PIT BACKFILLING
FINAL REPORT

for

JAGERSFONTEIN DEVELOPMENT

By

GHT CONSULTING

PROJECT TEAM
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Project No.: 386-30-ghd.907
Report No.: RVN 907.2/2134

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03 January 2022, Updated 18 February 2022

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Dear Mr Johan Combrink

JAGERSFONTEIN DEVELOPMENT (PTY) LTD. PIT BACKFILLIN INVETIGASTION

It is our pleasures to enclose the draft report *RVN 907.2/2146*: *" JAGERSFONTEIN PIT BACKFILLING, FINAL REPORT".*

We trust that the report will fulfil the expectations of Jagersfontein Development and we will supply any additional information if required.

Yours sincerely,

Shaun Staats
Geohydrologist

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EXECUTIVE SUMMARY

GHT Consulting was appointed by Jagersfontein Development (PTY) Ltd. to conduct the necessary geohydrological work to investigate the removal of the Wate Rock Dumps (WRD's) as indicated in Figure 1 to the pit as motivation to The Department of Water and Sanitation (DWS) with respect to previously declined authorization.

This report is to a great extent reliant on additional studies that have been performed since 2020 entailing a detailed impact assessment of the Tailings Storage Facility (TSF), GHT Consulting report RVN 905.2/2133. This involved reviewing historical magnetic surveys and conducting new magnetic and Electrical Resistivity Tomography (ERT) surveys south, east and north of the TSF. None of these were able to identify any anomalies associated with lineaments/intrusions such as dykes that may act as preferential pathways. The ERT survey in conjunction with the magnetic work revealed the possibility of different resistivities indicating a possible contact zone between different rock types east of the TSF, as well as a possible difference in weathering of the outcropping dolerite sill north of the TSF. These zones were targeted for percussion drilling. A contact zone between sedimentary rock and a dolerite sill was confirmed east of the TSF which may act as may act a preferential pathway promoting pollution migrations from the TSF and as such can be used for pollution plume interception. ***No fault zones or lineaments intersecting the pit were detected in any of the geophysical studies.***

Several field excursions were conducted by a professional structure geologist (Prof. W Colliston), mapping the different geological formations and incorporation the drilling logs of old and newly drilled boreholes. The detailed geological report that followed from this indicates the rocks mainly comprise of jointed fine-grained sandstones and siltstones which are underlain and overlain by thick dolerite sills. The prominently jointed outcrops of the upper dolerite sill form the hilltops surrounding the old mine and town. A lower dolerite sill merges with the upper sill in the northern part. The TSF overlies the contact between the upper dolerite sill in the north and the fine-grained sandstone to the south. Two aquifers were identified namely a very fine-grained lithofeldspathic sandstones with interbedded siltstone and minor mudrock separated by a regionally persistent lower thick dolerite sill in excess of 20 metres in thickness. The upper fine-grained lithofeldspathic sandstones form an unconfined aquifer termed the Valley Aquifer. The fine grained-sandstone (Valley aquifer) dips between 1 and 2 degrees to the east and south-east over a distance of 2.6km where it is once again bordered by the dolerite sill that defines the surrounding hills at Jagersfontein.

A contact zone exists between this upper Valley aquifer and lower secondary dolerite sill defined as an aquitard, although. weathering in shallower parts of the Valley aquifer may result in higher permeabilities acting as a preferential flow path with slightly higher conductivities but low sustainability as it is fed by the Valley Aquifer matrix from above. Secondary confined siltstone aquifer lenses are separated from the Valley aquifer by a regionally thick (>20m) dolerite sill and does not significantly contribute to yielding potential. Some overlying siltstone lenses occur to the north-west of the TSF, Pit and the surrounding jointed dolerite hills where recharge to the Valley aquifer occur through the weathered upper part of the merged dolerite sills with siltstone lenses. The combination of aquifers (Lower Dolerite Sill/ Siltstones and Valley Aquifer) in the region of the TSF and Pit can therefore be classified as ***minor*** *due to low permeabilities and low sustainable yields. It was deduced from this work that* ***the pit is not intersected by these aquifers and thus no interconnection between the Valley Aquifer or the contact between the Valley aquifer and the dolerite sills with the pit.***

The vulnerability of the unsaturated zone in the vicinity of TSF (and can be extended to the WRD's) is classified as Extreme due to the short distance to the aquifer, the thin permeable unsaturated zone, and a very high seepage velocity flowing from the topsoil to the water table. This stresses the importance of minimizing negative impacts upon these resources. The Valley aquifer underlies WRD's MD1, MD11, MD8 and MD9. Dumps MD2, MD4 and MTD are above the dolerite sill and sandstone lenses and thus have higher potential of pollution impacts due to the presence of gravel above the dolerite where recharge may be readily occurring. Some of these dumps are Class A dumps containing more clayey material reducing pollution impacts, and some are class B dumps with primarily course material and thus higher probability of seepages and causing pollution. Removal of these pollution sources will thus be beneficial to the complete region.

It was also established from a study conducted by the Water Research Commission in 2002: "Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs (WRC Report No. TT 179/02)" where it is explained that De Beers Consolidated Developments (Ltd.) ceased mining in 1971 and gave the Jagersfontein Municipality permission to abstract groundwater from the Development in 1980. It is stated *that during this time the piezometric level in open-pit and shafts recovered from 750 m to 183 mbgl. It was further concluded from the available information in the study that the water level and chemical information point to the existence of two separate aquifers, namely a shallow, more 'typical' Karoo fractured-rock aquifer at an average 4.8 mbgl water level and showing a water level of 4.8 mbgl), containing recently recharged water, and a deeper aquifer (intercepted in the shaft or Development, piezometric level 183 mbgl). This was confirmed by evaluating the graphs of relationship between rest groundwater elevations and topography. When the rest water level of the shaft is included an extremely poor relationship between groundwater elevations and topography is revealed as opposed to when removed from the data. This confirms that that the groundwater level of the shaft is not related to the regional groundwater level. It is further evident that the water level of the shaft reflects the levels of one or more confined or semi-confined aquifers.*

With regards to dewatering as a result of pumping from the shaft, dewatering can only be considered within the immediate proximity to the pit and primarily the dewatering of the local siltstone lenses that are not interconnected with any aquifer systems. Once again, the reason for this being that there is no water seeping into the pit via the pit faces and there is no dewatering of boreholes caused by dewatering of the pit via abstraction from the shaft (which is linked to the pit). Although the shaft is connected to the pit, the pit does not serve as the primary source of recharge to the shaft. In fact, the pit act merely as a sump when receiving rain- or storm water contributing to the overall availability to be abstracted from the shaft. The water level in the pit steadily declines after these storm events to a stage where the sustainable abstraction rate of the shaft is reached.

According to the reports from SRK 2016 and 2021, the tests performed on the slimes indicate conductivities as low as 4.8x10-8 m/d whereas the course tailings used to construct the walls may be as high as 0.86 m/d. The wall material however becomes compacted with time lowering these values substantially. The actual values may even be lower than these values derived from particle size analyses and evaluation (which is conducted by drying of the material and performing sieve analyses). Some layering would occur during disposal and the vertical conductivity would be an order smaller than the horizontal (similarly to what is normally assumed for general groundwater flow). The lowering of these values may be further compounded as there is some expansion in the saturated slimes (smectite) as well as compaction that would occur (both at the bottom of the TSF and definitely in the pit).

The initial conceptual model was updated with the knowledge gained from the additional investigations. Consequently, a completely new numerical model was constructed to reflect the upper superficial soils, the Valley aquifer, the contact between the Valley Aquifer and the dolerite sills, and the deep geology. Due to the absence of dewatering within the upper geology, no abstraction was simulated in this model. This model must however be updated when additional information becomes available regarding the deep aquifer, upon the implementation of the monitoring system (to be approved by DWS). Two scenarios were simulated namely a Do-Nothing scenario (where operations are seized by 2021 and all pollution sources are left on surface) and a scenario where operations continue with removal of the WRD's by the end of 2029.

The numerical groundwater simulations indicate that groundwater levels in the pit will not recover to regional ambient groundwater levels. Simulations of both scenarios of the 2129 pollution plumes indicate the edge of the 40 mg/L SO4 WUL limit to be mostly within 2km downgradient from the pollution sources. Decreasing pollution plumes both in extent and concentrations within the superficial soils, gravel and clay can be seen from as early as 2034 in the scenario where the on-surface WRD's were removed by 2029. Improvements are becoming more apparent from 2044 in this scenario as opposed to the do-nothing scenario. There are significant differences in the concentrations and footprints of the pollution plumes in the Valley aquifer and in the contact between the Valley aquifer and the dolerite sills between leaving the WRD's indefinitely on-surface as opposed to when the sources are removed. The diminishing pollution plume trends in the contact between the Valley aquifer and the dolerite sill are very similar to those of the Valley aquifer itself due to the explanation that Valley aquifer is the source of water to the contact and this zone. This zone has a slightly higher permeability and yield than the sedimentary Valley aquifer and is often targeted by drilling and pump inlet at this level.

The prolonged impacts from the class B dumps left on-surface can be seen in the simulated plumes of 2084 and 2129. Earlier removal of the on-surface WRD's would be a major improvement as the Valley aquifer is the main exploitable aquifer in the region feeding the contact between this aquifer and the dolerite sill beneath. The prolonged simulated activities since 1940 with the dolerite siltstone lenses seen as homogenous isotropic entity and low porosity show some imprints at a depth 40mbgl of between 5 to 25 mg/l SO_4 from the on-surface sources. There is however no lateral movement (as expected) from the pit in any of the images from 2025 to 2129.

No pollution is migrating in any of the simulations from the pit to the superficial soils, the Valley Aquifer, the contact between the Valley aquifer and the dolerite sills or the deep geology.

The main reason for this being that the permeability of the slimes is much lower than that of the host rock and groundwater movement (if any) will thus rather move around the slimes than into or through it. Furthermore, the property of the slimes (smectite clay) with regards to retention also means that the slimes will rather retain moisture than releasing it to the environment.

The north-west to south-east cross-sections images indicate that the simulated plume from the pit ***does not migrate vertically downwards and that it remains horizontally contained with the host rock*** *(dolerite and possible siltstone lenses).* ***Once again, because the permeability of the slimes is much lower than that of the host rock.***

A monitoring plan was compiled to address pollution detection in the deep and shallow aquifers. The positions of monitoring boreholes have been determined in accordance with the results from the numerical pollution plume model and groundwater flow directions. Three compulsory monitoring borehole pairs are advised north, east-southeast and one west-southwest. An optional pair is advised if needed south between the shaft and pit. The Pit also forms part of the monitoring network.

With the current pit bottom at approximately 260 mbgl, the deep borehole must extend to at least this depth, but it is strongly advised to 300 mbgl. Drilling of each of the deep (up to 300 m) boreholes within a pair must be performed first. The information obtained during drilling of the deep borehole will determine the deep borehole finishing (casing depth and perforation). This information must then be used to determine the borehole construction of the shallow borehole (up to 100m) in the pair. Surface influences upon the shallow borehole must be prevented by installation of solid casings at least the first 12 metres with perforation of the casings of the shallow boreholes from 12 meters to at least 6 metres into solid bedrock. The casing of the deep borehole must be solid from surface to at least 6 metres into solid bedrock, whereafter alternating perforated and solid casings must extend to the bottom of the hole. The casings of the boreholes must extrude at least 300mm above ground and protected by installation of a bee-proof sealable caps, marker posts and cement plinths. Geological logs must be recorded together with encountered water strikes (as possible future sampling depths). A level logger and attachable mechanism for a pully system must be installed at the deep boreholes to facilitate future sampling (only if water is detected in a borehole) using depth specific bailers. No pumping or purging is currently advised. It is also advised to conduct extensive aquifer test (pumping etc.) to determine aquifer parameters, not only for numerical modelling purposes, but for correct pump selection and pumping regimes (should this be necessary). Even though it is not envisioned that these monitoring boreholes will facilitate any pollution remediated with the shaft considered as the best remediation abstraction point it is advised to construct the deep boreholes to accommodate abstraction and thereby saving considerable cost in the future.

Groundwater levels of the shaft and Pit monitoring network (to be installed) must be measured on a monthly basis and properly evaluated against rainfall data and abstraction volumes utilising evaluation techniques such as trend analyses and comparing measured values against historical water level depths and evaluations. Groundwater samples must be collected quarterly form the monitoring network boreholes for analyses and properly evaluated against historical concentrations utilising the different evaluation techniques and trend analyses. In the event of pollution detection, pollution migration direction and rates must be determined which in turn will determine if additional boreholes may have to be drilled. Remedial action must then be taken according to the remedial plan.

Three different remediation techniques were evaluated, namely: withdrawal, treatment and re-injection, hydrodynamic control, and withdrawal, treatment, and use. Due to the underlying deep geological strata, and based on all the remediation techniques discussed above, withdrawal, treatment and use is the best available option to apply in the event of pollution being detected in the proposed monitoring boreholes. The shaft remains the best viable option for abstraction, with the deep monitoring boreholes as secondary options. For remedial response, the water purification plant must be kept in working condition and in ready preparedness for future use.

This plant will generate brine water to be disposed of. The properties of the slimes were already shown to form an impermeable barrier system and it is therefore proposed that the brine be disposed of on the TSF on a slimes region taking adequate measures to prevent overflows onto the side walls. The brine production rate must be considered when designating an area on the TSF with enough freeboard to accommodate the 1:100 flood event and allow for natural evaporation and precipitation of salts.

The qualities of the purified recovered water must be adequately monitored (especially that of arsenic) ensuring proper evaluation of final qualities (possible mixing may be required with other sources (as described by Bijengsi, 2012 with water from the Kalkfontein dam) to be safely made available to the community according to the relevant needs (drinking water or agricultural).

An update of the Hydrocensus report is advised at least once in two years to verify possible impacts upon the surrounding town and farms. A complete list of known hydro-census sites must be compiled (with maps) and updated when the hydro-census report is updated in the future.

The numerical groundwater model must be updated once the monitoring boreholes are installed, and the recorded data (geology and water strikes) must be incorporated the conceptual model and the updated numerical model. The model must be updated and re-calibrated at least once every two years incorporating the latest chemistry and abstraction rates.

It is important to prevent surface run-off entering the pit and take the appropriate measures with the installation of proper berm walls retaining natural surface flow along the stream to the east and south of the pit.

The relevant authorities (DWS) must be informed should any additional pollutants different from those specified by the WUL be detected. The WUL must then be amended in consultation with DWS. The monitoring programme must then be updated accordingly.

Any amendments to this programme must be liaised with DWS and approved before implemented.

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1 INTRODUCTION

1.1 Introduction

The feasibility of the complete Jagersfontein Development diamond recovery operation is hanging in the balance due to the limited available remaining capacity of the current Tailings Storage Facility (TSF). The livelihood of Jagersfontein Development is dependent upon an alternative to a new TSF due to the considerable financial implications associated with the construction of a secondary TSF and accompanying required liner system. Bringing the system to a sudden halt will not only have devastating social-economic impacts, but long-term negative environmental consequences upon surface- and groundwater resources due to on-surface dumps that will not be possible to be removed. The only alternative to the construction of a new a TSF would be backfilling of the Jagersfontein Pit by the following processes:

Course tailings are to be disposed of into the pit on the southern side of the pit via a conveyor belt system with the main purpose of acting as a buffer system preventing subsequent slimes deposition from possibly penetrating fine cracks within the geology or sealed shafts and reach the main shaft from which abstraction is currently taking place. Hereafter, co-disposal of course and fine tailings will commence filling the pit to approximately 60 metres below rim level (approximately 1351 mamsl).

1.2 Objectives of the Study

GHT Consulting was appointed by Jagersfontein Development (PTY) Ltd. to conduct the necessary geohydrological work to investigate the removal of the Wate Rock Dumps (WRD's) as indicated in Figure 1 to the pit as motivation to The Department of Water and Sanitation (DWS) with respect to previously declined authorization, letter 2 7 /2/2/C851 /2/ 1 dated 19 October 2020. The reasons (taken from the letter, page 22) to address are as follows:

4.1.1 The specialist reports provided by the applicant to the Department in support of the backfilling application did not sufficiently consider the critical risks such as pit instability, break back and vibrations associated with the proposed activity.

4.1.2 The reports from the applicant indicate that diamond mine residues will be utilised as aligning material for the base and sides of the mine pit. However, the proposed liner material was found not to be consistent with a Class C lining material which the applicant is expected to implement when backfilling a pit with mine residues.

4.1.3 The documents submitted to the Department in support of the backfilling activity indicate that the applicant is not concerned about the threats posed by the proposed activity on the surface and groundwater resources.

4.1.4 The reports provided by the applicant in support of a WULA did not assist the Department to comprehend the impacts of the activity to surface and ground water resource. Also the reports don't articulate sufficiently how possible pollution to the ground water resources that could emanate from the backfilling of the pit will be managed.

4.1.5 The applicant did not prepare a monitoring plan to monitor the impact of backfilling of the pit.

The purpose of this report is to address items 4.1.2 (limitedly), 4.1.3, 4.1.4 and 4.1.5.

This project builds upon a recently completed Tailing Storage Facility (TSF) impact assessment project by GHT consulting in October 2021 (report RVN 905.2/2133) in which a detailed geological mapping of the area around the TSF was completed by a qualified professional structural geologist, Prof W. Colliston. This study also included drilling of additional monitoring boreholes (locally east of the TSF and as far as 1.2 km to the south of the TSF) recording geological logs and performing aquifer permeability tests. An additional geophysical investigation (ERT and magnetic) was conducted a professionally qualified geophysicist Dr. F. Fourie east and north of the TSF. This information, together with all available geological information as well as geological logs of previously drilled boreholes encountered in the field and geological interpretations done by visual inspections of the pit geology were utilized by Prof. Colliston to interpret the geological information, and create detailed geological cross sections extending from the pit to south-eastern and southern areas of the operations areas.

This in turn improved the knowledge of the previously generalized understanding of the regional geology utilized in the numerical modelling exercises to such an extent that it was necessary to revise the conceptual model and ultimately the construction of a completely new numerical model.

1.3 Project Outline

1.3.1 Background

The following are specific items that were investigated in the referred Tailing Storage Facility (TSF) impact assessment study (report RVN 905.2/2133), gaining a knowledge and understanding of geological and geohydrological that extends beyond the immediate vicinity of the TSF:

- Groundwater conditions, properties, etc. (permeability, hydraulic conductivities, transmissivity, quality, etc.) and movement of pollution.
- Specific site aquifer characteristics and conditions (i.e. geological and aquifer delineation, aquifer classification, vulnerability, etc.
- Additional geophysical (magnetic and ERT) investigations were conducted to identify possible preferential pathways or structures.
- Auger holes were drilled to determine aquafer parameters and specifically properties of the unsaturated zone to quantify seepages from the TSF to the immediate subsurface.
- Impact assessment of the TSF on groundwater.
- Groundwater management report/plan with measures to mitigate and manage pollution including rehabilitation of the polluted aquifer.
- Recommendations of monitoring boreholes and design of network including borehole designs (casings, etc.).
- Numerical modelling and delineation of pollution plumes.
- Evaluate stormwater run-off and make recommendations regarding closure objectives with assessment of possible impacts on groundwater.

The following already available and additional information were utilized in conjunction with the above:

- Pollution source (TSF) material geohydrological properties

- Pollution source (TSF) material pollution potential as derived from waste classification and various acid base accounting (ABA) and leach tests
- Previously and newly gathered hydrocensus data (groundwater levels, surface- and groundwater chemistry respectively by GHT Consulting and in-house by Mr Johan Swanepoel from Jagersfontein Development
- All available surface- and groundwater monitoring data (water levels and chemistry).

1.3.2 Methodology

The knowledge and understanding of the above-mentioned information can be applied to the complete regional and operational area, and even the pit. It is therefore essential to include most of this information from the Tailing Storage Facility (TSF) impact assessment study (report RVN 905.2/2133) with special reference to the identified geology and aquifer delineation in this report.

With the purpose to assesses the local impact TSF, that of the WRD's were not implemented in the initial re-constructed model (report RVN 905.2/2133). However, the new numerical model was constructed to include the local catchment or drainage area within which all the Jagersfontein Development operations reside, and as such also the geology and aquifer(s) of the complete area. The model can therefore be updated with confidence to include the on-surface WRD's and to simulate these impacts and evaluate them against future removal.

Although the Department of Water and Sanitation did not refer to or request the re-evaluation of differences between removal of the on-surfaces sources as opposed to non-removal, the updated geology and aquifer delineation in the new model reflects differently from the first model presented to the department in 2020 (GHT Consulting Model Report Revision 2 RVN 885.3/2067) and it is therefore important to include the findings of the updated model in this report.

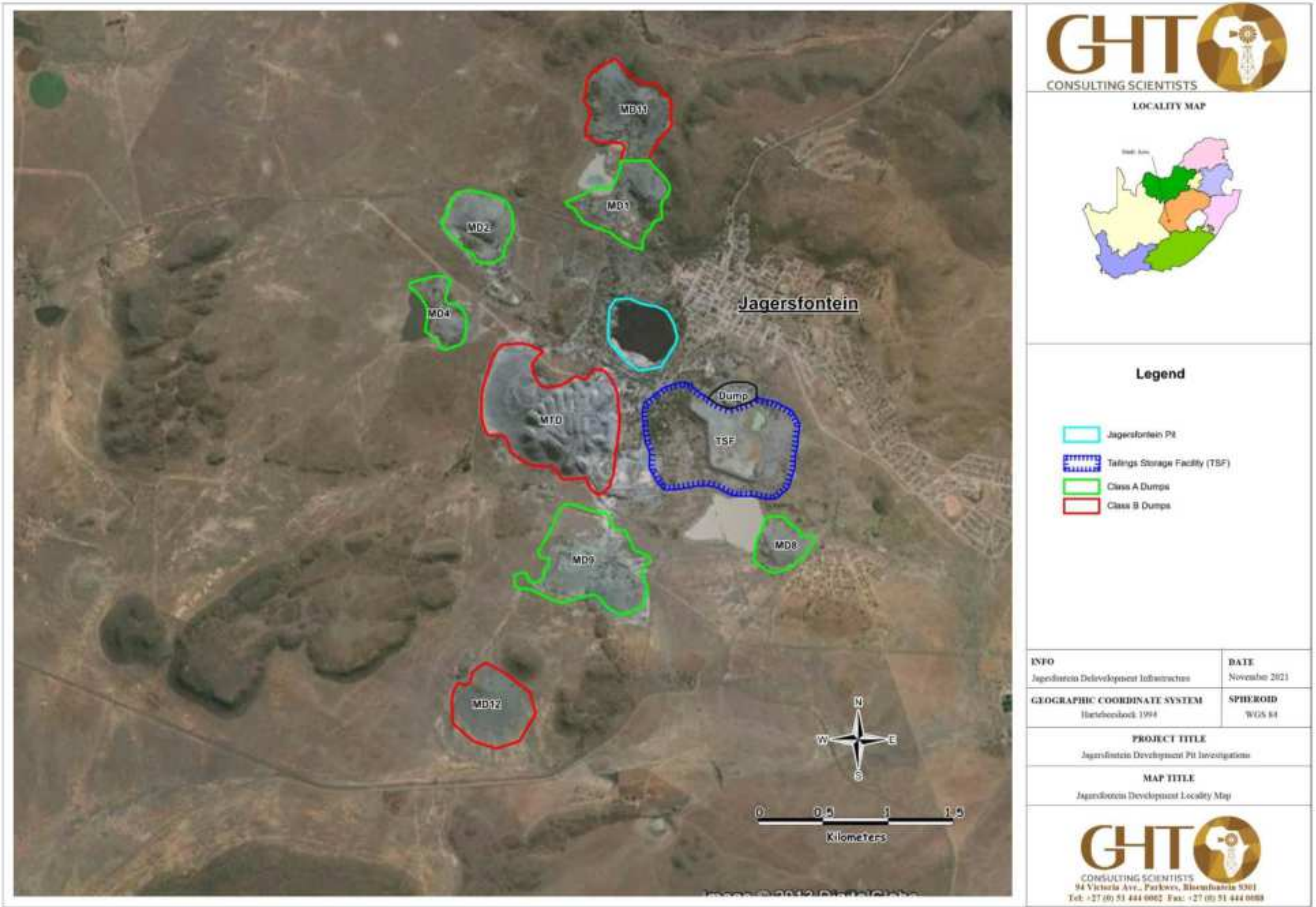

Figure 1. Jagersfontein Locality map and Pollution Sources.

2 PHYSICAL GEOGRAPHY

2.1 Geography

Jagersfontein / Itumeleng are located in south-western part of the Free State Province.

The Jagersfontein diamond recovery and processing operations site is situated within the borders of the town of Jagersfontein on Portions 15, 16 and a portion of the Remainder of the Farm Jagersfontein 14 IS.

2.2 Climate

2.2.1 Regional Climate and Drainage Region

The historic mine lies within drainage area C, rainfall zone C5B and Quaternary sub catchment C51H. (Surface Water Resources of South Africa, First Edition, 1994). Refer to Figure 2. The investigated area has a semi-arid climate characterized by very hot summers and cool winters, and a predominantly summer rainfall. The mean annual precipitation (MAP) for the Jagersfontein / Itumeleng area is 427.7 mm (Surface Water Resources of South Africa, 1990).

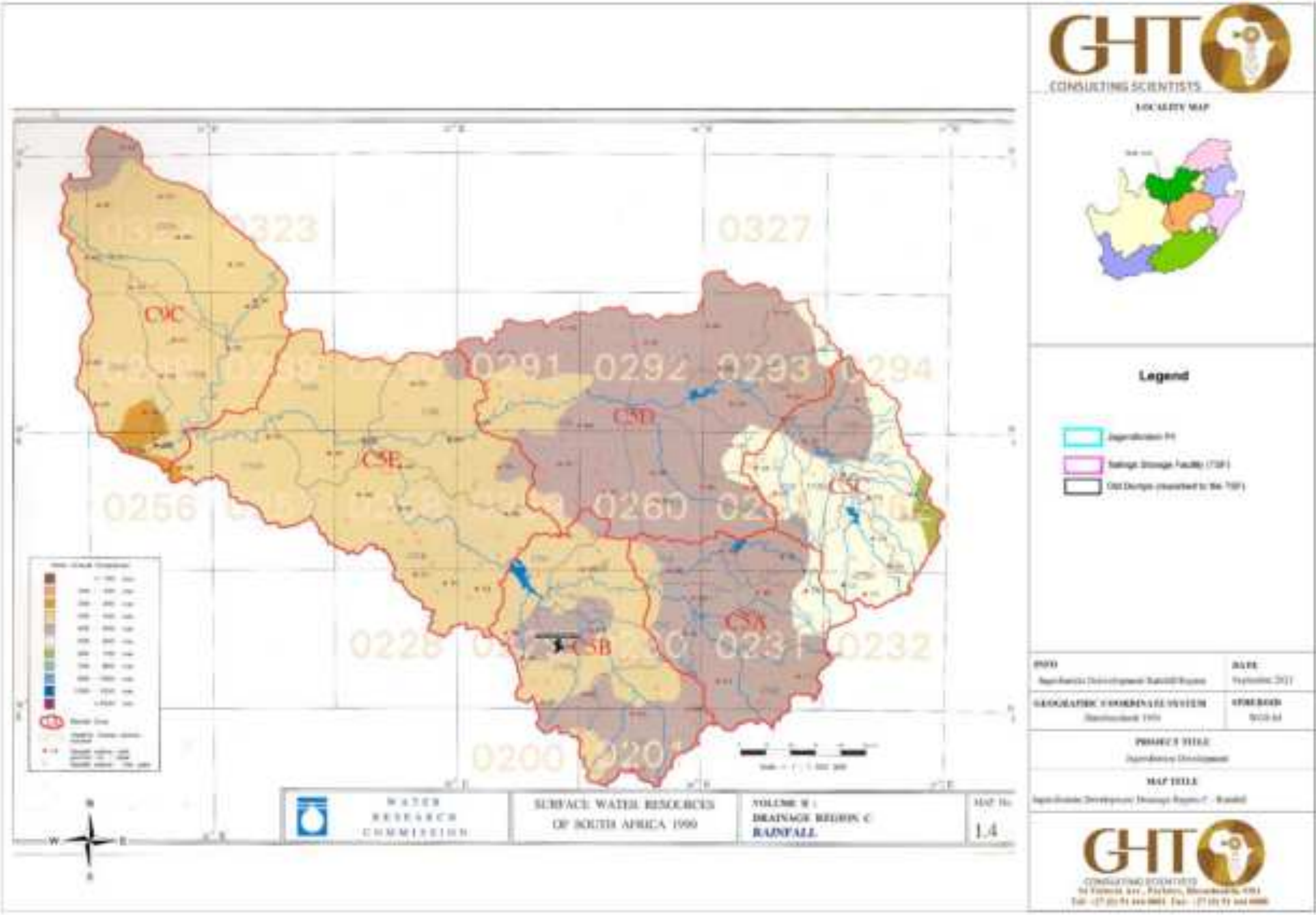

Figure 2.   Rainfall zone C5B (Water research commission 2005)

The average rainfall and precipitation for this region can be viewed in Figure 3.

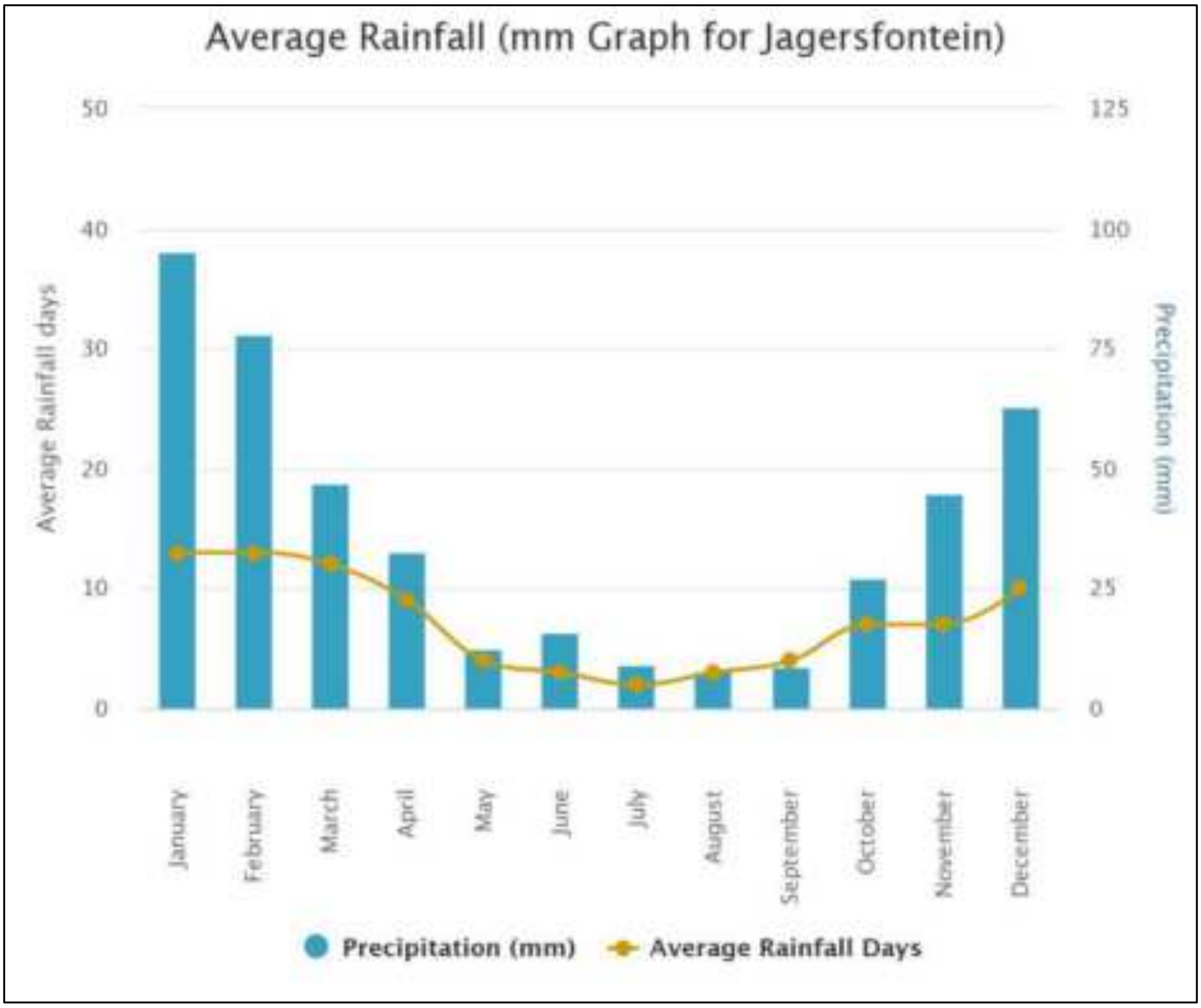

Figure 3 Average rainfall for Jagersfontein (WorldweatherOnline.com)

Air temperature ranges from an average maximum of 32 to 34 °C in January to an average minimum of 0 to 2 °C in July (South African Atlas of Agrohydrology and – Climatology, 1997).

The minimum, maximum and average temperature for this region can be viewed in Figure 4 and Figure 5.

Figure 4 Minimum, maximum and average temperature for Jagersfontein (WorldweatherOnline.com).

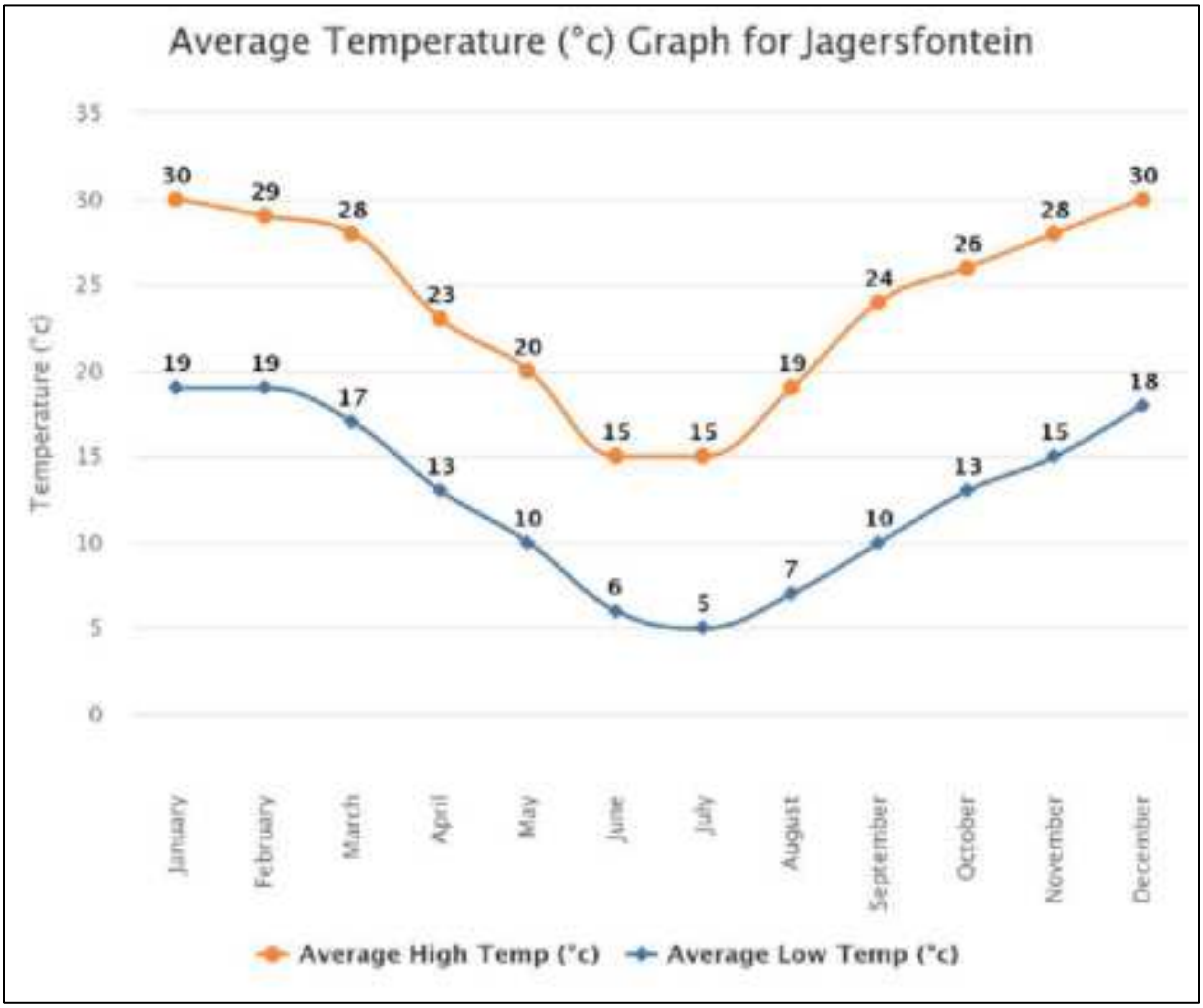

Figure 5 Average high and low temperatures for Jagersfontein (WorldweatherOnline.com).

2.2.1.1 Surface Topography and Drainage

With reference to Figure 6, surface drainage of the catchment area is generally from north-west at 1439 mamsl to the south-east at 1349 mamsl. Surface drainage in close proximity to the TSF follows the same north-west (1416 mamsl) to the south-east (1390 mamsl) drainage pattern towards the non-perennial stream at the south-eastern corner of the TSF.

2.2.1.2 Runoff

It is depicted on map shown in Figure 7 that Jagersfontein has a mean annual run-off between 20 – 50 mm.

2.2.2 Evaporation

The historic mine lies within evaporation zone 19A, with a mean annual evaporation (S-Pan) 1500 - 1600mm (refer to Figure 8).

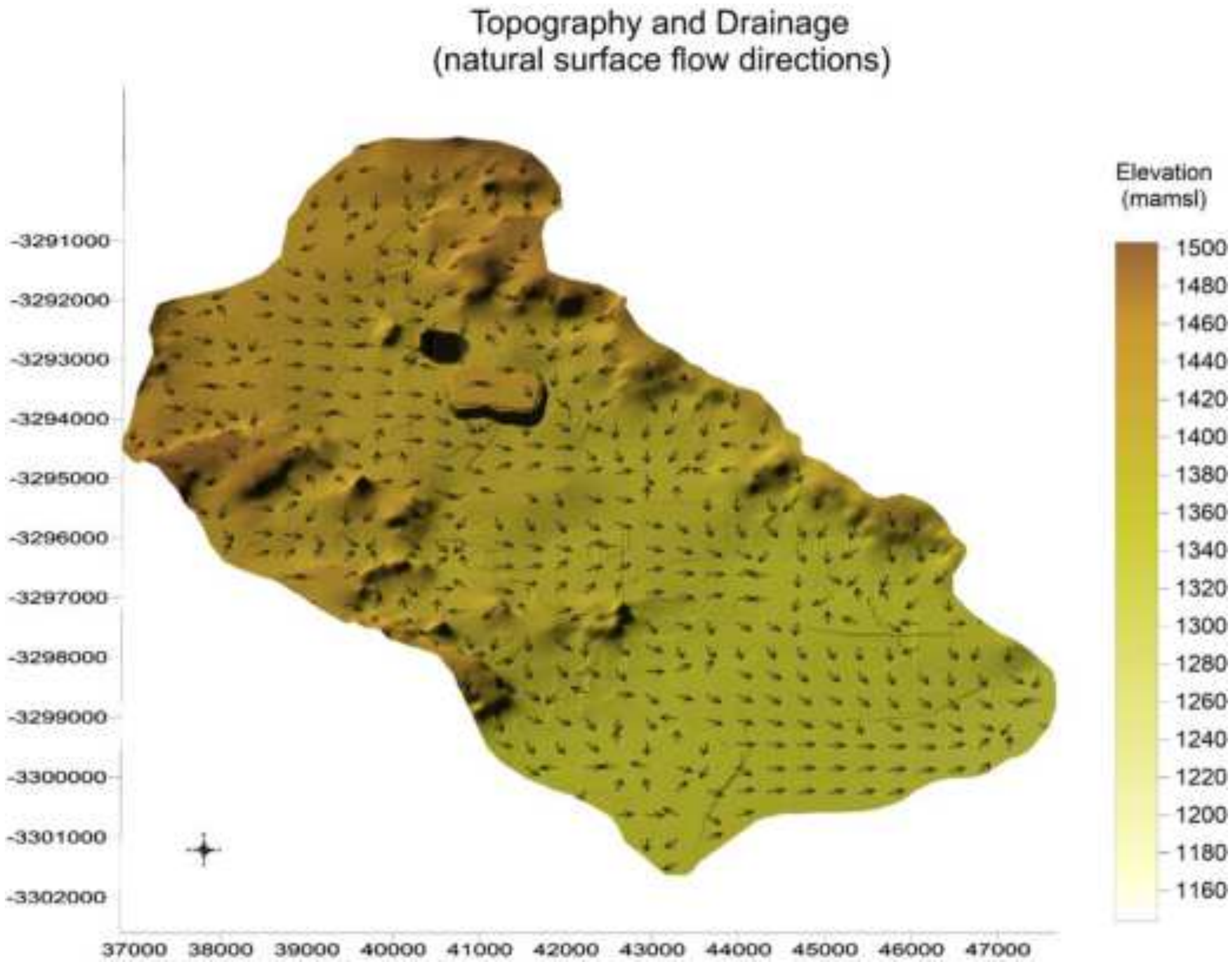

Figure 6. Natural drainage flow directions at Jagersfontein Development TSF Site. Note that natural run-off flow direction is generally from the north-west to the south-east towards the non-perennial stream.

