter Pays Principle

A person who generates waste or causes pollution should, in theory, pay the full costs of its treatment or of the harm, which it causes to the environment.

4.1.3. Environmental Management Act of Namibia (No. 27 of 2007)

The Act provides a broad definition to the term “*environment*” - land, water and air; all organic and inorganic matter and living organisms as well as biological diversity; the interacting natural systems that include components referred to in sub-paragraphs, the human environment insofar as it represents archaeological, aesthetic, cultural, historic, economic, paleontological or social values.

4.1.4. Water Resources Management Act (No. 24 of 2004)

The Act aims to provide management of the national water resources to achieve sustainable use of water for the benefit of all water users. This requires that the quality of water resources is protected as well as integrated management of water resources with the delegation of powers to institutions at the regional or catchment level.

The purpose of this Act is broadly to control the use and conservation of water for domestic, agricultural, urban and industrial purposes; to control, in certain respects, the use of sea water; to control certain activities on or in water in certain areas; and to control activities which may alter the natural occurrence of certain types of atmospheric precipitation.

4.1.5. The Draft Wetland Policy, 2003

Requires wetlands, of which the Orange River and its associated hydrological functions form a part, to be managed in such a way that their biodiversity, vital ecological functions and life support systems are protected for the benefit of present and future generations.

4.1.6. National Heritage Act of Namibia (No. 27 of 2004)

This Act provides for the protection and conservation of places and objects of heritage significance and the registration of such places and objects. The Client should ensure that if any archaeological or palaeontological objects, as described in this Act, are found in the course of the development, that such findings be reported to the line Ministry immediately. If necessary, the relevant permits must be obtained before disturbing or destroying any heritage significance as envisaged by this Act.

The Act defines as protected:

“1 (a) any remains of human habitation or occupation that are 50 or more years old found on or beneath the surface on land...”

and considers the possible impacts of:

“ (a) any physical intervention, excavation or action that may result in a change to the nature, appearance or physical nature of a place...”

Part VI, Section 55 of the Act makes provision for an archaeological impact assessment of activities or developments carried out where archaeological sites are believed to exist. Since the promulgation of the National Heritage Act, the mining industry has tended to adopt the precautionary principle and commissioned an archaeological impact assessment of large exploration and mining projects.

4.1.7. The National Monuments Act of Namibia (No. 28 of 1969) as Amended until 1979

“No person shall destroy, damage, excavate, alter, remove from its original site or export from Namibia:

- (a) any meteorite or fossil; or
- (b) any drawing or painting on stone or a petroglyph known or commonly believed to have been executed by any people who inhabited or visited Namibia before the year 1900 AD; or
- (c) any implement, ornament or structure known or commonly believed to have been used as a mace, used or erected by people referred to in paragraph (b); or
- (d) the anthropological or archaeological contents of graves, caves, rock shelters, middens, shell mounds or other sites used by such people; or
- (e) any other archaeological or palaeontological finds, material or object; except under the authority of and in accordance with a permit issued under this section.

4.1.8. Minerals (Prospecting and Mining) Act (No. 33 of 1992)

It states that any mining operations or any prospecting operations carried out, appropriate measures will be taken to minimize or prevent any pollution of the environment. Provides for EIAs in mining activities, and includes requirements for rehabilitation of prospecting and mining areas and for minimising or preventing pollution.

4.2. South Africa

Non-compliance of the Environmental Management Act in South Africa, could lead to a compliance notice, which is equivalent to the maximum penalty of 10 years imprisonment and/or R5 million.

4.2.1. National Environmental Management Act (No. 107 of 1998)

This governs South African environmental legislations and lays down basic environmental principles including: *Duty of Care*, *Polluter Pays* and *Sustainability*. The Department of Environmental Agriculture and Tourism (DEAT) regulate the Act.

4.2.2. National Water Act (No. 36 of 1998)

The *Act (No. 36 of 1998)* has requirements relating to pollution control, protection of water resources, dam safety and water use tariffs.

- (1) An owner of land, a person in control of land or a person who occupies or uses the land on which
 - (a) any activity or process is or was performed or undertaken; or
 - (b) any other situation exists, which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.
- (2) The measures referred to in subsection (1) may include measures to—
 - (a) cease, modify or control any act or process causing the pollution;
 - (b) comply with any prescribed waste standard or management practice;
 - (c) contain or prevent the movement of pollutants;
 - (d) eliminate any source of the pollution;
 - (e) remedy the effects of the pollution; and
 - (f) remedy the effects of any disturbance to the bed and banks of a watercourse.
- (3) catchment management agency may direct any person who fails to take the measures required under subsection (1) to
 - (a) commence taking specific measures before a given date;
 - (b) diligently continue with those measures; and
 - (c) complete them before a given date.
- (4) Should a person fail to comply, or comply inadequately with a directive given under subsection (3), the catchment management agency may take the measures it considers necessary to remedy the situation.
- (5) Subject to subsection (6), a catchment management agency may recover all costs incurred as a result of it acting under subsection (4).

Specific regulations (No. 704) on the use of water for mining and related activities exist and are aimed at protecting water resources in South Africa. Of particular reference to the development of the mine and the tailings dam, Parts 4, 5, 6 and 7 of regulation no.704 apply.

Part 4 states that no person in control of a mine or activity may:

- (a) locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse.

- (b) not carry out any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, whichever is the greatest;
- (c) place or dispose of any residue or substance which causes or is likely to cause pollution of a water resource, in the workings of any underground or opencast mine excavation, prospecting diggings, pit or any other excavation; or
- (d) use any area or locate any sanitary convenience, fuel depots, reservoir or depots for any substance which causes or is likely to cause pollution of a water resource within the 1:50 year flood-line of any watercourse or estuary.

Any person who contravenes or fails to comply with part 4, 5, 6 or 7 is guilty of an offence and liable on conviction to a fine or to imprisonment for a period not exceeding five years.

4.2.3. Hazardous Substances Act (No. 15 of 1973)

The Act deals with the management and control of hazardous substances. It allows for regulations relating to the manufacturing, modification, importation, storage, transportation and disposal of any grouped hazardous substances, which may cause injury, ill-health, or death to humans. The Act is regulated by the Department of Health.

4.2.4. Mineral and Petroleum Resources Development Act (No. 28 of 2002)

In accordance with applicable legislative requirements for pollution control and waste management, a holder of a mining right, prospecting right or mining permit in terms of the Act must

- (a) where possible, dispose pollution, waste and mine residue in a responsible and sustainable manner.
- (b) No sand dump or tailings dam shall be established on the bank of any stream, river, dam, pan, wetland or lake without written permission of the Minister in consultation with the relevant Government department and upon such conditions as he or she may determine and as approved in the environmental management programme or environmental management plan, as the case may be.

4.2.5. Environment Conservation Act (No.73 of 1989)

The Act provides for the effective protection and control utilization of the environment and for matters incidental thereto. 'Effective protection' indicates a non-utilitarian, ecocentric perspective, while 'controlled utilization' indicates a utilitarian, anthropocentric emphasis. In particular, Parts III, IV and V of the Act apply.

4.2.6. National Environmental Management Biodiversity Act (No.10 of 2004)

The Act provides for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Management Act, 1998; the protection of species and ecosystems that warrant national protection and the sustainable use of indigenous biological resource. Of particular reference, chapter 4 and 5 of the Act apply to the proposed development.

The purpose of chapter 4 is to,

- (a) provide for the protection of ecosystems that are threatened or in need of protection to ensure the maintenance of their ecological integrity;
- (b) provide for the protection of species that are threatened or in need of protection to ensure their survival in the wild;

- (c) give effect to the Republic's obligations under international agreements regulating international trade in specimens of endangered species; and
- (d) ensure that the utilisation of biodiversity is managed in an ecologically sustainable way.

The purpose of chapter 5 is,

- (a) to prevent the unauthorized introduction and spread of alien species and invasive species to ecosystems and habitats where they do not naturally occur;
- (b) to manage and control alien species and invasive species to prevent or minimize harm to the environment and to biodiversity in particular;
- (c) to eradicate alien species and invasive species from ecosystems and habitats where they may harm such ecosystems or habitats; and

to ensure that environmental assessments for purposes of permits in terms of the Genetically Modified Organisms Act, 1997 (Act No. 15 of 1997), are conducted in appropriate cases in accordance with Chapter 5 of the National Environmental Management Act.

5. DESKTOP REVIEW

A desktop review was conducted of available information related to groundwater and surface water in the area. This was mainly based on information received from various knowledgeable staff members of Namdeb; information obtained from the recent drilling programme (June 2010); as well as a review of a various geological maps of the area.

During the review it became evident that no meaningful information regarding rock type could be gathered from the digital exploration drill hole logs as rock types of the holes drilled were mapped only as bedrock. More detailed bedrock information would have been very helpful in the understanding of the hydrogeology of the area, specifically where a surface cover is present.

Information regarding the hydrogeology of the area as obtained from Zone 6 and 7, during the June 2010 drilling programme conducted indicates that bedrock was encountered at 23mbs in Zone 7 (borehole BH1), while water was intersected between 30 to 34mbs within the bedrock, see Figure 3. Borehole BH2 was drilled up to a final depth of 42mbs in Zone 6. Bedrock was intersected at 30mbs, while water was intersected between 34 to 36mbs. The rest water level in this borehole was measured to be 17mbs, one day after drilling had stopped.

6. RECEIVING ENVIRONMENT

6.1. Locality

The study area is the Sendelingsdrift Mine, in the Orange River Mining License Area (ML42). The area is situated approximately 20km south of Rosh Pinah., north of the Orange River bank and east of the road between Rosh Pinah and Oranjemund, see Figure 1.

6.2. Topography and Drainage

The site is located in a relative wide valley stretching from south of Rosh Pinah into a south-southeasterly direction to the Orange River, where the site is located. The Gumchavib Mountain is located on the western side of the site, with the Dreigratberg on the eastern side, see Figure 1. The Orange River, the southern boundary of the valley has cut through the rock formations to generally form a deep valley with steep sides. Where it intersected the valley stretching from Rosh Pinah, river deposits formed as the river migrated into a mainly southerly direction, creating the ore bodies mined today.

Drainage taking place through this valley is taking place mostly on the eastern side of the valley, with a smaller portion of the drainage flowing through the site, all eventually ending in the Orange River. Drainage on the western side is moderately developed and is

influenced by the road between Rosh Pinah and Oranjemund. The Orange River flows in a relative large meandering pattern in a southwesterly direction.