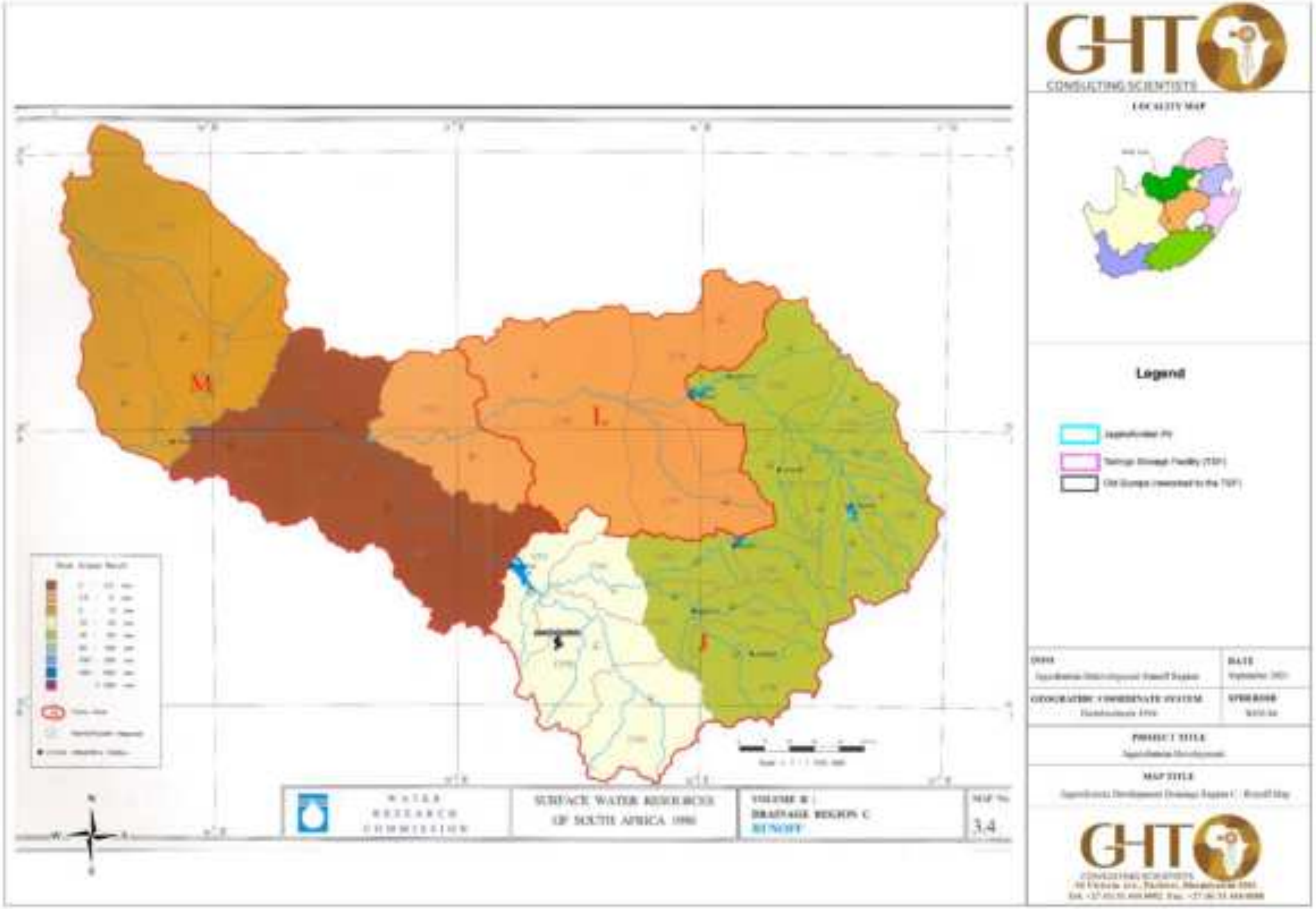

Figure 7. Runoff (Water research commission 2005)

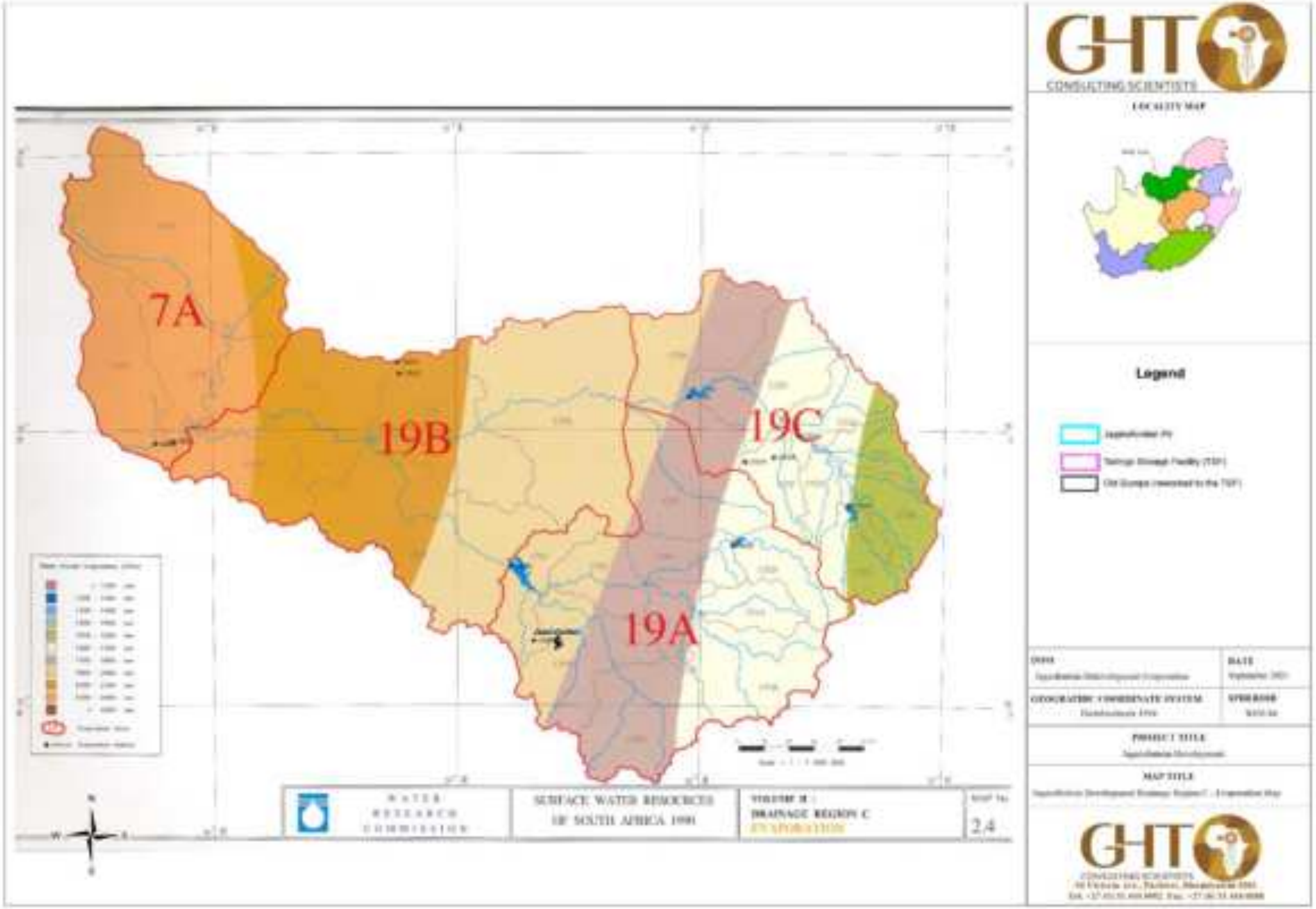

Figure 8. Evaporation zone 19A (Water research commission 2005)

3 GEOLOGY

This section contains the general geology collected during the completion of the project. A detailed geological and geophysical investigation was undertaken in June 2021 to expand on this general geological background and discussed in section 3.3.

3.1 Lithostratigraphy and Depositional History

This section has been adapted from the Hydrogeology of the Main Karoo Basin, WRC Report No. TT179/02 as well as the Geology of the Aquifer System in the Petrusburg Area, 2001. With reference to Figure 9 and Figure 10, the lithostratigraphy of the Jagersfontein district consists of the following:

Karoo Supergroup;

- Ecca Group;
- Tierberg Formation (Upper Ecca).

3.1.1 Ecca Group

The Permian-aged Ecca Group comprises a total of 16 formations, reflecting the lateral facies changes that characterise this succession. Except for the extensive Prince Albert and Whitehill Formations, the individual formations can be grouped into three geographical zones, the southern, western, north-western and north-eastern.

The basal sediments in the southern, western and north-western zones (Prince Albert and Whitehill Formations) of the basin will first be described, followed by the southern Collingham, Vischkuil, Laingsburg, Ripon, Fort Brown and Waterford Formations. The remaining western and north-western sediments of the Tierberg, Skoorsteenberg, Kookfontein and Waterford Formations and the north-eastern Pietermaritzburg, Vryheid and Volksrust Formations will then be considered. In addition, a relatively small area along the eastern flank of the Basin, between the southern and north-eastern outcrop areas, contains 600 – 1 000 m of undifferentiated Ecca mudrock.

3.1.1.1 Tierberg Formation (Upper Ecca)

The Tierberg Formation is a predominantly an argillaceous succession which reaches a maximum thickness of approximately 700 m along the western margin of the basin, thinning to about 350 m towards the northeast. It rests with a sharp contact on the Collingham or Whitehill Formations and grades upward into the arenaceous Waterford Formation or, where the latter is absent, into the Adelaide Subgroup (Beaufort Group). Where it is overlain by sandstone of the Skoorsteenberg Formation the contact is sharp and the formation is about 460 m thick.

The bulk of the Tierberg Formation comprises well-laminated, dark grey to black shale. Some yellowish tuffaceous beds up to 10 cm thick occur in the lower part of the succession along the western and northern margins of the Basin. Calcareous concretions are common towards the top of the formation. Clastic rhythmites occur at various levels in the sequence.

The transition zone at the top of the formation consists of several upward-coarsening sequences of 2–10 m thick mudstone, siltstone and very fine-grained sandstone layers. Thin clay-pellet conglomerates are present while calcareous concretions occur relatively frequently.

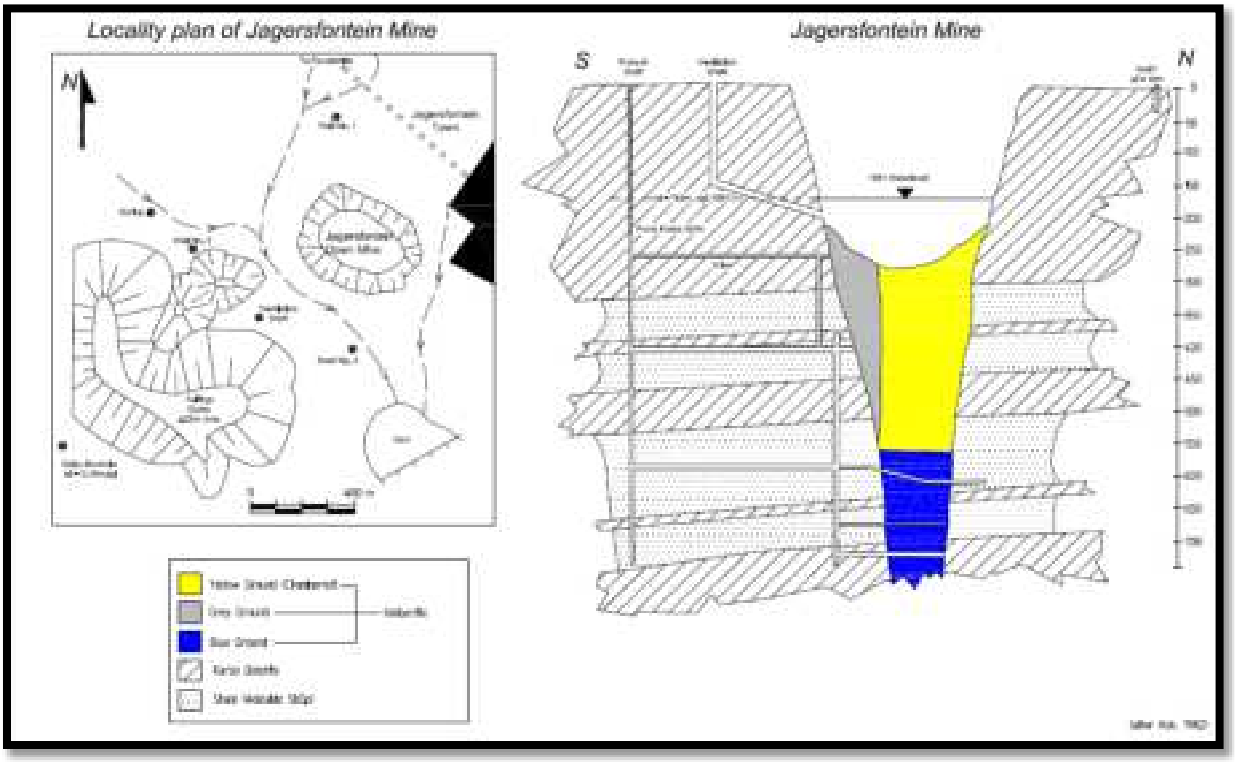

Figure 9. Jagersfontein Kimberlite ore body (modified from Woodford et al., 2002)

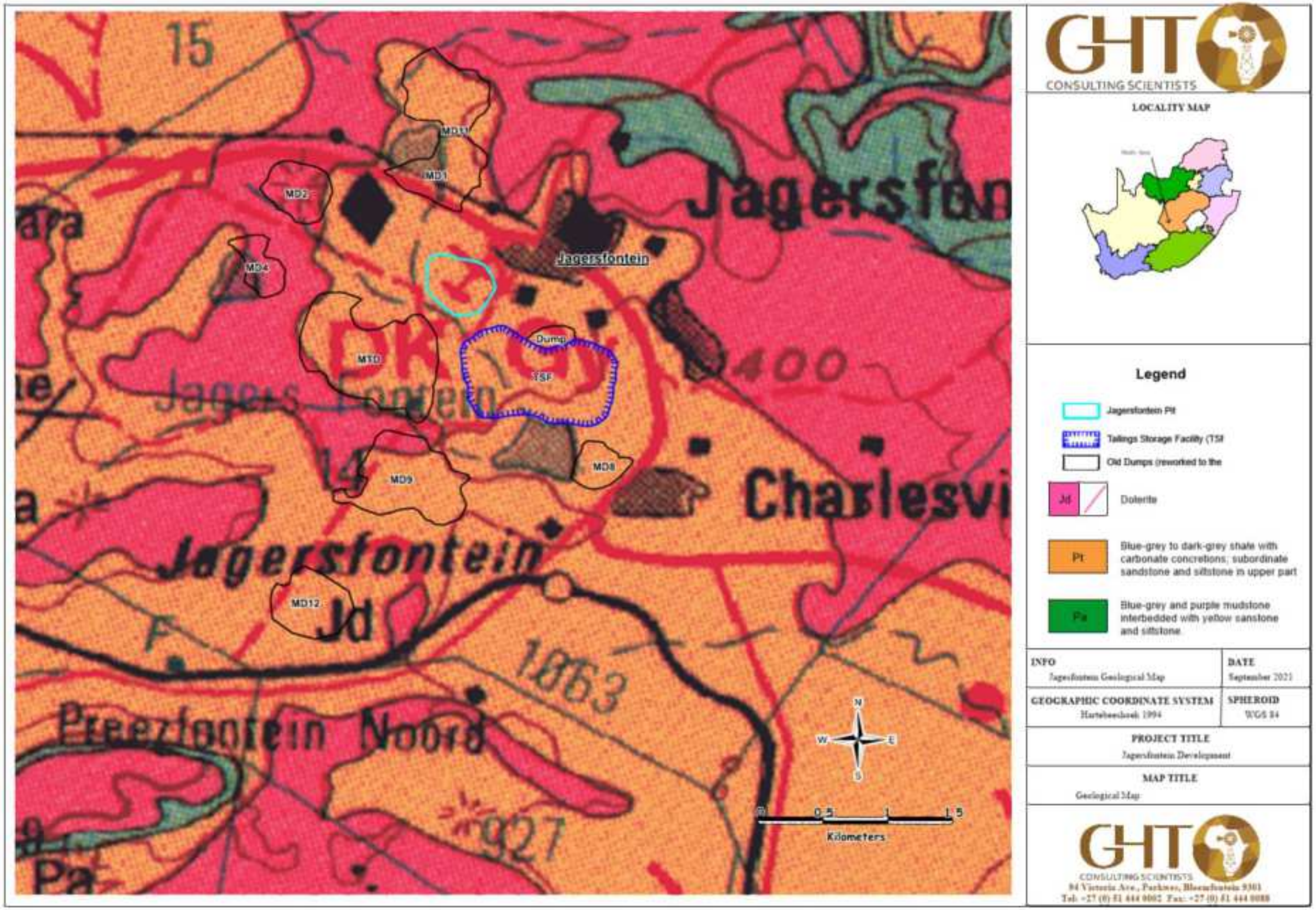

Figure 10. Geology map (Council of Geoscience).

3.2 Geophysical Investigation

This section includes the geophysical information obtained during the survey to detect possible geological features and structures, which may act as preferential pathways for groundwater flow and contaminant transport.

3.2.1 The Aerial Magnetic Method

Airborne magnetic surveys can encompass large areas in a relatively short period of time, using helicopters or low flying aircraft trailing a magnetometer. Although these surveys do not have the same spatial resolution of ground surveys, they are invaluable for tracing larger structural features, and especially major dyke intrusions into the Karoo sediments. The entire Karoo basin has been covered by aeromagnetic surveys, which were carried out on behalf of the Council for Geoscience and are available on digital format.

Airborne magnetometers all measure the total magnetic field and are of two main types, fluxgate magnetometers and proton magnetometers. The fluxgate magnetometer which measures the field relative to a selected datum uses two systems of coils, one, much as in ground magnetometers, measures the relative field, while the second system of coils together with associate electronics and motor driven gimbals maintains the measuring coil in the direction of the total magnetic field irrespective of aircraft heading and attitude. The proton magnetometer measures the absolute value of the total field and needs no sophisticated orient mechanism. Proton magnetometers are favoured in most recent installations. There are other more sensitive magnetometers used in petroleum surveys.

The sensing head of the magnetometer is either carried in an extended “stinger” on the tail, mounted on the wingtip or is towed in a “bird” to keep the measuring elements away from the magnetic influence of the aircraft.

Magnetic data is recorded continuously during flight on a paper recorder, magnetic tape or electronically. The flight path of the aircraft is recorded by photographing the ground traversed with a special 35 mm camera. Numbered timing marks, known as fiducials, are recorded on both the film and on the paper record (or magnetic tape) on which the magnetic data appears. A radio altimeter records the aircraft height above ground and feeds height information to the pilot. The aircraft is navigated with the aid of existing aerial photographs, large scale maps or by using electronic navigational aids. The sensitivity of the airborne magnetometers is in the order of 0.5 to 1 nT.

3.2.1.1 Aerial magnetic Data Interpretations

Intrusive magmatic dolerite sills are considered as secondary targets for groundwater resource development. Whereas successfully exploited dolerite dykes can yield sustainable abstraction volumes of between 1.0 to 20.0 L/s, the sills usually yield sustainable abstraction volumes of 0.5 L/s in general. These massive sills usually do not contain weathered zones or fractures of dimensions significant enough to yield sustainable groundwater in significant volumes. Usually minor water strikes are encountered on the contact zones between the dolerite sill and the sedimentary host rock, which in this area are represented by the Tierberg shales and sandstones of the Ecca Group.

The available aerial magnetic data available for the study area are of a low resolution, which bring about that the smaller dolerite dyke structures cutting through the sills or extending from them cannot be detected due to the spacing of the flight lines for the aerial magnetic survey. Therefore, field geophysical survey was conducted at the site to determine if smaller dolerite dyke structures do exist near the site and the immediate area. The results of the field magnetic survey can be perused in Section 3.2.2.1

3.2.2 The Magnetic Method

The magnetic geophysical method proved an effective method for the detection of dolerite structures, which includes dykes and sills.

The normal magnetic field of the earth can be visualised as a field of a bar magnet placed at the centre of the earth. Any changes in this "normal" magnetic field superimposed by dykes, for example, can be measured by a magnetometer. These measurements (changes) in magnetism can then, through the process of modelling, be interpreted in terms of the dip, strike, depth and width of the body that causes the anomaly. Since these geological magnetic features might be remnant (i.e. permanently) magnetised, a feature, which is normally not known to the modeller, no unique solution of the model exists. By making certain reasonable assumptions about the geology, restrictions can be placed on some of the geological features of the body. The magnetic method is an extremely useful method to map of dykes, which are good groundwater exploration targets.

3.2.2.1 Results of Field Geophysical Surveys

A geophysical field survey was conducted in 2017, which included twelve magnetic traverse lines, namely TV01, to TV12. Magnetic anomalies were recorded at traverses 1, 2, 3,4 , 5 and 6 that may indicate the presence of a possible dolerite structures (refer to Figure 13 and Figure 14 to Figure 25). The anomalies of traverses 1 and 2 may be associated with the same structure but cannot be inferred from aerial photos. It is indicated as a Kimberlite pipe on the Geological map (see Figure 11 to Figure 13). Similarly anomalies of traverses 3 to 5 cannot be inferred from aerial photos, but the anomaly at traverse 4 can be associated with the edge of the dolerite sill). Traverse 6 can be readily associated with a natural structure running in a southeast east – north-west direction (with lateral preferential flow) withing the weathered material or change in geology/fault structure. This may however act as a barrier to groundwater flow perpendicular to this structure. None of these findings indicate any direct geohydrological connectivity with the shaft or pit.

A geophysical field survey was also conducted in July 2020, which included four magnetic traverse lines, namely T01, to T04 (see Figure 11 to Figure 13 and Figure 26 to Figure 29).. No magnetic anomalies were detected.

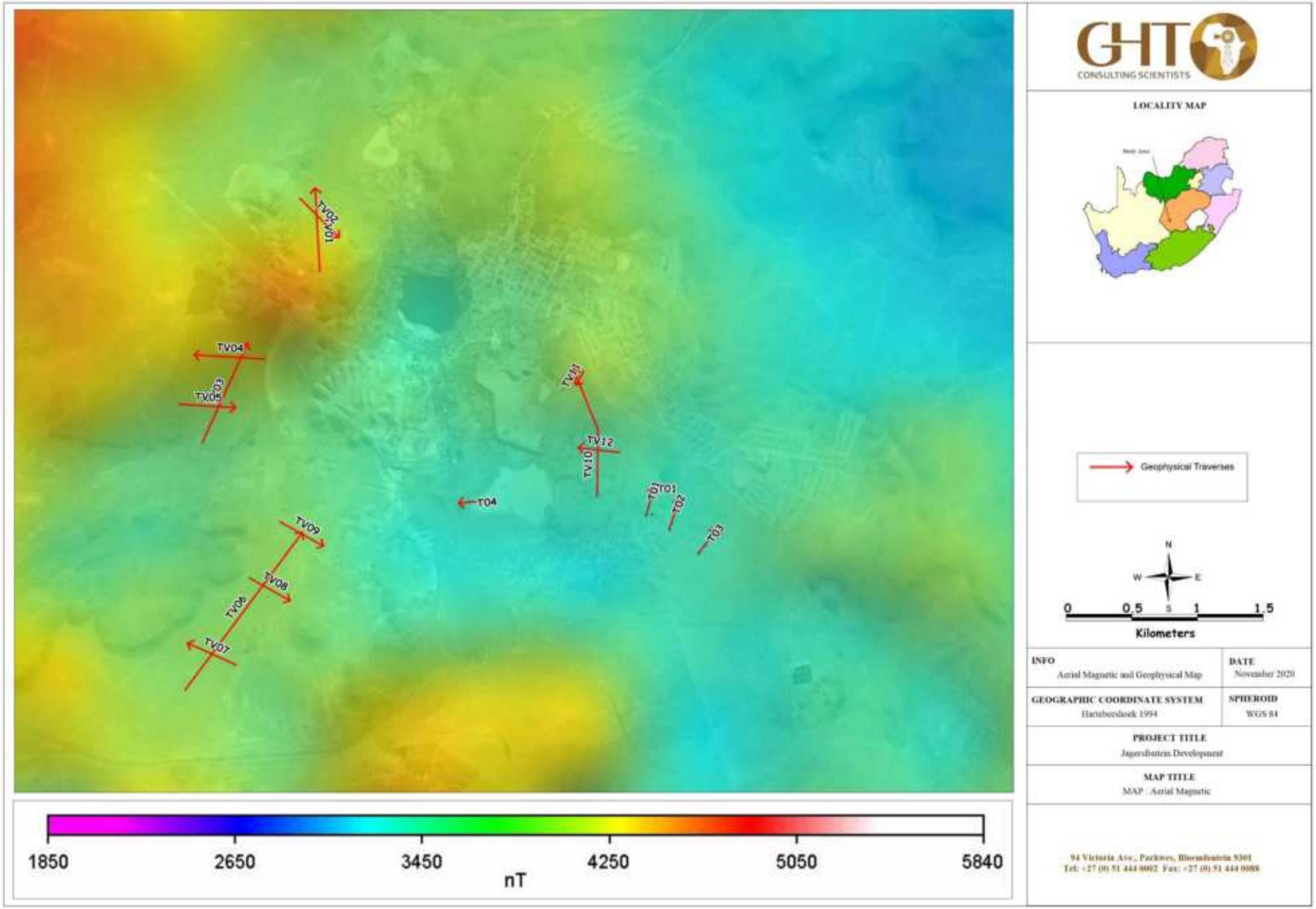

Figure 11. Aerial magnetic data contour map for the Jagersfontein / Itumeleng area.

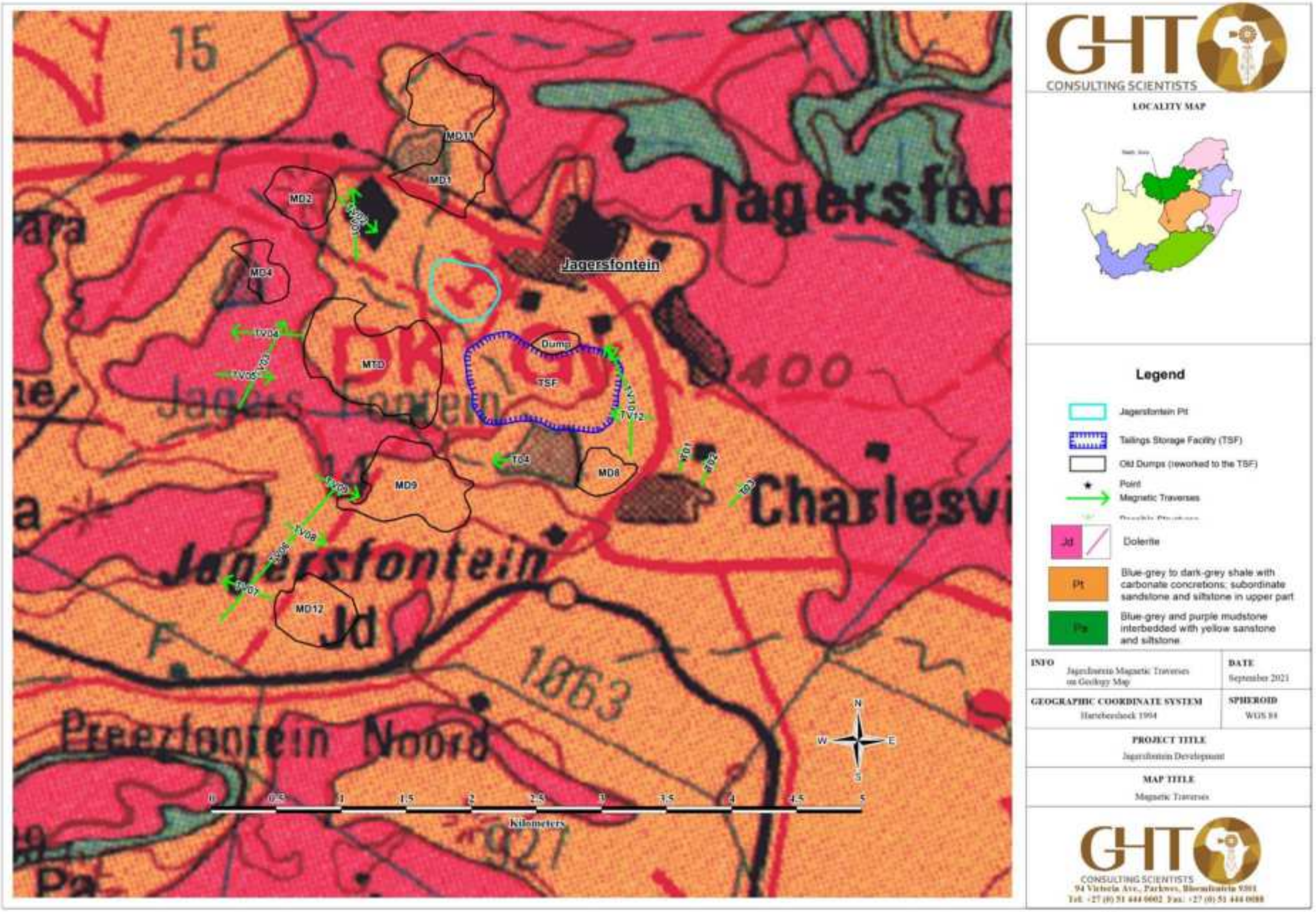

Figure 12. Magnetic traverses on Geology map (Council of Geoscience).

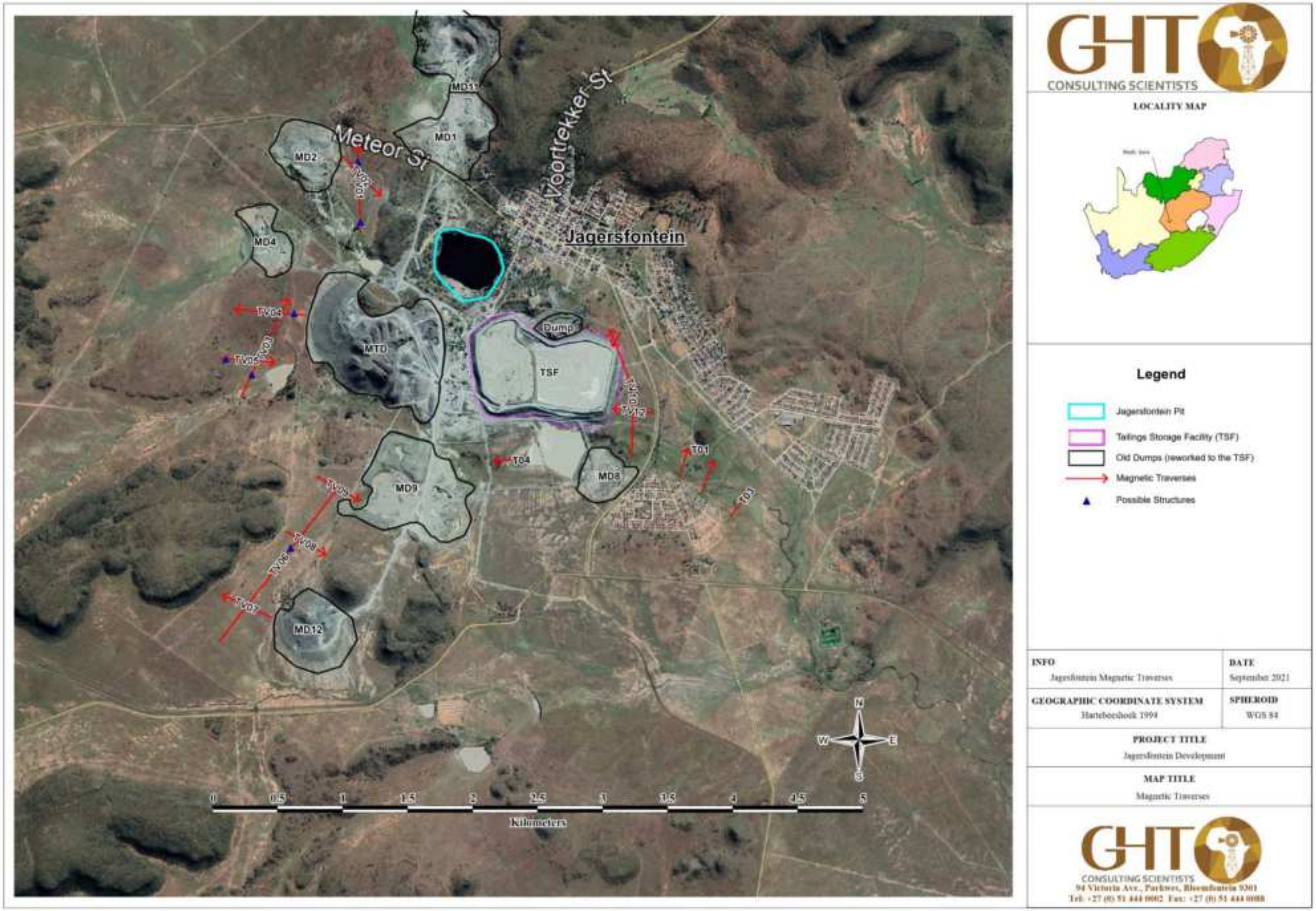

Figure 13. Geophysical magnetic traverses.

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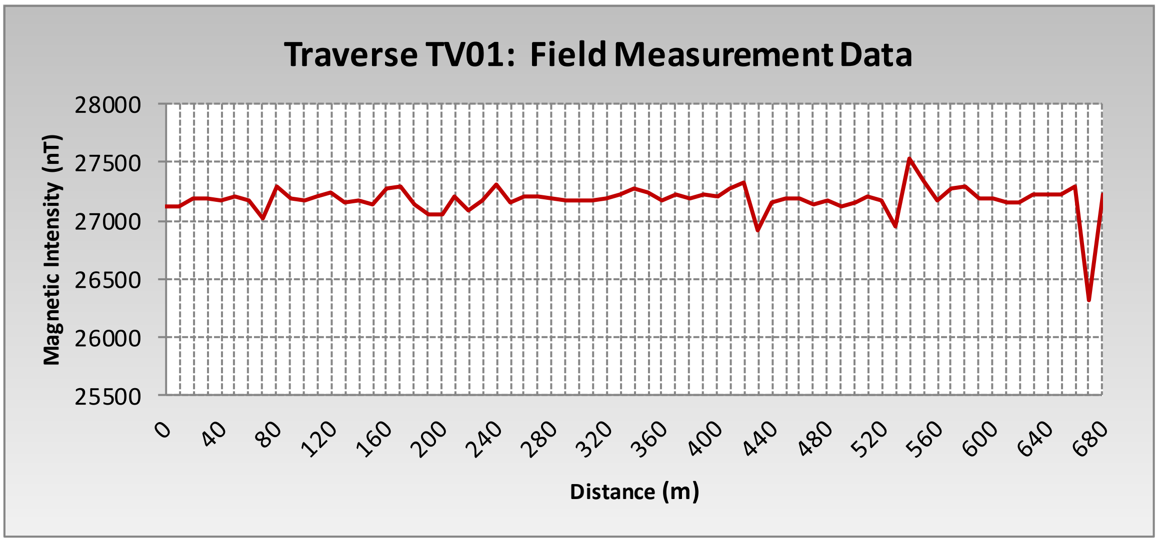
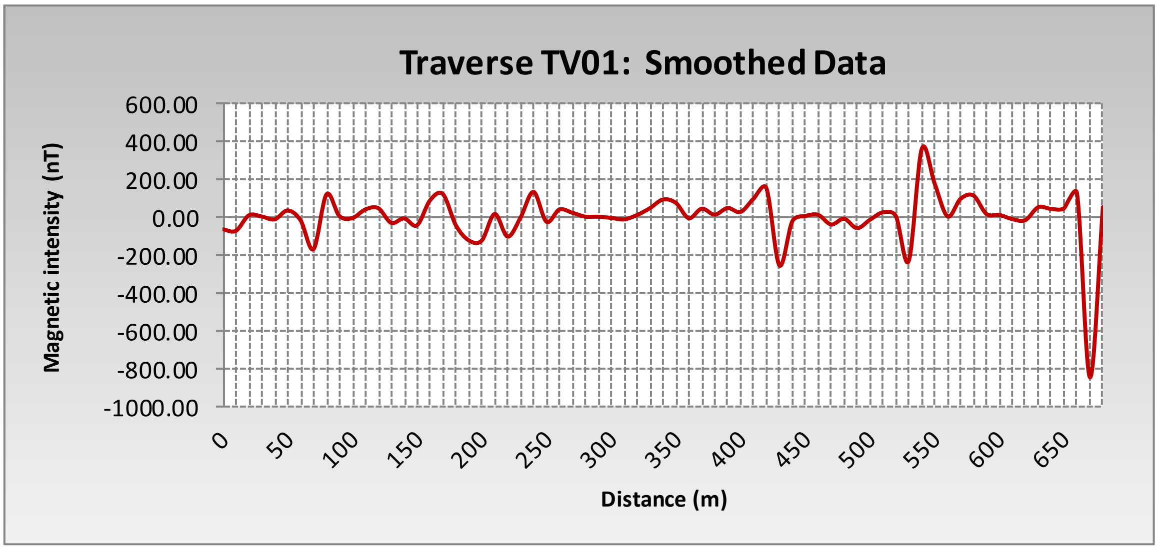
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV01
Project Number:		**Profile Direction:**	South to North
Survey Area:	North-west of Pit	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 14. Traverse TV01

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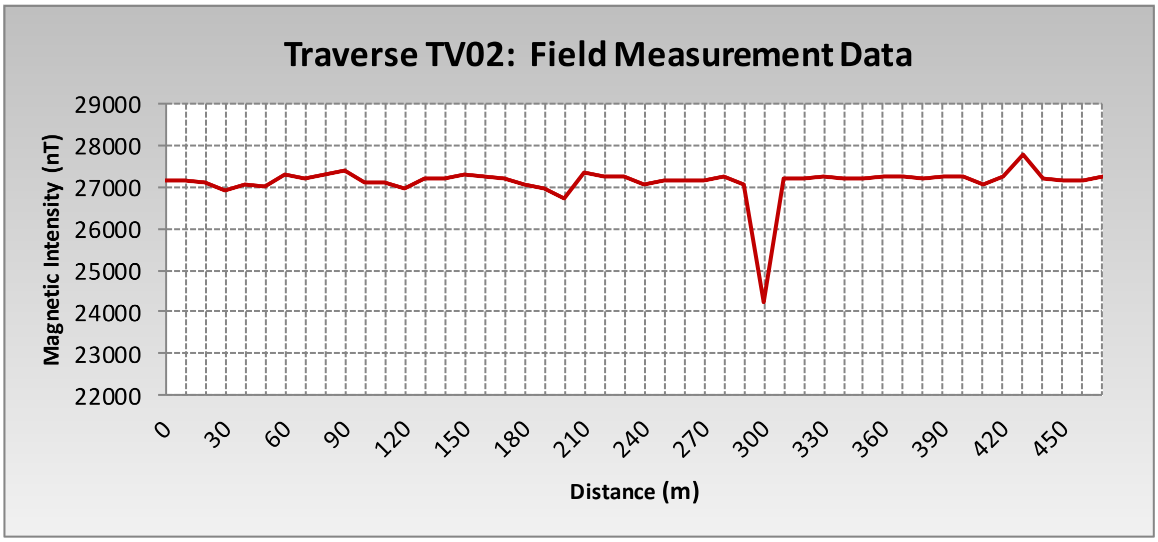
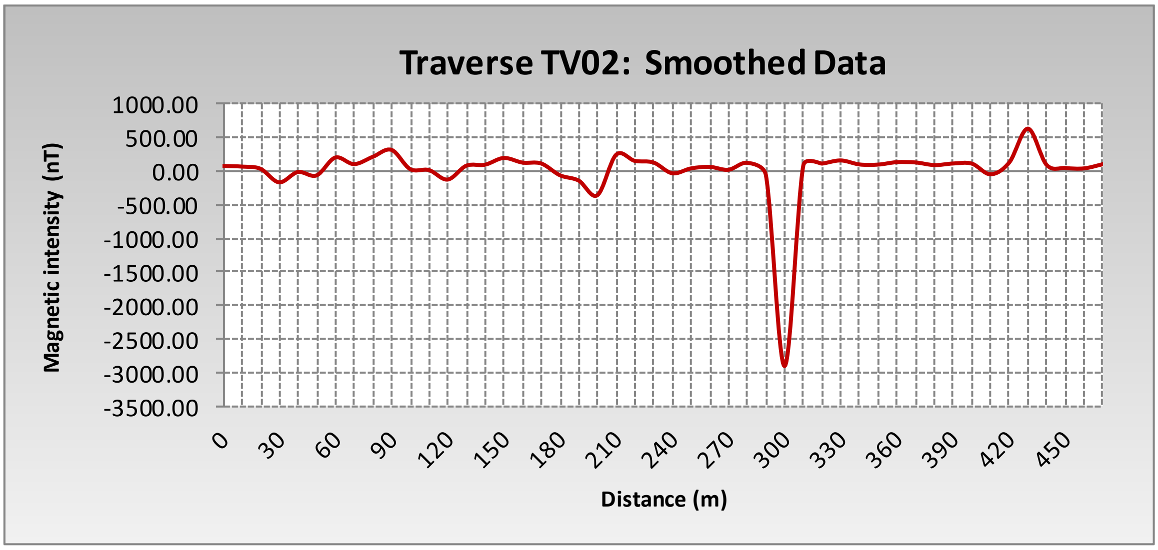
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV02
Project Number:		**Profile Direction:**	NW to SE
Survey Area:	North-west of Pit	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 15. Traverse TV02

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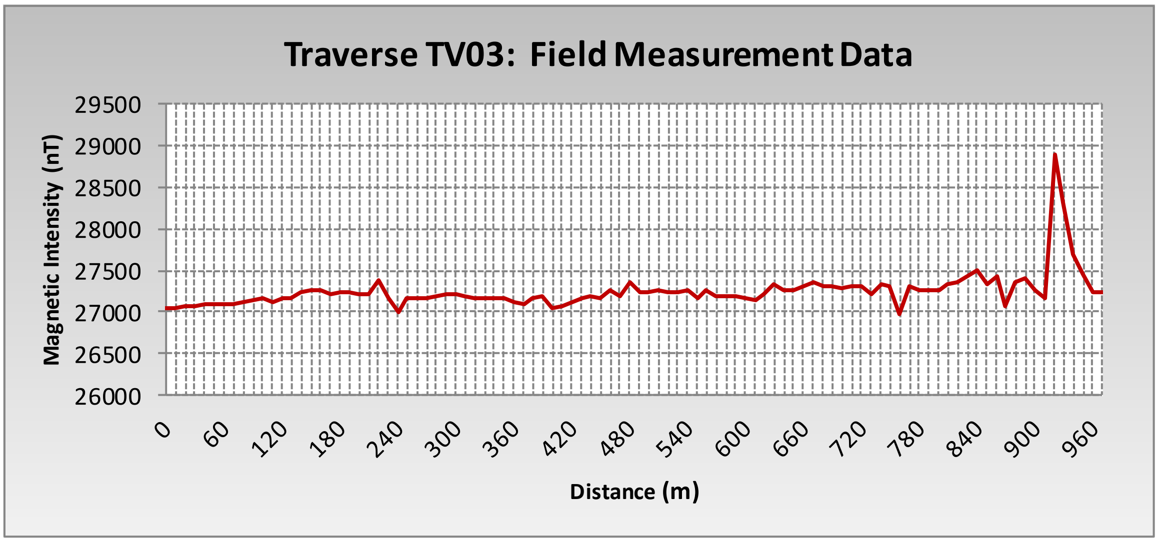
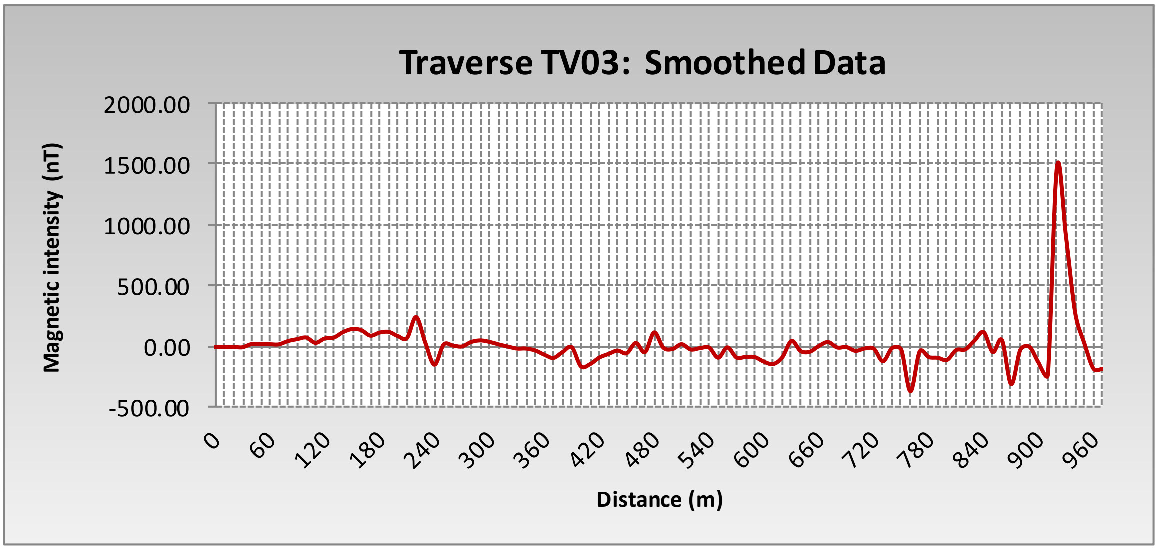
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV03
Project Number:		**Profile Direction:**	South-west to North-east
Survey Area:	West of MTD	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 16. Traverse TV03

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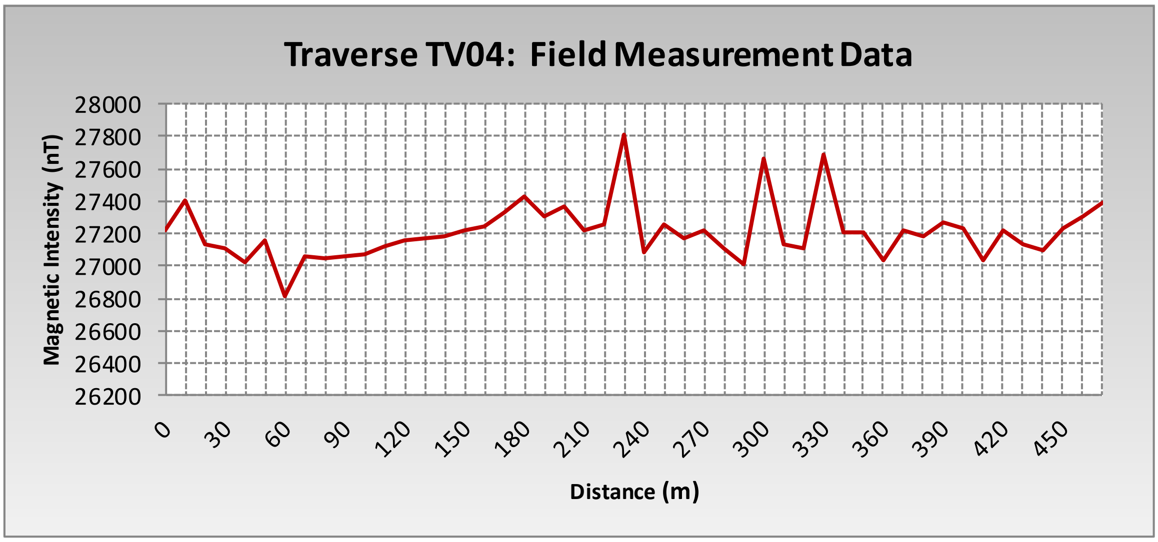
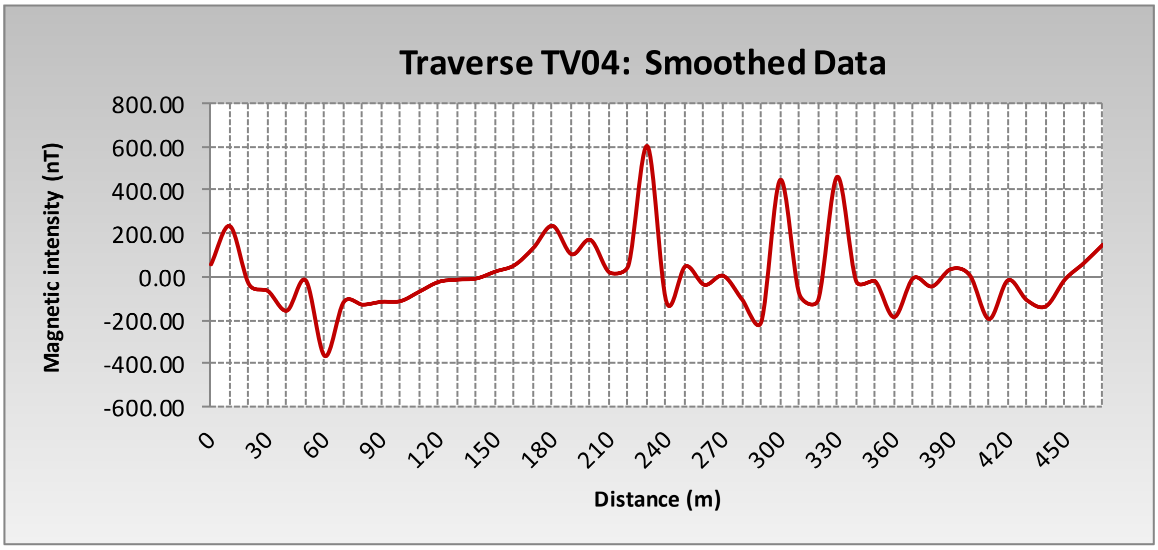
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV04
Project Number:		**Profile Direction:**	East to west
Survey Area:	West of MTD	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 17. Traverse TV04

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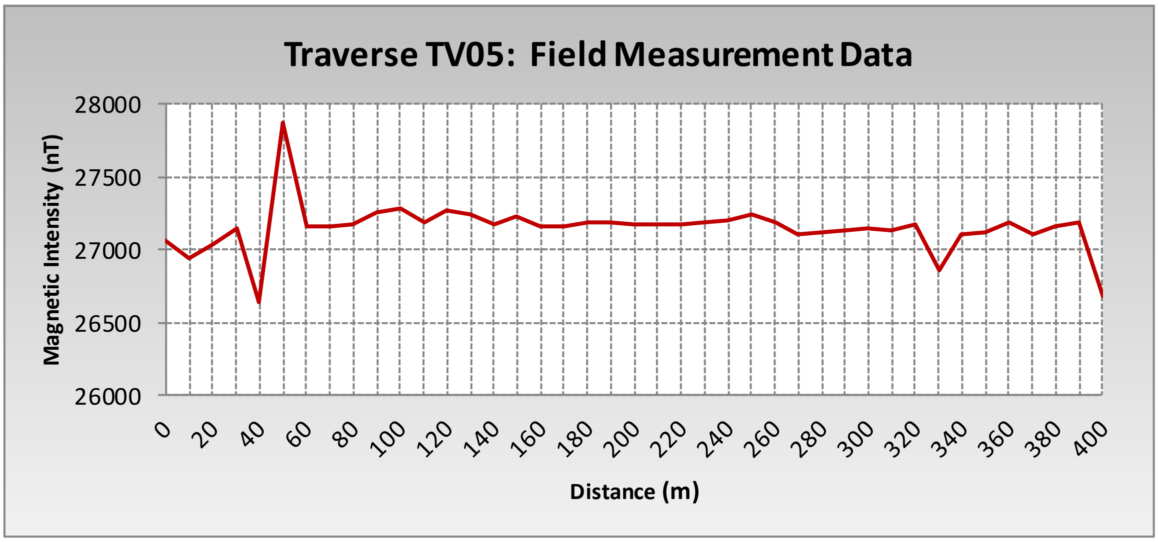
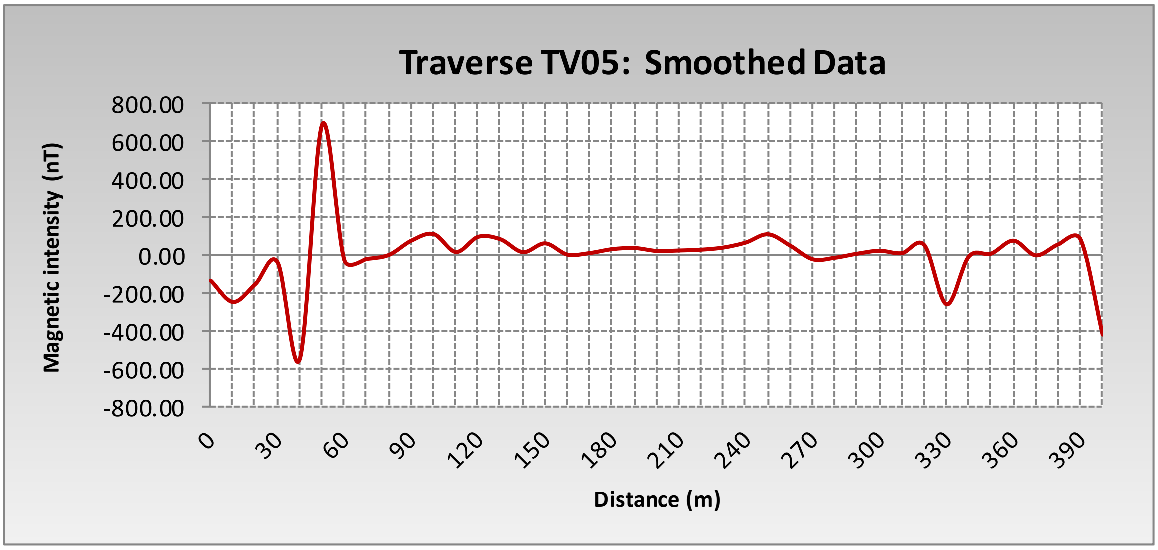
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV05
Project Number:		**Profile Direction:**	West to east
Survey Area:	West of MTD	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 18. Traverse TV05

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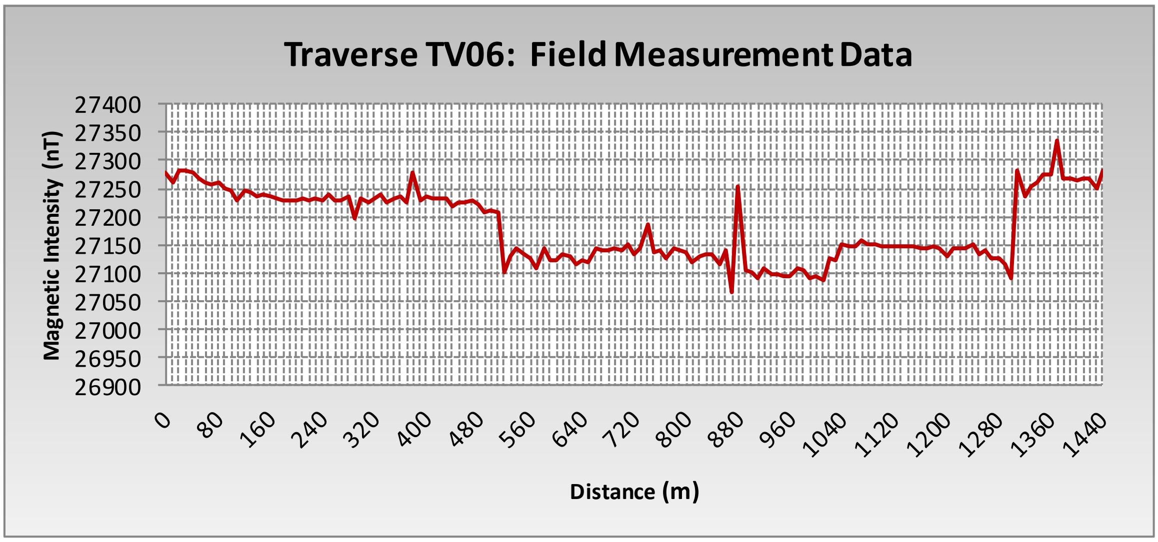
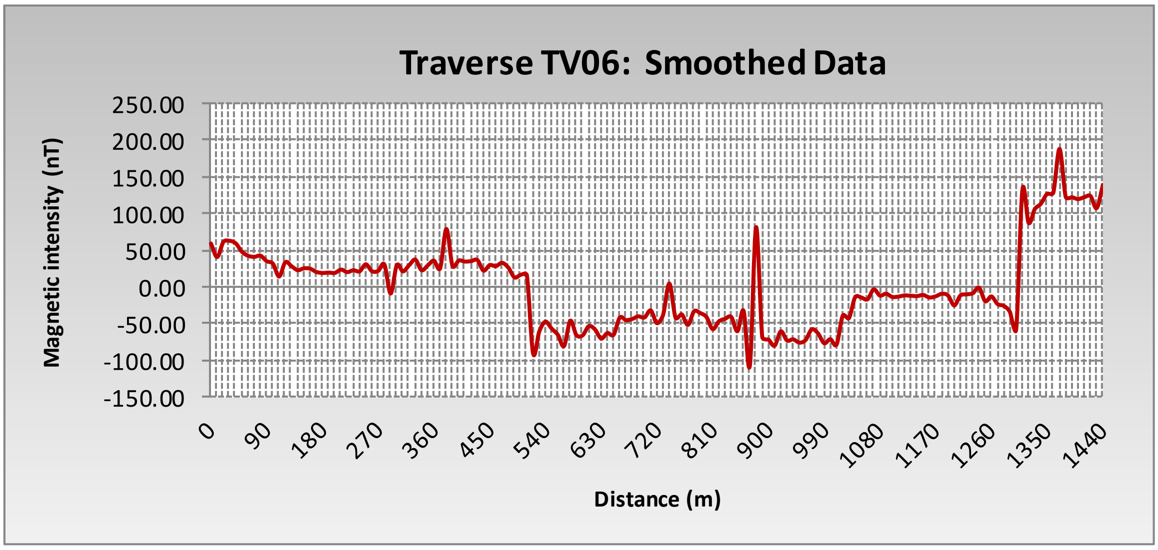
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV06
Project Number:		**Profile Direction:**	South-west to North-east
Survey Area:	West of MD12	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 19. Traverse TV06

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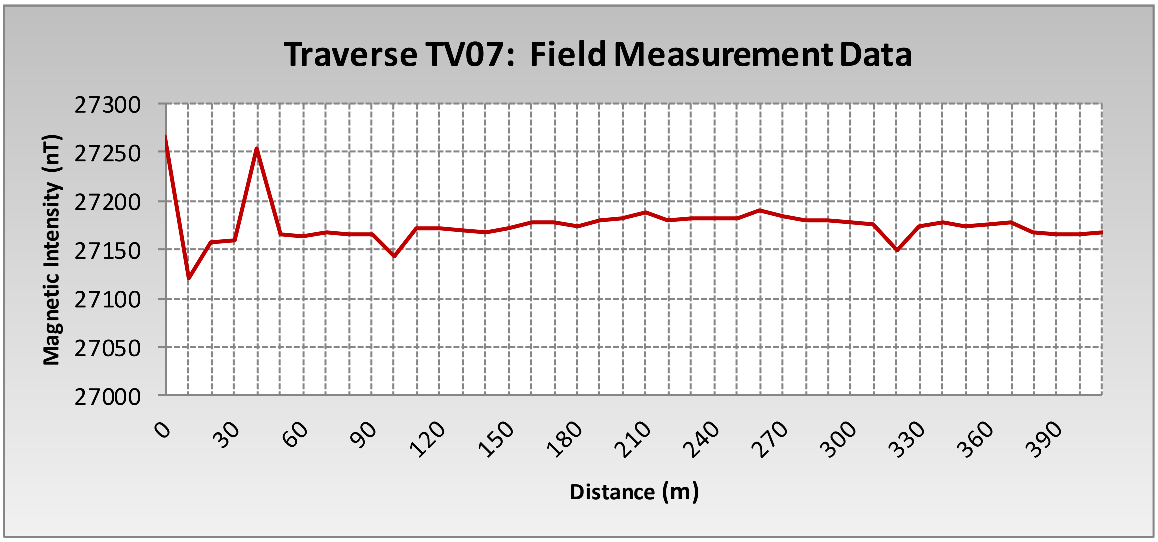
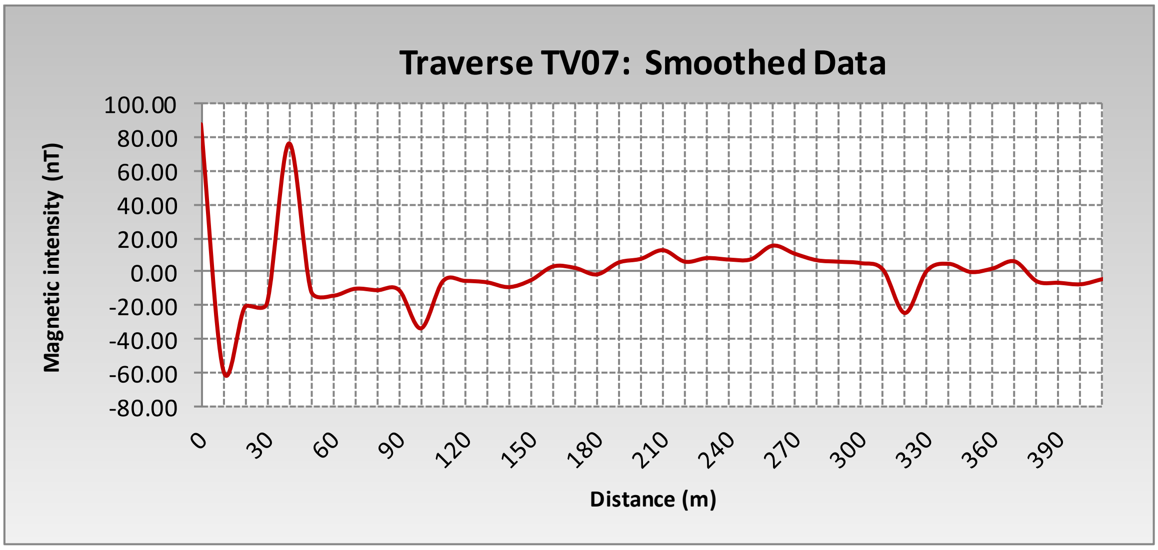
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV07
Project Number:		**Profile Direction:**	South-East to North-west
Survey Area:	West of MD12	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 20. Traverse TV07

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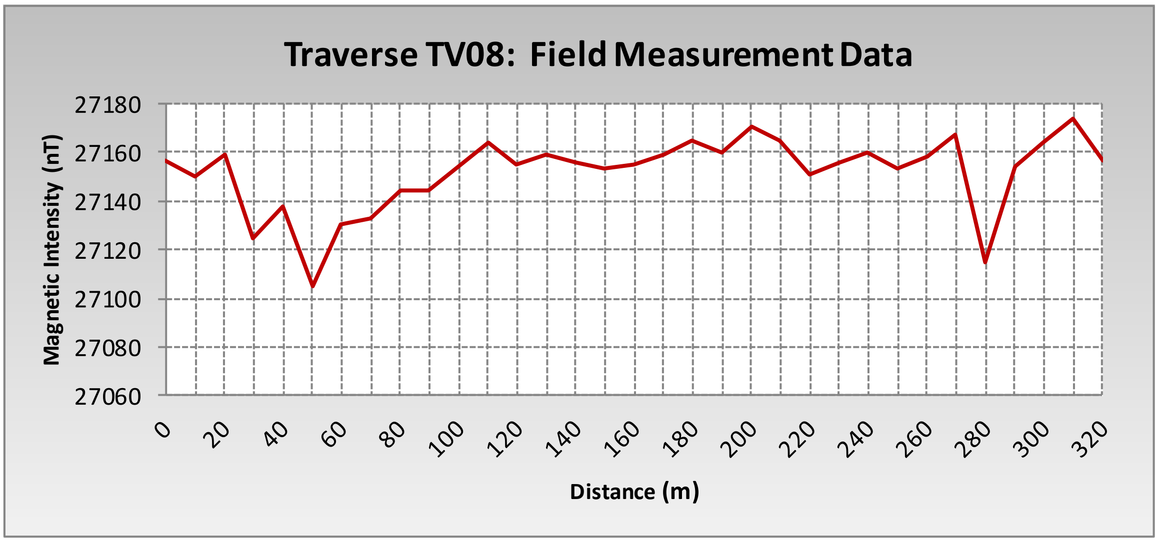
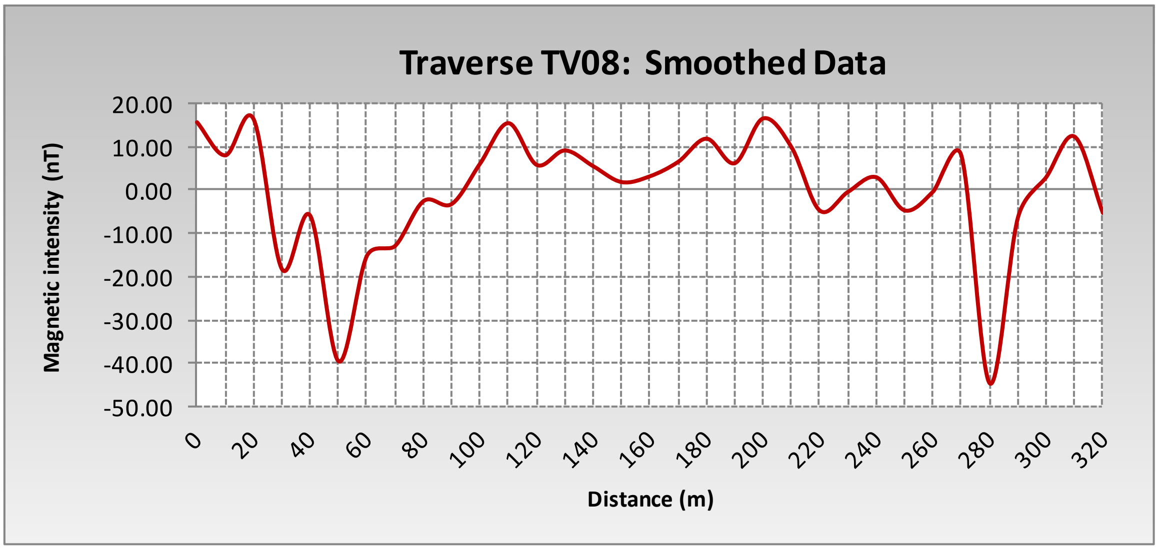
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV08
Project Number:		**Profile Direction:**	North-west to South-east
Survey Area:	West of MD12	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 21. Traverse TV08

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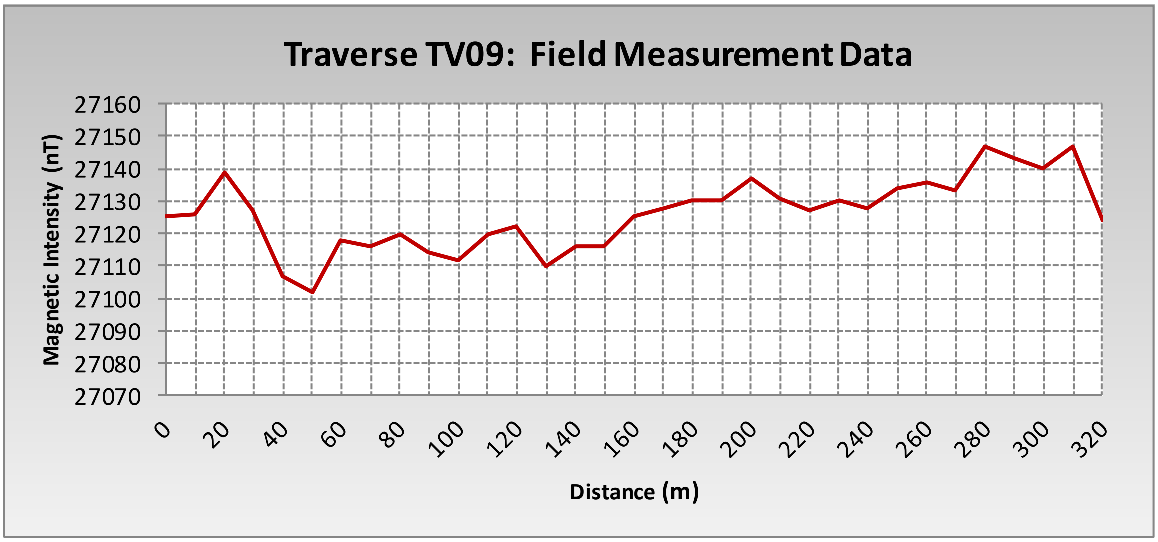
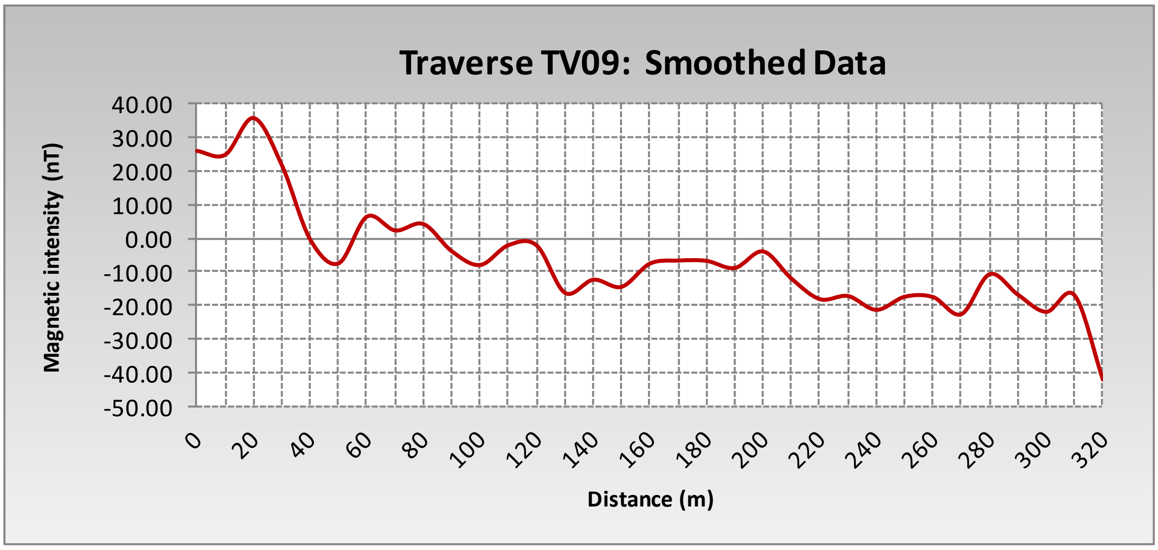
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV09
Project Number:		**Profile Direction:**	North-west to South-east
Survey Area:	West of MD12	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 22. Traverse TV09

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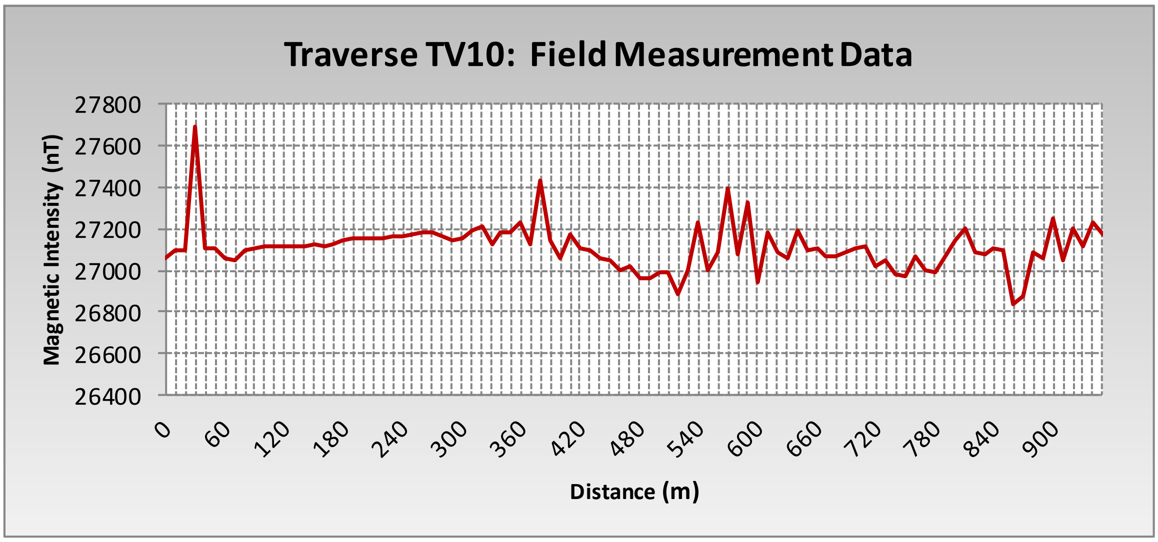
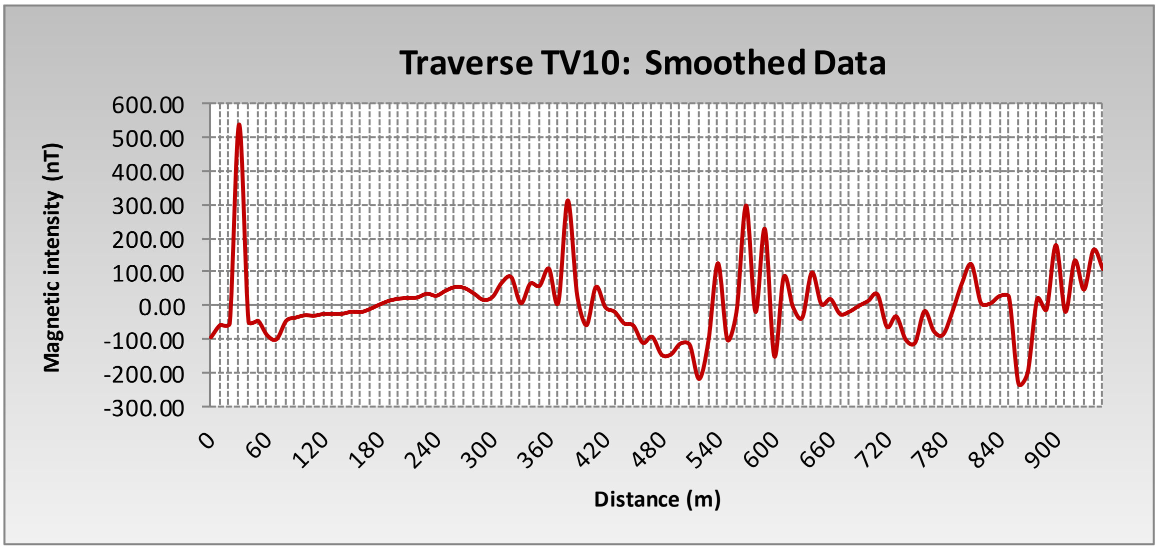
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV10
Project Number:		**Profile Direction:**	South to North, turning North-west
Survey Area:	East of Jagersfontein RE/14 Tailings	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 23. Traverse TV10

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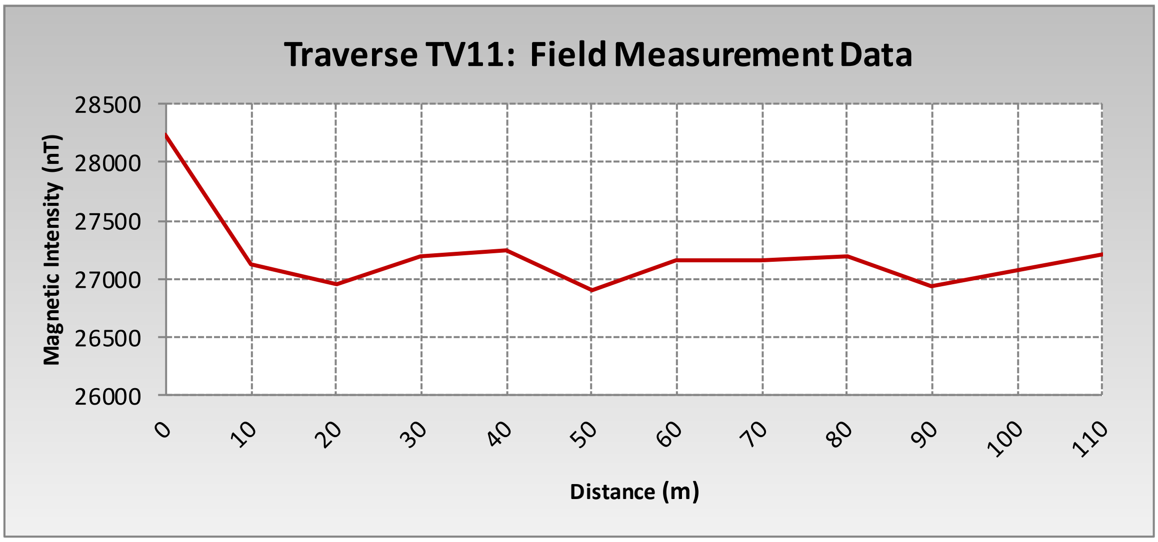
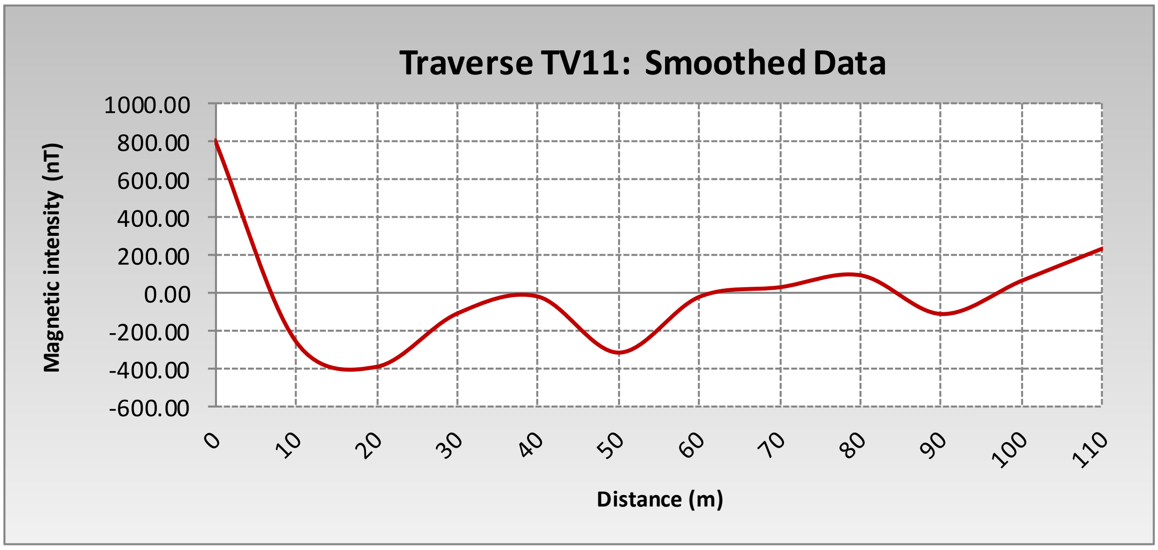
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV11
Project Number:		**Profile Direction:**	North-east to south-west
Survey Area:	East of Jagersfontein RE/14 Tailings	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 24. Traverse TV11

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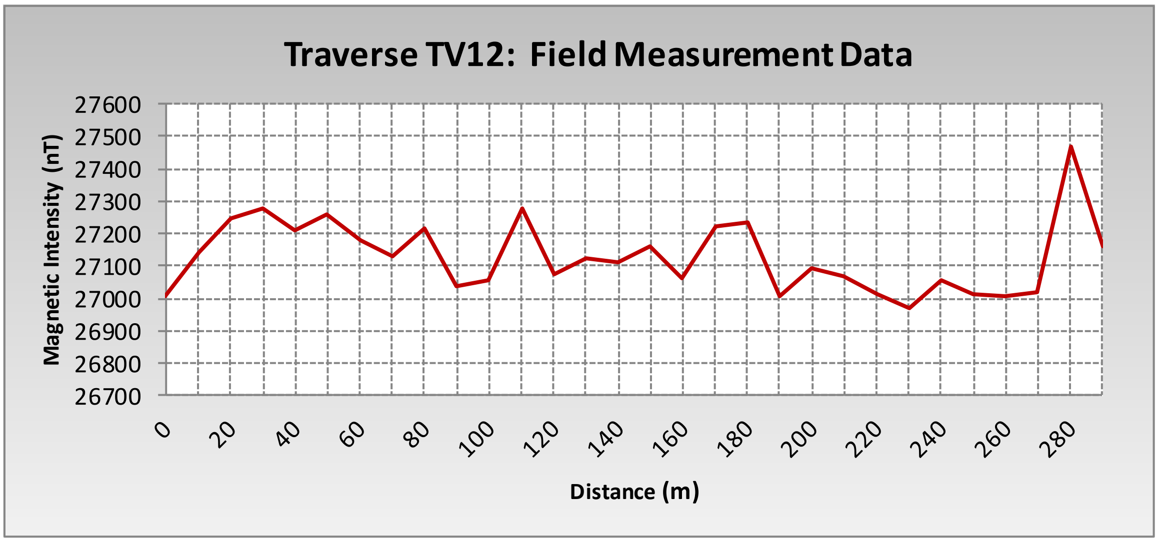
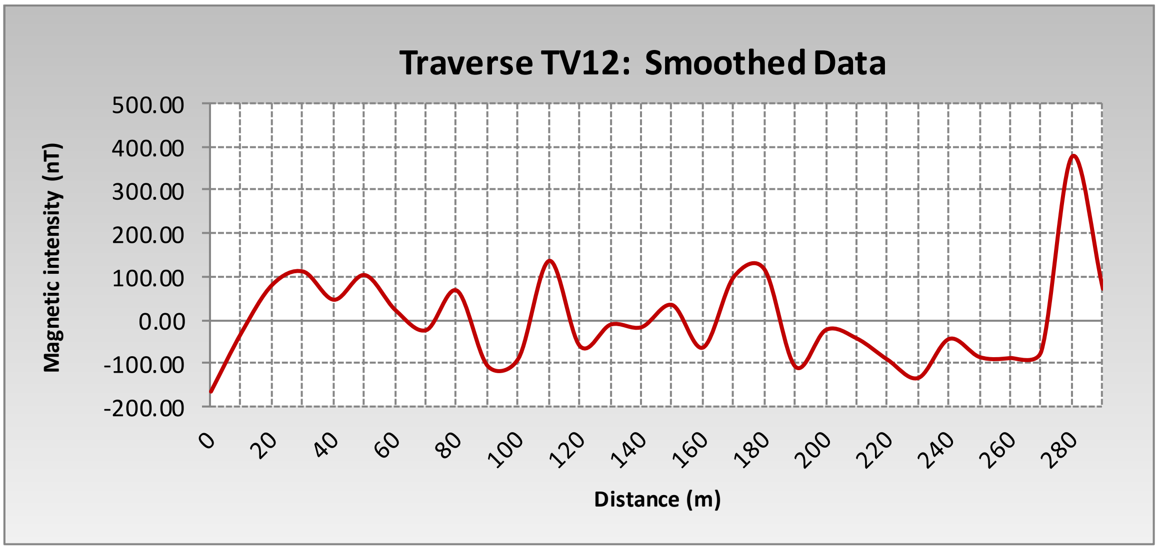
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	TV12
Project Number:		**Profile Direction:**	East to West
Survey Area:	East of Jagersfontein RE/14 Tailings	**Station Spacing:**	10 M
Date of Survey:		**Operator:**	

Figure 25. Traverse TV12

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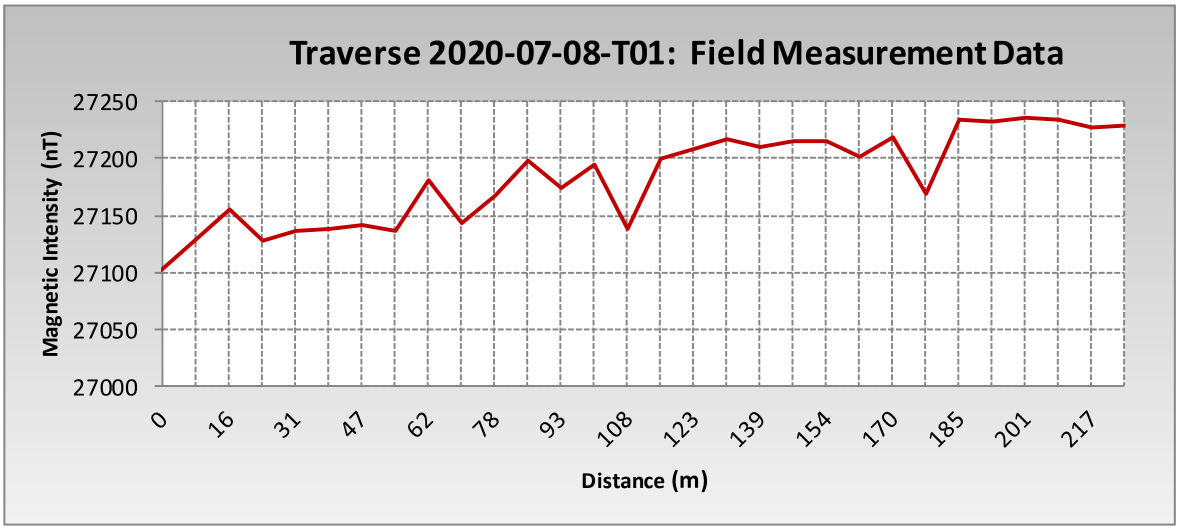
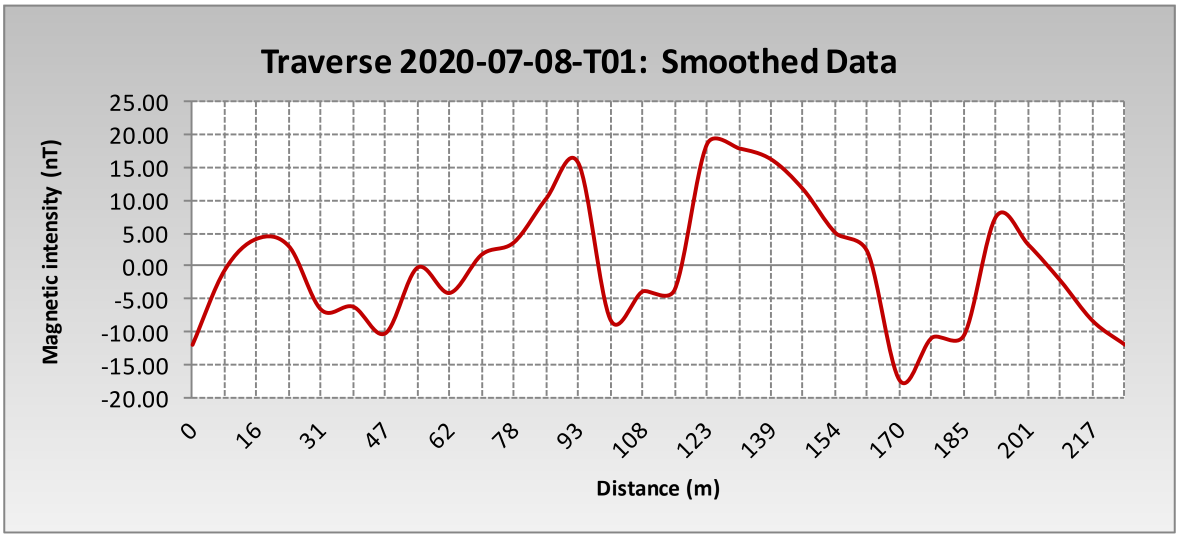
MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	Traverse 2020-07-08-T01
Project Number:		**Profile Direction:**	South to North
Survey Area:	JDT East of Slimes Dam	**Average Station Spacing:**	8 M
Date of Survey:	08-Jul-20	**Operator:**	Shaun Staats

Figure 26. Traverse T01

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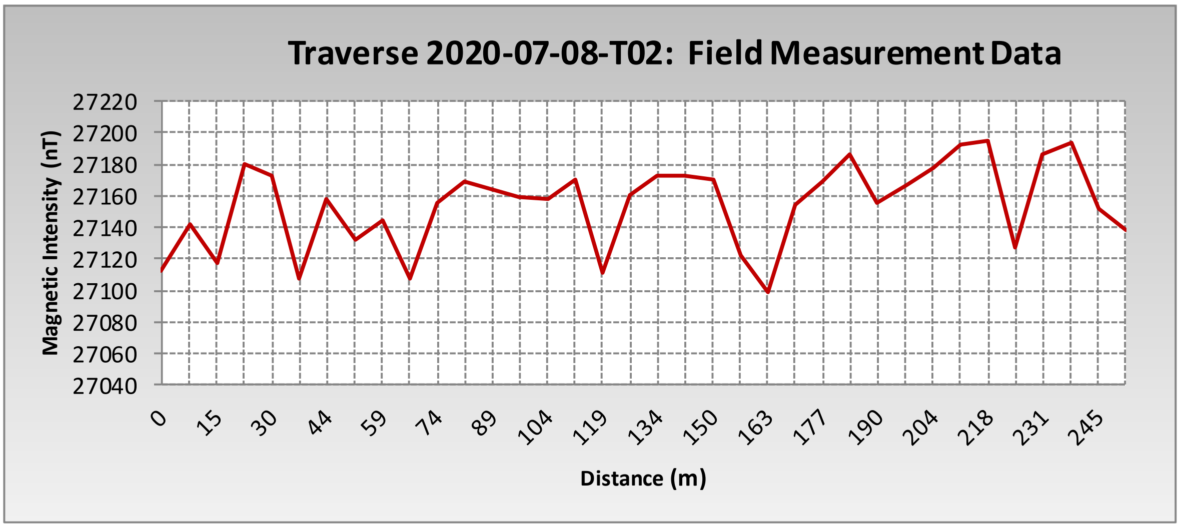
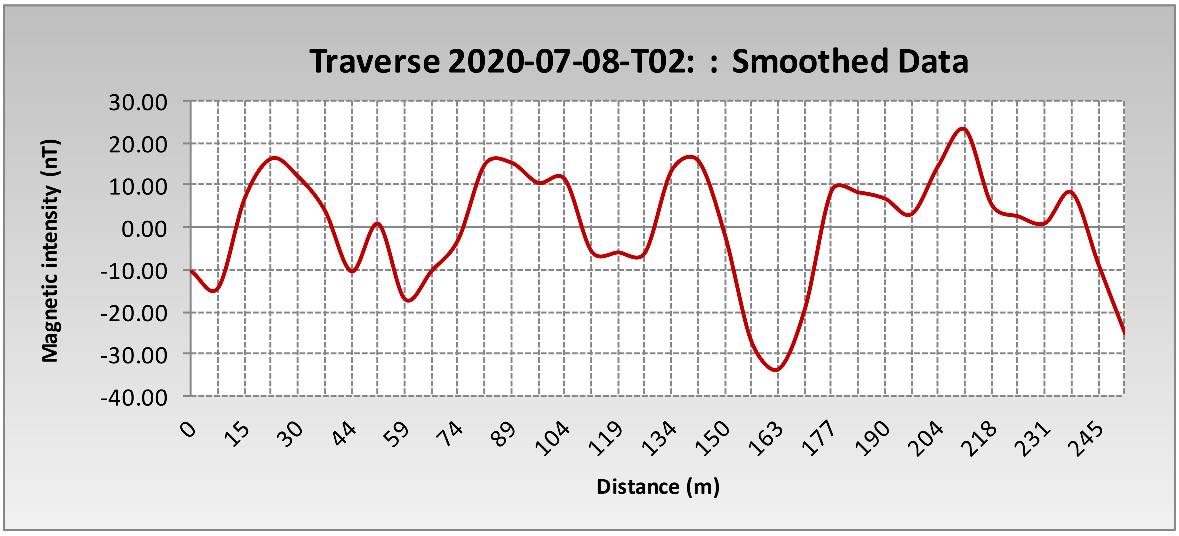
MAGNETIC PROFILES