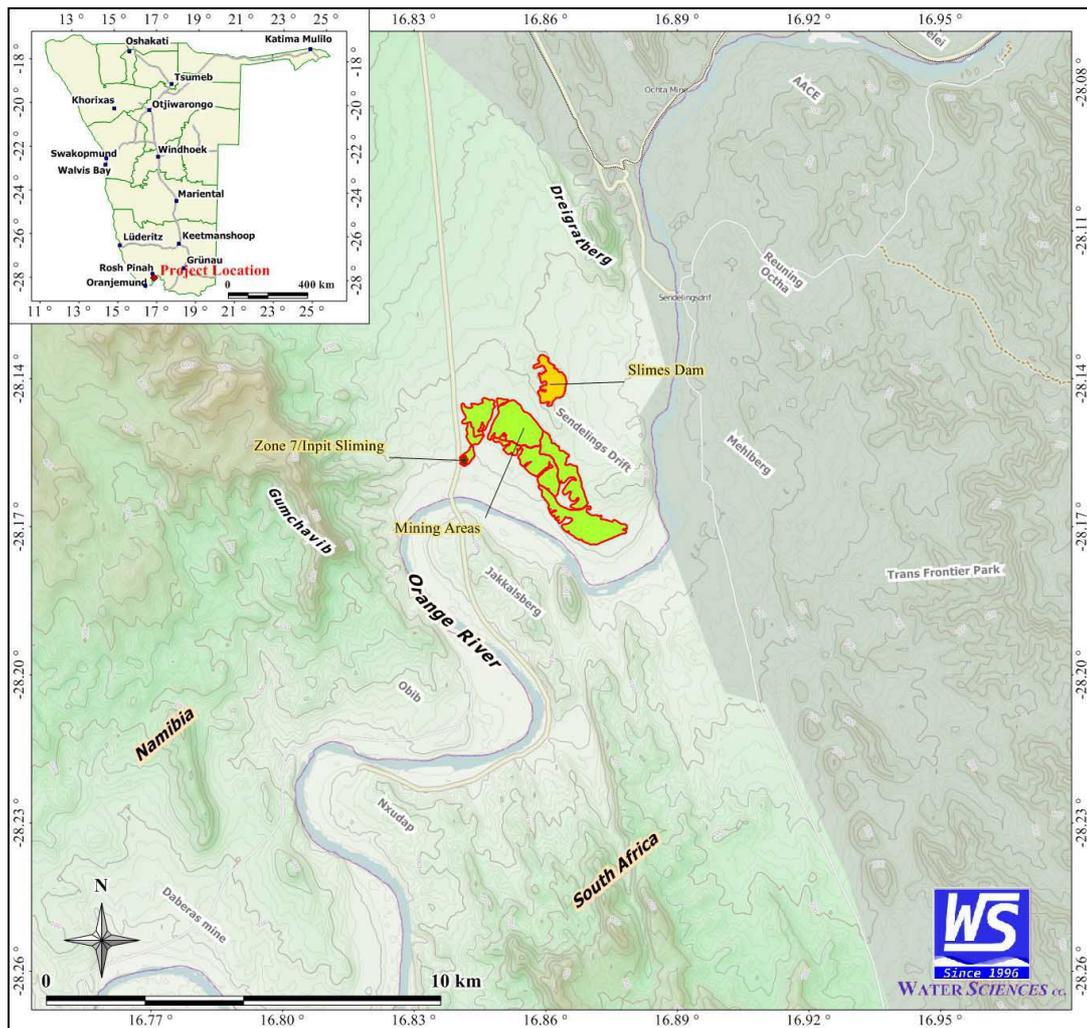


Figure 1. Location Map

6.3. Climate

The proposed Sendelingsdrift Mine is located in the southern Part of Namibia, which mainly receives winter rains. The area is arid with an annual average rainfall of 0-50mm and a variation in annual rainfall of between 60 – 70%. There is a higher incidence of rain in the period March to June at Rosh Pinah, see Figure 2.

Average annual rainfall (mm/a)	0-50
Variation in annual rainfall (%)	60-70
Average annual evaporation (mm/a)	3000-3200
Water deficit (mm/a)	2100-2300
Average annual temperatures (°C)	16-17

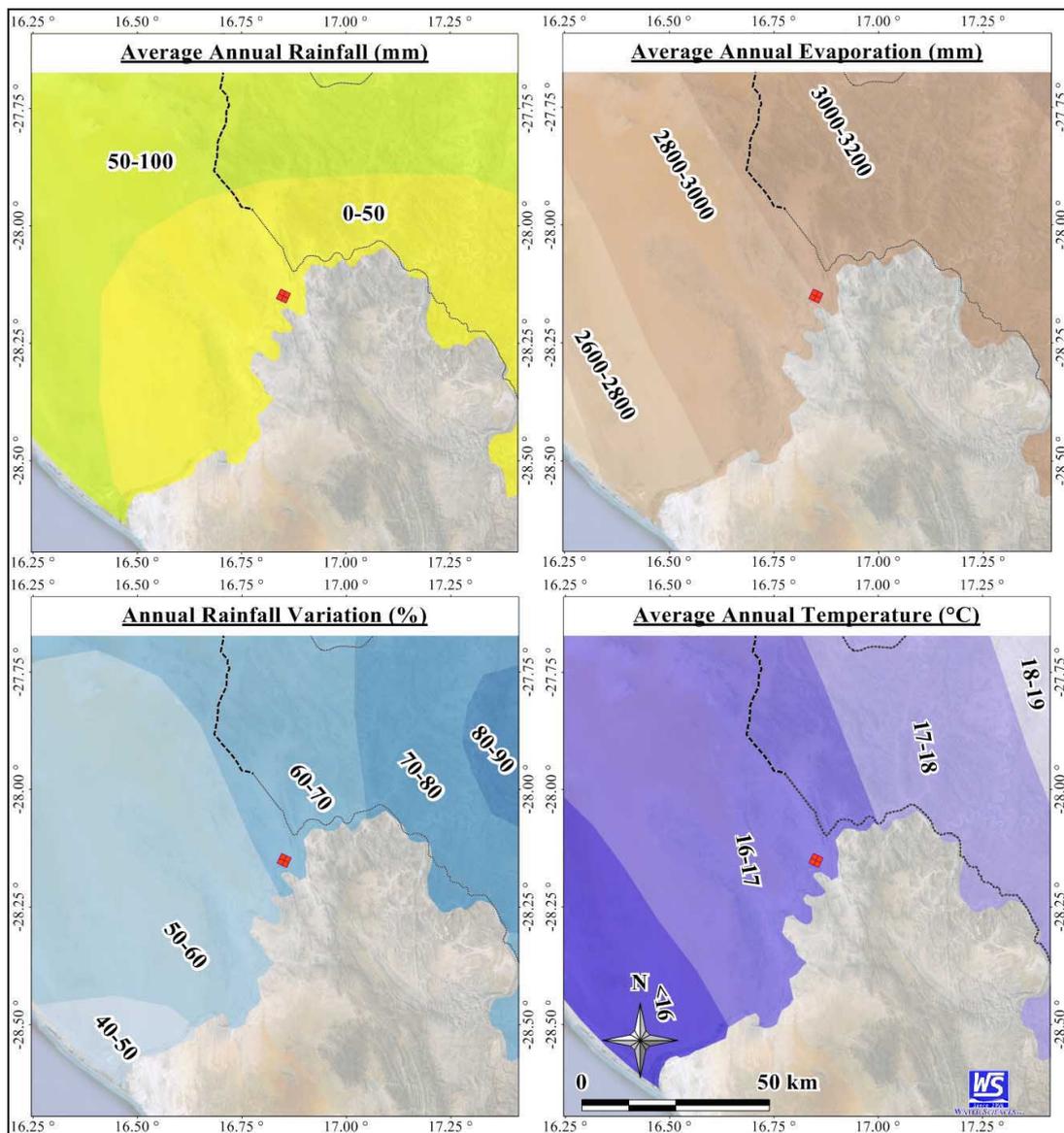


Figure 2. Climate Data

6.4. Geology and Hydrogeology

As previously indicated, meaningful information regarding rock type from previous exploration drill hole logs was not available in the area. As a result, a geological map of the area was compiled from secondary geological maps obtained.

The geological map (Sperrgebiet Prospect – Geological Mapping Sendelingsdrift, Bennet 1974), provided by Namdeb to the Consultant indicates that the general geology of the area is dominated by a sequence of older glacial and reworked glacial deposits and younger alluvial deposits. The glacial deposits must have formed during several ice ages of the Proterozoic era (2440-540 Ma) that is believed to have occurred in at least five glacial episodes during that era, hence the sequence. The glacial deposits, which appear to be the oldest rocks in the area and cover the entire area, comprise of thick tillite beds and thin dolomite beds, which are probably cap carbonate.

The lithology in the area is dominated by these thick tillite beds with quartz veins, thin dolomite beds and subordinate shale, phyllite, schist, small pebble conglomerate, green schist, ortho-/para-amphibolite rocks, quartzite, grit, intraformational and basal mixtite of the Namibian Age (900 – 450 Ma) - Numees Formation [Nu] of the Port Nolloth Group. The beddings have a general eastward dip direction, with a roughly northwest-southeast strike. The younger alluvial deposits, which overlie the glacial deposits, comprise pelitic

sediments, sheet flood deposits and most recent riverine deposits indicating a subsequent fluvial depositional environment following glaciation.

Two suites of gravel terraces lie on the bedrock. The higher (50m – 70m above current river level) and older of the two terraces is known as the Proto-Orange terrace, with the lower terrace, the Meso-Orange terrace, about 30 m – 40 m above current river level.

The gravel terraces consist of cobble gravel with a silty clay-sand and grit matrix, broken up by sand pockets and cemented (mostly carbonate cement) pockets of gravel. The gravels are layered with clay or silt lenses, and range in size from a few millimetres to over 300mm. Soils are loamy with sandy patches. (CSIR 2010). A gypsum crust is present on surface reaching depths of up to 1m below surface.

The presence of quartz veins in the area indicates that the area have enjoyed tectonic deformation which led to the folding and faulting seen in the geological cross section (Figure 3). Satellite image and aerial photograph interpretation indicates the presence of lineaments in the area, with the main structural direction being north-northwest and west to east. In particular, a large northwest-southeast striking fault is inferred to be running through the centre of mining zones 3 and 4, see Figure 3. This fault is clearly indicated south of the Orange River, on various geological maps.

Rock outcrop is present east of Zone 2, along the Orange River. Rock outcrops are also observed around the proposed fine tailings dam location; and the area west of zones 6 and 7. A natural spring in the area seems to be associated with some of the dolomitic beds (Figure 3).

6.5. Surface Water

Two prominent natural surface water bodies are located in the area. The Orange River (perennial river) is located west to southwest of the mining area, while a natural spring is located to the east, about 1.35km southeast of the slimesdam. Various smaller streams (non-perennial), tributaries of the Orange River are also present in the Sendelingsdrift area.