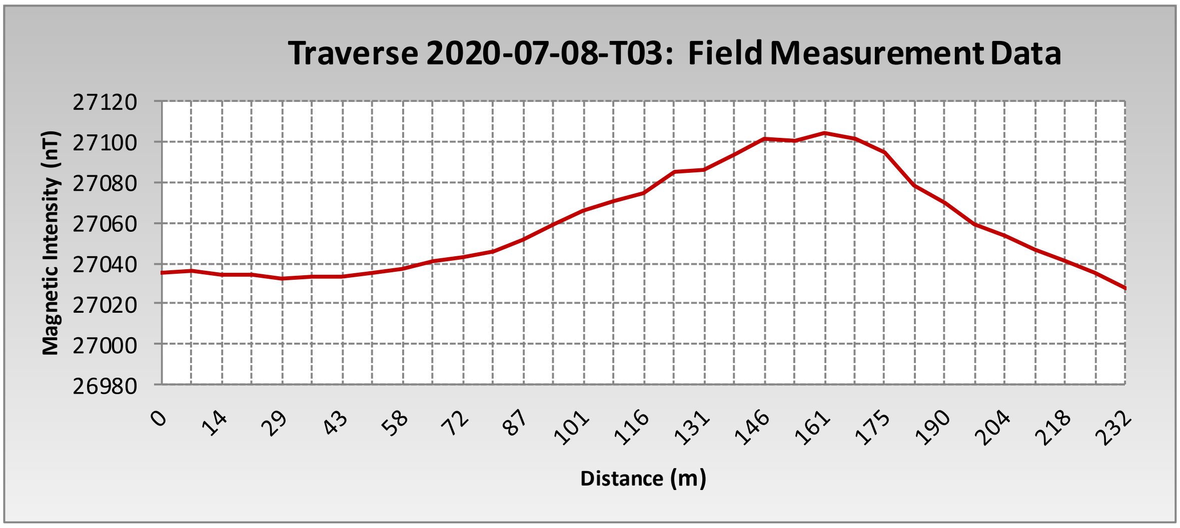


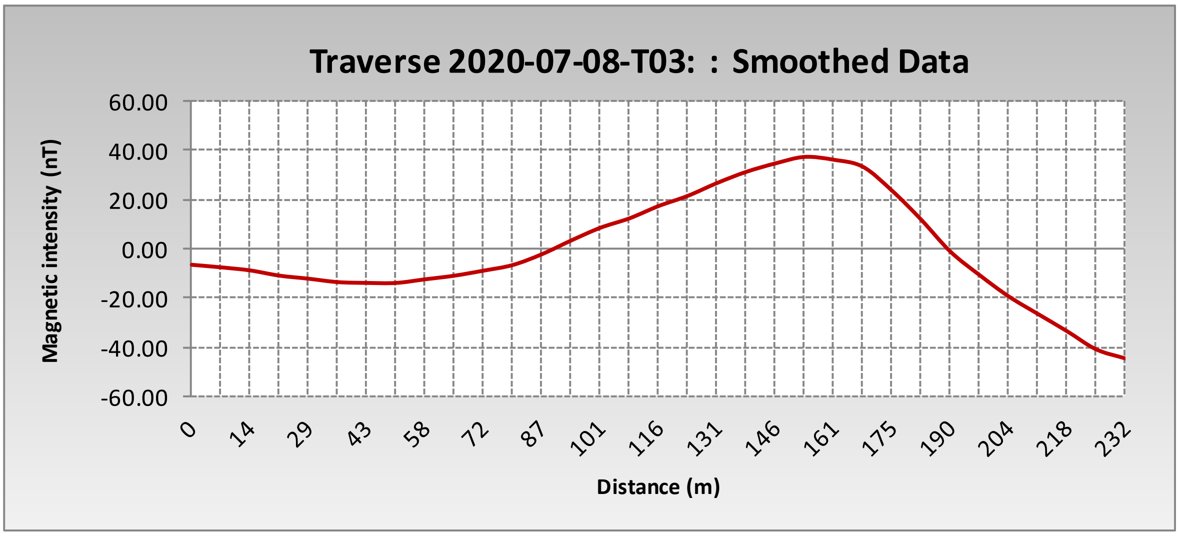


Project:	Geophysical Survey	**Profile Number:**	Traverse 2020-07-08-T02
Project Number:		**Profile Direction:**	South to North
Survey Area:	JDT East of Slimes Dam	**Average Station Spacing:**	8 m
Date of Survey:	08-Jul-20	**Operator:**	Shaun Staats

Figure 27. Traverse T02

MAGNETIC PROFILES



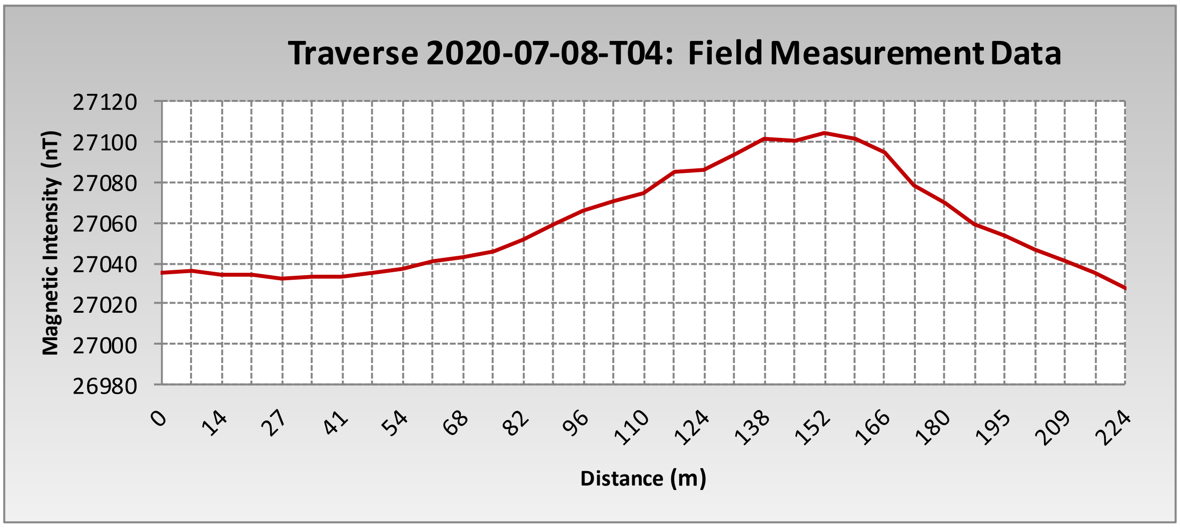


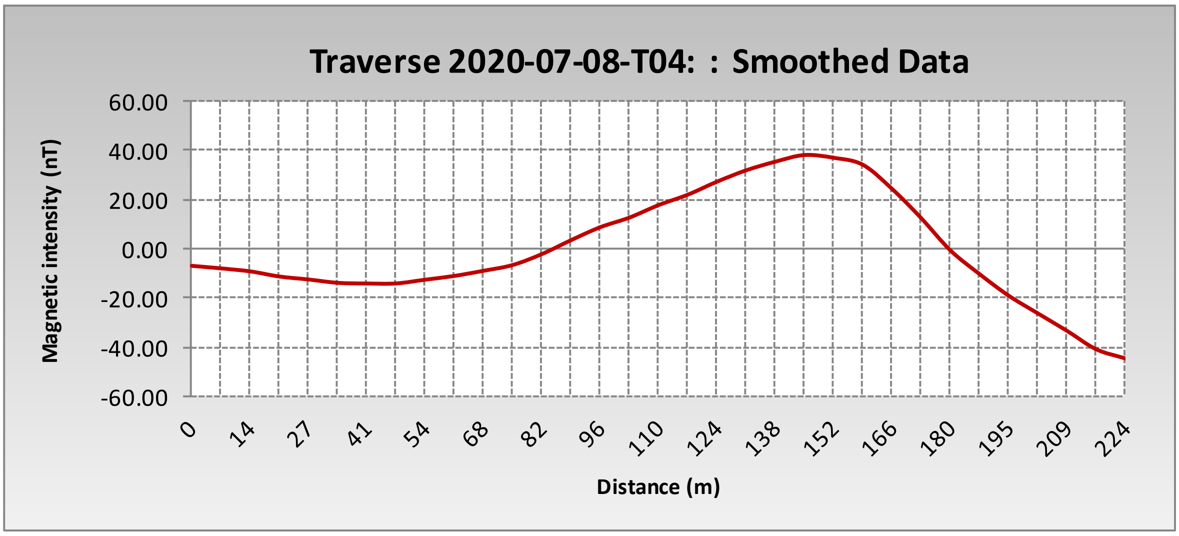
Project:	Geophysical Survey	**Profile Number:**	Traverse 2020-07-08-T03
Project Number:		**Profile Direction:**	South to North
Survey Area:	JDT East of Slimes Dam	**Average Station Spacing:**	7 m
Date of Survey:	08-Jul-20	**Operator:**	Shaun Staats

Figure 28. Traverse T03

CONSULTING SCIENTISTS

MAGNETIC PROFILES





Project:	Geophysical Survey	**Profile Number:**	Traverse 2020-07-08-T04
Project Number:		**Profile Direction:**	East to West
Survey Area:	JDT South of Slimes Dam and East of	**Average Station Spacing:**	7 m
Date of Survey:	08-Jul-20	**Operator:**	Shaun Staats

Figure 29. Traverse T04

3.2.3 Electrical Resistivity Tomography (ERT)

The purpose of the ERT survey was to detect and delineate resistivity changes in the subsurface in the vicinity of the slimes dam, and to relate such changes to the geological and geohydrological conditions at the site. An overview of the field investigation with a summary is given in this section. A description of this method and report can be studied in detail in Annexure B.

3.2.3.1 Field Investigations – Geological Mapping

Surface geological mapping was conducted by a qualified staff member of Jagersfontein Development (Mr J Swanepoel) on the eastern and south-eastern side of the TSF within the direct surface drainage from the TSF as indicated in Figure 30. This revealed a possible contact zone between dolerite outcrops in the north and sedimentary formations in the south to be further investigated by utilising magnetic and ERT surveys.

3.2.3.2 Field Investigations – Magnetic Surveys

The positions of three magnetic traverses that were conducted are indicted in Figure 31 with profile graphs in Figure 33.

“The magnetic data in the southern parts of the traverses are smoothly varying and display low variability, as is typical for measurements on Karoo sedimentary rocks. By contrast, in the northern parts of the traverses, the magnetic data are more erratic and display prominent anomalies with both positive and negative polarities. This high variability in the magnetic data is typical for measurement recorded on a dolerite sill.

A contour map of the total magnetic field intensity (TFI) is provided in Figure 32. The positions of ERT Profiles 01 and 02, as well as the positions of the dolerite (red), siltstone (yellow) and shale (green) outcrops are also shown. From the contour map it is evident that the dolerite sill that occurs in the northern parts of the survey area is associated with large magnetic variability characterised by both positive and negative anomalies. Much less variability is observed in the southern parts of the survey area where outcrops of sedimentary rocks occur.”

Figure 30. Rock outcrops of and exposed rock surfaces of dolerite (red), siltstone (yellow), and shale (green) at Jagersfontein Development. (Figure from attached Annexure B

Figure 31. Positions and orientations of the ERT profiles (red) and magnetic traverses (light blue) at the slimes dam at Jagersfontein Development. (Figure from attached report in Annexure B)

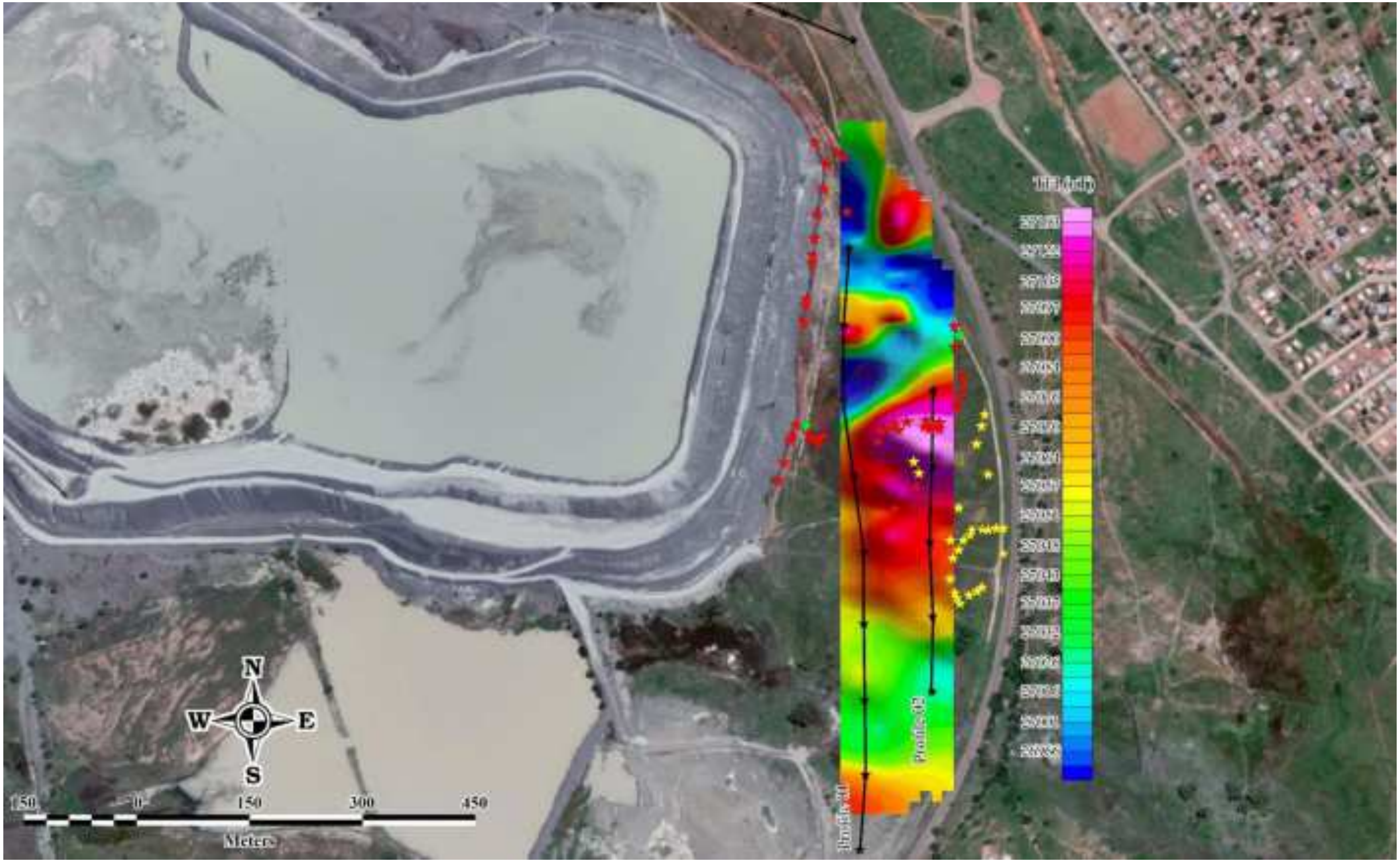


Figure 32. Contour map of the total magnetic field intensity (TFI) recorded at the slimes dam at Jagersfontein Diamond Min Annexure B)

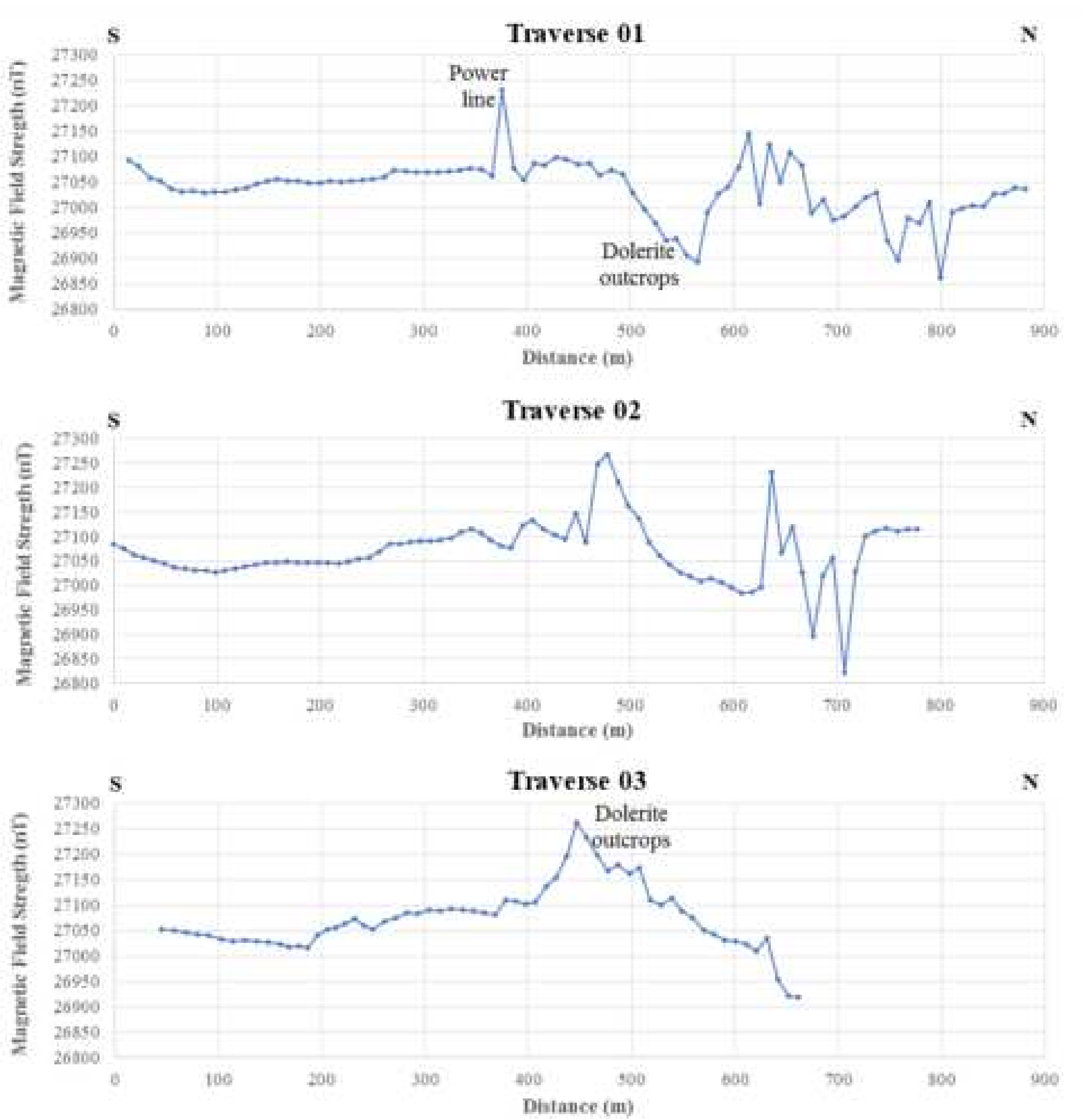


Figure 33. Magnetic data recoded along Traverse 01 to 03. (Figure from attached report in Annexure B)

3.2.3.3 Field Investigations – ERT Surveys

A set of two-dimensional ERT surveys (see Figure 31) were conducted by a qualified geophysics Dr FD Fourie with the following results:

"The inverse resistivity models obtained along the three profiles are shown in Figure 34. The inverse model of Profile 01 displays a zone of moderately high resistivities (~5000 Ωm) in the southern parts of the profile. This zone may represent the unweathered siltstone thought to occur in this area. Farther to the north, a body of high resistivities (>10 000 Ωm) is seen. This body occurs in the area where dolerite outcrops are observed and where large variability in the magnetic field occurs, and in all likelihood represents a dolerite sill. Farther to the north, near the end of the profile, the resistivity of the dolerite appears to decrease. The reason for this decrease is unknown.

The most prominent feature of the inverse resistivity model along Profile 01 is the vertical zone of low resistivities that separate the siltstone from the dolerite. This anomaly may be due to prominent contact zone between the lower dolerite and upper siltstone and might form a preferential pathway for groundwater migration and contaminant transport.

The resistivity model along Profile 02 shows a broad zone of high resistivities in the southern parts of the profile. Since dolerite outcrops are absent in this area, this high-resistivity zone is likely due to the siltstones known to occur near the southern parts of the profile. The high resistivities may indicate that the siltstones are massive and largely unweathered in this area. Farther to the north, near station 320, a localised zone of reduced resistivities is observed. As on Profile 01, this zone occurs near the contact between the siltstones and dolerites and could again be due to the contact between the different lithologies.

The resistivity model along Profile 03 generally indicates lower resistivities than along the two profiles east of the slimes dam. This profile occurs entirely on dolerite and it is currently not known why the dolerite is associated with lower resistivities in this part of the survey area. An apparent zone of deeper weathering may be identified from the resistivity model.

The results of the magnetic and ERT surveys revealed the presence of large magnetic and resistivity contrasts in the subsurface. These contrasts were interpreted in terms of the known local geological conditions. Possible geological structures (contacts, faults, weathered zones) were also identified from the results of the surveys. To confirm the interpretation of the geophysical data, it is recommended that investigative boreholes be drilled at suitable locations. These boreholes could also serve as monitoring boreholes during future monitoring events. The proposed drilling positions are indicated in Figure 35."

These anomalies have been investigated by percussion drilling. Four boreholes were drilled east of the TSF (Profile 01 and 02) and the contact zone between the upper fine-grained sandstone with the lower dolerite sill was confirmed. One borehole was drilled on the north-eastern corner of the TSF (profile 03) and verified the anomaly to be some local weathering. It can therefore be confirmed that **no fault zones or lineaments were detected.**

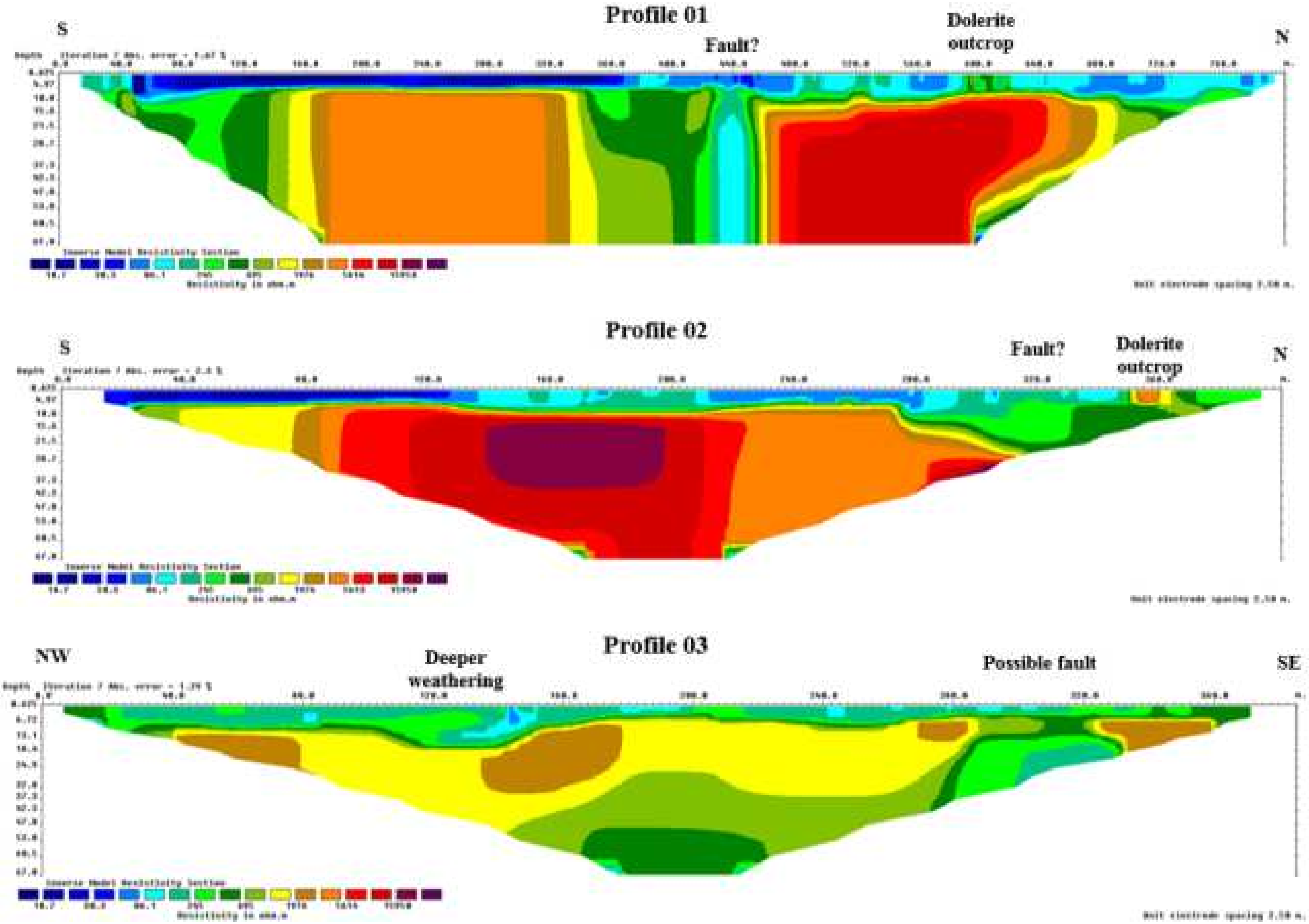


Figure 34. Inverse resistivity models along Profiles 01 to 03 (figure from attached report in Annexure B)

Figure 35. Positions of the proposed investigative and monitoring boreholes. (figure from attached report in Annexure B)

3.3 Detail Local Geology

An extensive, detailed geological investigation was conducted in August 2021 (by a professional structural geologist Prof Wayne Colliston) covering the surrounding aera of the TSF, extending to the east and south-east. The historical geological logs as well as the new information obtained through additional borehole drilling and field investigations were used in this investigation. Seven additional boreholes were drilled during this investigation as can be seen in Figure 36. These boreholes are H103, H104, H105, H106 (to the east of the TSF), H107 on the north-easter corner of the TS, H108 south-west of old dump MD8 and borehole H109 just south of the tailings dump MTD. All the available geological borehole logs are attached in ANNEXURE A.

This detailed geological investigation report is included as insert in full within this chapter. The refinement of the geological map as derived from this specialist investigation can be seen in Figure 37 and Figure 38 at the end of the insert.

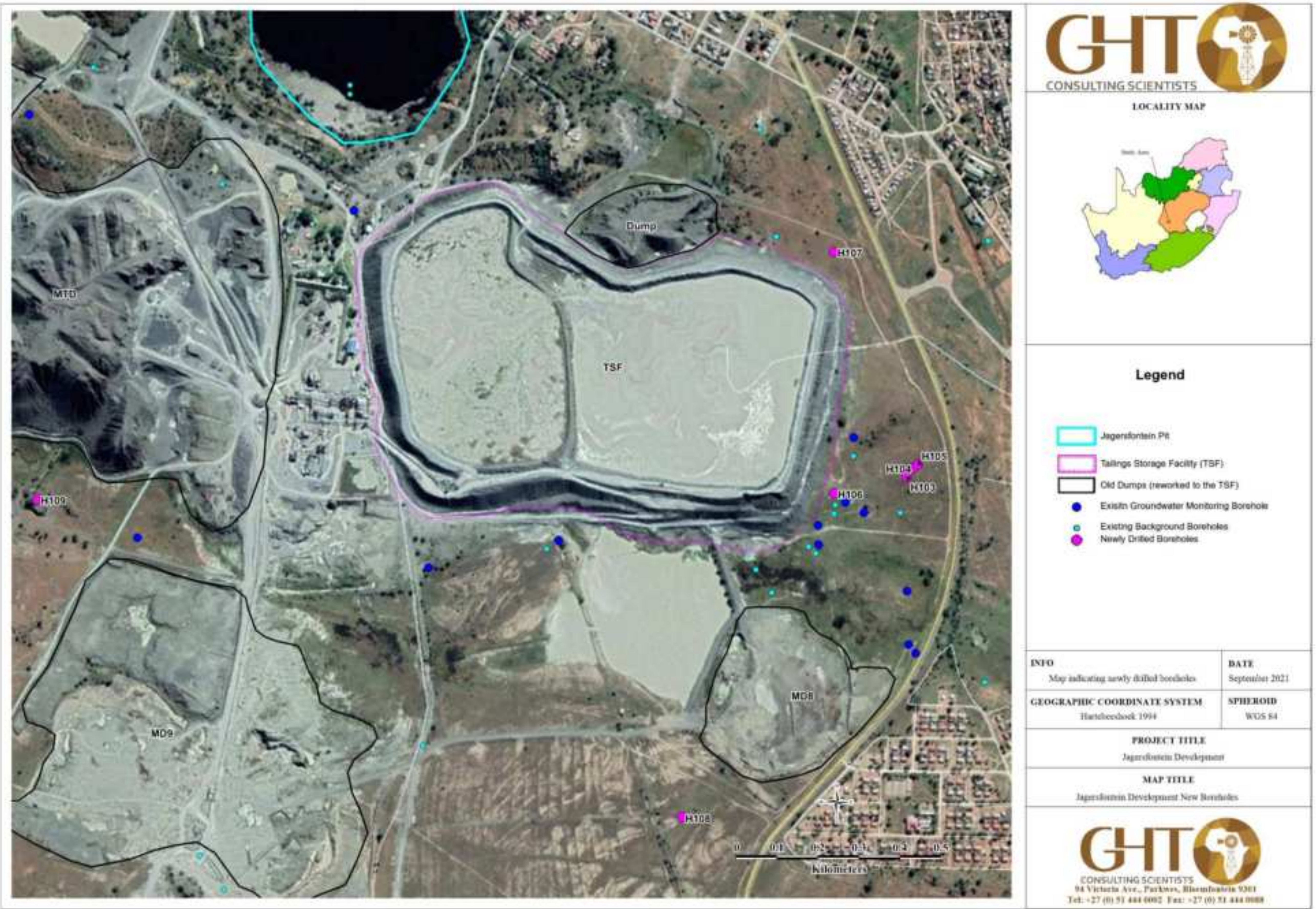


Figure 36. Newly drilled boreholes.

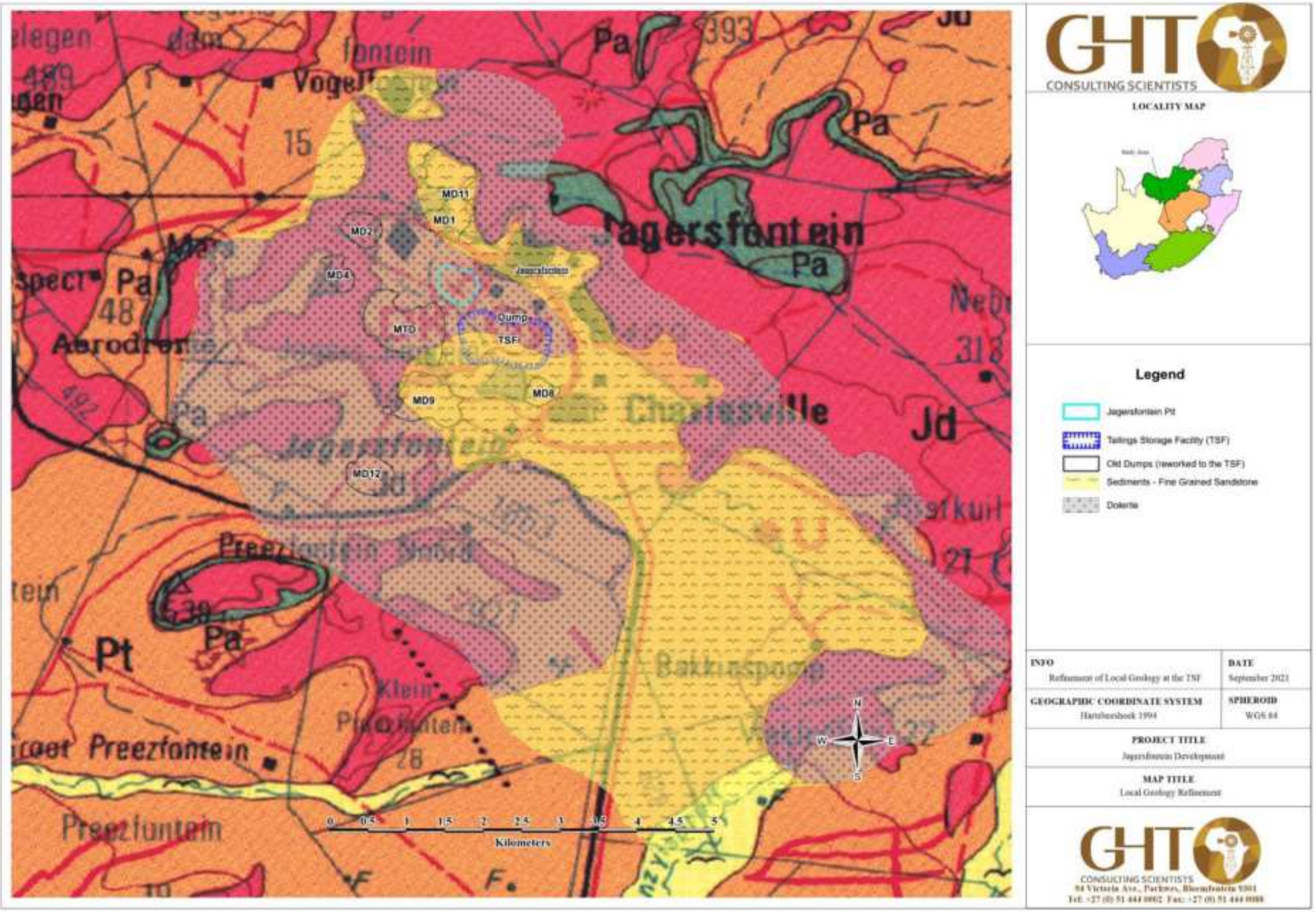


Figure 37. Refined local geological map with geological background map from the Council of Geoscience

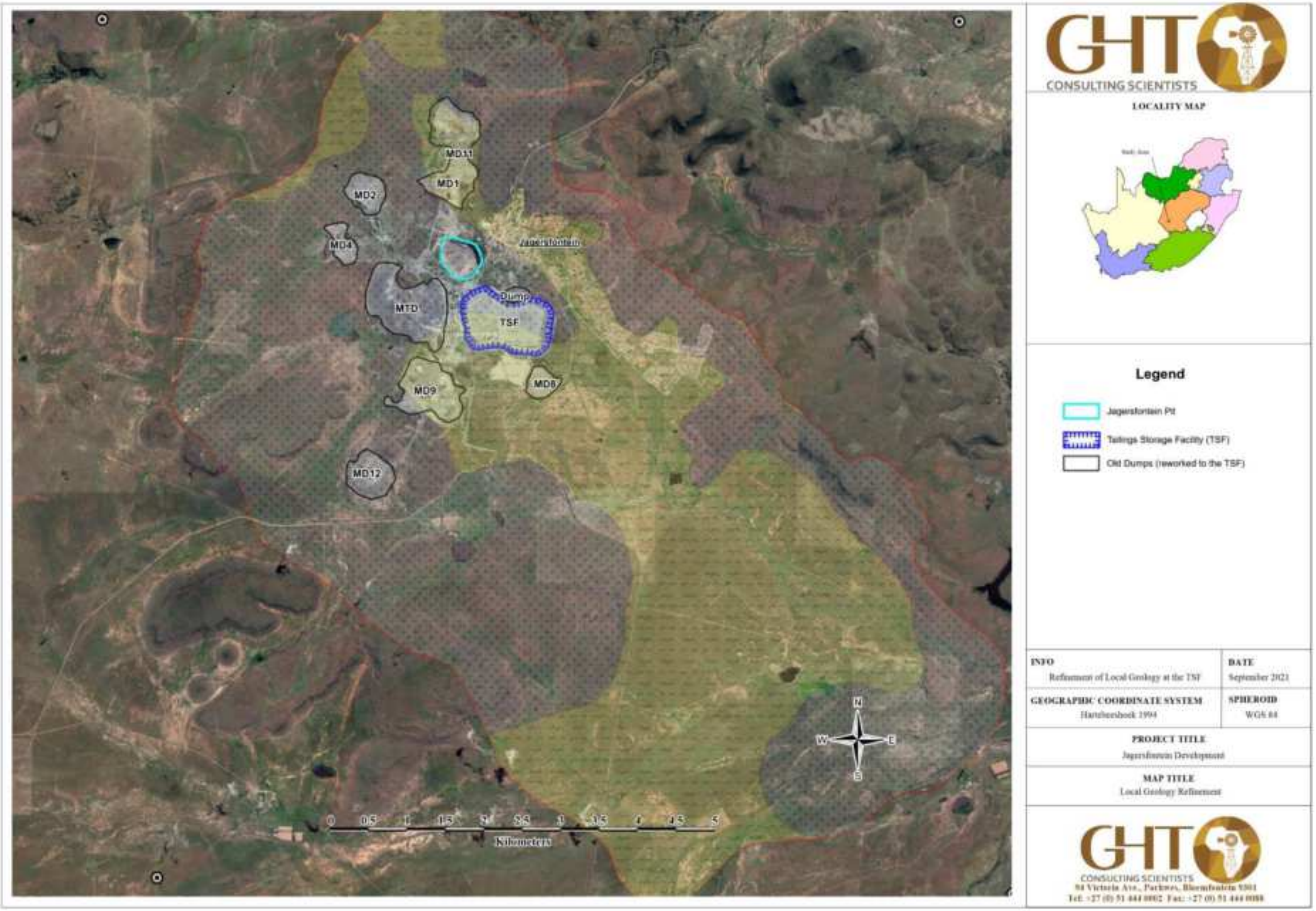


Figure 38. Derived local geological map background from Google Earth.

4 GEOHYDROLOGY AND AQUIFER CLASSIFICATION

This section contains a general description of the geohydrology, and aquifer classification in the local region of the TSF.

In order to classify the aquifer around the Jagersfontein TSF, focus was laid on the following parameters:

- What is an aquifer?
- Type of aquifers in South Africa
- Classification of South African Aquifers; and
- Aquifers in the region of the Jagersfontein TSF

4.1 Definition of an aquifer

Different rock types can be classified as aquifers or non-aquifers depending primarily on their permeability, but also on the amount of water that is required. An aquifer is any geological unit that can transmit water at a rate that is sufficient to supply a well – although in some cases that may be a very low-flow well. For some purposes, such as for domestic use, the production could be sufficient with permeability as low as 10^{-5} cm/s, while for others it might have to be much higher. As noted by Fetter, an aquifer may consist of unconsolidated sand or gravel, sandstone, carbonates, basalt or strongly fractured granite or metamorphic rock.

Non-aquifers are generally referred to as: confining layers, aquitards, aquicludes and aquifuges. They might include clay deposits or mudstone, or unfractured igneous or metamorphic rock. Confining layers that are relatively permeable are known as leaky confining layers.

4.2 South African Aquifers

The DWS developed aquifer regions to classify South African aquifers. South African aquifers consist of four main aquifer regions namely:

4.2.1 Intergranular Aquifers:

- These aquifers are generally unconsolidated but occasionally consolidated. In unconsolidated sediments (silts, sands and gravels) groundwater is stored in the pore spaces between loose grains of sediment. These aquifers can often provide very reliable supplies where there is a reasonable thickness of saturated sediment present. In some places, the aquifer may be perched above a clay layer which is not extensive enough to provide enough storage for a good supply.
- Groundwater within interstices in porous medium and in basal conglomerate;
- Moderate areal extent;
- Examples include Tertiary-Quaternary coastal deposits and alluvial deposits along river terraces.

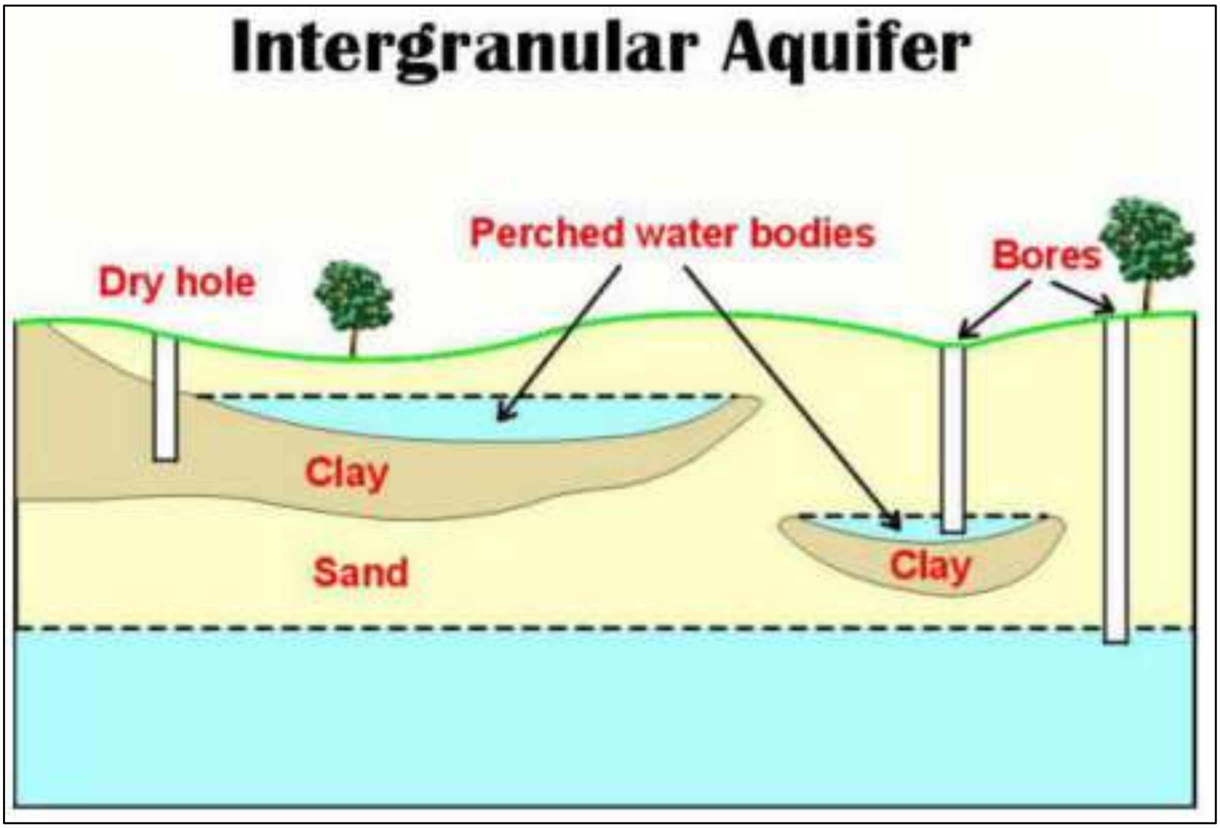


Figure 39. Example of an Intergranular aquifer.

4.2.2 Fractured Aquifers:

- In fractured rock aquifers, groundwater is stored in the fractures, joints, bedding planes and cavities of the rock mass. Fissured and fractured bedrock resulting from decompression and/or tectonic action. Water availability. is largely dependent on the nature of the fractures and their interconnection.
- Extensive in area.
- Examples include sedimentary and metamorphic rocks within limited overlying unsaturated residual weathered products.