The Orange River is an international river, which flows through a Ramsar Site at its mouth with the Atlantic Ocean, some 85km downstream. The northern bank of this river forms the border between South Africa and Namibia. Any impact on the Orange River would have potential international legal implications.

As the only permanent river in southern Namibia, the Orange River provides a favourable habitat for plants and animals. Some plant species are restricted to the lower Orange River valley, which makes the area environmentally highly sensitive. The entire Sperrgebiet was proclaimed as a National Park on 1 December 2008 (Draft Scoping Report, CSIR 2010), The Orange River licence area has however been a protected area since 1908, with mining as its land use.

The South African government through the National Water Act prohibits the location of any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, whichever is the greatest. No one may further locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse.

Note that a spring is a point where groundwater flows out of the ground, and is thus where the aquifer surface meets the surface of the earth. This spring is known to periodically contain water. A baseline water quality sample from the spring must be collected for future monitoring purposes, before the construction of the slimes dam. No other springs are known of in the area.

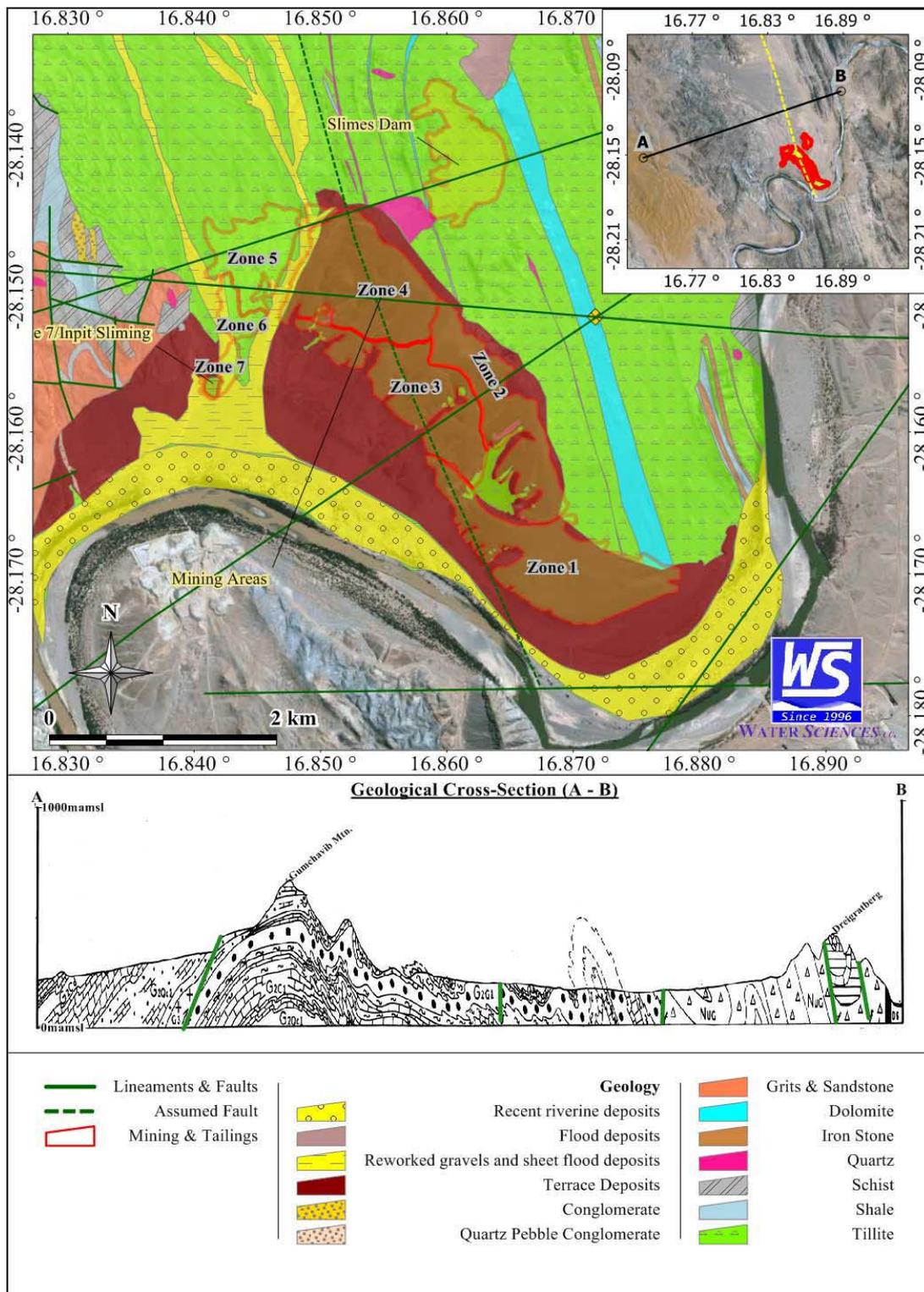


Figure 3. Hydrogeological Map

6.6. Seismic History

Historic seismic data, as sourced from the Geological Survey of Namibia, ranging from 1910 until present, is displayed in Figure 4. Geological structural features are also shown in this figure. From this figure it becomes evident that eight detectable seismic events were recorded in the last 20 years, within 100km from the project centre. Seven of these events ranged from 1.7 to 3.7 on the local magnitude (ML) or Richter scale, while one event recorded 5 on the body-wave magnitude scale (MB).

Focus of seismic events seems to be associated with the Kuboos-Bremen line of late Neoproterozoic to Cretaceous intrusives. In southern Namibia, seismicity is generally associated with both NE-SW and NW-SE trending fault lines.

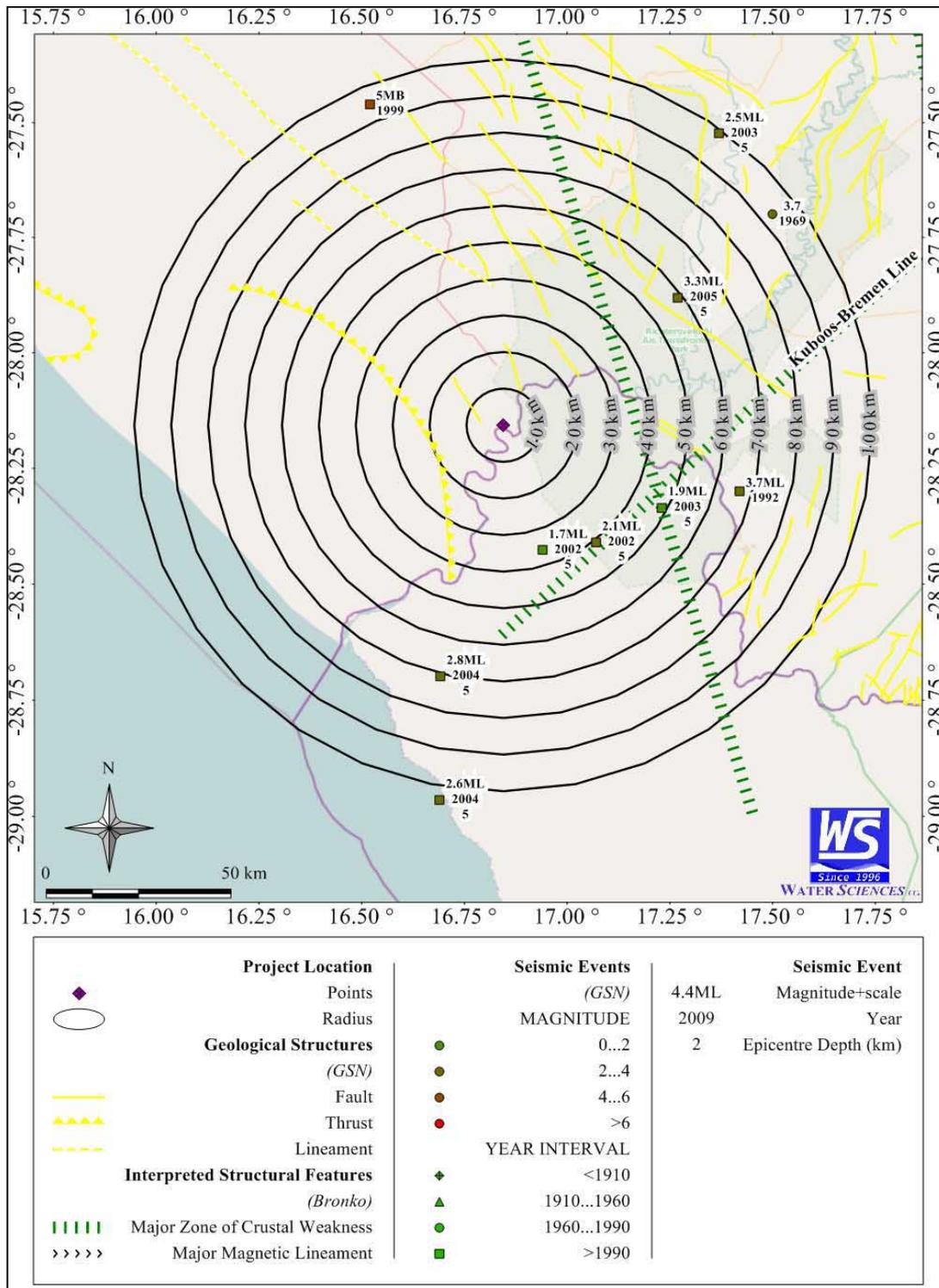


Figure 4. Seismic Events

7. HYDROGEOLOGICAL ASSESSMENT

Very little hydrogeological data is available on this area. Data available includes a spring located about 1.35km southeast of the project area as well as data from two boreholes drilled in zones 6 and 7. An old borehole located near the old German Police Station, southeast of the project area is considered to tap water from the Orange River and does not represent the groundwater conditions found in the project area.

7.1. Characterization of the Bedrock

Bedrock outcrops are present around the proposed fine tailings dam location. The main rock type is mapped to be tillite with quartz veins. Bedrock geology encountered in the area (zone 6 and 7) during the recent drilling programme, consisted mainly of schist. Groundwater in this area was intersected in bedrock during drilling. This indicates that the area is underlain by a fractured rock aquifer, covered by semi consolidated to unconsolidated sediments. Flow is expected mostly along fractures, faults (secondary porosity) and other geological structures present within the bedrock formations.

Tillite is prone to brittle deformation while the deformation in schist is more malleable. Fracturing of tillite would therefore produce a higher hydraulic conductive zone compare to fracturing in schist.

The groundwater level in the boreholes drilled (zone 6 and 7), stabilized above the bedrock after drilling had stopped. This indicates that groundwater found within the bedrock is assumed to be confined due to the relative impermeable nature of the rock, and the rise in water level above the point of water strike. It should be noted that no water was encountered above the bedrock surface before bedrock was intersected.