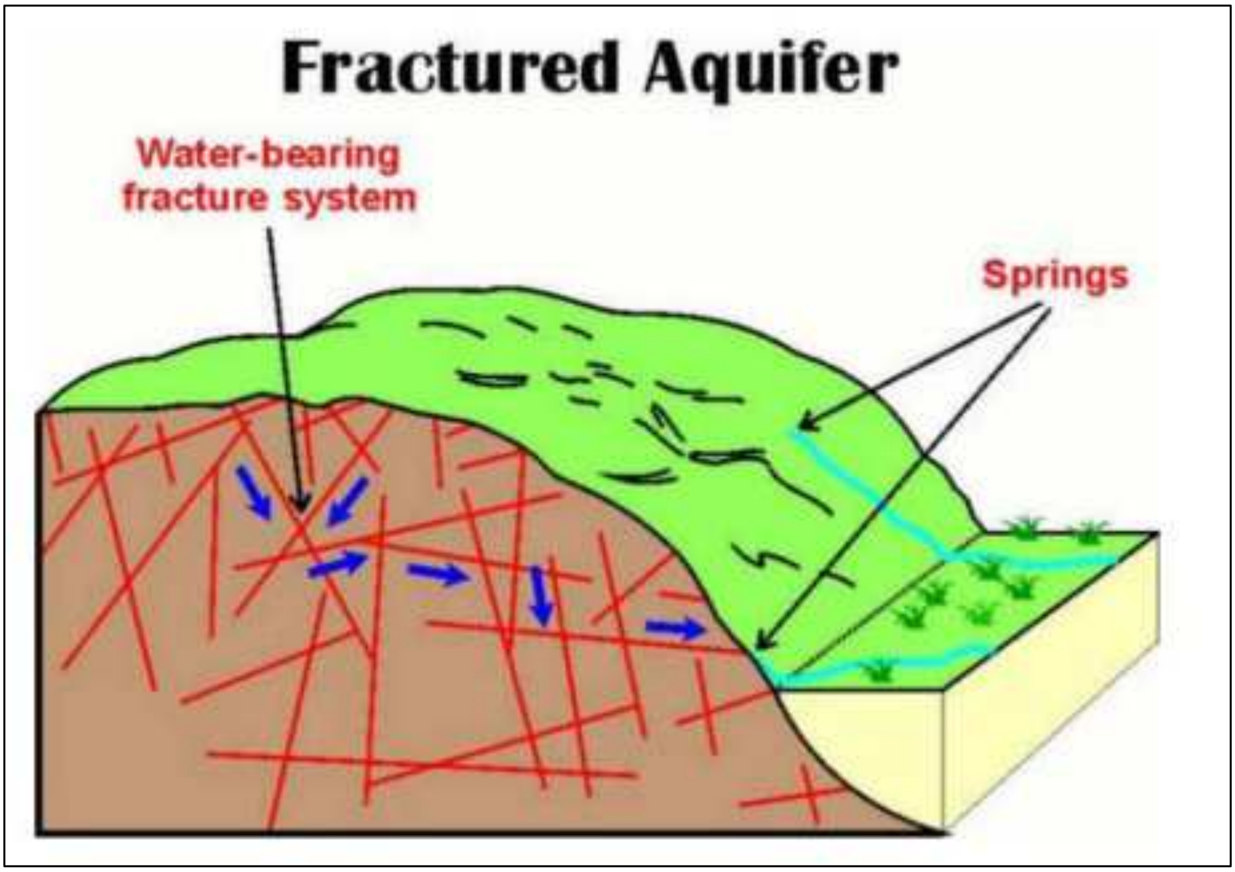


Figure 40. Example of a fractured aquifer.

4.2.3 Karstic Aquifer:

- Karst aquifers are related to soluble rocks (Limestone, dolomite, gypsum, anhydride and salt formation) where voids, caverns, open fractures and even caves have been formed under the effect of aggressive groundwater. Karst aquifers are formed in places where rocks, subjected to dissolving or leaching, are formed, porous and fissured enough to provide active movement of surface and groundwater through them aggressively, i.e. able to dissolve rocks.
- Very limited in areal extent

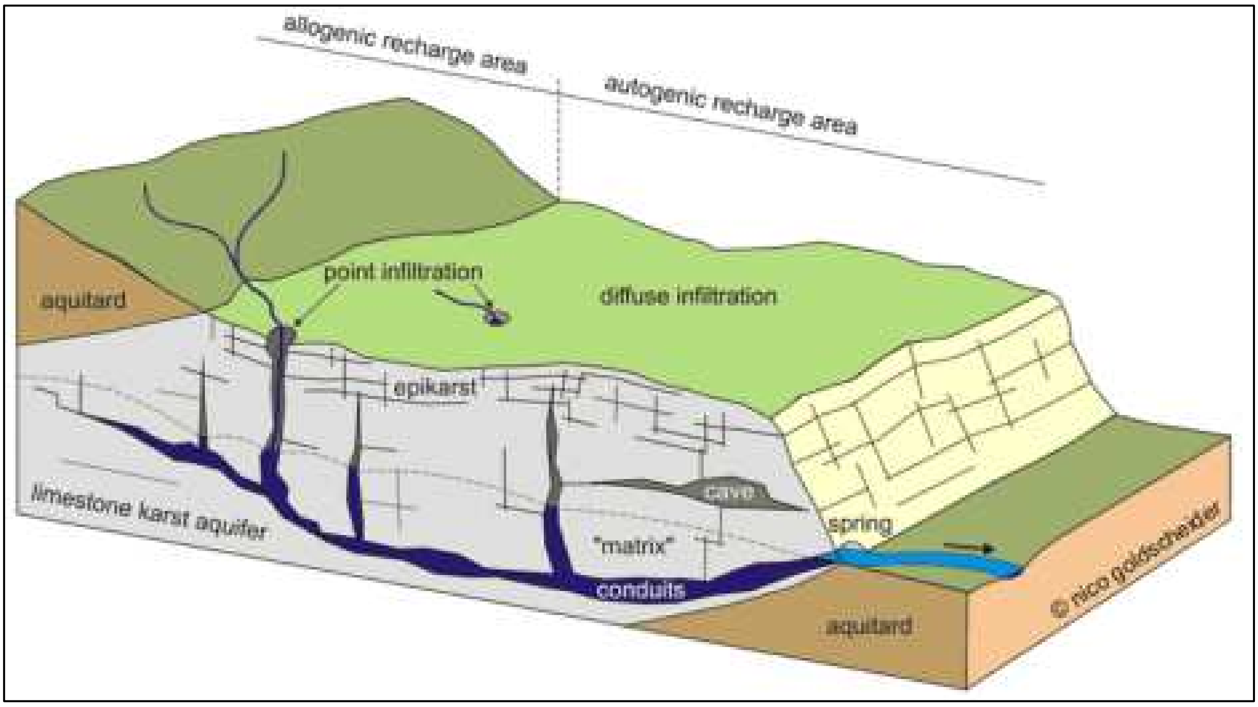


Figure 41. Example of a karstic aquifer.

4.2.4 Intergranular and Fractured Aquifers

- These aquifers largely include medium to coarse grained granite, weathered to varying thicknesses, with groundwater contained in intergranular interstices in the saturated zone and in jointed and occasional fractured bedrock.
- Occurs extensively throughout South Africa but its characteristics varies in space and time.

Most South African aquifers occur in fractured rock ranging in age from earliest Pre- Cambrian to Jurassic. Aquifers consisting of recent to Tertiary formations are restricted to coastal dune belts and unconsolidated deposits associated with rivers and Aeolian sands.

4.3 Classification of South African Aquifers, Susceptibility and Vulnerability

In the 1990's DWS had an initiative to develop a strategy to classify aquifer in South Africa. After a literature study of classification systems used elsewhere in the world and a series of Scoping Workshops to define the desired features and characteristics, a classification was developed and presented to a Technical Workshop for discussion and finalisation (Parsons, 1995).

The original South African aquifer system management classification developed (Figure 1) was based on the British Geological Survey aquifer vulnerability classification (NRA, 1992).

The work of Vegter (1995) was used as the basis for classifying geohydrological units as major, minor and poor groundwater regions. The terminology used differed slightly from that proposed by Parsons (1995) in order to accommodate the concepts used in developing the national groundwater maps. Refer to Table 1 for the Aquifer system management classifications and Definitions done by WRC (Report No KV 116/98). Important to note: The term poor aquifer system replaced that of non-aquifer system.

An Aquifer Vulnerability Map was compiled for DWS in 1999 by the CSIR and recompiled in 2012. Refer to Figure 42 for a representation of the aquifer classification map of South Africa.

This map indicates the aquifer classification system of South Africa. Blue presents the major aquifer region which is a high-yielding system of good water quality. Green represents the minor aquifer region which is a moderately-yielding aquifer system of variable water quality. Pink presents the poor aquifer region which is a low to negligible yielding aquifer system of moderate to poor water quality.

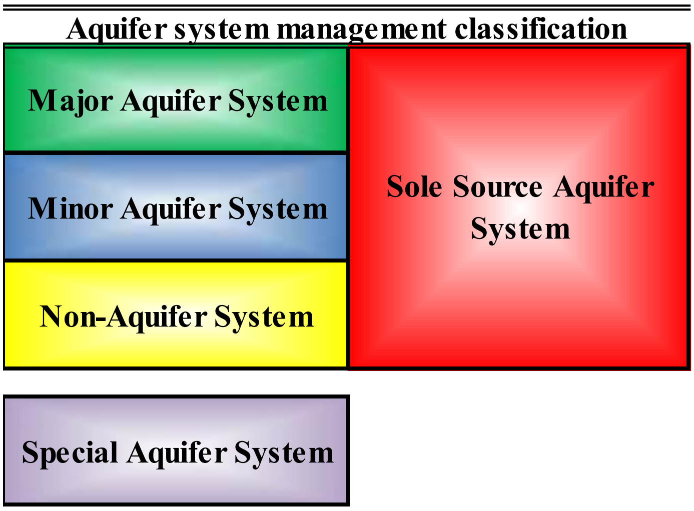
In general Exploration, development and protection of aquifers is receiving unprecedented attention as a result of the efforts of the Reconstruction and Development Programme (RDP) and the National Water Act to ensure equitable access to water for all. Groundwater is a particularly important resource for meeting water requirements in remote areas where rainfall is low and surface water resources are scarce.

Significant effort has already gone into mapping the country's groundwater resources. The national Groundwater Resources of the Republic of South Africa map produced by Vegter (1995) for the Water Research Commission (WRC), regional 1; 500 000 scale Hydrogeological maps produced by the Department of Water Affairs and Forestry (DWAF) and the national groundwater vulnerability map prepared by Reynders and Lynch (1993) are examples of this.

Simultaneously, protection of the quality of groundwater has also received greater attention. The development of a groundwater quality management strategy (Braune *et al.,*1991; DWAF, 1997) identified a differentiated protection approach as the only viable means of implementing an effective strategy with the resources available for such a task. In preparation for the adoption of such a strategy, an aquifer classification was developed (Parsons, 1995) as a means of identifying important aquifers which require priority attention. This classification has been applied to the country and a map was produced in order to provide national planners and managers with an overall perspective.

4.3.1 Aquifer Classification

Table 1. Aquifer system management classifications and Definitions. (After WRC Report No KV 116/98).



Definitions aquifer system management classes	
Sole Source Aquifer System	An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major Aquifer System	Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m).
Minor Aquifer System	These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers.
Poor Aquifer system	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.
Special Aquifer System	An aquifer designated as such by the Minister of Water Affairs, after due process.

Table 2. Modified aquifer system management classification. (*after WRC Report No KV 116/98*).

Aquifer Type	Description
Sole source aquifer	An aquifer used to supply 50% or more of urban domestic water for a given area and for which there are no reasonably available alternative sources of water.
Major aquifer region	A high-yielding aquifer system of good quality water.
Minor aquifer region	A moderately-yielding aquifer system of variable water quality.
Poor groundwater region	A low to negligible yielding aquifer system of moderate to poor water quality.
Special aquifer region	An aquifer system designated as such by the Minister of Water Affairs and Forestry, after due process.

The map indicates the aquifer classification system of South Africa. Blue represents the major aquifer region which is a high yielding system of good water quality. Green represents the minor aquifer region which is moderate yielding aquifer system of variable water quality. Pink represents the poor aquifer region which is low to negligible yielding aquifer system of moderate to poor water quality. According to this broad-based classification map (see Aquifer Classification of South Africa, 2012 in Figure 42, location of Jagersfontein indicated/enlarged), the aquifer of the area under investigation is classified as a **minor aquifer**. This means, a moderately-yielding aquifer system of variable water quality.

Water bearing aquifers in the vicinity of the Jagersfontein TSF are further distinguishable as sedimentary and fractured rock aquifers. The term fracture refers to cracks, fissures, joints and faults, which are caused by (i) geological and environmental processes, e.g. tectonic movement; secondary stresses; release fractures; shrinkage cracks; weathering; chemical action; thermal action and (ii) petrological factors like mineral composition, internal pressure, grain size, etc.

From a general hydrogeological point of view, a fractured rock mass can be considered a multi-porous medium, conceptually consisting of two major components: matrix rock blocks and fractures. Fractures serve as higher conductivity conduits for flow if the apertures are large enough, whereas the matrix blocks may be permeable or impermeable, with most of the storage usually contained within the matrix. Actually, a rock mass may contain many fractures of different scales. The permeability of the matrix blocks is in most cases of practical interest a function of the presence of micro-fractures. A rock mass which consists only of large fractures and some matrix blocks with no micro-fissures (or smaller fractures) lead to a term called purely fractured rocks. In this case, the domain takes the form of an interconnected network of fractures and the rock matrix, comprising the blocks surrounded by fractures, is impervious to flow. However, there may still be porosity. In the case where the domain is a porous medium (or a micro-scaled fractured medium) intersected by a network of interconnected fractures, the rock is termed a fractured porous rock and the domain is therefore characterized by at least two subsystems, each having a different scale of inhomogeneity (called scale effect).

Due to the scale of this general classification, it was deemed of utmost importance to conduct a detailed site investigation involving geological mapping (see section 3.3, page 46) drilling additional boreholes and performing pump tests determining aquifer parameters (section 4.4.2, page 100).

4.3.2 Aquifer Susceptibility

The aquifer susceptibility index is classed as medium vulnerability and depicted on the map in Figure 43. The map indicates the qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

According to the map of Aquifer Susceptibility Classification of South Africa, 2013, the susceptibility of the aquifer(s) of the area under investigation is classified as moderate (depicted in Figure 43 with the location of Jagersfontein indicated/enlarged).

4.3.3 Aquifer Vulnerability

The aquifer vulnerability for the study area indicates the least tendency for contamination if pollutants are discharge or leeched over the long term and is depicted on map in Figure 44. The map indicated the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Green represents the least vulnerable region that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached. Yellow presents the moderately vulnerable region, which is vulnerable to some pollutants, but only when continuously discharged or leached. Red presents the most vulnerable region, which is vulnerable to many pollutants except those strongly absorbed or readily transformed in many pollution scenarios.

According to the map of Aquifer Vulnerability Classification of South Africa, 2013, the vulnerability of the aquifer(s) of the area under investigation is classified as moderate (depicted in Figure 44 with the location of Jagersfontein indicated/enlarged). A detailed, local site vulnerability investigation was however performed to augment this in report RVN 905.2/2133.

Results from this detailed aquifer vulnerability (report RVN 905.2/2133) in the immediate vicinity of the TSF can be extended to the complete area of operations in . This study indicated that the vulnerability of the unsaturated zone can be classified as Extreme. The unsaturated zone has an extreme vulnerability due to the short distance to the aquifer, the thin permeable unsaturated zone and a very high seepage velocity flowing from the topsoil to the water table. The upper aquifer is vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface.

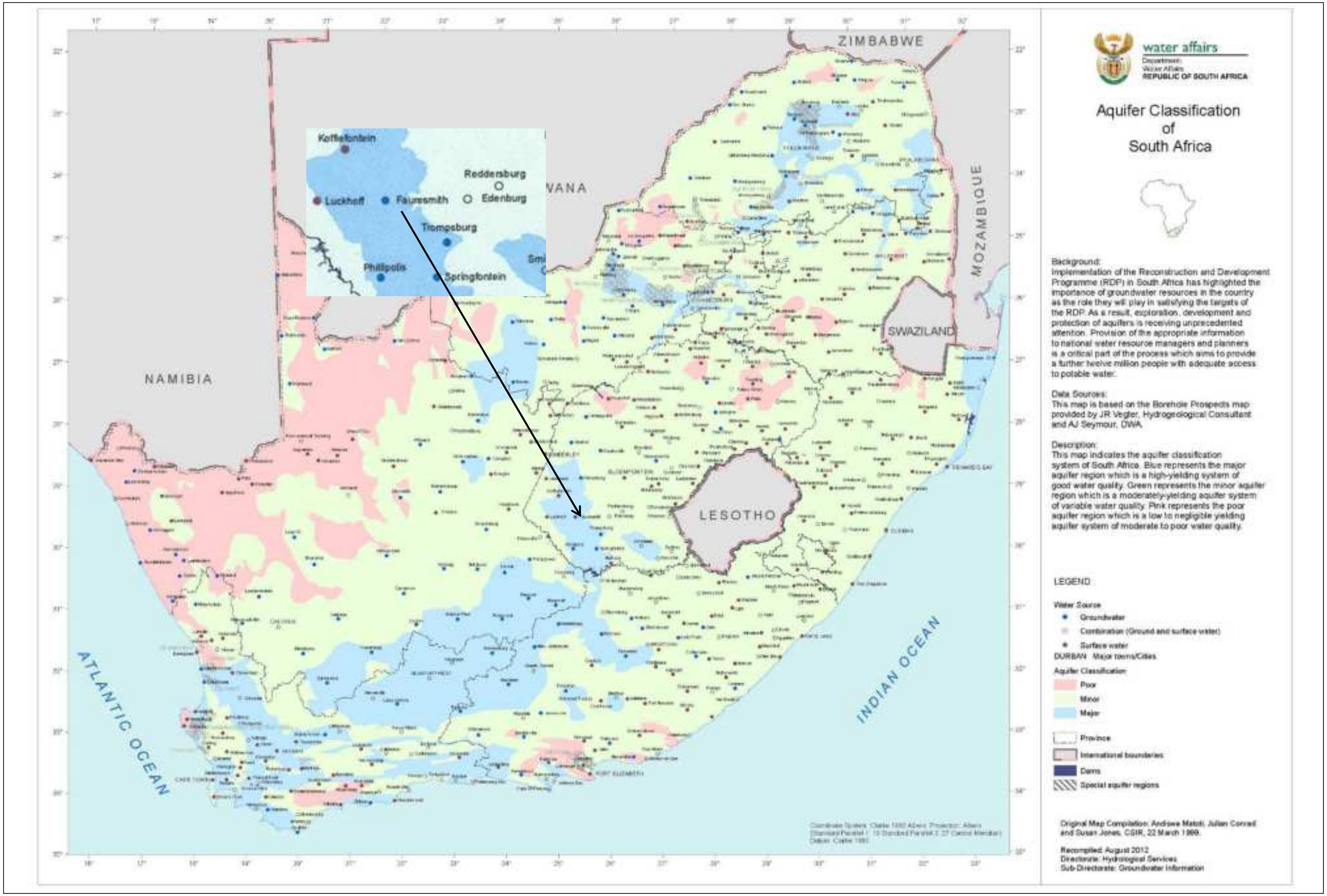


Figure 42. Aquifer classification of South Africa (DWS 2012).

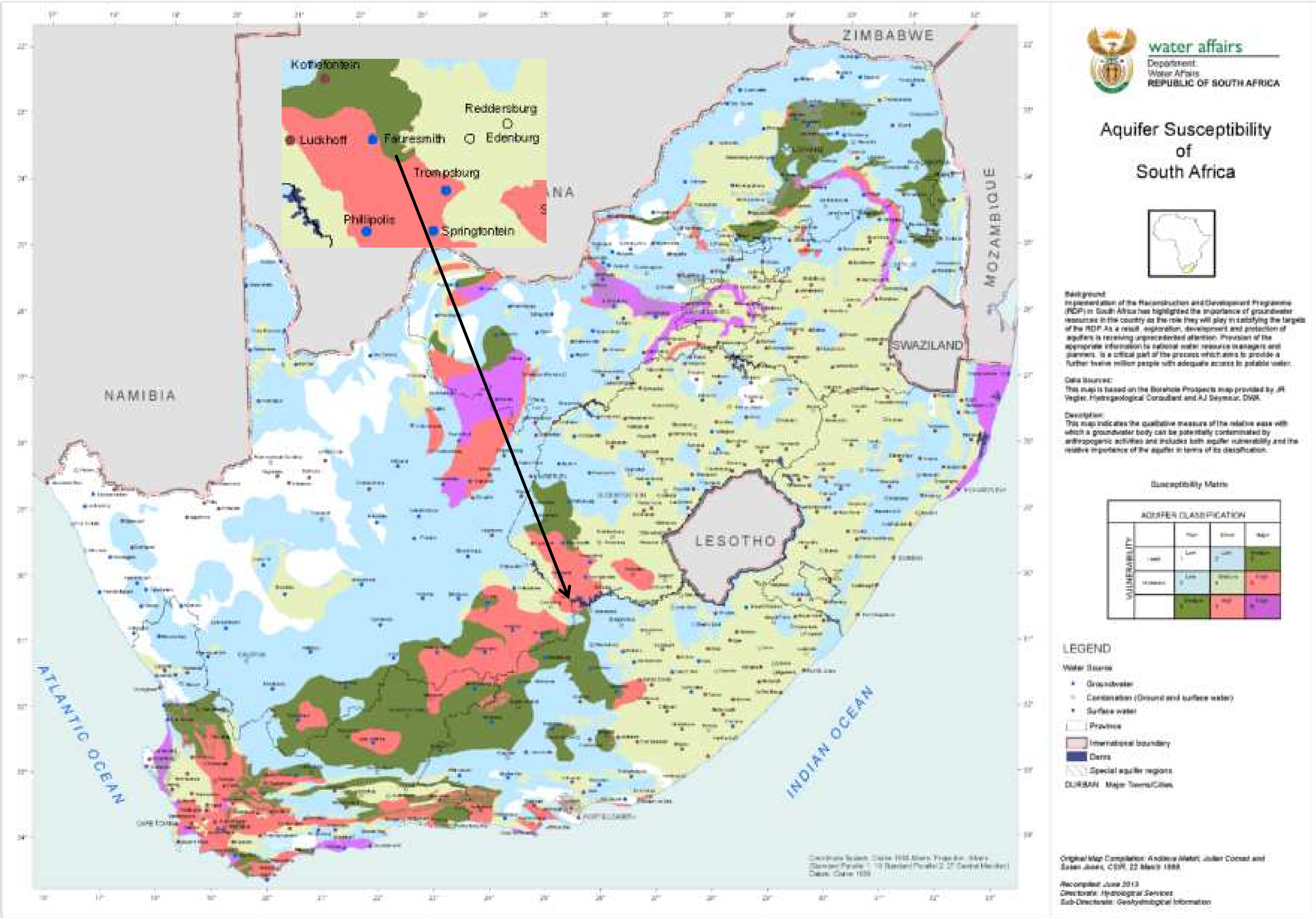


Figure 43. Aquifer Susceptibility of South Africa, 2013.

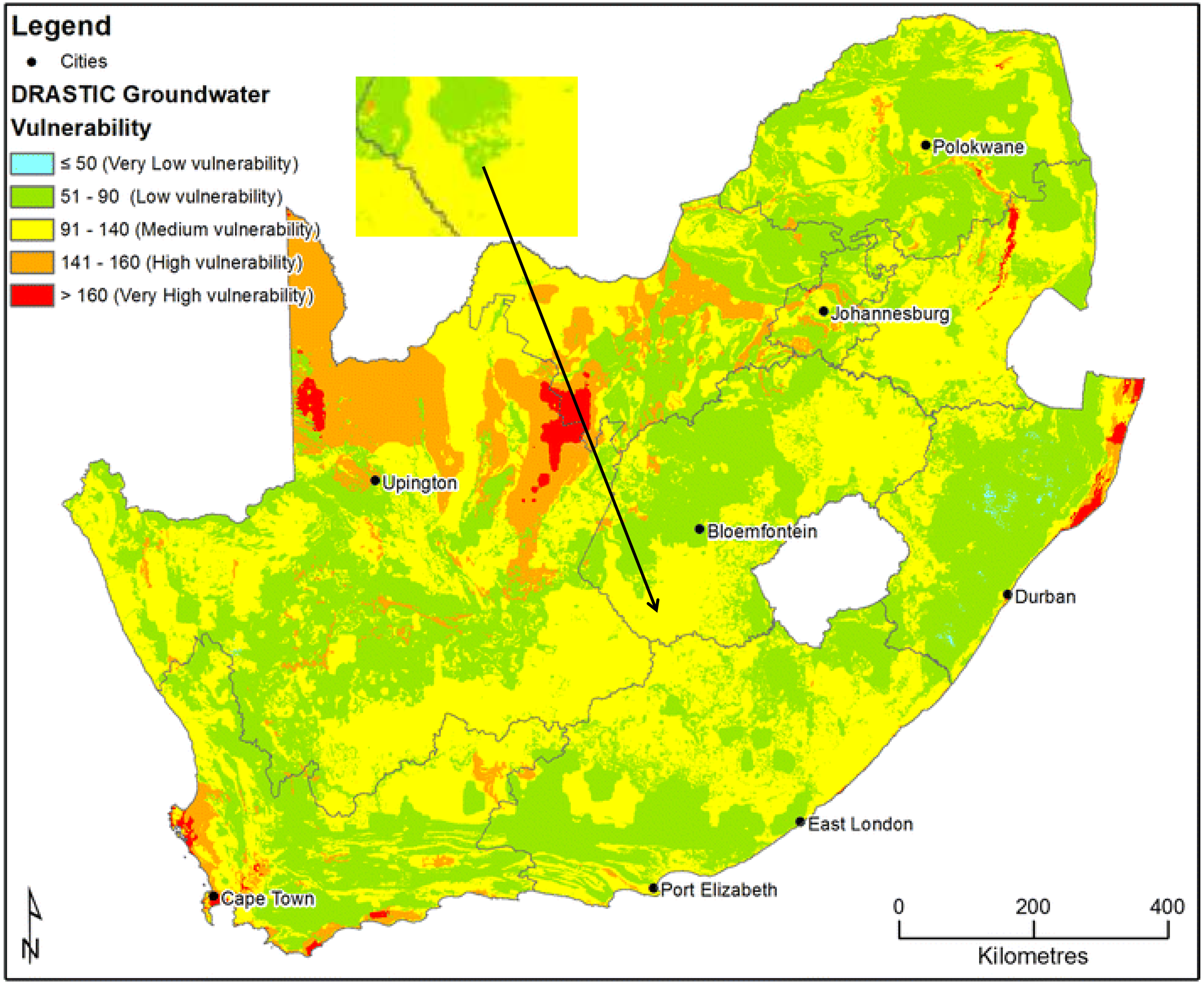


Figure 44. Aquifer Vulnerability of South Africa, 2013.

4.4 Geohydrology

4.4.1 Topography and Groundwater Flow

Normally the groundwater table mimics the topography if not disturbed by artificial recharge from manmade activities or dewatering activities. Evaluating this relationship can be accomplished by a simple graph of groundwater versus topography. The linear regression between the two sets of data can be express as the so-called R^2 statistical value which measures the strength of the relationship between the two sets of variables. This regression coefficient is expressed as a percentage or fraction, being closer to 1 (one or 100%) meaning the stronger the relationship.

The graph of groundwater elevations (excluding the water level elevations of the Shaft being used for abstraction) versus topography is shown in Figure 45. A regression coefficient of 0.97 with a correlation of 98.73% indicate an extremely strong relationship of groundwater elevations and topography at the Jagersfontein. This indicate therefore that groundwater elevations follow Jagersfontein TSF and surrounding areas.

In a study condcted by the Water Research Commission in 2002: "Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs (WRC Report No. TT 179/02)", it is explained that De Beers Consolidated Developments (Ltd.) ceased mining in 1971 and gave the Jagersfontein Municipality permission to abstract groundwater from the Development in 1980. It is stated that during this time the piezometric level in open-pit and shafts recovered from 750 m to 183 mbgl. It was further concluded from the available information in the study that the water level and chemical information point to the existence of two separate aquifers, namely:

- A shallow, more 'typical' Karoo fractured-rock aquifer at an average 4.8 mbgl water level and showing a water level of 4.8 mbgl), containing recently recharged water, and
- A deeper aquifer (intercepted in the shaft or Development, piezometric level 183 mbgl).

This is further confirmed when evaluating the relationship when this rest water level of the shaft is included (see Figure 46, regression coefficient of 0.32 and correlation of 57.44%) an extremely poor relationship between groundwater elevations and topography is revealed. This confirms that that the groundwater level of the shaft is not related to the regional groundwater level. It is further evident that the water level of the shaft reflects the levels of one or more confined or semi-confined aquifers.

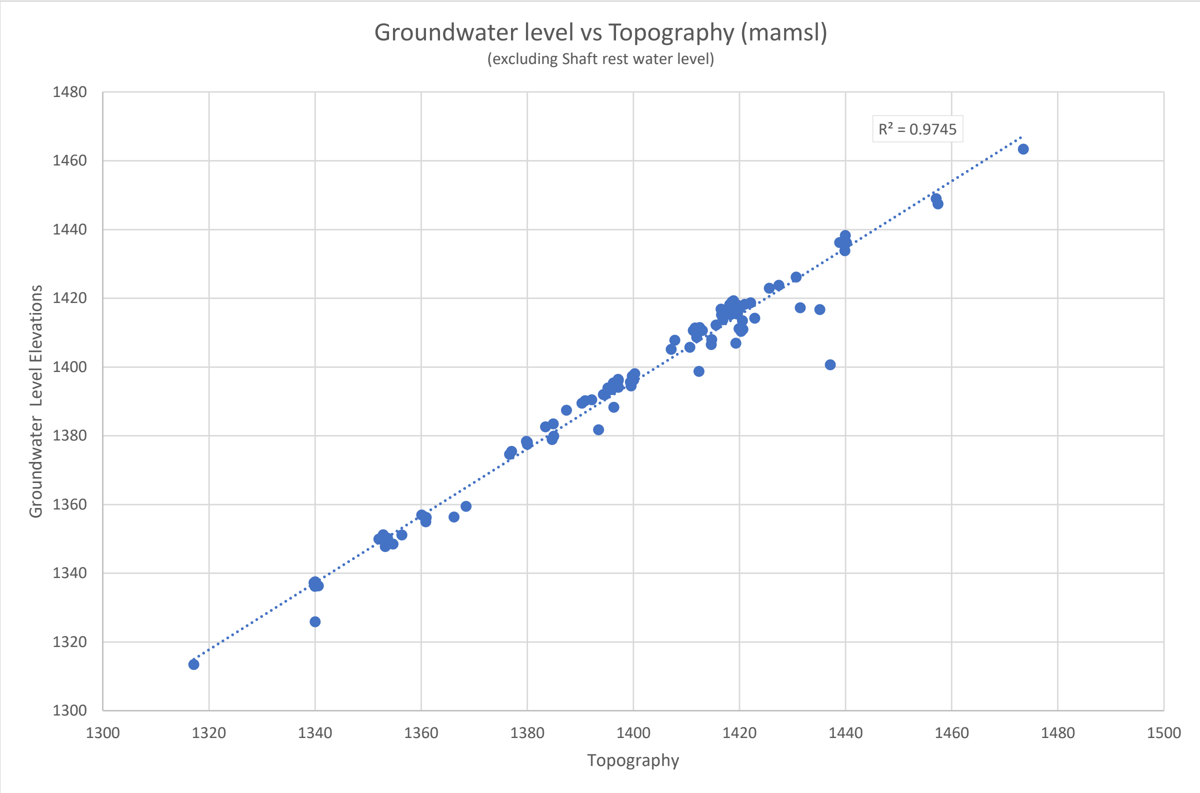


Figure 45. Groundwater elevations versus topography

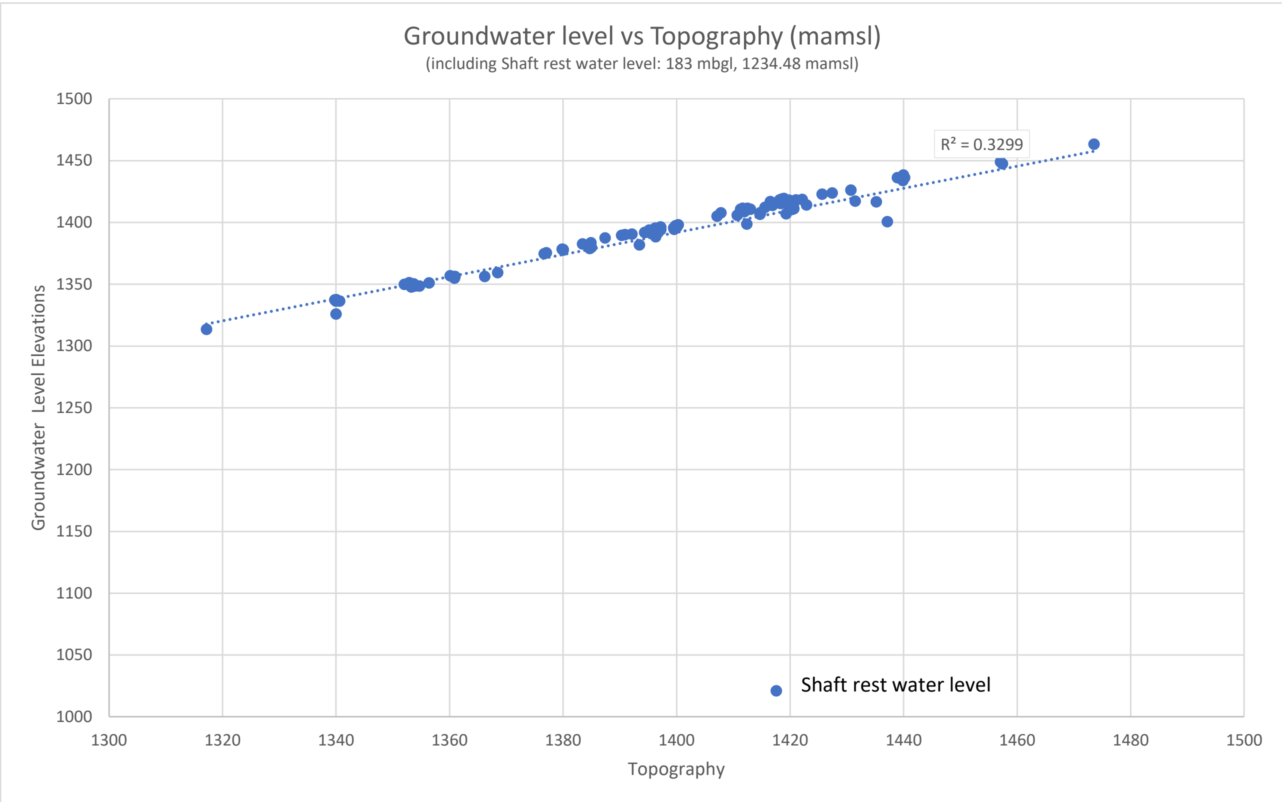


Figure 46. Groundwater level elevations including the historical rest water level of the shaft versus topography

Based upon this correlation between groundwater elevations and topography, a groundwater flow vector map was constructed using the Bayes interpolation technique (refer to Figure 47).

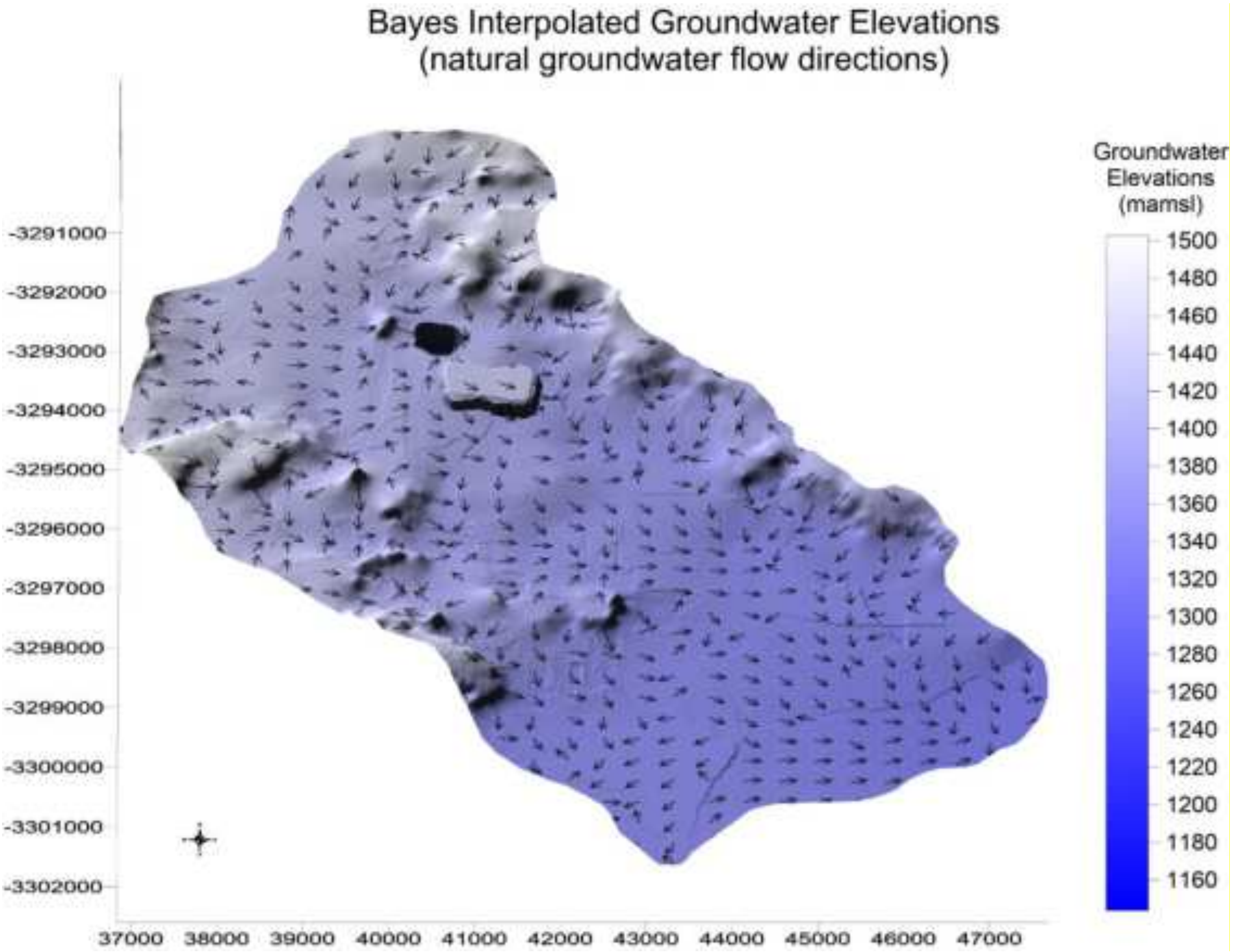


Figure 47. Natural topography and groundwater flow vectors

4.4.2 Aquifer Parameters

Several pump tests analyses have been conducted since 2009. These results are summarised in Table 3, with conductivities inferred from given transmissivities using an average aquifer thickness of 40m. The borehole positions shown Figure 48 on the next page.

Table 3. Summary of pump test analyses.

Borehole Number

Nr	Method Evaluation	Transmisivity (m^2/d)	Conductivity (m/d)		Source
BH7	FC	14.9	0.3725		Vermaak C, 2012
	Cooper-Jacob	128.6	3.215		
Bh4	FC	13.1	0.3275		
	Cooper-Jacob	144.9	3.6225		
Rietkuil BH2	Basic FC	14.5	0.3625		Vermaak C, 2013
	Cooper-Jacob	292.5	7.3125		
VV mon	FC	14.5	0.3625		
	Advanced FC	14.5	0.3625		
	Cooper-Jacob	292.5	7.3125		
BH1	FC	21.2	0.53		De Lange, F. and Swanepoel, J 2021
	Cooper-Jacob	32.2	0.805		
BH2	FC	15.5	0.3875		
	Cooper-Jacob	33.1	0.8275		
BH 3 (JD)	FC	1	0.025		
	Cooper-Jacob	21	0.525		
BH7	FC	105.6	2.64		
	Advanced FC	105.6	2.64		
	Cooper-Jacob	177.2	4.43		
VV Mon	FC	18.7	0.4675		
	Cooper-Jacob	52	1.3		
Rietkuil BH2	FC	23	0.575		
	Cooper-Jacob	53.7	1.3425		
Bh1 Town	FC	62.8	1.57		
	Cooper-Jacob	68.3	1.7075		
Bh2 Town	FC	111	2.775		
	Cooper-Jacob	137.7	3.4425		
ICMHH01	Slug Test	2.67	0.1414		GHT Consulting 2009
Bh3 Town	Slug Test	6.41	1.6964		GHT Consulting 2016

Minimum	0.0250
Maximum	7.3125
Average	1.8242
Geomean	0.9806

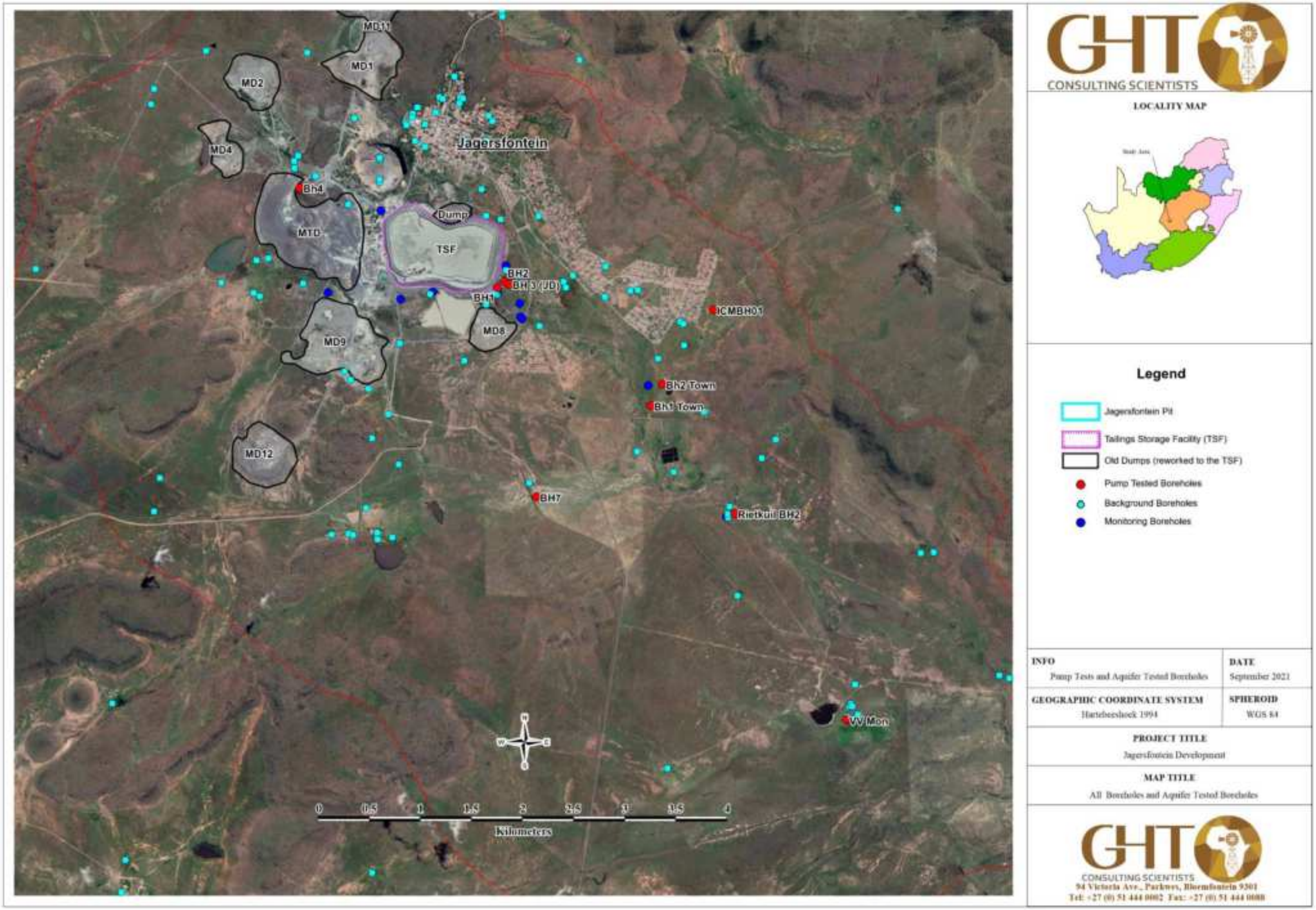


Figure 48. Pump tested boreholes

4.5 Conclusions - Jagersfontein Aquifer Classification

Given the above information and the detailed information regarding the aquifer classification in the vicinity of the TSF (report RVN 905.2/2133), the following aquifers have been identified in the TSF region, but can with confidence be extended to the complete region as follows:

- The main fine-grained unconfined sandstone Valley Aquifer within the extensive valley between the regionally dolerites sill that defines the surrounding hills at Jagersfontein. It varies in thickness from approximately five metres where it pinches against the lower secondary dolerite sill in the west, dipping between one and two degrees towards the south and south-east thickening to approximately 50 m over a distance of 2.6 km. This is the main water bearing, low yielding aquifer with an average permeability of between 0.05 m/d and 0.07 m/d.