An open excavated pit observed in the Zone 7 mining area during the drilling program was excavated as part of exploration work conducted in the area a few years ago. No water was observed in the pit throughout the duration of the drilling program, although according to Namdeb staff, it is reported that water has been observed in this pit in the past. Water observed periodically in the pit is presumably due to flow of infiltrated rainwater along the bedrock surface towards the lower laying drainage points in the area.

7.2. Potential Flow Paths

Flow within the bedrock would be controlled by geological structures in the bedrock formations.

An analysis of the bedrock slope direction was made to predict groundwater flow on the bedrock surface, due to the lack of water level data. Note that this analysis does not consider flow within the bedrock, which would be controlled by geological structures. Figure 5 presents the predicted flow directions on top of the bedrock, considering the bedrock as more impermeable than the cover material above the bedrock. No sink removal was made on this data and flow accumulation in gullies is thus indicated. Figure 6 represent the same data, but with the filling of sinks. This means that sink areas have been filled so that flow would pass through such areas. This is best visible by comparing Figure 5 and Figure 6, around Zone 7.

From Figure 5 and Figure 6 it becomes evident that the main flow direction on the bedrock from the proposed tailings location would be in a southerly direction towards the Orange River. Flow on the bedrock is expected to collect in the deep gullies in zones 6 and 7, where it is expected to overflow when the sink areas have been filled.

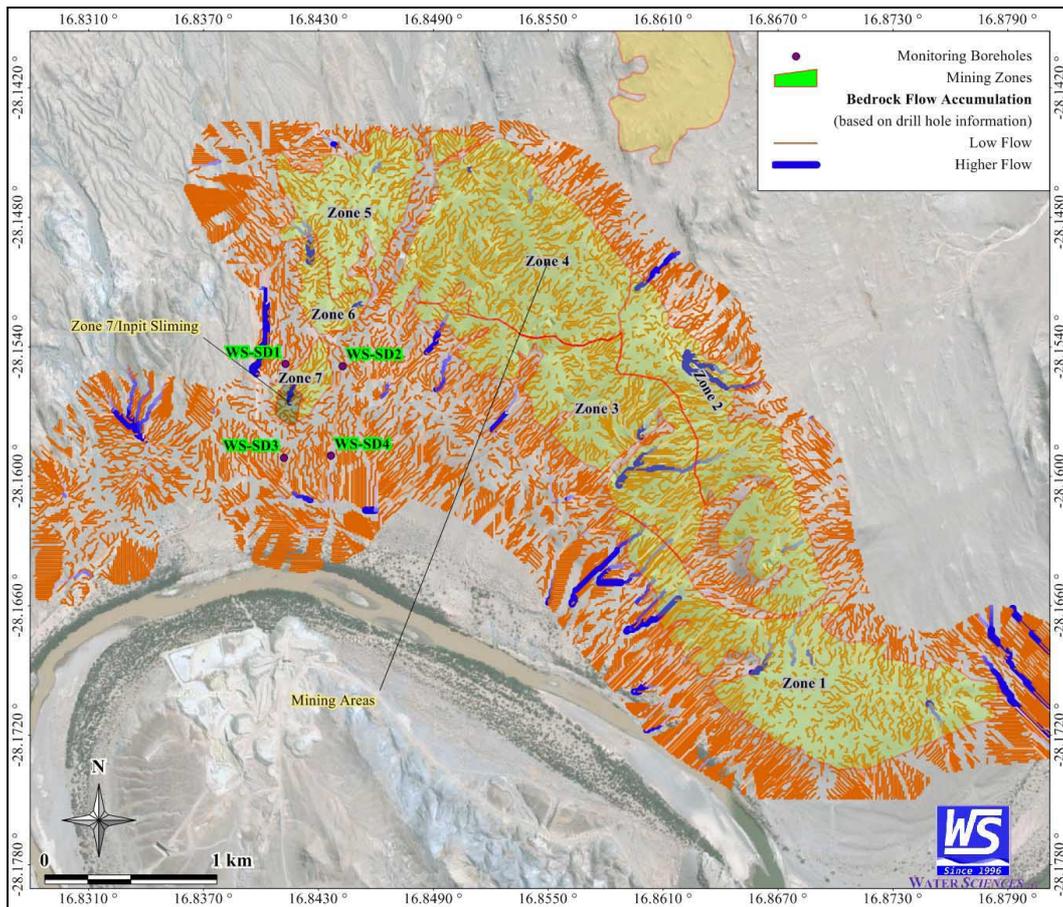


Figure 5. Bedrock Flow Paths (No Sink Removal)

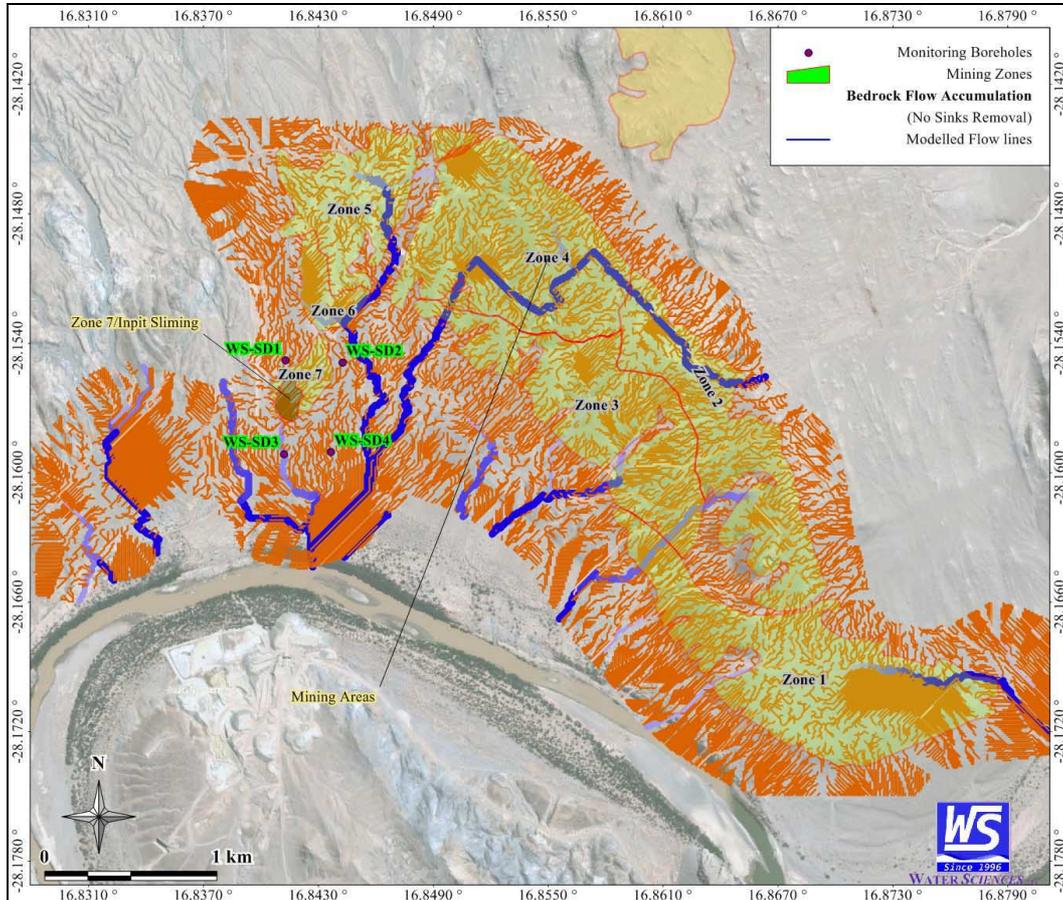


Figure 6. Bedrock Flow Paths (Sinks Removed)

8. FLOODLINE INVESTIGATION IN THE ORANGE RIVER

Results of flood hydrology in the lower Orange River is not readily available; discussions with the Sub-Directorate: Flood Studies of the Department of Water Affairs and Forestry (DWAF) in South Africa on 13 October 2009 revealed that no flood peak return periods have been calculated in the lower Orange River downstream of Kakamas since the early 1990's. Hence current available methods need to be employed.

A desktop method of determining flood peak return periods, which is widely used in Southern Africa for large catchment areas, is described in the "TR 137: Regional Maximum Flood Peaks in Southern Africa" by Zultan Kovačs. Note that the Regional Maximum Flood (RMF) method is an empirically established upper limit of flood peaks that can be reasonably accepted at a given site (Kovačs, 1988). Also note that Kovačs determined coefficients, which represent the 20-year, 50-year, 100-year and 200-year flood peaks as fractions of the RMF. These fractions of the RMF were used to determine the flood peaks presented in this report.

From DWAF the entire catchment area upstream of Sendelingsdrift was obtained. This total catchment area is 970,560km² and includes the Fish River. The size of the catchment area is confirmed in copies of Annexure A of the DWA Technical Report, TR 132, regarding the 1974 floods. To calculate the RMF at Sendelingsdrift one first has to convert the total catchment area (A) into effective catchment area (A_e). An assumption adopted for the A_e is that the entire Fish River catchment area, and the other tributaries downstream of Vioolsdrift, contributes to the river discharge. Hence the effective catchment area at Sendelingsdrift will consist of the total area less the ineffective area upstream of Vioolsdrift weir:

Sendelingsdrift D8M06	A	= 970,560 km ²
	ΔA	= 446,530 km ²
	A _e	= 524,030 km ²

The K value, used for the RMF method, is indicated as 2.8 along the lower Orange River (Kovačs; 1988). The result of the RMF flood peak as well as the 200-, 100-, 50- and 20-year flood peaks follows below:

Sendelingsdrift	Q _{RMF}	= 22 829 m ³ /s
	Q ₂₀₀	= 14 839 m ³ /s
	Q ₁₀₀	= 13 127 m ³ /s
	Q ₅₀	= 11 414 m ³ /s
	Q ₂₀	= 4 566 m ³ /s

Conclusions regarding the flood hydrology for the lower Orange River:

- ◆ DWAF have indicated that they are in the process of updating the TR 137 catchment areas using geo referenced CAD drawings and specialized software; the 1988 TR 137 areas were previously measured using hard copy plans and a planimeter.
- ◆ An in-depth investigation is required to update the Kovačs RMF method with the flood peak data captured over the last 25 years. The result could have an effect on the RMF envelope curves. This will be a separate project and is not dealt with in this report.
- ◆ The RMF method, which represents upper limit values, is conservative; no flood peaks have been reported which exceed the RMF discharge rate.
- ◆ As a rule of thumb, the RMF values should not be reduced because of upstream dams (Kovačs; 1988). To confirm this, DWAF Sub-Directorate: Flood Studies indicated that an Orange River RMF flood will displace the volume of the Gariep Dam several times.
- ◆ It may however be noted that a smaller flood such as the 100 year flood peak is likely to be significantly reduced by upstream dams, hence using the RMF-calculated flood peaks for the 50-, 100-, 200 year return periods will produce conservative figures.

8.1. Hydraulic Study – Floodline Calculation

For the hydraulic floodline calculation a one dimensional flow model was used. The motivation for this choice is that the river consists of a single concave channel opposed to a complex river system such as a braided channel. A simple concave section is ideally suited for the one dimensional flow model.

Note that the one-dimensional model assumes a horizontal water level laterally across the river. This however is not the case for bends in a river; the water surface on the outside of a bend is higher than on the inside. Therefore where areas of concern, such as roads, lies on the outside of a bend, the freeboard required for curvilinear flow (vortex motion) at a bend is calculated separately and added to the modelled water level. (It was calculated at approximately 200mm for the 50-year flood).

The one-dimensional model used in this study is the Hydrologic Engineering Centre River Analyses System by the US Army Corps of Engineers, commonly known as the HEC-RAS model. It is based on the iterative standard step method employing Manning's equation to calculate the friction slope (energy gradeline).

The modelled river-reach is approximately 42km long and it starts approximately 1km upstream of an area identified as Sendelingsdrift. Thirty-six (36) cross-sections were entered into the model, taken at strategic points along the river. The model run-cycle assumes a steady state flow for the peak discharge rate, which typically represents a stretched out hydrograph, as one would expect in the lower Orange River. See Figure 7 for the floodline map in the Sendelingsdrift area.

The upstream and downstream reach slopes of 0.05% and 0.04% used in the model were determined from a contour chart with 20m contour intervals. Hence the water velocity in this study may be slightly reduced and the depth of flow increased when compared to previous work.

The cross-sections were generated from a 5 metre contour chart based on Shuttle Radar Tomography (SRTM) data (90m grid) and from ASTER GDEM (30m grid) data. Note that all calculated flood levels relate to the datum height used for the contour chart. Note also that reference pegs related to the contour datum height need to be established on site to be able to transfer the modelled heights to levels along the riverbank.

Roughness coefficients for the model are taken as $n = 0.045$ for the main channel and 0.040 for the flood plains (SANRA; Manning's n -value). These n -values may be seen as conservatively high; however it addresses the numerous deep pools in the river, which impose a significant increase in the roughness of a riverbed.

Relative to the datum level of the contours, the following heights in Table 1 represent water levels and average velocity at areas of interest along the modelled river reach (see Table 2 for more detailed data and Figure 7 for station locations):

Table 1. Relative heights of the water level at selected points

Station	*Water level above datum (m)**	Average Water Velocity (m/s)
Sendelingsdrift	38.49	1.8
Obib River confluence	32.48	2.5
Road section upstream	32.20	1.1
Road section downstream	32.08	1.6
Mining area upstream	27.06	2.4
Mining area downstream	24.60	0.9

* Note that the water levels represent the energy level of the water which is approximately 150mm higher than the actual water level for the velocities indicated.

** These water levels do not include the approximate 200mm freeboard for curvilinear flow at bends.

Note that the velocities are low enough to utilize gabion structures to protect roads or other works along the bank of the river. When velocities reach 5m/s, gabions stand the risk of being washed away. For embankment protection, one could also consider using graded rip-

rap on constructed embankment slopes. The rip-rap can be designed to withstand the calculated velocities.

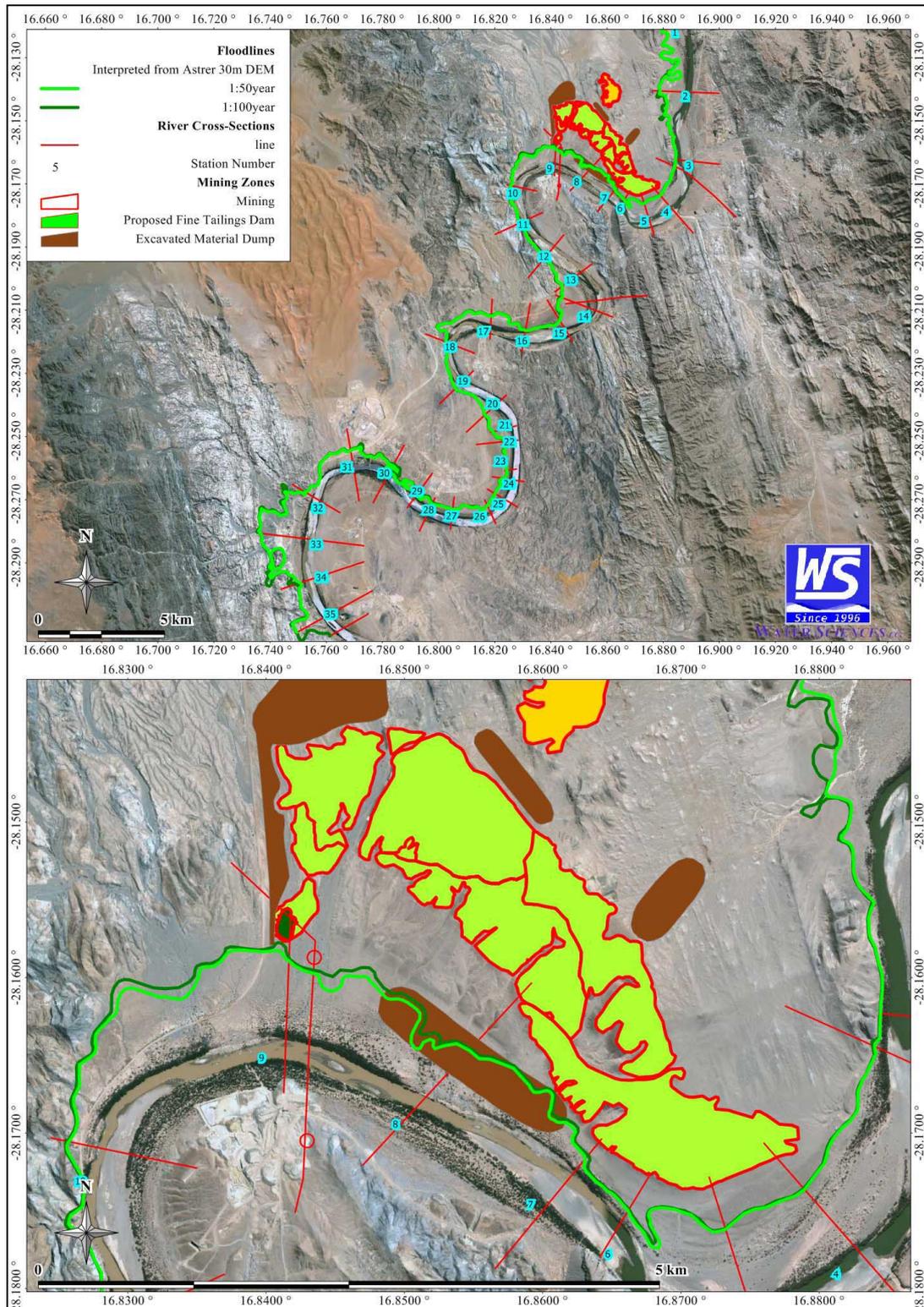


Figure 7. Orange River Floodline Map

Conclusions regarding the Hydraulic Modelling of the river:

- ◆ The one-dimensional flow model is suitable for the modelling of flood levels in the lower Orange River in the vicinity of Sendelingsdrift.
- ◆ The calculated flood levels are associated with the 50 and 100-year return floods.

- ◆ All calculated flood water levels are relative to the datum level of the 5m contour charts.
- ◆ The calculated 20-year flood peak of 4,566m³/s, using the RMF method, is significantly lower than the proposed 23 year flood peak of 9,830m³/s with reference to the 1974 flood (TR 132). Note however different methods of calculation were applied and also it was stated in a later report that the 23-year return period is “somewhat low” for the size of the flood peak, implying it may be too conservative (The TR132 report calculations utilised the entire catchment area opposed to the RMF method which uses the effective catchment area). Note also that the RMF method produces an upper limit of flow hence it still is conservative.
- ◆ The energy level of the floodwater is the dynamic head to which the water will “jump” if an obstruction blocks a part of the stream flow. The practice of indicating energy levels instead of actual water level for flood lines is increasing in popularity in South Africa because of the unpredictable tree stump, or vehicle or other debris, which cause temporary obstructions in the stream flow and which force the water level to reach the energy level.

Table 2. Floodwater levels

Station	Profile	Q Total (m ³ /s)	W.S. Elev (m)	E.G. Elev (m)	Vel Chnl (m/s)	Flow Area (m ²)	Station	Profile	Q Total (m ³ /s)	W.S. Elev (m)	E.G. Elev (m)	Vel Chnl (m/s)	Flow Area (m ²)
1	RMF	22829	43.65	44.67	4.61	5275.3	10	RMF	22829	39.12	39.27	1.71	13711.6
	Q100	13127	41.46	42.3	4.09	3319.2		Q100	13127	35.22	35.3	1.26	10537.1
	Q50	11414	41.17	41.9	3.81	3082.4		Q50	11414	34.36	34.43	1.17	9869.9
2	RMF	22829	42.62	42.76	1.76	13774.2	11	RMF	22829	38.38	38.96	3.6	7241
	Q100	13127	39.02	39.17	1.79	7672.1		Q100	13127	34.52	35.03	3.25	4451.8
	Q50	11414	38.34	38.49	1.79	6620.6		Q50	11414	33.69	34.17	3.14	3923.1
3	RMF	22829	41.86	42.04	1.9	12387.1	12	RMF	22829	37.92	38.26	2.68	9288.6
	Q100	13127	37.87	38.02	1.68	7882.1		Q100	13127	34.1	34.31	2.09	6666.4
	Q50	11414	37.04	37.18	1.64	7005.2		Q50	11414	33.27	33.45	1.97	6145.9
4	RMF	22829	41.78	41.83	1.06	23321.6	13	RMF	22829	37.85	37.95	1.51	16208
	Q100	13127	37.79	37.82	0.81	17176.4		Q100	13127	33.99	34.06	1.21	11531.2
	Q50	11414	36.96	36.99	0.76	15951.2		Q50	11414	33.15	33.21	1.14	10571.5
5	RMF	22829	41.7	41.78	1.38	19148.9	14	RMF	22829	37.78	37.85	1.28	20839.6
	Q100	13127	37.73	37.78	1.08	13801.8		Q100	13127	33.93	33.97	1.01	15373.8
	Q50	11414	36.91	36.95	1	12810.7		Q50	11414	33.09	33.13	0.93	14274.8
6	RMF	22829	38.99	41.38	6.92	3430.2	15	RMF	22829	37.39	37.7	2.65	9720.3
	Q100	13127	35.22	37.42	6.57	1999.9		Q100	13127	33.62	33.84	2.19	6607.6
	Q50	11414	34.36	36.59	6.62	1723.8		Q50	11414	32.81	33.01	2.07	6009.2
7	RMF	22829	39.69	39.93	2.55	10846.7	16	RMF	22829	37.15	37.34	2.04	12125.5
	Q100	13127	35.72	35.91	2.21	7277.5		Q100	13127	33.44	33.54	1.53	9384.9
	Q50	11414	34.85	35.02	2.14	6552.5		Q50	11414	32.64	32.73	1.42	8812.9
8	RMF	22829	39.68	39.8	1.55	15387.6	17	RMF	22829	36.63	37.02	3.02	9044.9
	Q100	13127	35.7	35.78	1.24	10880		Q100	13127	32.97	33.27	2.6	5807.8
	Q50	11414	34.83	34.9	1.17	9952.5		Q50	11414	32.19	32.48	2.47	5229.5
9	RMF	22829	39.37	39.58	2.23	11419.9	18	RMF	22829	36.52	36.65	1.6	14877.6
	Q100	13127	35.42	35.57	1.84	7625.9		Q100	13127	32.91	32.98	1.15	11663.2
	Q50	11414	34.55	34.69	1.77	6882.3		Q50	11414	32.15	32.2	1.05	11027.8