- The Valley aquifer extends is approximately 9.5 km in length from north to south. It stretches from the north, approximately 1.8km north of Jagersfontein in a relative thin band of approximately 600 meters widening south of the TSF to approximately 3.7 km and 4.7 km further south.

- A contact zone between this upper Valley aquifer and lower secondary dolerite sill. This zone can be defined as an aquitard, although weathering in shallower parts of the Valley aquifer may result in higher permeabilities acting as a preferential flow path with slightly higher conductivities but low sustainability as it is fed by the Valley Aquifer matrix from above.

- A lower confined lithofeldspathic siltstone aquifer lens (approximately 40 metres thick) separated from the Valley aquifer by a regionally thick (>20m) dolerite sill and not significantly contributing to yielding potential.

- The overlying siltstone lenses to the north-west of the TSF and the surrounding jointed dolerite hills where recharge to the Valley aquifer occur through the weathered upper part of the merged deep and lower dolerite sills with siltstone lenses.

- Lastly the deep aquifer system (s) with a rest water level of 183 mbgl which at this stage will be referred to as the deep geology with the intend to gain additional knowledge when a monitoring system is installed (drilling deep and shallow boreholes).

The combination of aquifers (Lower Dolerite Sill/ Siltstones and Valley Aquifer) **in the region of the TSF** can therefore be classified as **minor** due to low permeabilities and low sustainable yields. The identified aquifers can be seen in Figure 49 below. It must be noted that the Valley aquifer somewhat increases with thickness to the south with possible increasing sustainability further south due to more available drawdown.

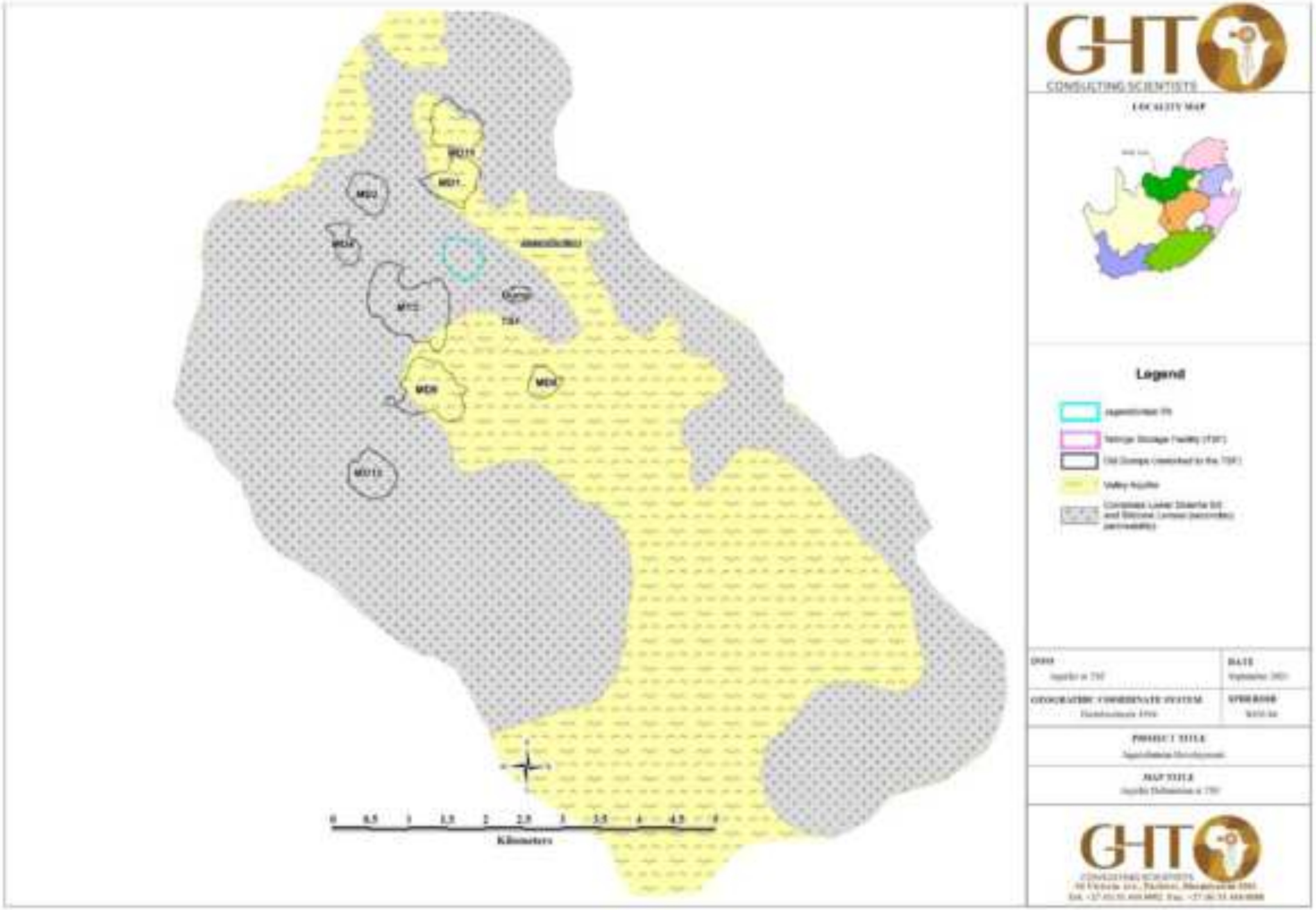


Figure 49. Aquifer description

5 HYDROCENSUS AND MONITORING DATA

The chapter includes a brief summary of the hydrocensus undertaken in January 2017, incorporating new data collected by Jagersfontein Development in 2021. The field activities involved the locating, surveying, sampling, water level measurement and accumulation of general borehole information. A substantial knowledge of the surrounding sites was obtained from 156 sites in and around Jagersfontein. Information regarding these sites (many of which serves as background information) will be utilised to assist with the aquifer vulnerability determination.

5.1 Sample Localities

- For map with all the known sites is indicated in Figure 50.

5.2 Field Inspection and Sampling Method

The following procedures were followed during the field investigation:

- Static Water Level (SWL) measurements were taken at all accessible existing bores.
- Where possible, samples were taken at all the bores using a bailer that allowed a sample to be taken from a selected depth below the static water level. The selected depth was identified according to the main water strike and down the hole logging methods. All the relevant pump installations and diameters were recorded where possible.

5.3 Surveying

Boreholes were surveyed by means of a Garmin GPS (Global Positioning System) to obtain accurate coordinates. The coordinates will be utilised for the following:

- The construction of a GIS Map (Map Info);
- The creation of data point sites in a GIS capable electronic database;
- To facilitate in the location of boreholes during future sampling events.

5.4 General Borehole Information

The following table (refer to Table 4) contains the known sites in and around Jagersfontein Development.

Table 4. Sites with Available Information.

SiteName	Water Levels			Chemical Analyses
	Date	mbgl	mamls	Date
10 Voottrekker street (10 Vstr)				29-Apr-12
11 Fauresmith Street (11 Fstr)				18-Apr-12
11 Ooskloof street (11 Ostr)				26-Oct-11
17 Weil street (17 Wstr)				30-Apr-12
20 Ooskloof street (20 Ostr)				23-Apr-12
35 Harrington street (35 Hstr)				19-Apr-12
6 Ried street (6 Rstr)				25-Apr-12
6 Wekstreet (6 Wstr)				26-Oct-11
9 Ooskloof street (9 Ostr)				26-Oct-11
BB01	11-Jan-17	8.030	1388.290	16-Jan-17
BB02				16-Jan-17
BB03				16-Jan-17
BB04				16-Jan-17
BB05				16-Jan-17
BB06				16-Jan-17
BB07				16-Jan-17
BB08				16-Jan-17
BB10				16-Jan-17
BB11				16-Jan-17
BB12				16-Jan-17
BB13				16-Jan-17
BB14	19-Jan-17	14.200	1417.260	16-Jan-17
BH 105	30-Apr-20	4.5	1426.18	
BH 3 (JD)	15-Mar-21	0.900	1395.330	15-Mar-21
BH 3 (Town)	17-Jun-21	1.84	1378.16	19-Mar-21
BH 8	17-Jun-21	1.650	1390.480	15-Mar-21
BH R704	17-Jun-21	0.81	1389.48	19-Mar-21
BH R704.1	17-Jun-21	0.680	1390.220	19-Mar-21
BH SPD	17-Jun-21	3.28	1408.65	15-Mar-21
BH1	24-Feb-21	1.390	1395.440	16-Sep-20
Bh1 Town	17-Feb-21	2.28	1377.72	04-Aug-16
BH10	17-Jun-21	0.000	1407.790	15-Mar-21
BH11	17-Jun-21	2.25	1394.57	15-Mar-21
BH12	17-Jun-21	0.860	1382.570	19-Mar-21
BH2	17-Jun-21	0.96	1396.22	17-Mar-21
Bh2 Town	17-Feb-21	2.520	1377.480	04-Aug-16
Bh4	24-Feb-21	9.92	1410.38	15-Mar-21
Bh6	17-Jun-21	3.110	1416.890	15-Mar-21
Bh9	17-Jun-21	0.76	1396.38	15-Mar-21

Table 4 Sites with Available Information - continue

SiteName	Water Levels			Chemical Analyses
	Date	mbgl	mamls	Date
Bridge Down				16-Sep-20
Bridge Up				15-Mar-21
BS01				16-Jan-17
BS02				16-Jan-17
BS03				16-Jan-17
BS04				16-Jan-17
B-up				15-Mar-21
Dam 10				19-Mar-21
Dam D1 and D11				15-Mar-21
FMP				15-Mar-21
H1	17-Feb-21	3.690	1313.470	
H10	17-Jun-21	4.74	1349.09	
H100	17-Jun-21	2.000	1405.110	23-Apr-21
H101	17-Jun-21	13.64	1398.73	17-May-21
H103	13-Aug-21	2.430	1393.400	13-Aug-21
H104	13-Aug-21	2.32	1393.6	13-Aug-21
H105	13-Aug-21	2.410	1393.500	13-Aug-21
H106	13-Aug-21	1.25	1395.82	13-Aug-21
H107	13-Aug-21	3.810	1396.220	13-Aug-21
H108	13-Aug-21	2.17	1398.09	13-Aug-21
H109	13-Aug-21	0.160	1419.310	
H11	17-Jun-21	4.88	1348.96	
H12	17-Jun-21	5.310	1348.580	
H14	17-Feb-21	3.75	1336.22	
H17	17-Feb-21	2.520	1337.490	
H18	17-Feb-21	4.29	1336.32	
H23	17-Feb-21	10.150	1463.370	
H25	17-Feb-21	9.96	1447.44	
H26	22-Feb-21	1.730	1438.230	
H27	22-Feb-21	3.13	1413.74	
H28	22-Feb-21	3.070	1415.240	
H29	22-Feb-21	1.82	1415.5	
H3	17-Feb-21	9.030	1359.430	
H30	22-Feb-21	7.07	1413.47	
H31	22-Feb-21	9.700	1410.950	
H32	22-Feb-21	8.74	1411.16	
H33	22-Feb-21	1.440	1415.160	
H36	17-Feb-21	5.07	1379.91	
H39	17-Feb-21	1.440	1383.470	

Table 4 Sites with Available Information - continue

SiteName	Water Levels			Chemical Analyses
	Date	mbgl	mamls	Date
H4	17-Feb-21	1.68	1351.17	
H41	17-Feb-21	5.100	1394.470	
H44	17-Feb-21	36.5	1400.63	20-Apr-12
H45	17-Feb-21	3.440	1418.660	
H46	17-Feb-21	2.76	1418.24	
H47	17-Feb-21	3.610	1423.800	
H48	31-Mar-21	4.92	1405.74	31-Mar-21
H49	17-Feb-21	6.230	1348.460	
H5	17-Feb-21	2.08	1349.95	
H51	19-Feb-21	3.190	1356.920	
H52	19-Feb-21	12.38	1406.92	
H54	19-Feb-21	2.400	1391.950	
H55	19-Feb-21	5.78	1378.91	
H56	19-Feb-21	2.090	1374.570	
H57	19-Feb-21	5.26	1351.12	
H58	19-Feb-21	9.850	1356.330	
H6	17-Feb-21	2.56	1337.22	
H60	19-Feb-21	2.430	1397.360	
H61	19-Feb-21	2.4	1410.61	
H63	19-Feb-21	1.020	1411.470	
H64	19-Feb-21	0.43	1411.18	
H65	19-Feb-21	0.290	1411.350	
H66	19-Feb-21	-0.37	1418.94	
H67	19-Feb-21	0.000	1418.130	
H68	19-Feb-21	-0.3	1416.8	
H69	19-Feb-21	8.140	1406.550	
H7	22-Feb-20	14.15	1325.85	
H70	17-Jun-21	4.180	1415.410	17-May-21
H71	24-Feb-21	3.4	1412.18	
H72	24-Feb-21	1.830	1395.120	
H73	24-Feb-21	8.69	1414.19	
H74	24-Feb-21	6.760	1407.990	
H76	24-Feb-21	2.71	1391.97	26-Apr-12
H77	24-Feb-21	3.080	1394.090	
H81	24-Feb-21	1.31	1393.87	27-Apr-12
H82	24-Feb-21	1.480	1378.340	
H83	24-Feb-21	2.66	1436.22	
H84	24-Feb-21	-0.390	1419.290	
H85	24-Feb-21	2.84	1416.06	

Table 4 Sites with Available Information - continue

SiteName	Water Levels			Chemical Analyses
	Date	mbgl	mamls	Date
H86	24-Feb-21	4.030	1436.120	
H87	24-Feb-21	6.05	1433.83	
H88	24-Feb-21	8.100	1448.950	
H89	15-Mar-21	2.7	1422.93	15-Mar-21
H9	22-Feb-20	5.500	1347.750	
H90	24-Feb-21	18.44	1416.72	
H91	24-Feb-21	1.630	1417.910	
H92	24-Feb-21	2.13	1417.07	
H93	17-Jun-21	1.330	1417.140	31-Mar-21
H94	17-Jun-21	3.85	1395.6	
H96	24-Feb-21	2.260	1417.560	
H97	24-Feb-21	1.87	1417.92	
H98	24-Feb-21	1.610	1375.420	
ICMBH01	04-Nov-09	11.68	1381.76	03-Dec-09
Itumeleng				28-Apr-12
Koos1	19-Feb-21	0.78	1410.99	
Koos2	19-Feb-21	0.650	1410.630	
Loskop Dam				15-Mar-21
MTD Trench				16-Mar-20
Municipal Water (Mw)				22-Apr-12
NG Kerk				26-Oct-11
P01				16-Jan-17
P03				16-Jan-17
Palmerston street (Pstr)				24-Apr-12
Penstock				13-Dec-19
RK BH	17-Jun-21	5.91	1354.94	06-Jul-19
RK mon BH	23-Mar-21	4.730	1356.210	
Seepage 1				16-Sep-20
Seepage 2				15-Mar-21
Shaft	21-Nov-16	396.5	1021.04	15-Mar-21
SPD				19-Mar-21
Test Hole 2	13-Aug-21	1.7	1395.3	13-Aug-21
Test Hole 4	13-Aug-21	1.100	1395.810	13-Aug-21
Test Hole 5	13-Aug-21	1.7	1395.37	13-Aug-21
TSF				21-Dec-20
VV BH	17-Feb-21	3.5	1350.17	
VV BH2	17-Jun-21	2.880	1350.340	
VV mon	17-Jun-21	4	1349.54	
Well	17-Feb-21	0.000	1387.400	

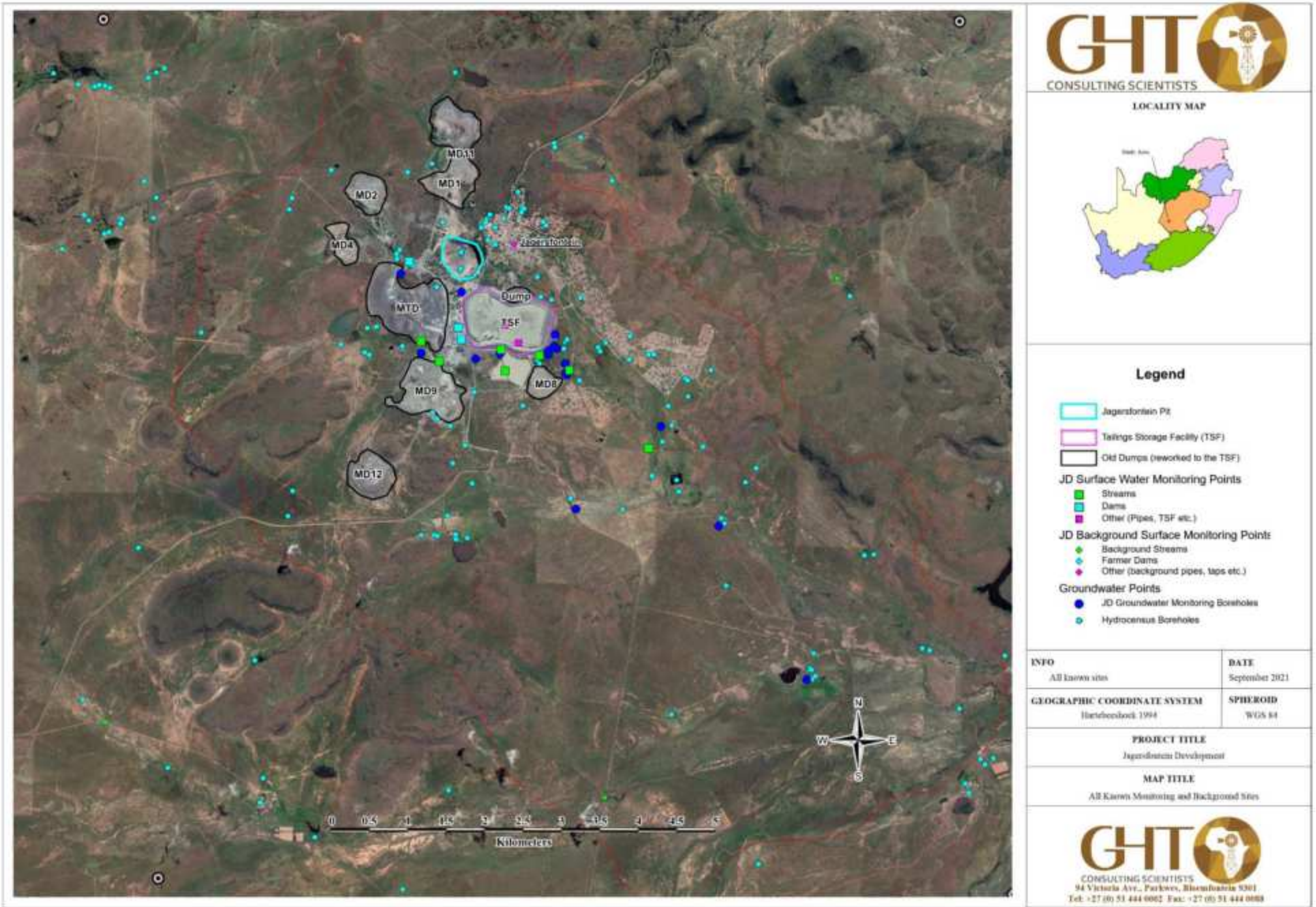


Figure 50. Jagersfontein Development Monitoring and Hydrocensus Sites

6 NUMERICAL MODEL

6.1 Introduction

This chapter is based on the Series G – Best Practice Guidelines – G4, Best Practices Guideline: Impact Prediction.

6.2 The Risk-Based Approach for Jagersfontein Development PTY Ltd

The approach for Jagersfontein TSF operations is based on the general risk assessment components of a source, pathway and a receptor (refer to Figure 51).

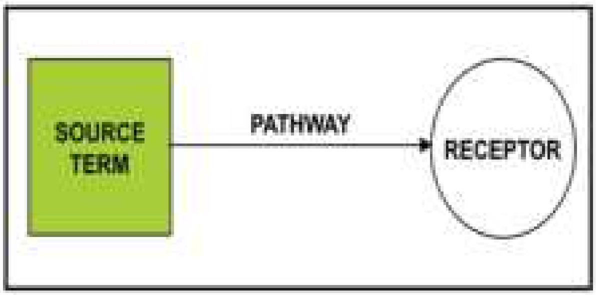


Figure 51. General risk assessment components.

6.2.1 Defining the Source Terms

The source term for this modelling exercise considered are as follows:

- The TSF (old and new depositions)
- The different Class A Dumps (old dumps with fines at the base causing a seepage barrier) are:
    - MD1 –Dump 1 north of the Pit
    - MD2 –Dump 2 west of MD1
    - MD4 –Dump 4 north-west of MTD
    - MD8 –Dump 8 south-east of TSF
    - MD9 –Dump 9 south of MTD
- The different Class B Dumps are: (newer dumps with course material and prolonged seepages) are:
    - MTD – Main Tailings Dump west of the TSF
    - MD11 –Dump 11 north of MD1
    - MD12 – Dump 12 further south of MD9
- The Pit, if backfilled

The site layout with the TSF and different WRD's can be seen in Figure 1.

6.2.1.1 Pollution Source Properties

This initial study was concerned with the combined old and new TSF as the major pollution source and will therefore be summarized as this is the material to be disposed of into the pit

In 2016, SRK collected course and fine tailings form the Jagersfontein Development to characterise the tailings in terms of the Waste Classification and Management Regulation and Acid-Base Accounting (ABA) test work.

The study assessed the tailings against the N&S for the Assessment of Waste for Landfill Disposal and the N&S for Disposal of Waste to Landfill (Government Gazette, No. 36784, 23 August 2013).

The type of waste was determined by comparing the Total Concentration (TC) and the Leachable Concentration (LC) of the elements and chemical substances in the waste with the Total Concentration Threshold (TCT) and the Leachable Concentration Threshold (LCT) limits specified in Section 6 of the N&S (No.R.635).

Based on the TC and LC limits of the elements and chemical substances in the materials exceeding the corresponding TCT and LCT limits respectively, the waste type and the landfill disposal requirements was determined.

SRK determined that the tailings contain predominantly silicates, mainly as smectite (43% - 54%) and phlogopite (12% - 13%), as well as fast acid neutralising mineral, calcite (4.9% - 6.0%). The tailings are alkaline (paste pH 9.1 - 9.2) and non-acid forming. The tailings were assessed to be Type 3, **Low Risk** waste, due to the total Ba, Co, Cu and Ni, and leachable SO4 and Total Dissolved Solids (TDS) (SRK Consulting, April 2016).

In 2020 test were repeated by SRK. The results of the test showed that higher total concentrations of trace metals, As, B and Ba were detected in the tailings in the 2020 study relative to the 2016 study. The variability noted for these metals in the tailings is not unusual for geological materials and may be attributed to differences in sample locations.

In summary, the assessment indicates that there is an increase in the solubility of metals and metalloids in acidic conditions. Arsenic solubility increases in alkaline conditions, but TDS decreases. The changes in the solubility of the metals and metalloids in mildly acidic and alkaline conditions do not change the assessment of the tailings as Type 3 waste, **Low Risk**.

The properties of the slime were further determined as summarized in the table below from SRK (2021):

Table 5. Slimes and tailings material properties.

Material	USCS	Cv (m^2/year)	Hydraulic conductivity/permeability (k)		Source
			m/s	m/year	
Coarse Tailings	SW-SM		$1x10^{-5}$	315.36	Grading analysis
Fine Tailings		0.0034	$5.56x10^{-13}$	$1.76x10^{-5}$	k:cv relationship
			$1x10^{-12}$	$3.15x10^{-5}$	BRT Report
	CL-ML	Soil lab	$1x10^{-8}$	$3.15x10^{-2}$	Grading analysis

The equivalent of these parameters of hydraulic conductivities for the course tailings and slimes are respectively 0.86 m/d and 4.8×10^{-8} m/d.

6.2.2 Defining the Pathway

The typical pathways to potential impacts on the groundwater resource considered are as follows:

- Movement through the vadose (unsaturated) zone.
- Movement through an aquifer.

Within the context of defining the pathways it is important to note that the pathways may have the following features:

- A hydraulic conduit (pathway) for the mobilization and movement of the contaminants of concern from the source term to the receptor
- Attenuation of contaminants, release of new contaminants and alteration of the chemistry of the discharge from the source term through a variety of chemical reactions
- Habitat for receptors such as surface streams (primarily non-perennial)

The detailed pathway assessment that was followed for from the conceptual model made use of a combination of the following tools:

- Geohydrological models (possibly with consideration of attenuation mechanisms)
- Hydrology / runoff models
- Water quality models for receiving aquifer

6.2.3 Defining the Receptor

As the final component of the risk assessment, the receptors in the context of the water resource would be users of the water resource itself and typical receptors defined included:

- The groundwater aquifer.
- Groundwater user abstracting contaminated groundwater through a borehole for domestic, livestock watering or irrigation use.
- Aquatic fauna and flora in a receiving watercourse. Non-perennial run-off streams or creeks exist to the west, north and south-east of the operations, with the Prosesspruit approximately 6.5 km south-east of the TSF.

6.3 Numerical Modelling

The numerical modelling exercise aims at simulating groundwater flow and pollution contaminants with the use of a computer program which is governed by the mathematical flow equation. This flow equation is solved by iterative methods utilising all known information as recorded in the real world. This information includes geology, geohydrological parameters (such as conductivities, porosities and storativities), water levels, chemistry, rainfall, recharge, abstraction and pollution sources. It also acknowledges encountered uncertainties and limitations which in turn influences the accuracy and confidence of simulated results. The understanding of these parameter and information is generally a simplification of the physical complexities of the real-world situation referred to as conceptualization upon which a numerical model is constructed.

6.3.1 Assumptions and Limitations

It should be understood that numerical modelling solutions are non-unique and that the selection of different combinations and values for input parameters may yield similar solutions. It must be seen as a tool for assessment of different scenarios to assist decision making with regards to management strategies.

There are several shortcomings with regards to aquifer parameters. These include parameters such as porosities, effective porosities, and conductivities. Literature values will be assumed for sedimentary material as well as for igneous rocks. Values for conductivities will be applied as derived from pump test analyses but will be assumed as homogenous for the different geological and hydrogeological units as respectively described in chapter 3 and section 4.5. The parameters of the upper igneous lithology units (dolerite) were assumed for the deep geology. The deep aquifer (s) systems were however not implemented due inadequate knowledge of the system. Given the rest water level of the deep aquifer system (WRC Report No. TT 179/02) to be approximately 183 mbgl, it can be deduced that the deep aquifer system has a piezometric pressure that is higher than the bottom (260 mbgl) of the pit. Filling of the pit with slimes which have a lower permeability than the host rock will act as restoring of the perched conditions of the confined deeper aquifer at the pit bottom and leaving the shaft as the only remaining perched location.

If any dewatering is caused by the pit, dewatering can only be considered within the immediate proximity to the pit and primarily the dewatering of the local siltstone lenses that are not interconnected with any aquifer systems. Once again, the reason for this is that there is no water seeping into the pit via the pit faces. It is further evident that abstraction form the shaft has no effect upon water levels of the surrounding boreholes as no dewatering is experienced in any of the surrounding boreholes. Thus, there is no interconnectivity between the shaft (which is linked to the pit) and the surrounding aquifers. Although the shaft is connected to the pit, the pit does not serve as the primary source of recharge to the shaft. In fact, the pit act merely as a sump when receiving rain- or storm water contributing to the overall availability to be abstracted from the shaft. The water level in the pit steadily declines after these storm events to a stage where the sustainable abstraction rate of the shaft is reached. For these reasons, the deep aquifer is not simulated in this model as well as no dewatering from the pit or shaft.

The focus is given in these numerical modelling simulations upon the shallow aquifer systems comparing the removal of the pollution sources against leaving the pollution sources on surface. The deep geology and deeper aquifer(s) remain an extremely important part to be implemented in the conceptual and numerical model once additional information is derived from drilling logs (geology and water strikes) when establishing a Pit monitoring network.

It is unknown how long pollutants (at a considerable concentrations) will seep from the dumps, but according to Harris, J.R. (1990), is dependent upon the type of material and precipitation and can be between 25 and 100 years. The only assumptions made with regards to the properties of the WRD's are that seepages diminish over time from the class A dumps (because of the previously explained clay factor) but class B dumps can be considered as eternal sources. This assumption concerning class A dumps is supported by noticeable cleaner monitoring result at boreholes H93 and H101 at dump MD9. However, surface run-off from these dumps (not simulated in this model) remain a source of pollution firstly acting upon surface water resources and secondly upon groundwater.

6.3.2 Conceptual Setting

The understanding of the historical and current operations can be conceptualised as follows:

Mining started as early as 1870 which was hand dug until 1909 and closed in the 1930's. It was re-opened in the late 1940's when the eastern path of the TSF and several WRD's were constructed. It remained in operations until 1973 when it was finally shut down. With establishing the feasibility of recovering of diamonds from the WRD's and tailings, the old eastern part of the TSF has been reworked in 2012 and reconstructed together with the western part which in total now represents the TSF receiving re-worked material from the different WRD's. The recovery operations are expected to end in 2029. Simulation will be performed beginning in 1940 with the eastern part of the TSF active until 1978, re-activated in conjunction with the western part in 2012. Simulations will end in 2129, 100 years after closure.

For the purposes of evaluating the removal of the on-surface pollution sources, two different scenarios will be evaluated where the on-surface pollution sources are removed as opposed to not being removed. In the event of sudden closure in 2021, the class B WRD's will remain an infinite pollution source whereas the Class A (with the already explained assumption of diminishing leachate) will be removed from the model in 2084.

Two scenarios that will therefore be simulated, are:

- Scenario A: - Do-nothing scenario simulating with immediate seizure of all operations and no removal of pollution sources. Pollution from Class A WRD's to be turned off in 2084 with impacts from Class B dumps remaining indefinitely.
- Scenario B: - A scenario with TSF operatorial until 2029 with removal of all the WRD's to the pit in 2029.

Except for immediate seizure of all operations, the current modus operandi with the installed trench to the east of the TSF and limited abstraction from identified boreholes as indicated in the previous study (TSF Impact Assessment GHT Consulting report RVN 905.2/2133) will form part of scenario B.

Groundwater pollution specifically at the TSF may primarily occur by recharge through the TSF side walls from both natural rainwater or additionally from water that forms due to settlement on top of the freshly pumped slimes onto the TSF and overflows on top of the slimes into the TSF walls. With the properties of the slimes which consists of extremely low permeable smectite clay forming an impermeable barrier, movement occurs below the side walls and run-off through typical pathways such as the vadose (unsaturated) zone and aquifer.

The properties of the course tailings and slimes are well defined by various laboratory tests performed in the past. It also exhibits similar properties to other slimes facilities in South Africa (van Niekerk et al.). A so-called capillary fringe or barrier zone is created once the phreatic level within the slimes recedes below a certain depth (800mm to 2m) whereby precipitation does not reach the phreatic level within the slimes. Simply put, if the facility is properly rehabilitated, shaped or, sloped, all precipitation should be evaporated. Infiltration of the vadose zone during prolonged rainfall events will only impact this fringe, whereby evaporation will again dry the upper part. This furthermore means that no more seepage or pollution would occur from the slimes (apart from surface runoff) and that the moisture retention capacity of the slimes would keep the water within the slimes encapsulated for an indefinite amount of time. For simulation purposes however, recharge will still be simulated in order to evaluate pollution plume migration.

Drainage is as described section 2.2.1.1 is generally from north-west at 1439 mamsl to the south-east at 1349 mamsl. Surface drainage in close proximity to the TSF follows the same north-west (1416 mamsl) to the south-east (1390 mamsl) drainage pattern towards the non-perennial stream at the south-eastern corner of the TSF.

A trench was installed around the perimeter of the TFS in 2021 with the eastern part the only part readily receiving seepages. It is also planned to abstract water from some boreholes (possibly one south and four east of the TSF).

6.3.3 Conceptual Model

The conceptual geology setting as described in in section 3.3 together with topography, water level elevations and chemistry can be conceptualized as follows:

- The main aquifer (Valley aquifer) is a fine-grained unconfined sandstone aquifer between the regionally dolerites sill that form the surrounding hills at Jagersfontein. This aquifer runs from north of town, between the hills to the south and south-west.
- The upper part of the sills and sandstone are weathered forming respectively gravels and clayey sand. The gravels above the dolerite sill form the predominant area of recharge.
- The Valley aquifer is the main water bearing aquifer and varies in thickness from approximately five metres where it pinches against the upper secondary dolerite sill in the west, dipping between one and two degrees towards the south and south-east thickening to approximately 50 m over a distance of 2.6 km.
- A lower confined lithofeldspathic siltstone aquifer lens (approximately 40 metres thick) separated from the Valley aquifer by a regionally thick (>20m) dolerite sill and not significantly contributing to yielding potential.
- A TSF was constructed that partially overlies the merged lower and deeper dolerite sills within the norther part and the Valley aquifer in the southern part of the facility. The TSF is separated from direct contact with the lower geological formations by the respective weathered gravels and clayey sand (alluvium).
- The Valley aquifer underlies WRD's MD1, MD11, MD8 and MD9
- Dumps MD2, MD4 and MTD are above the dolerite sill and sandstone lenses and thus with higher potential of pollution impacts due to the presence of gravel above the dolerite where recharge may be readily occurring.
- The merged lower and deeper dolerite sills and the lower lithofeldspathic siltstone representing a regionally confined layer can be simulated for modelling purposes as a layer with lower permeability extending below the Valley Aquifer as well as to the north-west as siltstone lenses above the impermeable dolerite sill.

The system can therefore be simplified for numerical modelling purposes into the following primary layers:

- Layers 1: Man-made infrastructures (TSF with slimes and walls and WRD's) and superficial clay and sand (in the Valley aquifer region) and soils (weathered dolerite hills). The TSF partially overlies the merged dolerite sills within the norther part and the Valley aquifer in the southern part.
- Layer 2: The merged lower and deeper dolerite sills/lithofeldspathic sandstone and sandstone Valley aquifer.
- Layer 3: The merged lower and deeper dolerite sills/lithofeldspathic sandstone extending below Valley aquifer.

- Layer 4 to 7: Host rock, impermeable dolerite sill with possible siltstone lenses (subdivided to accommodate the pit and filling to 60 mbgl).

For modelling purposes, some of these layers have been subdivided for model discretization but with essentially the same geohydrological properties.

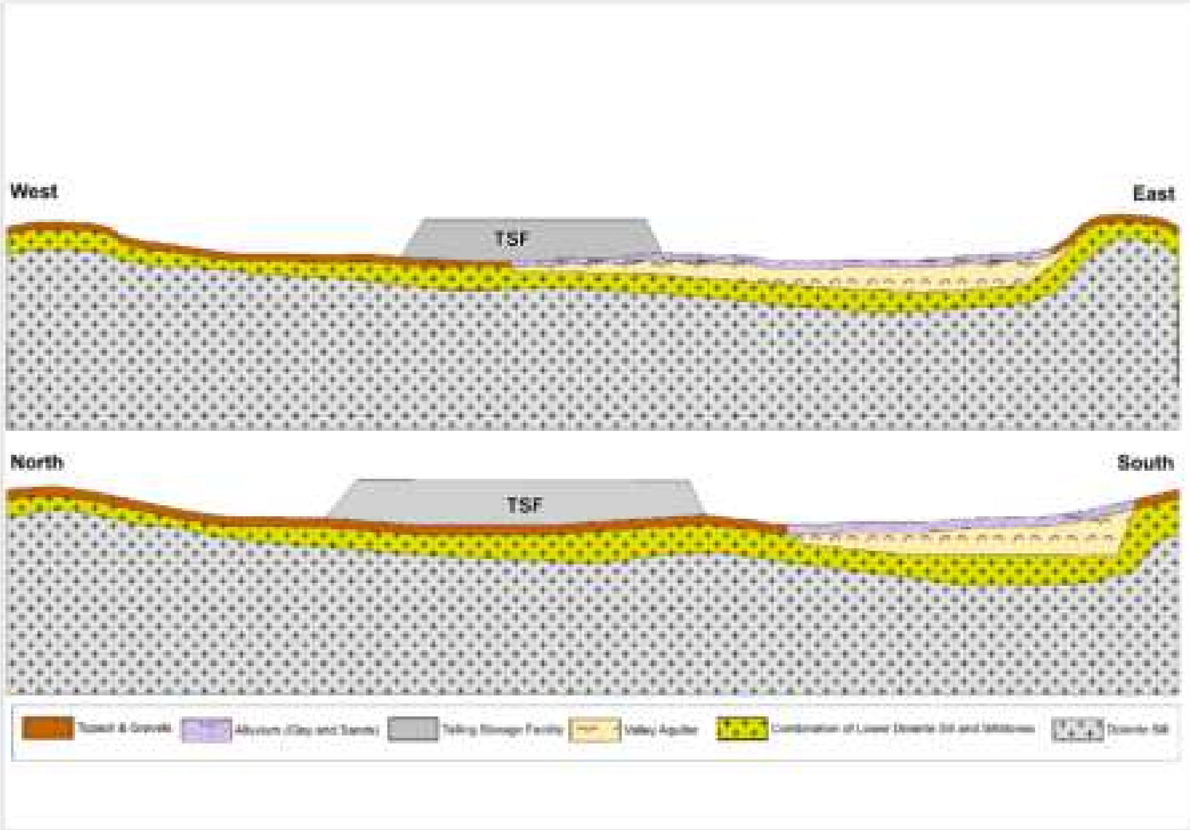


Figure 52. Simplified conceptual geology from Figure 37)

6.3.4 Numerical Model Aquifer Parameters

6.3.4.1 Conductivities

Average conductivities for the upper soils (above the dolerite sills) and alluvium (above the sedimentary fine grained sandstone Valley aquifer) were respectively indicated by the vulnerability study and lab test result (see report RVN 905.2/2133) to be in the ranges of 3.15 and 0.00217 m/d.

Data from historical pump tests (see Table 3) suggest conductivities of between 0.025 and 0.0832 m/d for the Valley Aquifer. A value to be representative of the lower dolerite sill with possible fracture zones together with the siltstone lenses is calculated at between 0.01 and 0.001 m/d.

According to the reports from SRK 2016 and 2021, the tests performed on the slimes indicate conductivities as low as 4.8x10-8 m/d whereas the course tailings used to construct the walls may be as high as 0.86 m/d. The wall material however becomes compacted with time lowering these values substantially. The actual values may even be lower than these values derived from particle size analyses and evaluation (which is conducted by drying of the material and performing sieve analyses). Some layering would occur during disposal and the vertical conductivity would be an order smaller than the horizontal (similarly to what is normally assumed for general groundwater flow). The lowering of these values may be further compounded as there is some expansion in the saturated slimes (smectite) as well as compaction that would occur (both at the bottom of the TSF and definitely in the pit).

The following table summarizes the conductivities of the different material and lithologies of the aquifers. This indicates the slimes to be two orders lower than the host rock of the pit into which it is intended to dispose of the slimes.

Table 6. Conductivities of the different material.

Conductivities (m/d)								
Course Tailings	Slimes	Weathered Dolerite	Slimes	Topsoil Alluvium	Fresh Dolerite	Clay	Sediments	Contact
8.64E-01	4.80E-08	3.15E+00	4.80E-08	2.17E-01	8.64E-06	3.28E-03	6.00E-02	1.20E+02

6.3.4.2 Porosity, Specific Storage and Specific Yield

The difficulty in determining general porosity of geological formations is widely acknowledged, resorting to assuming literature values of between 10 and 35% for the sedimentary Valley aquifer and less than 10 % for the deep geology. In relation, storage parameters coinciding with literature ranges from 0.01 m^{-1} (upper geology) to 0.00001 m^{-1} (deep geology). Course tailings may have porosities as high as 60% (according to SRK, 2016) with the specific yield (referred to as drain fillable porosity in Feflow) initially conservatively take at 30%. With specific storages orders of magnitude smaller than porosities, yet more readily releasing water, initial estimates will be taken at 0.001 m^{-1} (in case of confined conditions, if any).

6.3.4.3 Dispersivity

The degree in which mixing (or dilution) of the plume occurs due to groundwater flow velocity is referred to as dispersion. These parameters are not known, and initial values were taken from literature (Freeze and Cherry et al.). Longitudinal dispersivity (parallel to flow) of between 5 and 50 m and transversal dispersivity (perpendicular to flow) of 10% of longitudinal dispersivity are expected.

6.3.5 Water Levels

During drilling, water strikes were generally encountered between 5 and 40 mbgl and within the contact zone between gravels, shales and sandstones and lower dolerite sill. Water levels were integrated utilising the oldest available data on record and used as initial heads for the steady state model.

6.3.6 Rainfall and Recharge

Normal recharge in the area is expected to be in the order of 2 to 3% of the annual rainfall (12.5 to 17 mm/a). Addition recharge (simulated as a source explained below in section 6.3.7) may occur through the TSF walls which are systematically reduces as these become compacted in the process of the height being increase. Recharge through the slimes will be lower (to negligible) than natural recharge due to the low permeability and high moisture retention of the slimes within the TSF. Although recharge may be higher at class B dumps and diminish with time at class A dumps, natural recharge was applied to these sources.

6.3.7 Sources and Sinks

Sources and sinks to be considered are groundwater inflow or outflow as well as pollution concentrating introduced into or removed from the system.

With regards to groundwater sinks, no dewatering is evident in any of the monitoring or background boreholes surrounding the pit or shaft. For this reason, and as indicated in section 4.4.1 that the water from the shaft is originating from a deeper confined aquifer, dewatering from the pit or shaft is not implemented in this model.

The limited abstraction (0.5 L/s per borehole) form boreholes to the south and east will be implemented to evaluate impacts on groundwater levels as well as influences on the pollution plume migration.

Evaluating surface chemistry and pollutants detected in boreholes, a worst-case value for SO_4 is taken at 2000 mg/l. This concentration may arise from oxidation of on-surface material historically scattered downgradient from the TSF and WRD's, or due to concentration because of evaporation of surface water run-off.

6.3.8 Numerical Model Procedures and Quality Assurance

6.3.8.1 Model

The software package Feflow 6.2 was chosen for the numerical finite element modelling developed by DHI-WASY (GmbH, 2014).

Model discretization is shown in Figure 53with 417 155 elements. The pit void was simulated by marking the pit elements as inactive, reactivating these elements in 2021 from 60 mbgl to the pit bottom of 260 mbgl.