Description:

RMF = Regional Maximum Flood (Kovacs)

Q100 = 1 in a 100 year flood

Q50 = 1 in a 50 year flood

W.S.Elev = Water Surface Elevation above Datum

E.G.Elev = Energy Gradeline Elevation above Datum

Vel Chnl = Average Velocity in the River Channel

8.2. Flood Hydrology for Tributary Near Sendelingsdrift

With reference to the 1:50 year flood peak that discharges from a tributary near Sendelingsdrift. The stream route runs through Zone 6 and 7, as indicated in Figure 8. Five metre contour lines were used to calculate the area, the stream length and the average slope. Note however that the contour interval over the floodplain makes it difficult to accurately identify the watershed and main river channel. The catchment boundaries were copied onto an AUTOCAD drawing to determine the area and main channel length.

The catchment area is 28.5km². The main river channel length, which is used to determine the average riverbed slope and time of concentration, is 12km.

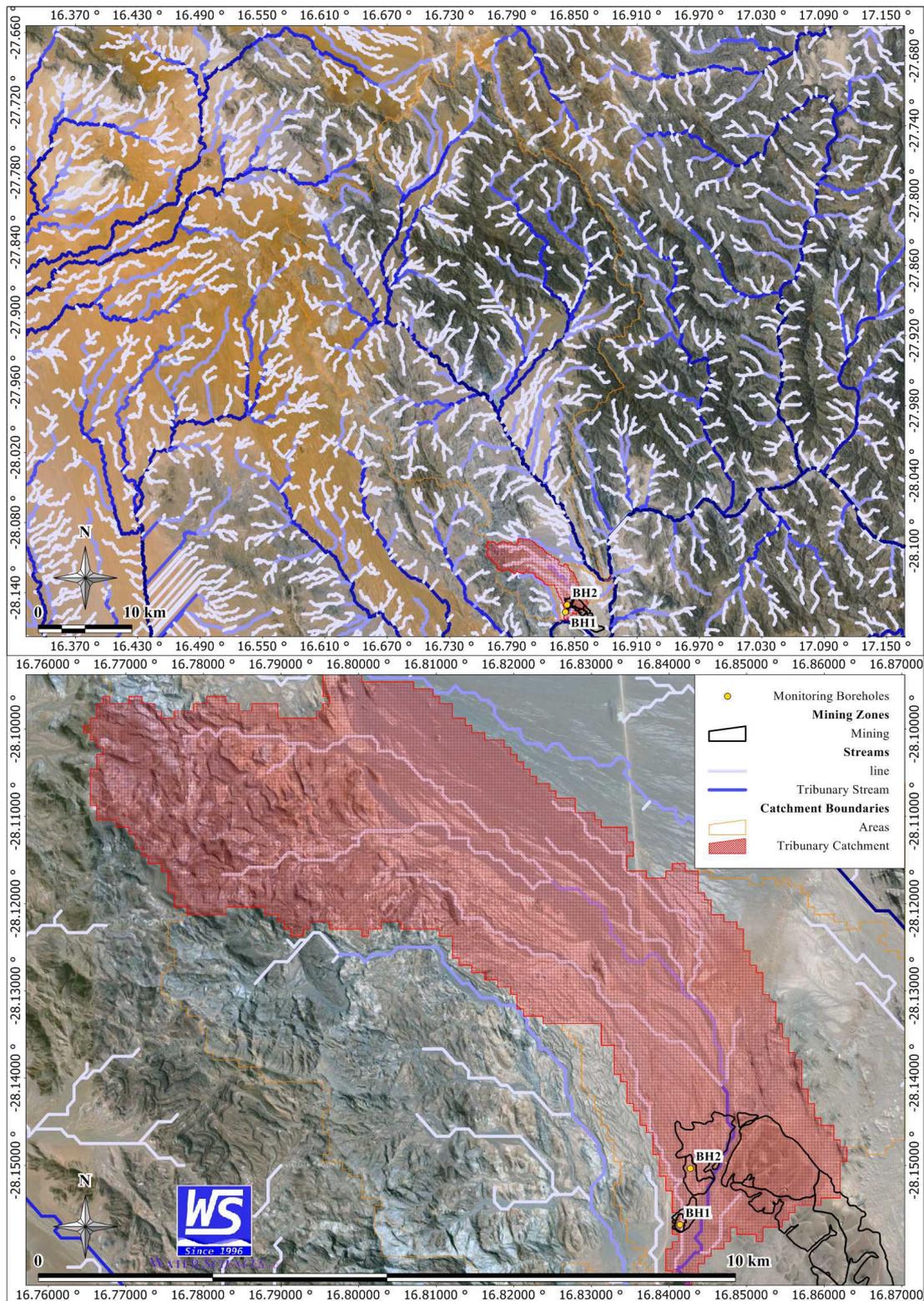


Figure 8. Streams and Catchment Area

The Rational Method and the Hydrology Empirical Maximum (HEM) method were used to calculate flood peaks. Note however the HEM method only provides an upper boundary for a 20-year return flood peak.

The Midgley & Stern Method was also used to calculate flood peaks, however the catchment area under question lies just outside the boundary of the area applicable to the

Midgley & Stern method. Hence these values were only used for comparison. For results of the flood peak analysis, using the various methods, refer to Table 3 below.

Table 3. Flood Peak Results

Flood Return Period	Rational	Method	Hydrological	Empirical Max.
Q ₂₀	83m ³ /s	122m ³ /s	60m ³ /s	83m ³ /s
Q ₅₀	131m ³ /s	-	92m ³ /s	131m ³ /s
Q ₁₀₀	190m ³ /s	-	140m ³ /s	190m ³ /s

* Q₅₀ describes a flood peak with recurrence interval of 50 years.

The Rational Method flood peak lies between the empirical maximum and the Midgley & Stern peaks. The use of the Rational Method results without any modification is proposed. In general the use of the upper limit empirical method is recommended only for comparative purposes.

Conclusions and recommendations regarding the flood hydrology of the tributary near Sendelingsdrift:

- ◆ The available 5m contour map does not give suitable definition to accurately determine the catchment area boundaries and main river watercourse.
- ◆ The scaled area represents the actual area and is suitable for the calculation of the flood peak size.
- ◆ The Midgley & Stern figures are not reliable at the point of application, but only used as a comparison.
- ◆ The rational method results lie between the empirical maximum flood peak and the Midgley & Stern flood peak values, which implies that it is not an outlier.
- ◆ Use the Rational Method results (Final Results in Table 3) for the 50-year Return flood without any modification to the figures.

9. THE MINING OPERATION

This section, describing the mining operation, is an excerpt from the Environmental Impact Assessment and Environmental Management Plan of Orange River Life of Mines Extension Project (CSIR 2010). The Sendelingsdrif resource is a near-surface deposit that can be exploited with conventional open pit mining methods. Diamond-bearing material is mined with heavy earthmoving machinery, such as hydraulic excavators, Rigid Frame Trucks (RTFs), bulldozers, front-end loaders and graders. Contractors may also use Articulated Dump Trucks (ADTs). Ore retrieval will comprise of stripping, ore excavation, bedrock cleaning, drilling and blasting, stockpiling and hauling. The bulk excavation of material will be undertaken with a 200-ton hydraulic backhoe excavator assisted occasionally by dozing and bedrock cleaning. Severely cemented portions of the deposit will require drilling and blasting.

Backfilling of mined-out areas will form part of rehabilitation of the area. There will be a need to make provision for residue materials management i.e., storage areas for waste dumps, oversize dumps, low-grade dumps and a safety berm between the Rosh Pinah road and the mining area. The total material to be moved/managed is approximately 47 million tons.

It is not practically possible to backfill all the material and in some areas dumps may remain. Remaining dumps will be profiled to fit in with the surrounding topography so that the future land use of nature based tourism or the visual acceptability of the area post mining is not compromised. Some of the waste material and residue will temporarily be used for storm water control and terracing, but is intended to also be eventually returned to mined-out areas.

9.1. Treatment

Relocation of the mobile DMS plant (MDMS) at Daberas to Sendelingsdrif is the optimal solution for a stand-alone operation at Sendelingsdrif. Processing involves dry screening, wet screening, degrit, Dense Medium Separation, recovery and residue disposal.

- ◆ **Treatment** of the material through the MDMS plant at Sendelingsdrif. Gravel will be transported to the MDMS plant with mining trucks. There are two categories:
 1. Low grade material of <0.3cpt will not go to the treatment plant and this material will be stockpiled. This may be treated in the future if it becomes feasible to mine it again.
 2. Run of Mine (ROM) material will be fed to the MDMS and on average consists of $\pm 40\%$ +70mm boulders and $\pm 20\%$ fines <3mm.

The oversize and the residue stockpiles will be loaded by front-end loader onto the mining trucks and dumped into mined-out areas as part of progressive rehabilitation. For the first ± 5 years, insufficient mined-out areas will be available to back-fill into and subsequently temporary stockpiles will be created for backfill once the areas become available. A conveyor may be considered for the building of a dump close to the plant.