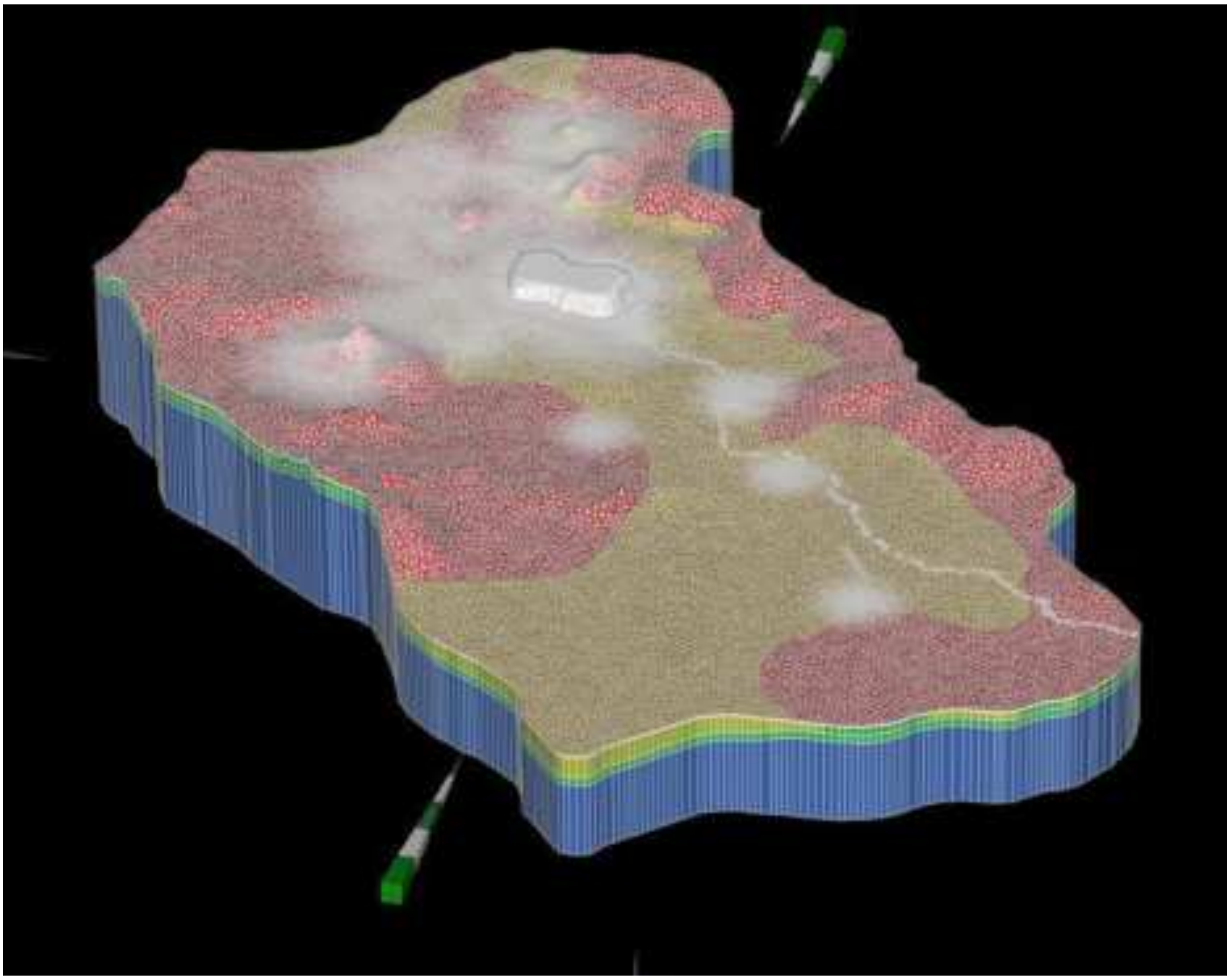


Figure 53. Model discretization.

As the geometry of the mesh design can have undesirable effect on simulated spreading of the pollution plume due to numerical dispersion (if the elements are too large in relation to the dispersion length), care was taken to ensure the area of interest comply with the so called Péclet criteria. This criterion relates the element length, Darcy velocity and dispersivity. The mesh was refined within the main study area and pollution transport area to fall within this criteria Pe < 2.

$$Pe = \frac{|q|h}{D}$$

Where q = flow velocity per cell,

h = longest dimension of an element in direction of flow length

D = dispersion

Due to the possibility that the groundwater level may fall below the cell bottom within a layer, Feflow has the option to set specify the layering as "Free Surface" whereby allowing the surface topography to be adjusted to follow the water level. This option was utilized to simulate water level recovery in the pit and further preventing modelling convergence problems due to so called "dry" cells.

6.3.9 Principles of Uncertainty

6.3.9.1 Numerical Model Uncertainties

Apart from model parameters, there are some unknown historical events and processes that influenced the system prior to the earliest recorded available data. Numerically simulating these unknown events to achieve an initial state calibration is not possible.

As stated earlier, uncertainties relating to the hydrological parameters exists. This is mainly due to the inability in conducting tests on such a large scale such as the model area. However, with the simplification of the model geology, the approximation of all the upper Valle aquifer layer to a porosity of 20% and 10% (at most) for the combined lower dolerite sill and siltstone lenses yielded the best results.

With regards to conductivities, with sparsely spaced tested boreholes, measured conductivities only representative of point locations, interpolation between these sparsely distributed point locations cannot be considered representative of the area. The conductivity (main parameter contributing to flow) of 0.06 m/d and 0.001 for the Valley aquifer and merged lower and deeper dolerite sills (with siltstone lenses) yielded best calibration results. These values are comparable to values encountered at similar sites with Karoo geology

6.3.9.2 Sensitivity Analyses

The automated sensitivity analyses using parameter estimation (PEST) were conducted relating to modelled groundwater levels with regards to geohydrological parameters. In specific the conductivities and porosities of the Valley aquifer and the merged lower and deep dolerite sills (with siltstone lenses). Evaluation these results as indicate Figure 54 indicate the highest sensitivities to the porosities of the Valley aquifer and the merged lower and deep dolerite sills (with siltstone lenses).

The differences between initial and estimated parameters are shown in Figure 55, indicating the initial values for the conductivities were within acceptable boundaries. The uncertainty of the values for porosities are reflected in relative changes suggested by the estimation software. The initial values were used in the simulations as the changes to these parameters caused elevated water levels within simulated result over long term predictions in 2129.

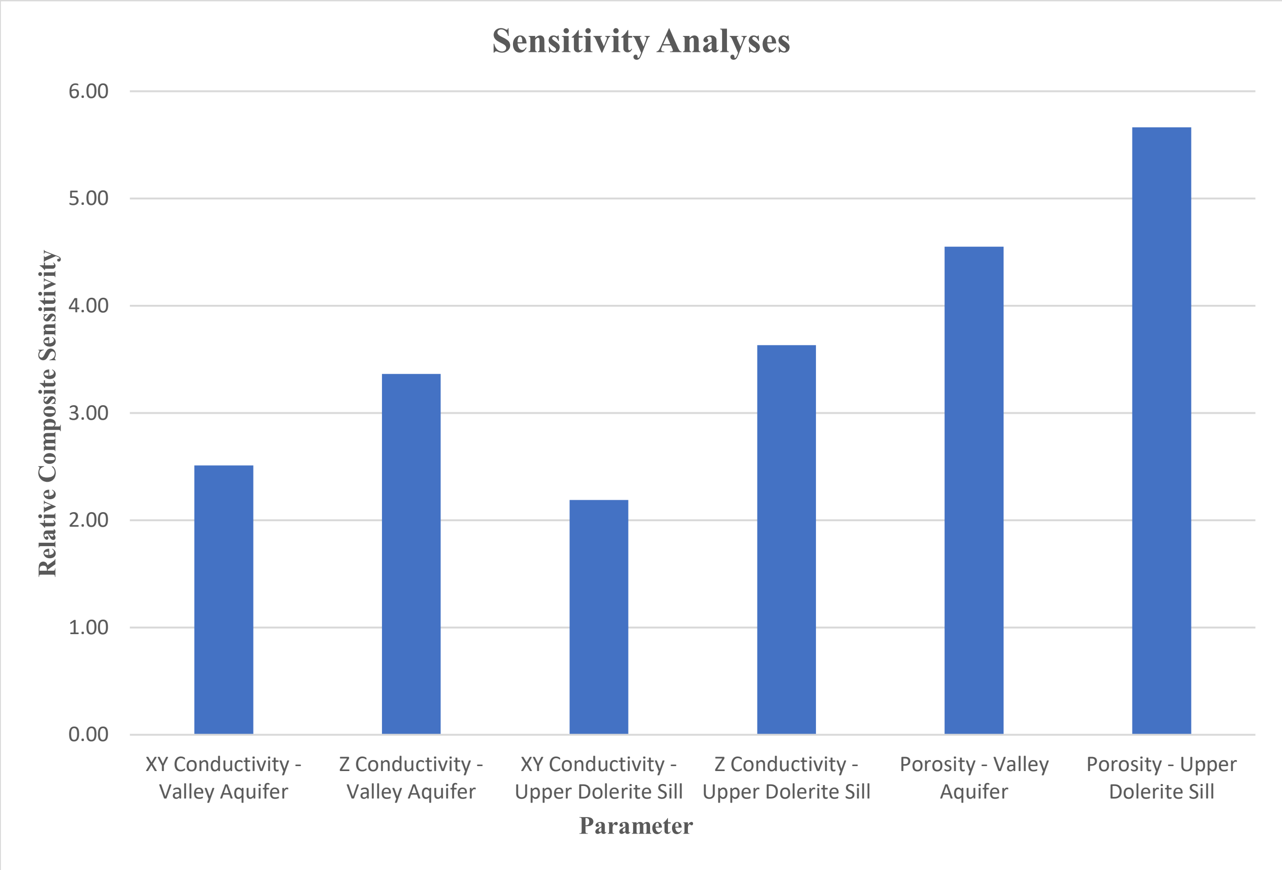


Figure 54. Parameter sensitivity graphs.

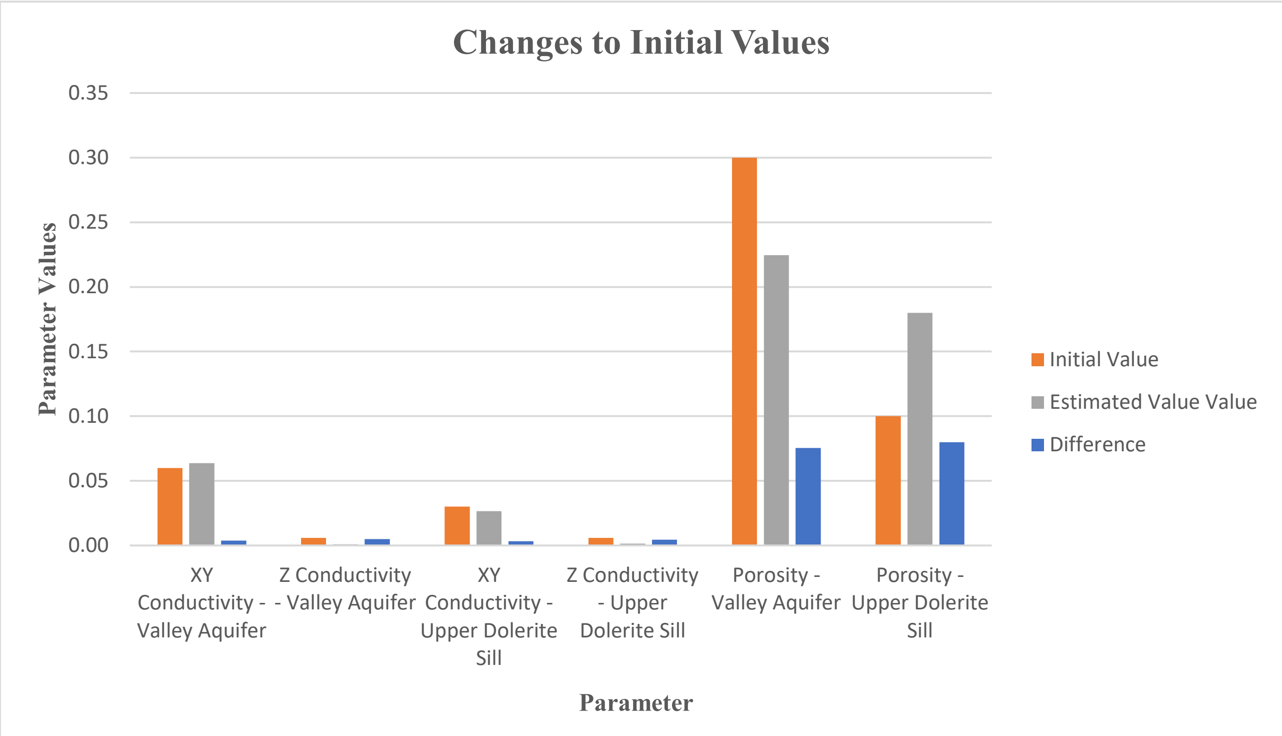


Figure 55. Relative changes between initial and estimated parameters.

6.3.9.3 Calibration - Defining Acceptable Confidence Limits

The water levels and mass transport obtained from a steady state solution (day) were used for transient state calibration to compare against measured values (water levels and chemistry from

2012 to 2021). Considering the large scale of the area with sparsely borehole distribution, confidence limits were set in the model calibration process for both the water levels and SO_4 concentrations aiming to prediction of water levels to within several meters of measured values.

6.3.9.3.1 *Groundwater Elevations*

A regression coefficient of 0.95 with a correlation of 97% were obtained between the measured and simulated water level and model predictions can therefore be considered "good" with more than 75% confidence.

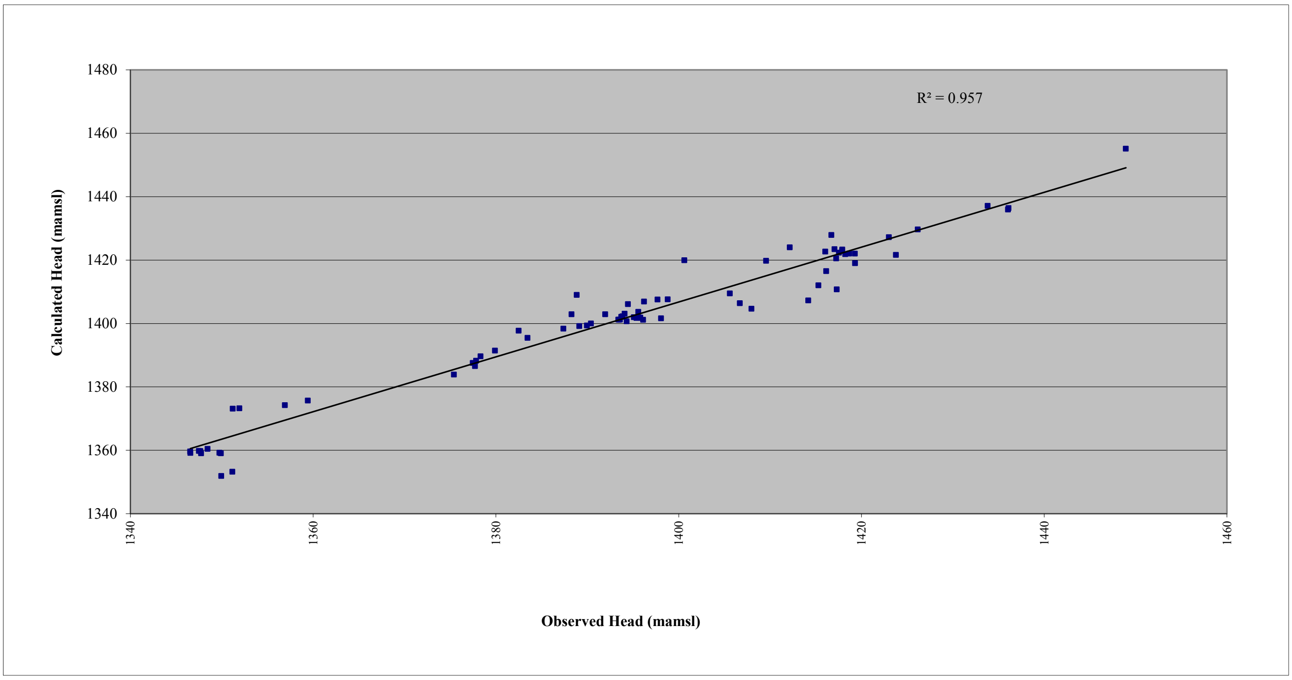


Figure 56. Calculated vs observed heads.

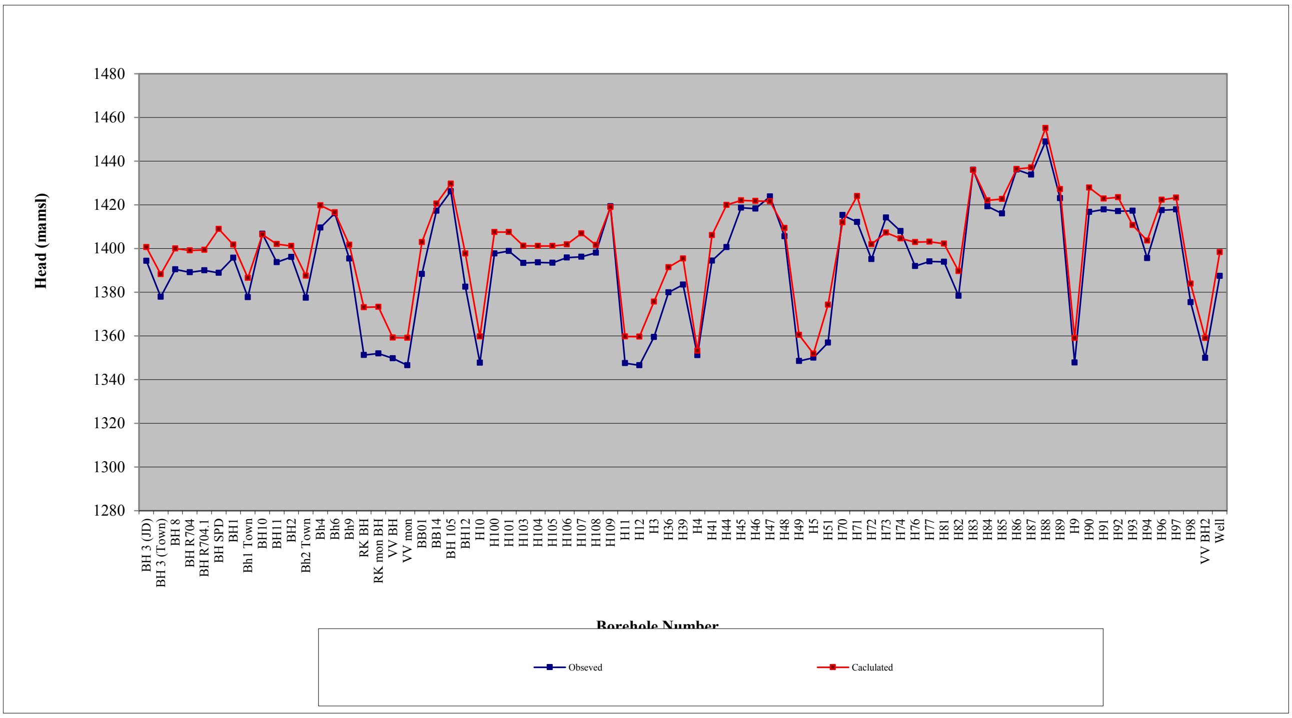


Figure 57. Calculated and observed heads.

6.3.9.3.2 SO_4 Concentrations

Given that background and detected SO_4 concentrations are between 50 and 2400 mg/L, deviations between simulated and observed concentrations were aimed at less than 300 mg /L When including the background and town boreholes a regression coefficient of 0.63 with and correlation of 79% were obtained between the measured and simulated SO_4 concentrations of 2016 (the last date with available data from possibly impacted town boreholes).

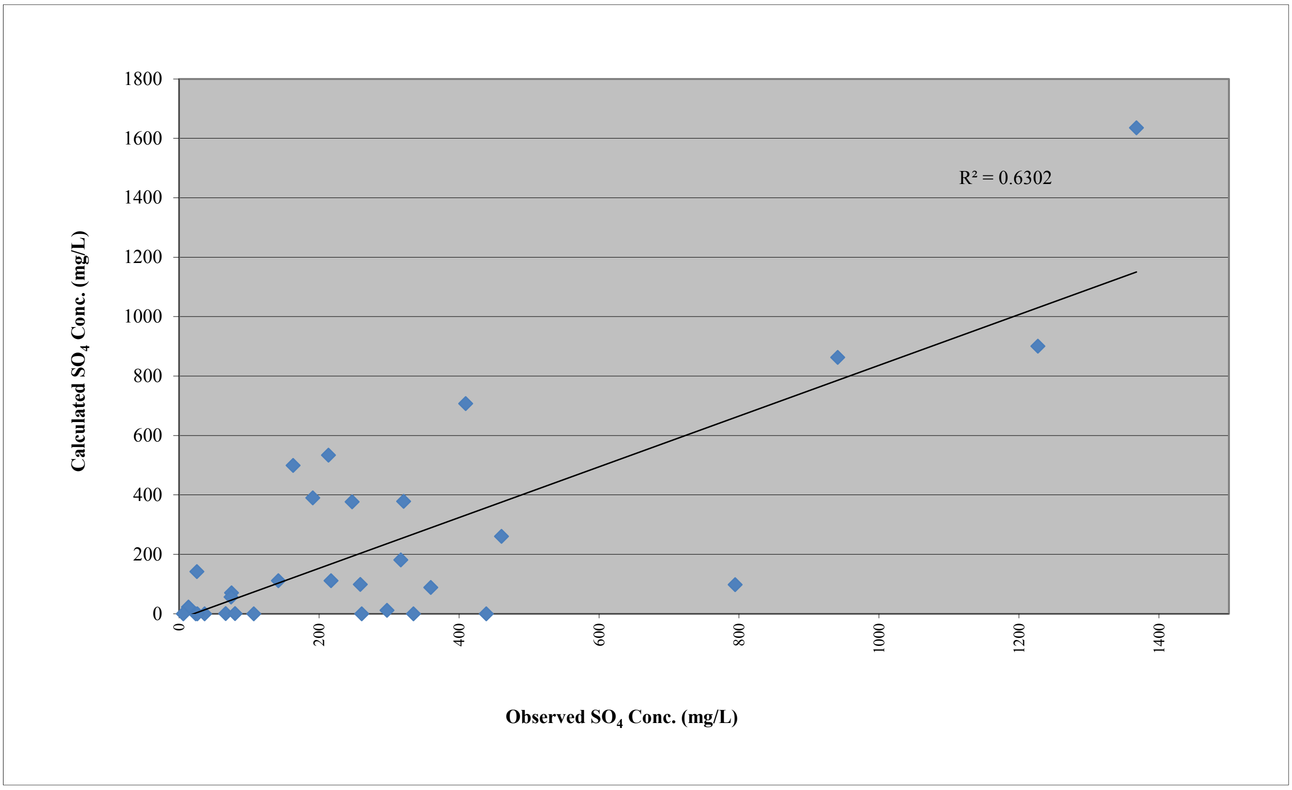


Figure 58. Calculated vs observed SO_4 concentrations.

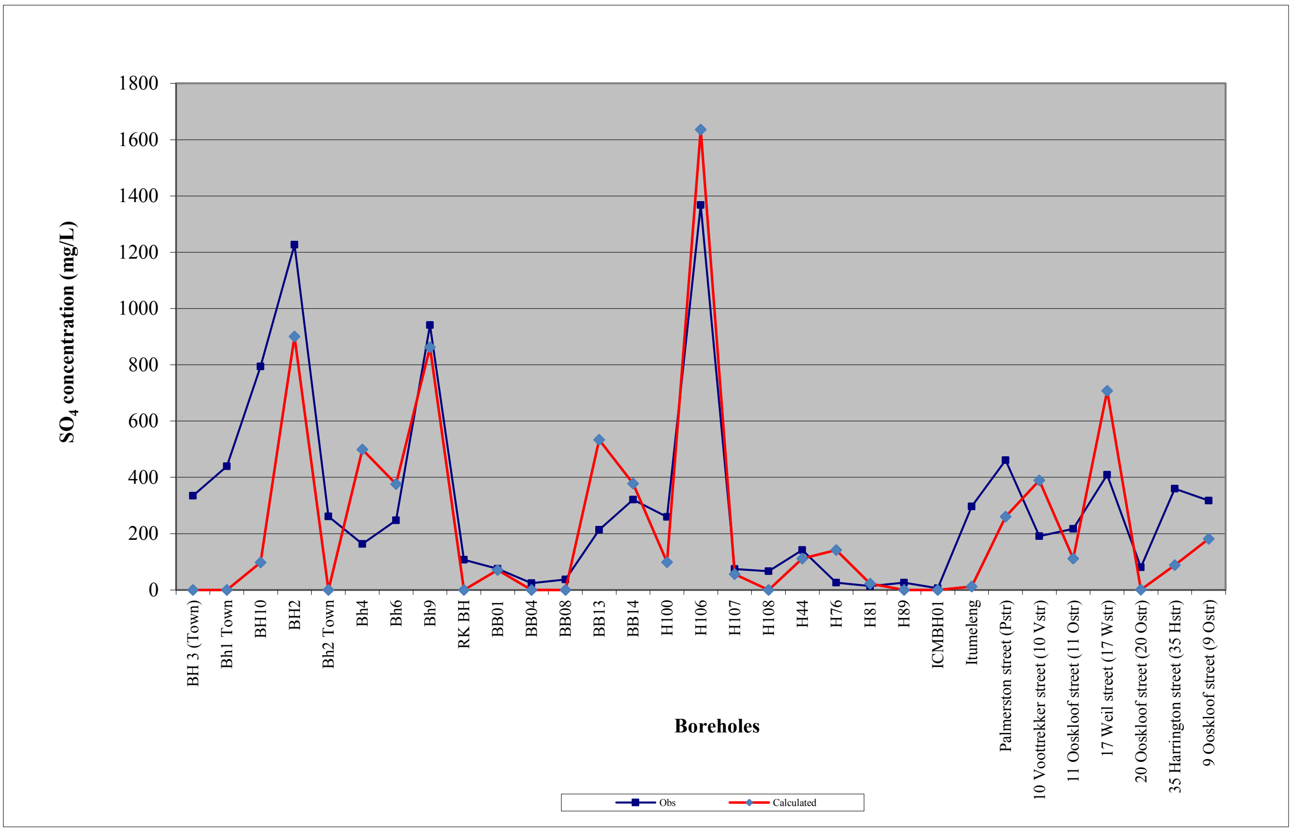


Figure 59. Calculated and observed SO_4.

6.4 Numerical Model Results

6.4.1 Groundwater Elevations

The comparison between the simulated water level elevations of the two scenarios is given in Figure 60 with the only visible difference being the rest water level elevations in the pit. In the first scenario where the pit is not filled, the rest water depth of 183 mbgl translates to 1230 mamsl and when the pit is filled to 60 mbgl to 1353 mamsl.

Jagersfontein Development Regional Water Level Elevations

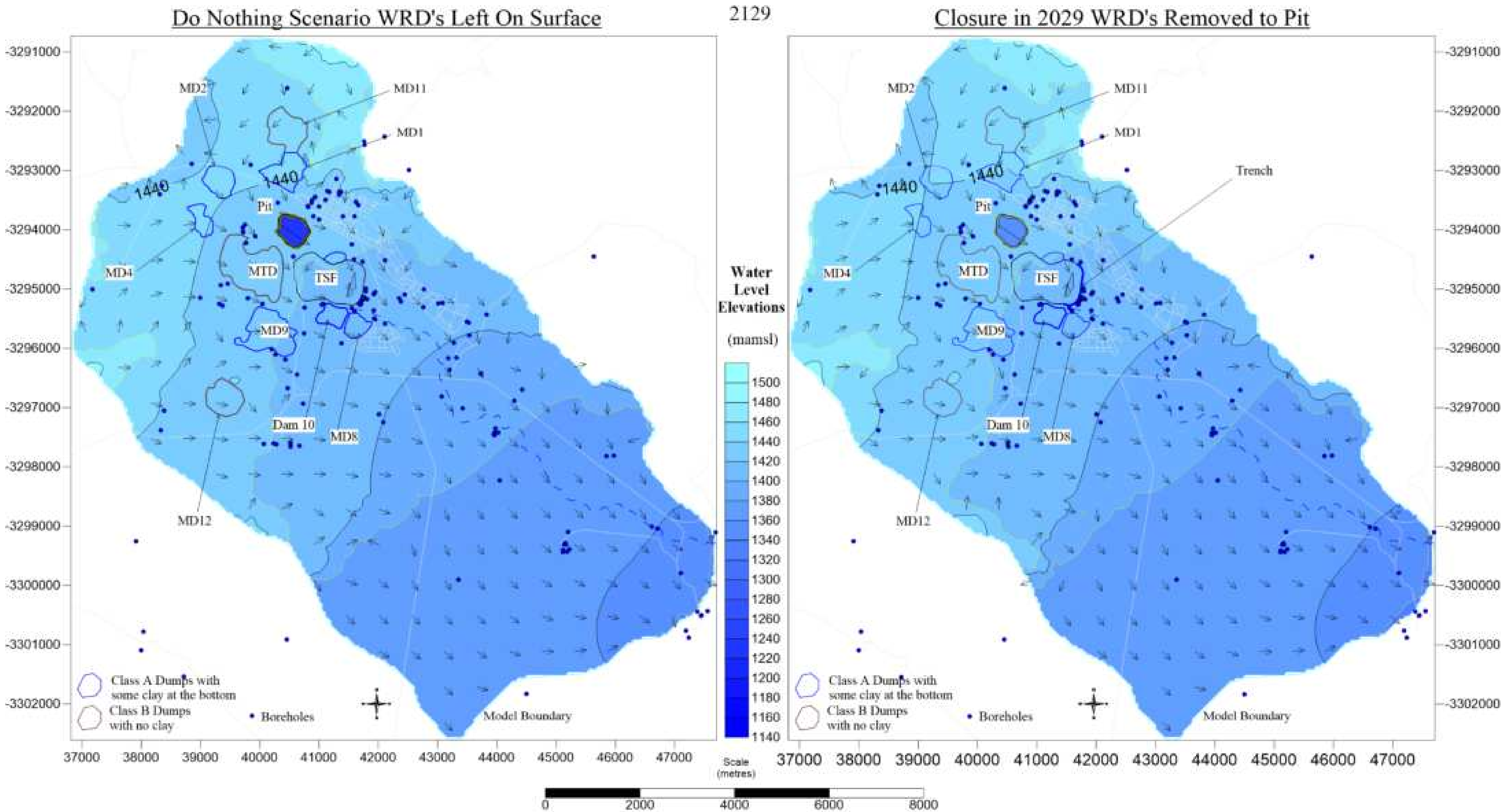


Figure 60. Comparison between the simulated groundwater elevations of the different scenarios (year 2129).

6.4.2 Pollution Plumes

Comparisons between the simulated SO_4 pollution plumes of the two scenarios (Don-Nothing and Filling the Pit) are presented in Figure 61 to Figure 81.

6.4.2.1 Superficial Soils

The simulated results of pollution plumes within the superficial soils are displayed in Figure 61 to Figure 67. The effect of the trench can be seen in all these figures with less pronounced influences from the simulated abstraction boreholes (due to be operational within the lower Valley aquifer). With the pit area marked as inactive, possible pollution emanating from the WRD's to the north of the pit migrates past the pit. In reality though, no flow is taking place or migrating past the pit as already explained. The superficial soils (approximately 4 metres thick) above the dolerite sills are simulated as weathered material receiving recharge and as such will propagate pollution in the model due to the homogenous isotropic modelling assumptions.

No pollution is migrating in any of the simulations from the pit to the superficial soils.

Operational Phase

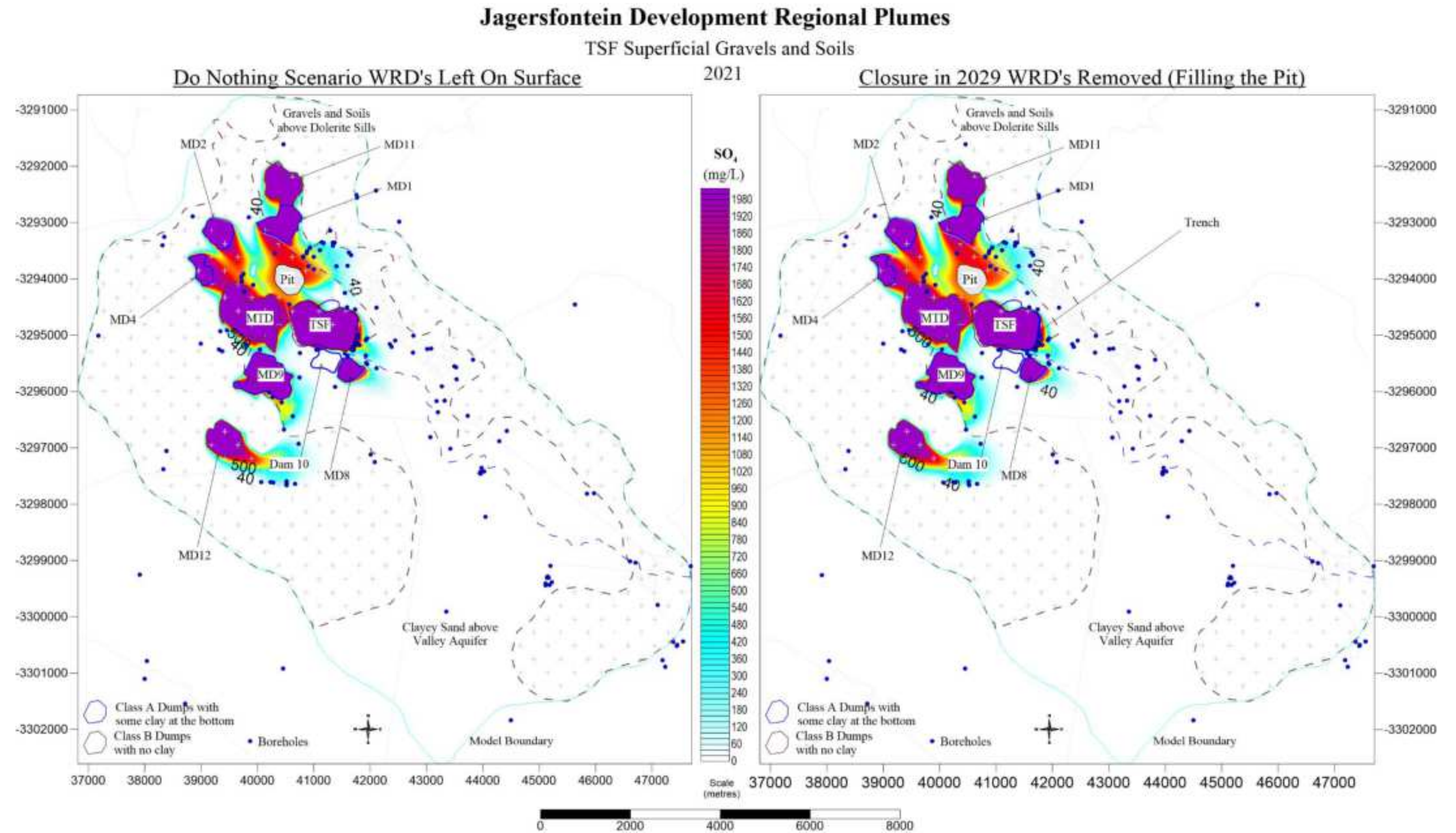


Figure 61. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2021).

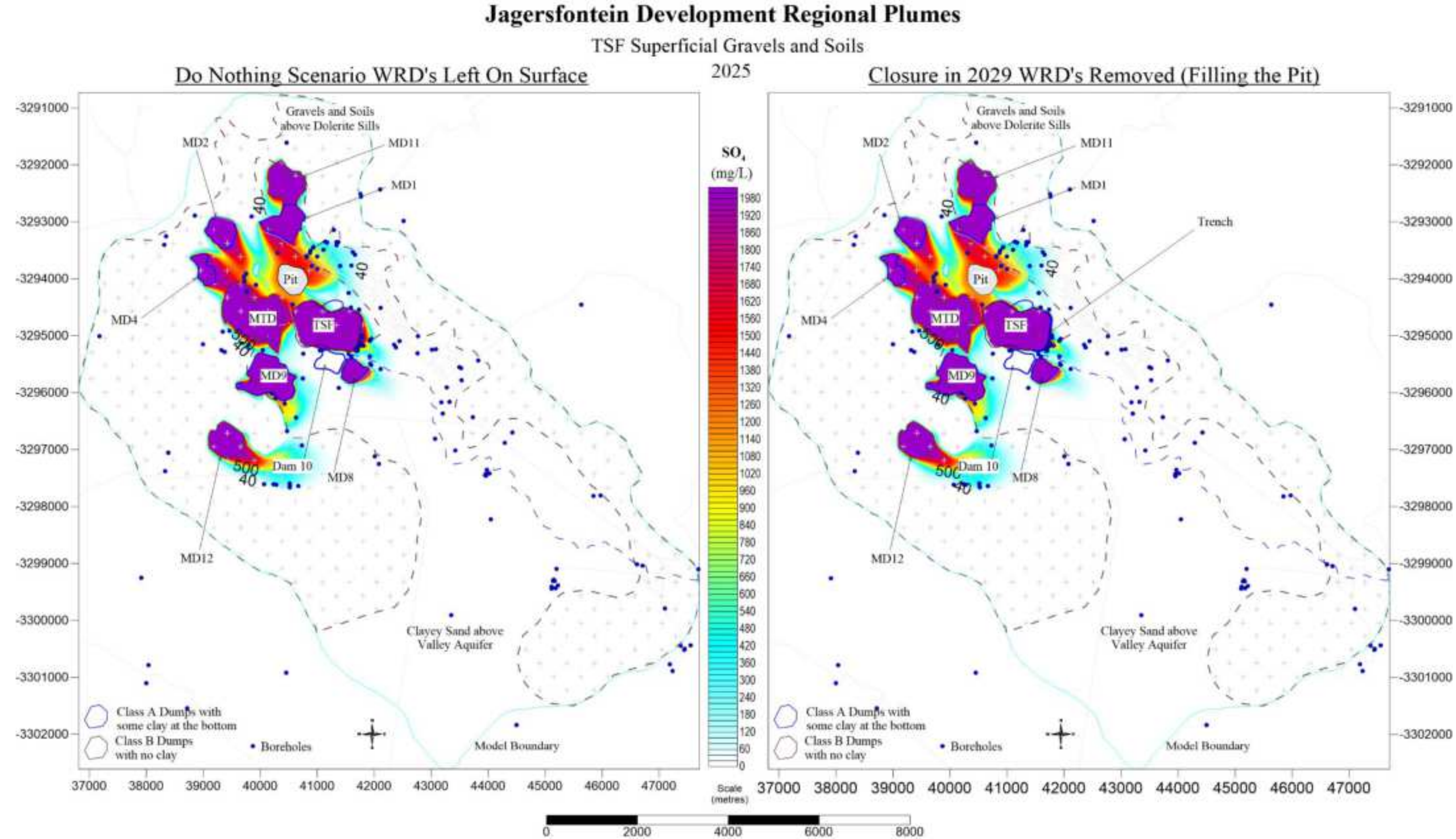


Figure 62. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2025).

Closure

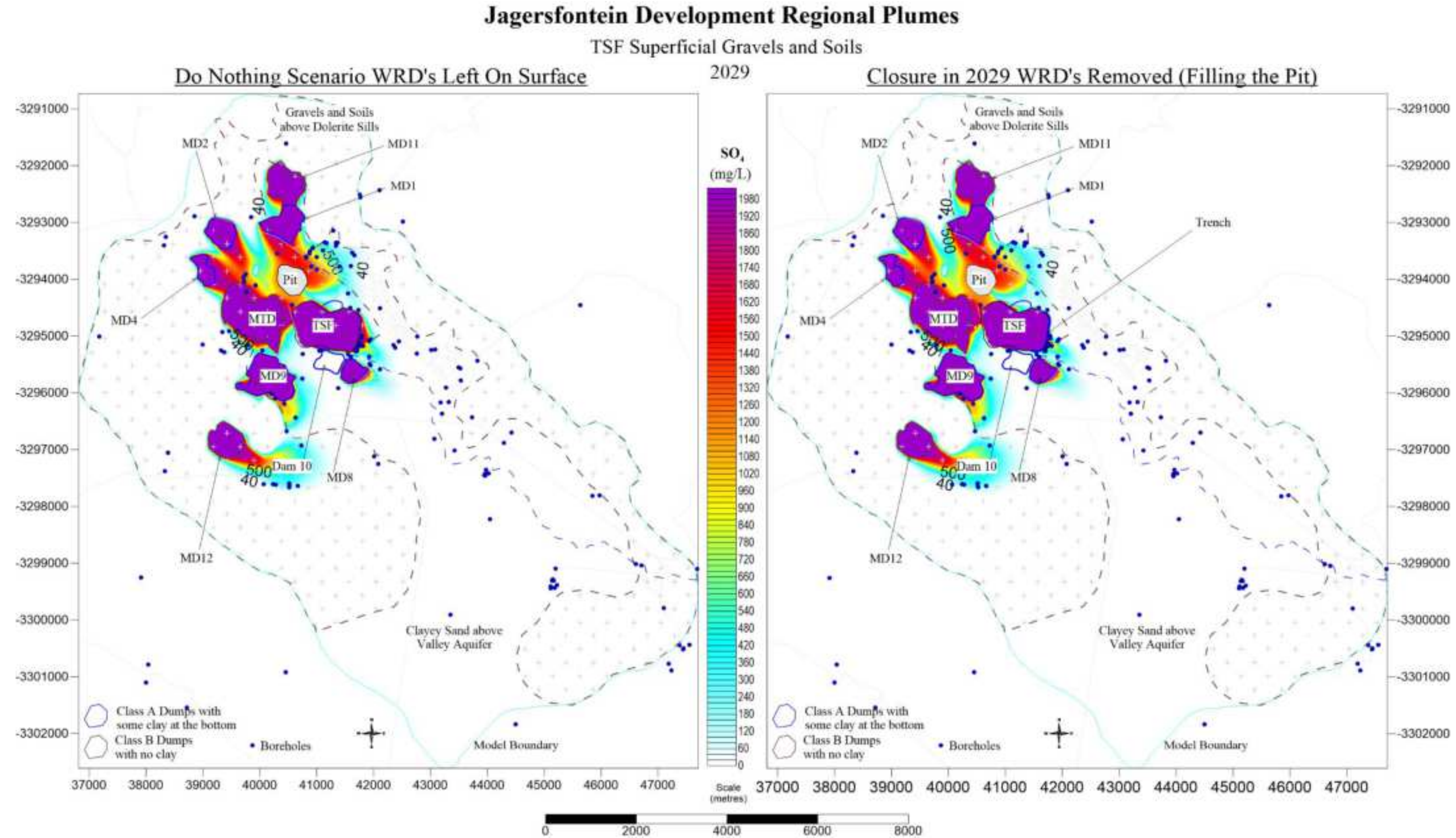


Figure 63. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2029 at end of operations).

Post Closure

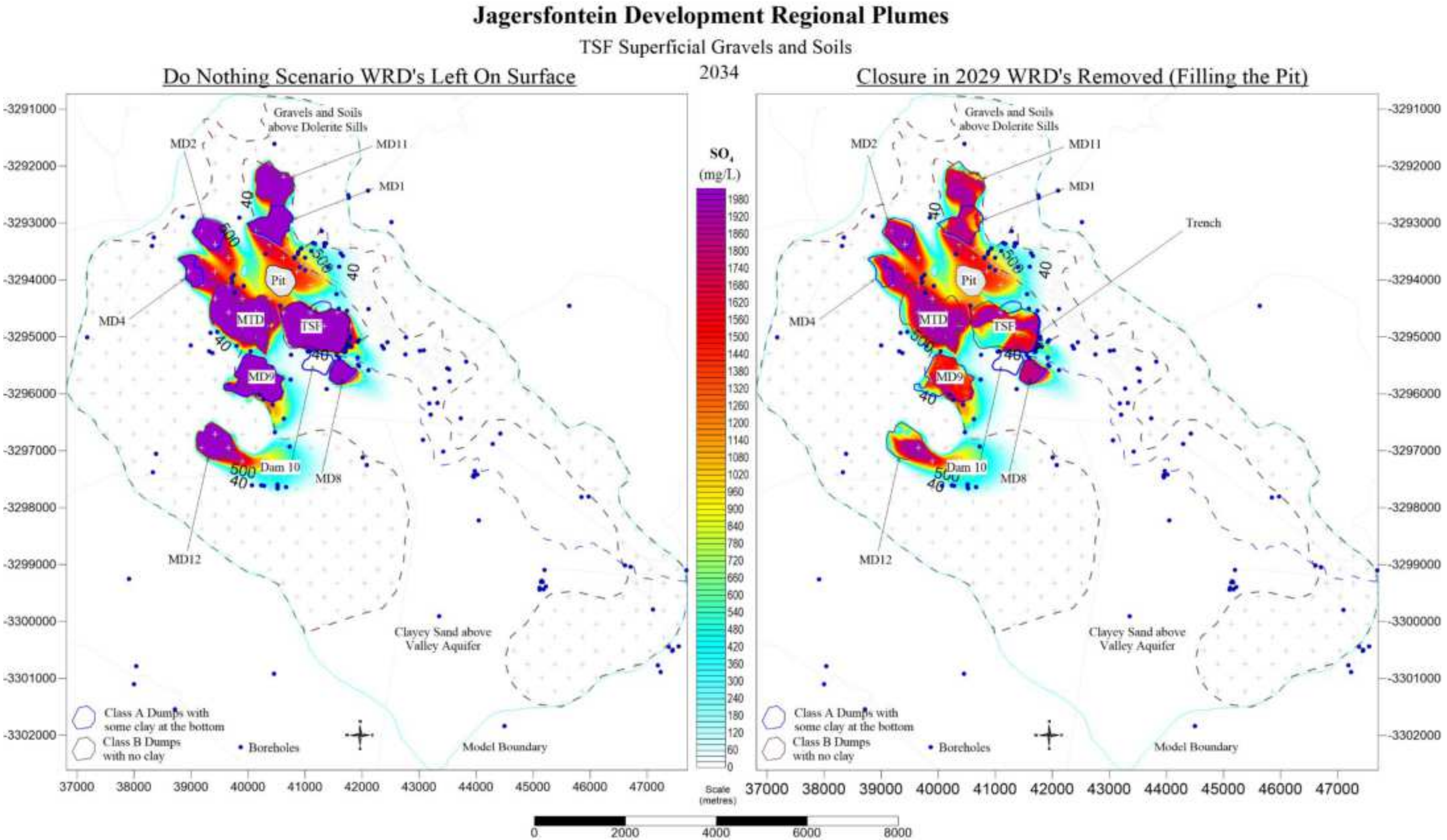


Figure 64. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2034).