- ◆ **Final Concentration:** Dense Media Separation. The +3 mm -25 mm product from wet screening will be concentrated further using a process called dense medium separation (DMS).
- ◆ **Fine Tailings Disposal.** The mobile DMS plant requires a wet process to deliver the concentrate, and results in a fines residue that must be disposed of. Separation of the wastewater originating from the pre-DMS processes and that coming from the DMS process is being investigated. This may enable different fines residue disposal methods for the two streams to be implemented, which may in turn benefit the project.

9.2. Tailings Facility

Two tailings disposal options are considered at this stage. The first is a slimesdam, located northeast of the mining areas. The second option is the disposal in the mined out pit of Zone 7, see Figure 1.

Construction of the Slimesdam, northeast of the mining area will take place on an elevated area with rock outcrop or rock very close to surface. Drainage from the site is expected mainly into a southeasterly direction, but some drainage may take place to the south and the southwest. Construction would include levelling of the previously undisturbed area, installation of a clay or other liner to prevent or reduce the magnitude of leakage from the dam. This would be followed by the construction of earth containment walls, in extend of more than 800m, mostly on the western side of the facility. The natural topography will form containment on the sides not covered by containment walls. This facility would create a new feature in the current landscape.

The second option, in-pit sliming will take place within Zone 7 after the mining is completed in this zone. Mining will create a deep excavation through the topsoil (overburden) into a depression within the schistose bedrock. The excavation will form natural walls with the surrounding soil lending support when slimes are disposed off in the excavation. The disposed tailing will cover the exposed bedrock and have a mitigation effect on the mining operation, in the sense that the excavation would be backfilled.

9.2.1. Tailings Facility Threats

Potential threats to tailings facility are discussed in Table 4:

Table 4. Potential Threats to Tailings Facilities

Potential threats to tailings facility	Slimesdam	Inpit Sliming Zone 7
Water tributary and water precipitation	The slimesdam is located on an elevated area and little runoff is expected to enter the slimesdam, reducing the risk of failure. This facility is well above the flood lines of the Orange river.	The inpit sliming area is located in a low-lying area with a drainage channel located directly south of the facility. The Facility will further be below ground level, creating a risk of runoff entering the facility. If this do happen it is expected that no walls would be put at risk, as the facility do not have walls that can fail to release the contained material. The water would enhance leachate and may create operational delays. This facility is well above the flood lines of the Orange river.
Construction and other human processes		Potential threat from road users on the road connecting Rosh Pinah and Oranjemund.
Chemical reactions	Chemical reactions in the material used in the containment walls or in the underlying soil/rock (e.g. dissolution of dolomite) may cause a failure of the containment wall.	The absence of containment walls reduces this risk. Site seems to be located on schist, having a lower risk of impact, compared to dolomite.
Actions from fauna and flora	Animals digging holes into or underneath containment walls may cause failure of such walls. Plants growing on containment walls may reduce the strength of such walls.	The absence of containment walls reduces this risk.
Mass deformation and sliding	Mass deformation and sliding may cause containment wall failure.	The absence of containment walls reduces this risk. Mass deformation and sliding would cause a failure into the facility. Potential risk for nearby roads.
Seismic events	Liquefaction of saturated fines during seismic activity or other vibration may cause containment wall failure.	The absence of containment walls reduces this risk. Liquefaction of saturated fines during seismic activity or other vibration may cause a failure into the facility.
Terrorism	Attacks would most likely be aimed on the dam wall to cause failure of the wall, with subsequent release of tailings into the Orange River. This is expected to have limited impact on the functionality of the country or the mine and the risk is thus considered to be low.	The absence of containment walls reduces this risk. It is unlikely that terrorism would have a significant impact, except for causing a delay in the disposal of tailings.

The following three classes of failure mechanisms should be considered

- ◆ Slope failures in the foundation or in the dam itself
- ◆ Extreme events such as floods, earthquakes and high winds
- ◆ Slow deterioration actions, such as water and wind erosion, weathering of fill materials and intrusion by vegetation and animals.

10. TYPICAL IMPACTS FROM MINING OPERATIONS

Impacts describe the potential effect that a risk source may have on one or more environmental receptors. Receptors can include affected humans (mine personnel, local communities) as well as natural ecosystems. Potential surface and groundwater related environmental impacts from mining, engineering, treatment and disposal activities, products and services have been assessed in this study, by characterizing the natural receiving environment with theoretical knowledge of typical effects of exposure to the identified risk sources. Potential impacts on the hydrology of the river will also be considered to ensure enough data is gathered to aid the decision on the optimal solution for fine tailings disposal at the Sendelingsdrift mine.

10.1. Groundwater Impacts

Impact on the groundwater can be expected. Impacts can be directly via infiltration through the bedrock to the shallow groundwater, where chemical changes would be less compared to indirect impacts where the seepage water is first in contact with saline (gypsum) soil.

Soil at Sendelingsdrift mine does contain gypsum and other minerals, specifically in the top layer of up to 1mbs. It can be expected that the water quality of any release of water from the tailings dams will deteriorate due to contact with the soil through which it travels as well as due to evaporation. It can thus be expected that the further the tailings dam is from the Orange River, the worst the water quality would get, assuming the same soil conditions, due to the distance travelled.

In a study conducted during 2004, at the nearby Daberas Mine (Geo Pollution Technologies 2004), it was found that the deterioration in the water quality between the existing tailings dam and the Orange River can be attributed to an increase in concentration due to evaporation and to ion exchange. During ion exchange ions are normally adsorbed to clay and soil particles in the following order: $Cs^+ > K^+ > Na^+ > Li^+ > Ba^{2+} > Sr^{2+} > Ca^{2+} > Mg^{2+}$. This should explain the increase in Ca^{2+} and Mg^{2+} and the decrease in Na^+ . As the water that enters the tailings dam is anionic in nature due to the presence of Yangfloc, it must be assumed that cations will be take-up by the water to balance the polarity of the water. During normal water quality evolution the following changes in dominant anion species takes place (Chebotarev Sequence):



Increase distance
Increase in residence time or age →

It can therefore be expected that the water quality changes are probably mostly not due to pollutants added to the water, but rather due to natural processes. The same processes are expected to take place at Sendelingsdrift.

Heavy metal contamination and leaching of metals contained in excavated rock and gravel on the mine may come in contact with water through precipitation and human actions. As a result, metals can be leached out and infiltrate into the bedrock or carried downstream towards the Orange River.

Storage tanks (above and underground) holding petroleum products, solvents and chemicals can develop leaks from corrosion, defects, improper installation or mechanical failure of the pipes and fittings and can contaminate groundwater. Spillages during transportation of the said products are also a potential risk. The improper disposal of both hazardous and non-hazardous waste (i.e. chemical waste, batteries, unserviceable used tyres, hard scrap, domestic refuse and sewage) from mining operations and activities may contribute to groundwater contamination.

Dewatering of the mine pits at Sendelingsdrift mine may lower the water level in the area. This is however unlikely to have an impact on other users or on the spring situated east of the mining area. The bedrock profile data indicates that mining areas are above the level of

the Orange River, thus flow on the bedrock would be towards the river. River hydrology is thus not expected to be impacted by any dewatering of pits in the current mine plan.

10.2. Surface Water Impacts

The only surface water features in the area are the nearby spring and the Orange River. The border between South Africa and Namibia is formed by the northern bank of this river. Any impact on the Orange River therefore would have potential international implications. Leached contaminants from the exposed bedrock and/or excavated rock and from the tailings facility may be carried downstream towards the Orange River. Mine construction activities may result in damage to vegetation, and most importantly, an increase of sediment loads into the Orange River, which can harm water quality and aquatic organisms. Substantial amounts of sediments from disturbed soil and rock at the mine may be carried through erosion into the river. Excessive sedimentation can clog the riverbeds and smother vegetation, wildlife habitat and aquatic organisms.

Indirect impacts on the river are expected mainly via seepage, but direct impact can take place due to overtopping of the dams and failure of tailings containment structures. Polluted soil and contaminants may be washed to the Orange River.

Placement of structures like waste rock dumps within the flood areas of the Orange River may cause an impact on the opposite side of the river, as well as higher flood levels for the section. This would mean an impact on potential receptors in South Africa.

Drainage structures should be considered during the construction of excavated material dumps to route surface runoff pass such dumps. Damming of runoff behind dumps should be avoided to eliminate the creation of habitats and to limit the artificial recharge of the groundwater.

10.3. Geology Impacts

The area around the proposed slimesdam location consists of thin dolomitic beds dipping towards the east, with a roughly northwest-southeast strike.

Aggressive karstification can take place where dolomite and gypsum are in contact within the same aquifer. Gypsum dissolution may drive the precipitation of calcite, thus consuming carbonate ions released by dolomite. This may lead to the formation of sinkholes, which can cause soil instability and wall failure if such structure would form near a containment wall.

No such impacts are expected on the schist underlying the Zone 7 inpit sliming area.

11. ENVIRONMENTAL RISK ASSESSMENT

This section will look at the potential environmental impacts on groundwater and surface water, which may arise during the construction and operations of the mine (*i.e.* long-term impacts) as well as potential decommissioning related impacts (*i.e.* short-term).

A summary of risk events and proposed management controls associated with these activities are discussed. This identifies key potential impacts and assesses their risk ranking, and makes suggestions on possible mitigation measures for the potential impacts identified. The following assessment methodology will be used to examine each impact identified, see Table 5.

Table 5. Criteria for Impact Evaluation (DEAT 2006)

Assessment Evaluation Criteria	Rating (Severity)	
Impact Type	POS	Positive
	0	No Impact
	NEG	Negative
Extent of impact being either	I	Immediate (the site and immediate surrounds)
	L	Local (Sendelingsdrift Mine, <i>including the Orange River</i>)
	R	Regional (Karas Region, <i>including the northwestern part of South Africa</i>)
	N	National (Country wide)
	IT	International
Duration of impact being either	ST	Short term (0-5 years)
	MT	Medium term (5-15 years)
	LT	Long term (lifetime of the development)
Intensity of impact being either	L	Low (where natural, cultural and social functions and processes are not affected)
	M	Medium (where the affected environment is altered but natural, cultural and social functions and processes can continue)
	H	High (where the affected environment is altered to the extent that natural, cultural and social functions and processes will temporarily or permanently cease)
Probability of impact being either	LP	Low probability (possibility of impact occurring is low)
	P	Probable (where there is a distinct possibility that it will occur)
	HP	Highly probable (where the impact is most likely to occur)
	D	Definite (where the impact will occur)
Significance of impact being either	L	Low (where natural, cultural and social and economic functions and processes are not affected). In the case of adverse impacts, mitigation is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means of achieving this benefit are likely to be easier, cheaper, more effective and less time-consuming
	M	Medium (where the affected environment is altered but natural, cultural, social and economic functions and processes can continue). An impact exists but is not substantial in relation to other impacts that might take effect within the bounds of those that could occur. In the case of beneficial impacts, other means of achieving this benefit are about equal in time, cost and effort.
	H	High (where the affected environment is altered to the extent that natural, cultural, social and economic functions and processes will temporarily or permanently cease). In the case of adverse impacts, there is no possible mitigation that could offset the impact, or mitigation is difficult, expensive, time consuming or a combination of these. In the case of beneficial impacts, the impact is of a Substantial order within the bounds of impacts that could occur.

11.1. Development of the Tailings Facilities

This section only looks at the input sliming in Zone 7.

Impact on river hydrology – Potential impact on the natural flow of the Orange River. The Orange River is 1km south of the facility. The flow of the Orange River is not expected to be altered in any way, as the facility is located well above the 1:100 year flood line.

Soil and groundwater contamination – Potential health impact on groundwater users due to seepage and/or infiltration of contaminated water emanating from the tailings facility. Potential impact on natural environment from polluted groundwater, typically on vegetation and wildlife. Nearest vegetation are along the Orange River. No groundwater users, excluding vegetation, are expected to be impacted.

Surface water contamination – Potential health impact on surface water users and on the natural environment associated with the river. Socio-economic impact on surface water users. The Orange River is 1km from the proposed fine tailings dam. Rate of seepage is expected to be low and the dilution effect of the river is expected to lower the risk on surface water users.

Damage to tailings pipelines – Transfer pipelines can be damaged by the mine's heavy earthmoving machinery and surface runoff. Potential release of contaminated water into the environment can impact on groundwater quality. The tailings facility is relatively close (0.76km) to the proposed treatment plant. Pipelines and associated infrastructure should be

properly constructed and monitored regularly. Special care must be taken to avoid damage of the pipeline from surface runoff.

Dam failure – The input facility relies on the containment formed by the sides of the excavation. Failure would most likely result in slumping into the pit. No or very little release of slimes is expected if this happens. The risk of slumping would decrease as the level of tailings in the pit increases.

Dam overflow – Dam overflow may occur due to heavy precipitation and or excessive water release into the dam, resulting in contamination of both groundwater and surface water pollution.

Table 6. Impacts Evaluation – Tailings Dam

Identified Impact	Impact Type	Extent	Duration	Intensity	Probability	Significance	
						Unmitigated	Mitigated
Impact on river hydrology	NEG	I	ST	L	LP	L	L
Groundwater contamination	NEG	I	ST	L	P	M	L
Surface water contamination	NEG	I	ST	L	P	M	L
Impact on tailings pipelines	NEG	I	ST	M	P	L	L
Dam failure	NEG	L	ST	H	P	M	M
Dam overflow	NEG	L	ST	H	P	H	M

11.2. Mining Activities

Impact on river hydrology – The mining areas at Sendelingsdrift mine are well above the level of the Orange River. Possible dewatering of the mine pits are not expected to impact the river hydrology in any way.

In general, the abstraction of water for Namdeb mining activities in the area is not expected to reduce the flow of the Orange River noticeably and thus affect the downstream ecology. However, the cumulative effect of all current and future users may significantly reduce the water flow in the Lower Orange River.

Placement of structures in the Orange River flood plain should be avoided where possible as it may influence the natural flow of the river. This would include the placement of rock discard dumps. Such structures may lead to higher flood levels in the section area, with resultant larger impact areas on the opposite side (South Africa) of the river. Clearance must be obtained from both the Namibian and the South African Departments of Water Affairs if such structures are placed in the flood plain.

Impact on groundwater – Impacts on the groundwater is mostly related to releases of chemicals.

Excessive dewatering – This may inevitably lower the water level in the area. This can cause springs to dry up; and lower water levels in any boreholes present in the area.

Surface water contamination – No waste material may be disposed off in the river. No hazardous chemicals, fuel or other lubricant storage facilities and/or storage drums should be erected in close proximity to the river. Leakage from heavy-duty vehicles and machinery might occur during the operations of the mine. Care must be taken in avoiding contamination of soil and groundwater, as surface - groundwater interaction might take place.

Failure of dewatering pipelines – Potential release of potentially contaminated water into the environment, impacting on groundwater quality.

Generation of waste – Waste in the form of contaminated soil due to spillages or leakages from petroleum products, solvents and chemicals might occur. This should be prevented through proper training of mine operators and the use of proper containment areas. Oil

water / separator effluent originating from storm water runoff, tank bottoms and washing activities should be separated before disposal of the water.

Proper servicing of the vehicles should also be conducted. Any waste generated during operations of the mine will be accumulated at the point of generation and disposed off at a suitable waste disposal site at the mine.

Generation of waste rock – Waste rock will be generated during the construction and operations of the mine. Leaching of metals contained in the excavated rock and gravel on the mine may occur through precipitation. Contaminated water may infiltrate into the bedrock, putting groundwater at risk. Flow on the bedrock may also take place, putting surface water at risk.

The presence of large quantities of rock containing sulphide minerals in the mine can react with water and oxygen to create sulphuric acid. The acid leaches from the rock as long as its source rock is exposed to air and water, until all sulphides are leached out. Some of the contaminated water infiltrates into the bedrock, while some of the water is carried off the mine site by rainwater or surface drainage and deposited into nearby river.

The risk to both ground and surface water is considered low in the area, as the area has a low average annual rainfall.

Erosion of disturbed waste rock – Erosion of the disturbed and exposed rock may carry substantial amounts of sediment into the river. This may result in an increase in turbidity in the water, that limits light penetration and prohibits healthy plant growth on the riverbed. Excessive river sedimentation can also clog riverbeds affecting wildlife habitat and aquatic organisms. This should be prevented.

Destruction of vegetation – Damage or destruction to vegetation can promote soil erosion. This might result in an increase of sediment loads into nearby water body. If limited to the proposed planned outline of the mine at Sendelingsdrift, the impacts during the mining activities are likely to be non significant.

Spillage of hazardous chemical during delivery – Spillage during the transport of hazardous chemicals is mainly related to damage to tankers during vehicle accidents. These hazardous substances can enter drainage systems and nearby water bodies. Namdeb's road signs and regulations should be adhered to.

During delivery, spillages might occur during delivery to the tanks. Risk of impact from this can be lowered through proper training of staff and the installation of suitable containment structures.

Table 7. Impacts Evaluation – Mine Operations

Identified Impact	Impact Type	Extent	Duration	Intensity	Probability	Significance	
						Unmitigated	Mitigated
Impact on river hydrology	NEG	L	ST	M	LP	M	L
Mine dewatering	NEG	L	LT	M	P	M	L
Surface water contamination	NEG	L	ST	M	LP	M	L
Failure of dewatering pipelines	NEG	I	ST	M	LP	M	L
Generation of waste	NEG	I	ST	L	HP	L	L
Generation of waste rock	NEG	I	LT	M	HP	M	L
Erosion of disturbed waste rock	NEG	L	LT	M	P	M	L
Destruction of vegetation	NEG	L	ST	M	LP	M	L
Spillage of hazardous chemical during delivery	NEG	I	ST	L	P	M	L

As depicted above in Table 6 and Table 7, most impacts are expected to be low to medium, short lived and localized. An Environmental Management Plan (EMP) will ensure that in general the impacts of the tailings dam and the various mining activities are minimised and includes measures to reduce the identified impacts.

It should also be noted that construction activities may increase surface water run-off during the rainy season and may cause localised flooding within the mining area. The implementation of a storm water management plan will also reduce the negative effects of increased runoff.

The appointed mine constructors and operators should be made aware of the content and environmental requirements of this report so as to plan the tailings dam and mine operations accordingly.

12. MONITORING PROGRAMME

Four monitoring boreholes are to be strategically drilled around the proposed tailings facility. The purpose of monitoring these boreholes is to obtain background values of water quality in the area; to progressively monitor any changes in water quality and to investigate inferred flow paths in the area, see Figure 5 and Figure 6.

It is recommended that the initial monitoring should consist out of water level monitoring of all boreholes on a monthly base. Water samples should be collected from all boreholes where water is present. Additional water samples should be collected from the spring in the area, as well as from the Orange River at an upstream and a downstream position of the Sendelingsdrift Mine. It is recommended that this initial sampling be commenced at least a month before tailings disposal will commence at the mine. It is proposed that initially a short monitoring interval be applied until a trend is set and initial seepage, if any, stops. The gathered data should then be evaluated to extend the monitoring interval time to an interval time not exceeding 3 months. Any visual signs of seepage or impact on vegetation should be reported immediately and such observations noted into the monitoring reports. Follow up investigations on such observations should be conducted to assess the risk of impact on potential receptors. The monitoring report should be compiled on a monthly bases.

It is advised that the following parameters be monitored for: Ammonia Nitrogen; BOD; Calcium; Chloride; CO₃; COD; Dissolved Oxygen; Electrical Conductivity; Fluoride; HCO₃; Iron; Magnesium; Nitrate; Nitrite; Oxidation reduction potential, pH; Potassium; Sodium; Sulphate; Silica; Total Dissolved Solids; Total Suspended Solids; Turbidity.

13. CONCLUSIONS

Very little hydrogeological data is available on this area. In general, most impacts identified are expected to be low to medium, short lived and localized. An Environmental Management Plan (EMP) will ensure that in general the impacts of the tailings dam and the various mining activities are minimized.

Water Sciences cc

Pierre Botha
B.Sc. (Hons.) Hydrogeology
April 2011

14. REFERENCES

1968; McMillan MD; GEOLOGICAL MAP OF THE WITPUTS - SENDELINGSDRIFT AREA.

1974 May; Bennet RS; SPERRGEBIET PROSPECT – GEOLOGICAL MAPPING SENDELINGSDRIFT.

2004 September; Geo Pollution Technologies; ORANGE RIVER MINES ENVIRONMENTAL RECOMMENDATIONS

2008 January; Enviro Sciences cc; REHABILITATION PLAN FOR NAMDEB'S LICENCE AREAS

2010 December; CSIR and Enviro Dynamics; DRAFT SCOPING REPORT – ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL MANAGEMENT PLAN OF ORANGE RIVER LIFE OF MINES EXTENSION PROJECT, SENDELINGSDRIFT.

2010 September; Water Sciences cc; SENDELINGSDRIFT BOREHOLE DRILLING REPORT - ORANGE RIVER MINES.

2010 February; Water Sciences cc; FLOOD INVESTIGATION OF THE ORANGE RIVER DOWNSTREAM OF SENDELINGSDRIFT.

2010 September; Water Sciences cc; FLOOD HYDROLOGY FOR TRIBUTARY NEAR SENDELINGSDRIFT.