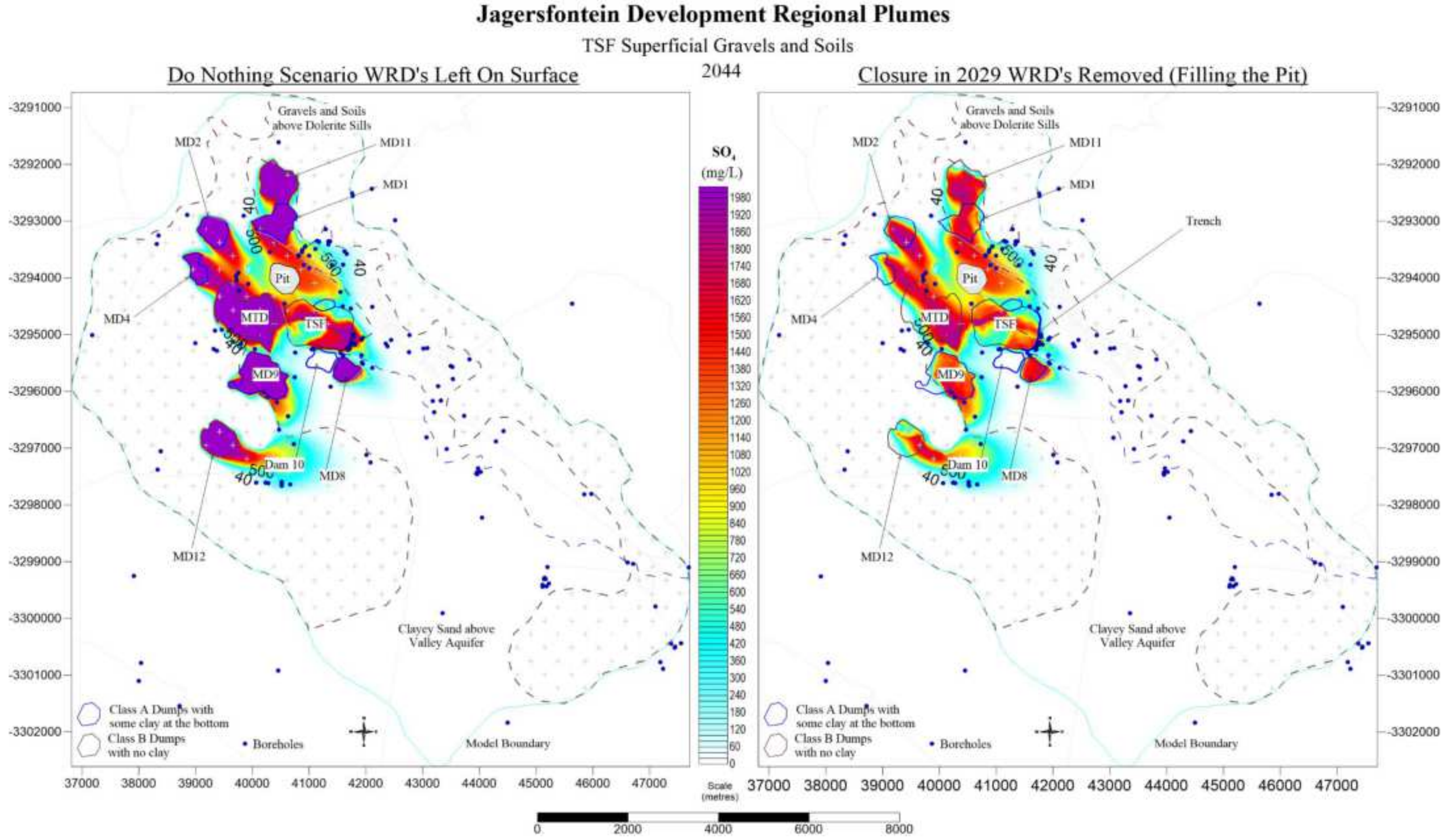


Figure 65. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2044).

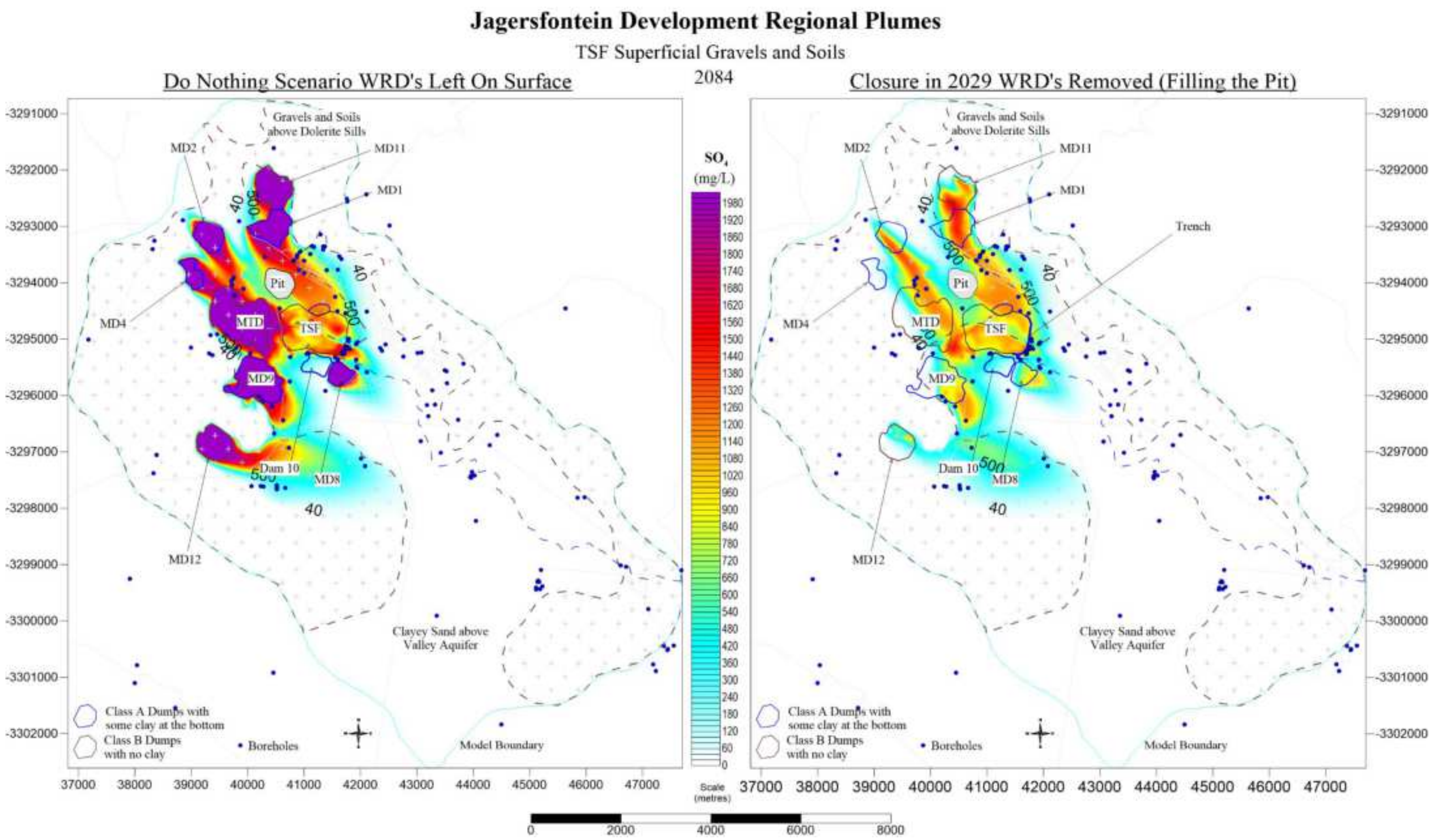


Figure 66. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2084).

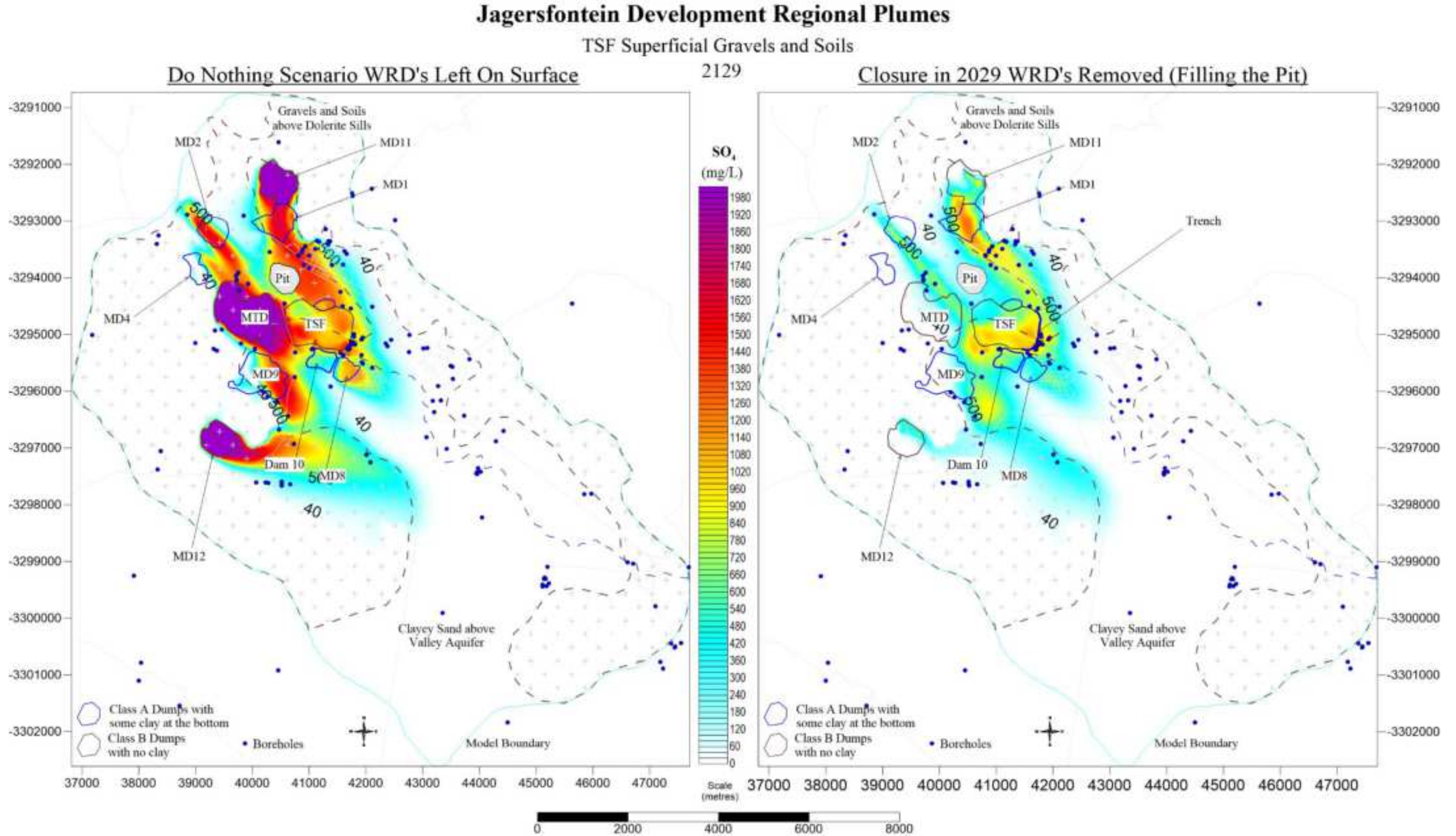


Figure 67. Comparison between the simulated pollution plumes of the different scenarios within the superficial soils (year 2129).

6.4.2.2 Valley Aquifer

Similarly to the regional pollution plumes within the superficial soils, gravels and clays, the simulated pollution plumes within minor Valley aquifer are displayed in Figure 68 to Figure 74.

Decreasing pollution plumes both in extent and concentrations can be seen from as early as 2034 (Figure 71) in the scenario where the on-surface WRD's were removed by 2029. Improvements are becoming more apparent from 2044 (see Figure 72) in this scenario as opposed to the do-nothing scenario.

The prolonged impacts from the class B dumps left on-surface can be seen in see Figure 73 (2084) and Figure 74 (2129). Earlier removal would be a major improvement as the Valley aquifer is the main exploitable aquifer in the region feeding the contact between this aquifer and the dolerite sill beneath.

Simulations of both scenarios of the 2129 (see Figure 74) pollution plumes indicate the edge of the 40 mg/L SO4 WUL limit to be mostly within 2km downgradient from the pollution sources. However, there is a significant difference in the concentrations and footprint when the sources are not removed as opposed to removal.

No pollution is migrating in any of the simulations from the pit to the Valley aquifer.

Operational Phase

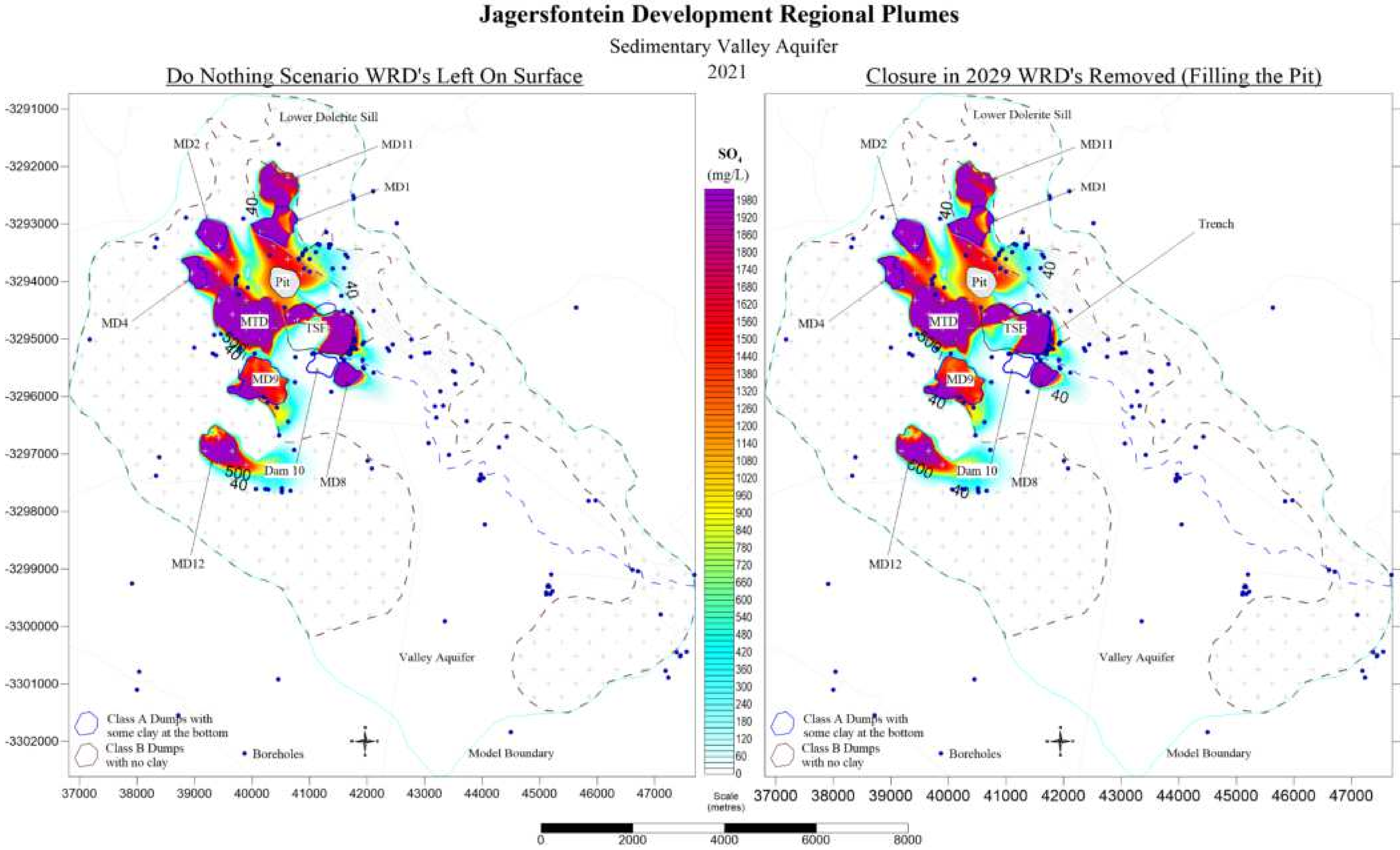


Figure 68. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2021).

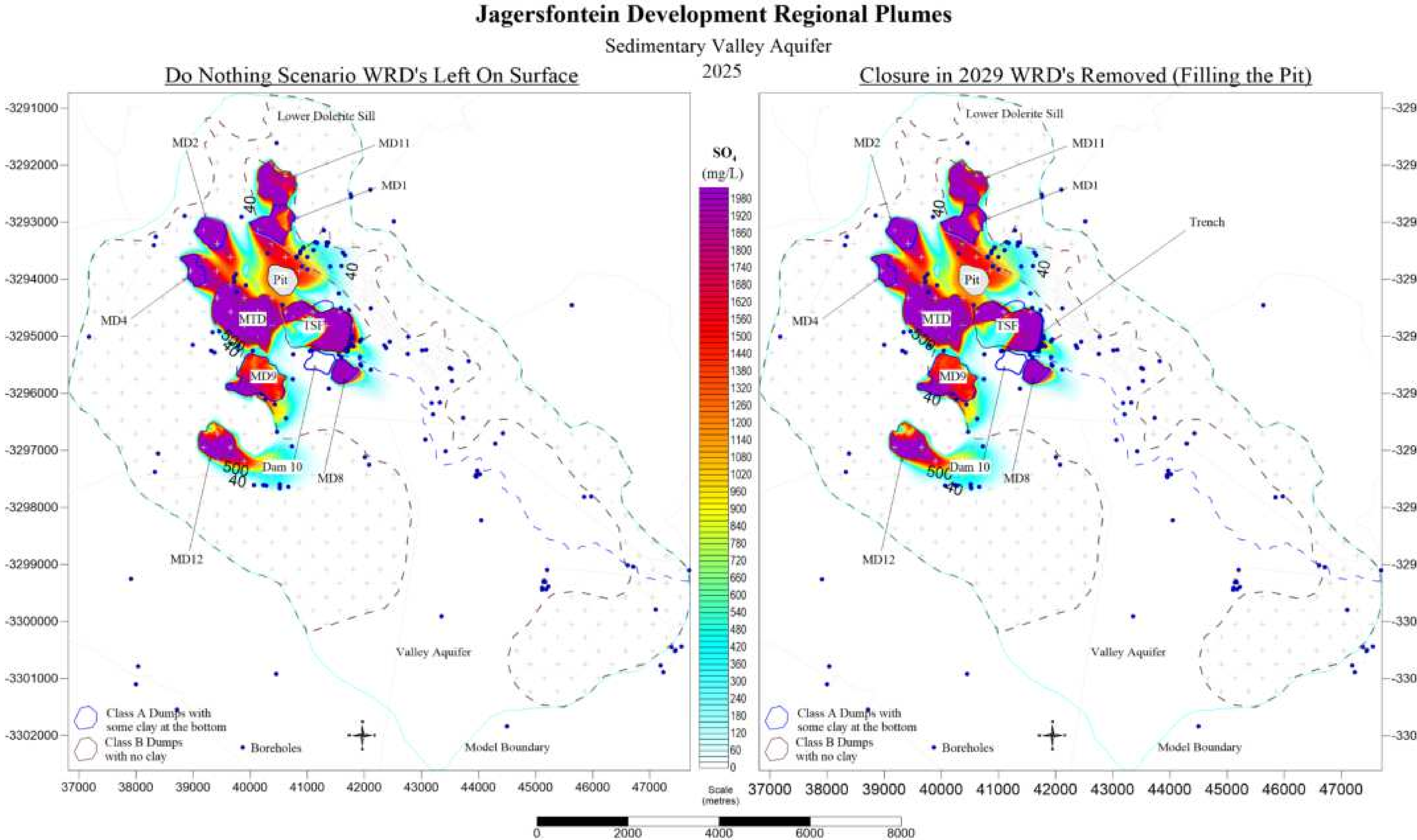


Figure 69. *Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2025).*

Closure

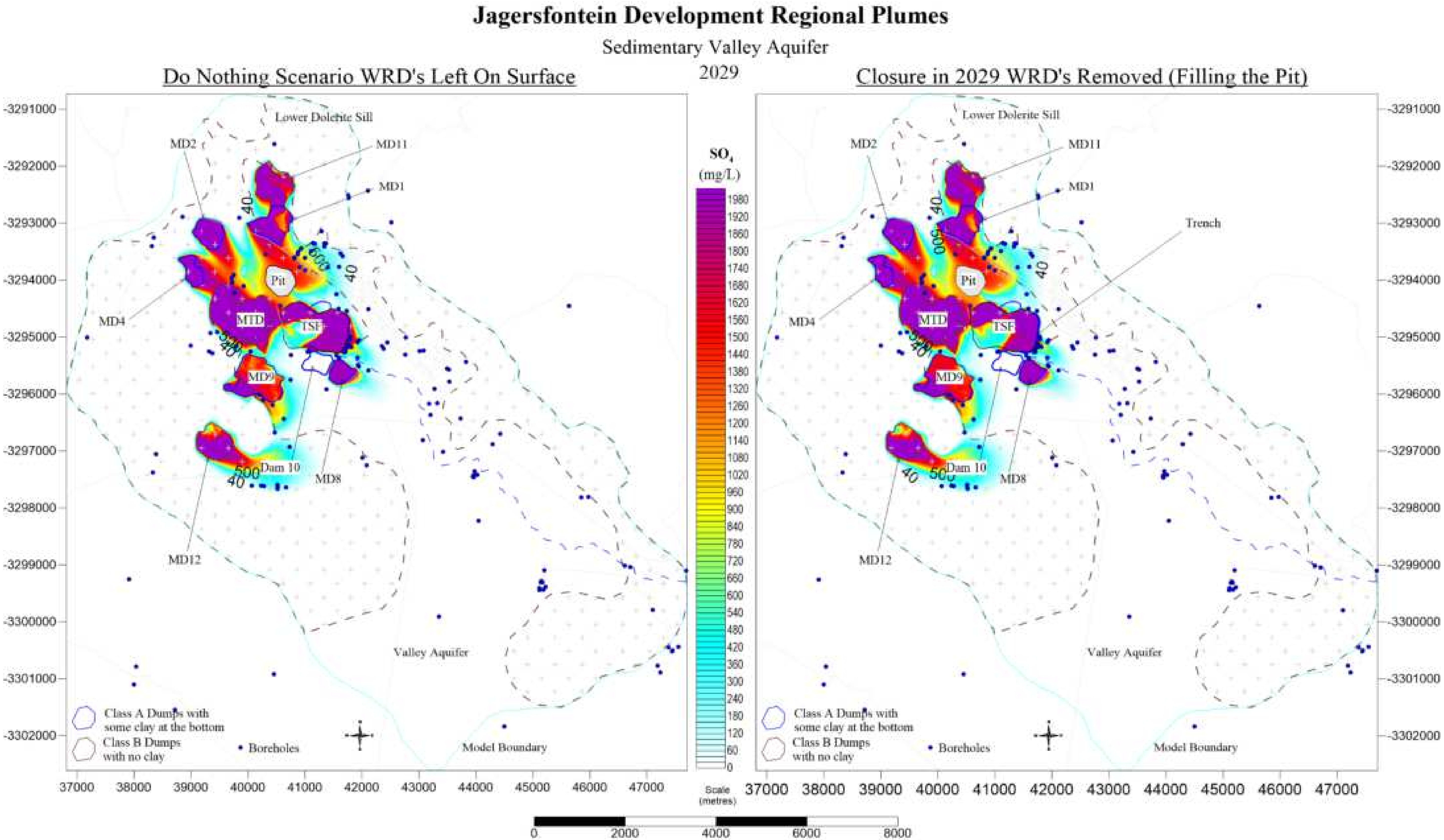


Figure 70. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2029 at end of operations).

Post Closure

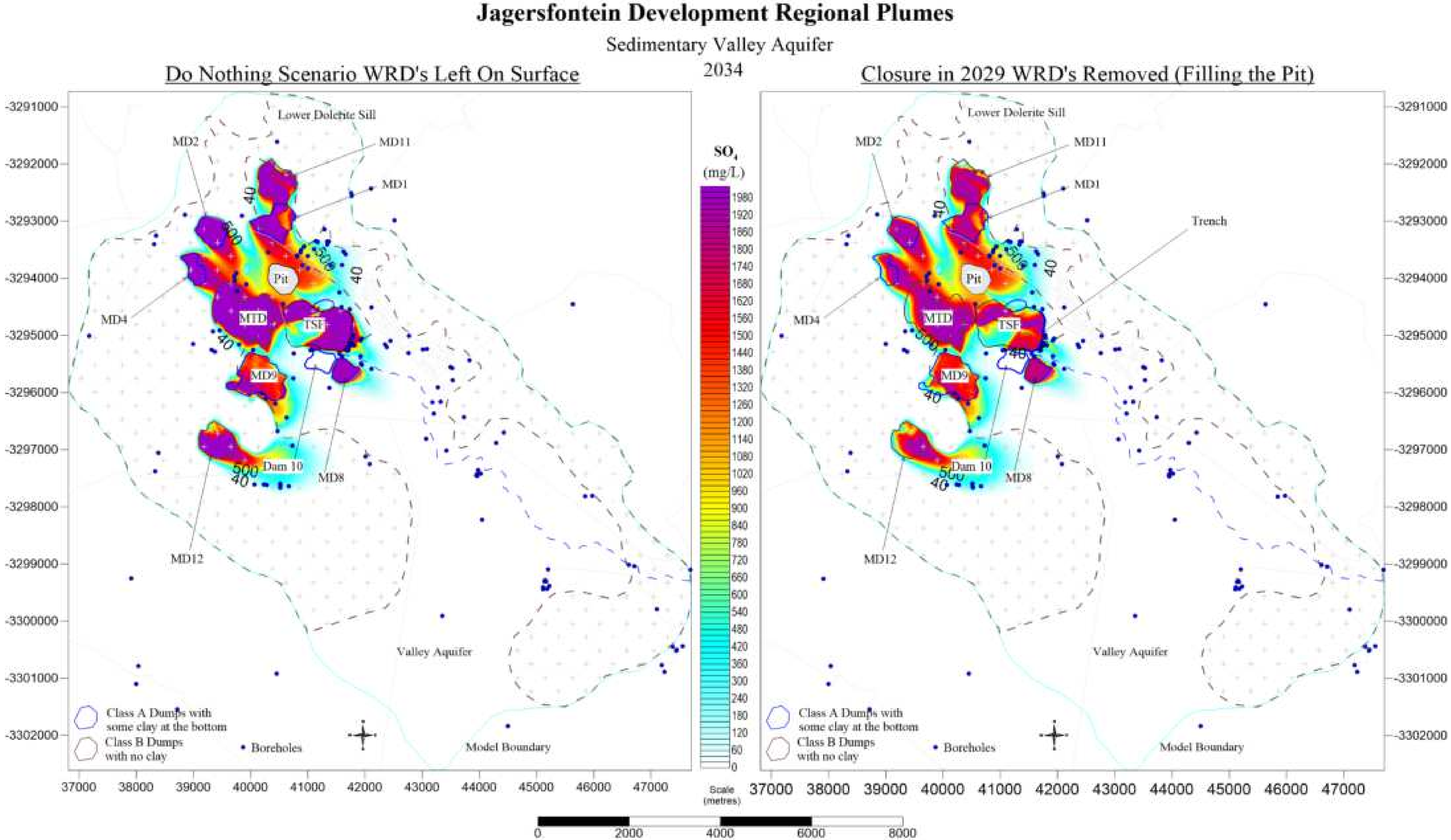


Figure 71. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2034).

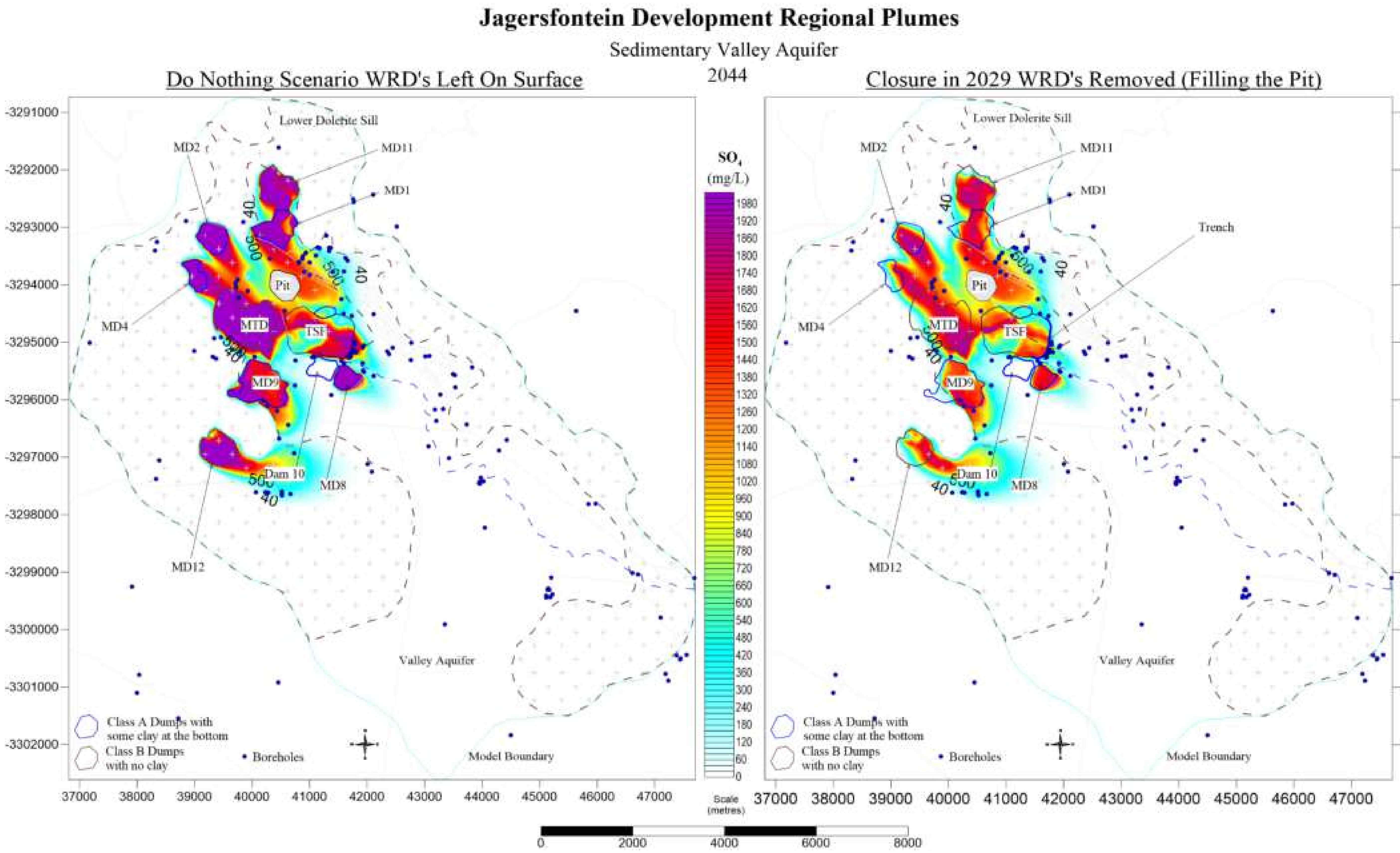


Figure 72. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2044).

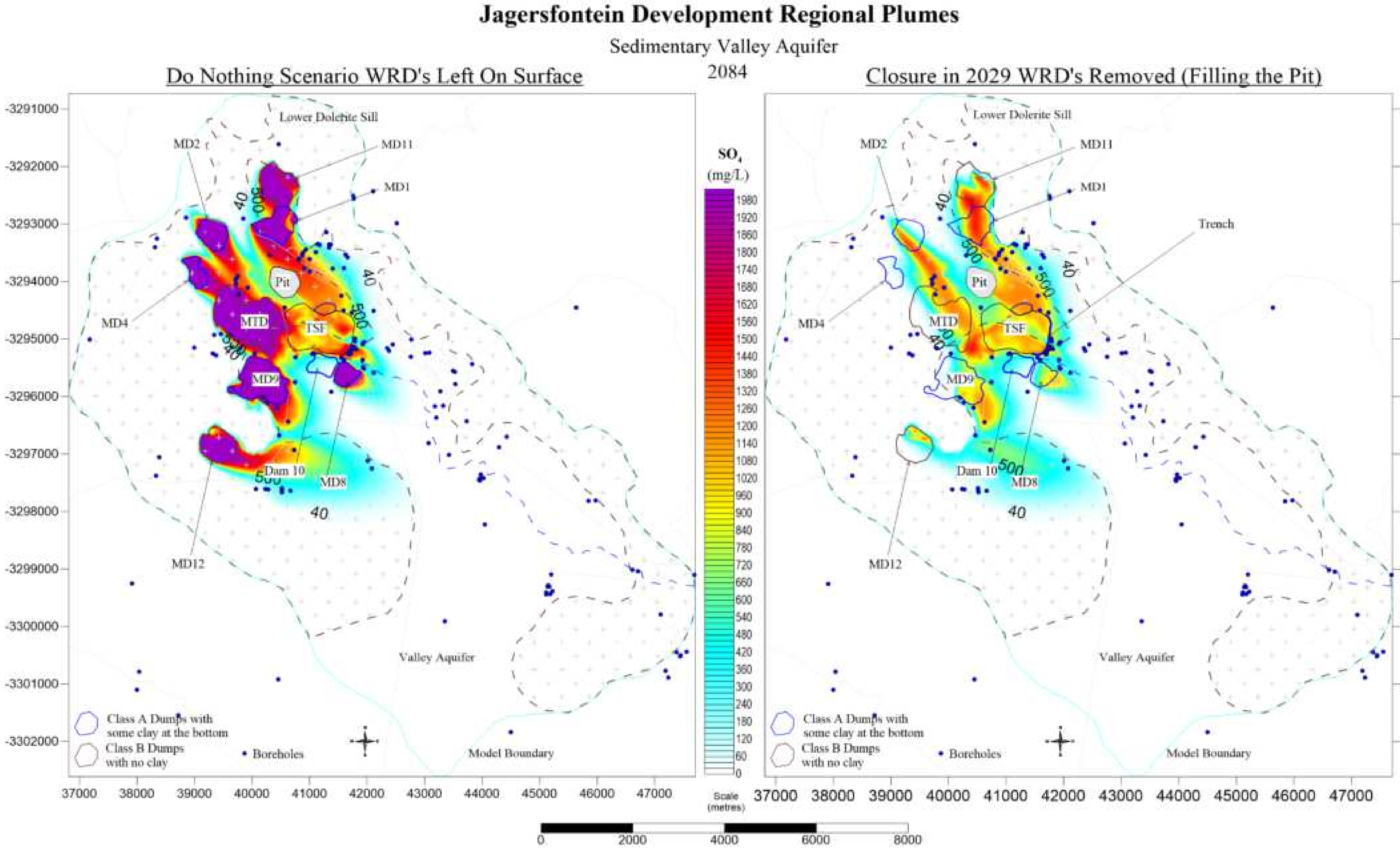


Figure 73. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2084).

Jagersfontein Development Regional Plumes

Sedimentary Valley Aquifer

2129

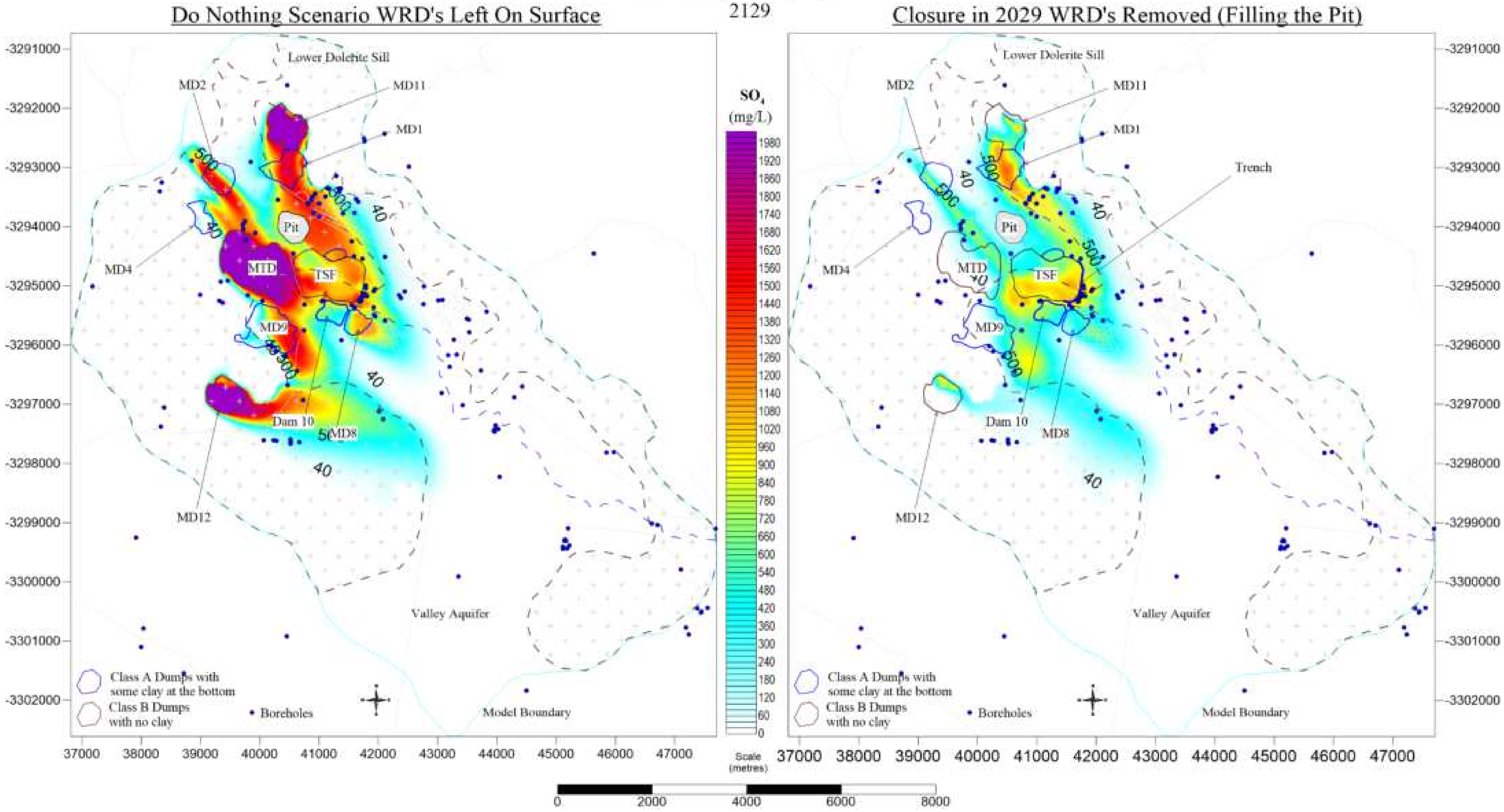


Figure 74. Comparison between the simulated pollution plumes of the different scenarios within the Valley aquifer (year 2129).

6.4.2.3 Contact between Valley Aquifer and Dolerite Sill

The simulated pollution plumes within the contact between the Valley aquifer and the lower dolerite sill are displayed in Figure 75 to Figure 81.

The diminishing pollution plume trends in the contact between the Valley aquifer and the dolerite sill are very similar to those of the Valley aquifer itself due to the already explanation that Valley aquifer is the source of water to the contact and this zone. This zone normally has a higher permeability and yield than the sedimentary Valley aquifer and is often targeted by drilling and pump inlet at this level. Removal of the on-surface WRD’s will thus cause the readily improvement of this source.

No pollution is migrating in any of the simulations from the pit to the contact between Valley aquifer and the dolerite sill.

Operational Phase

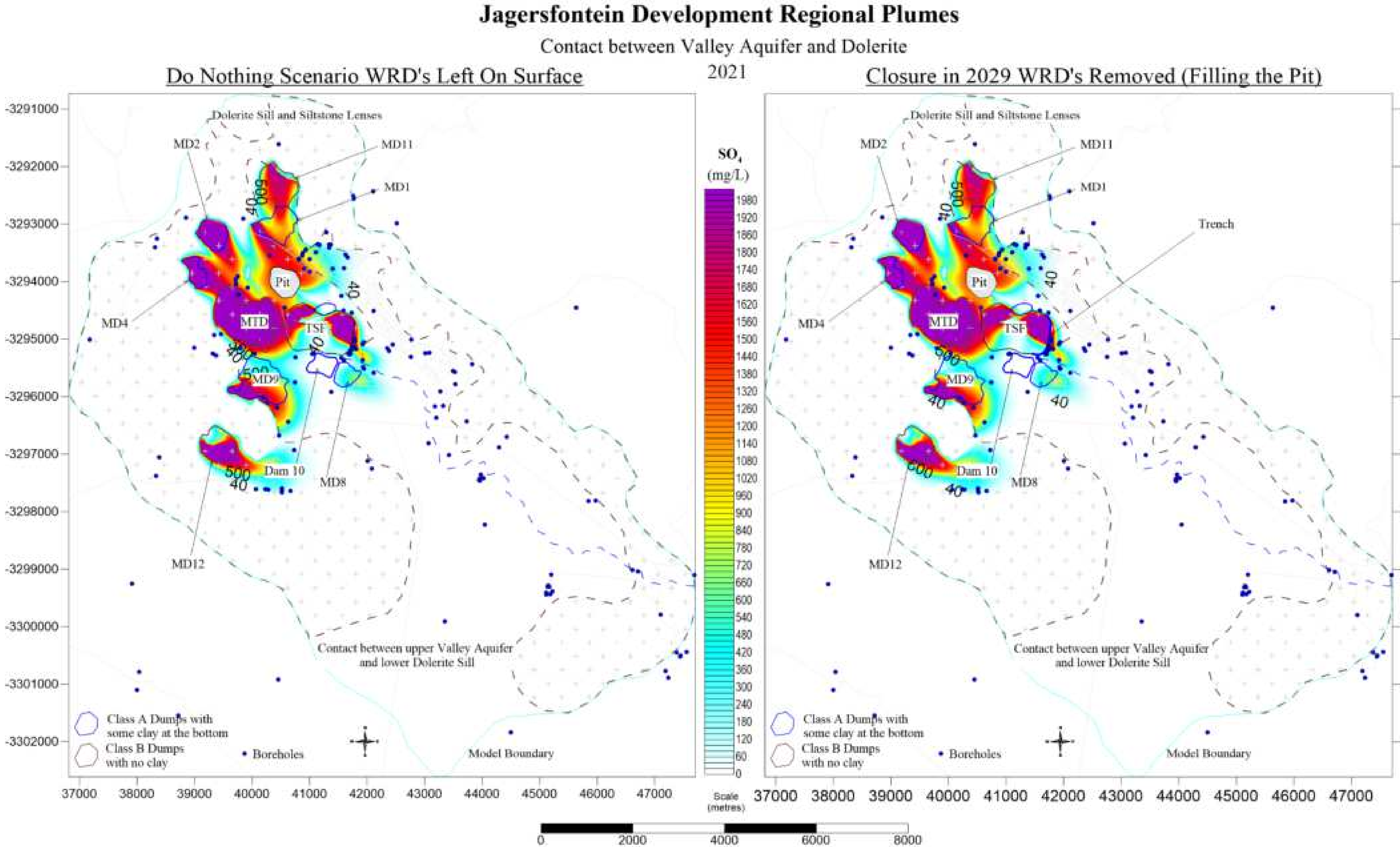


Figure 75. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2021).

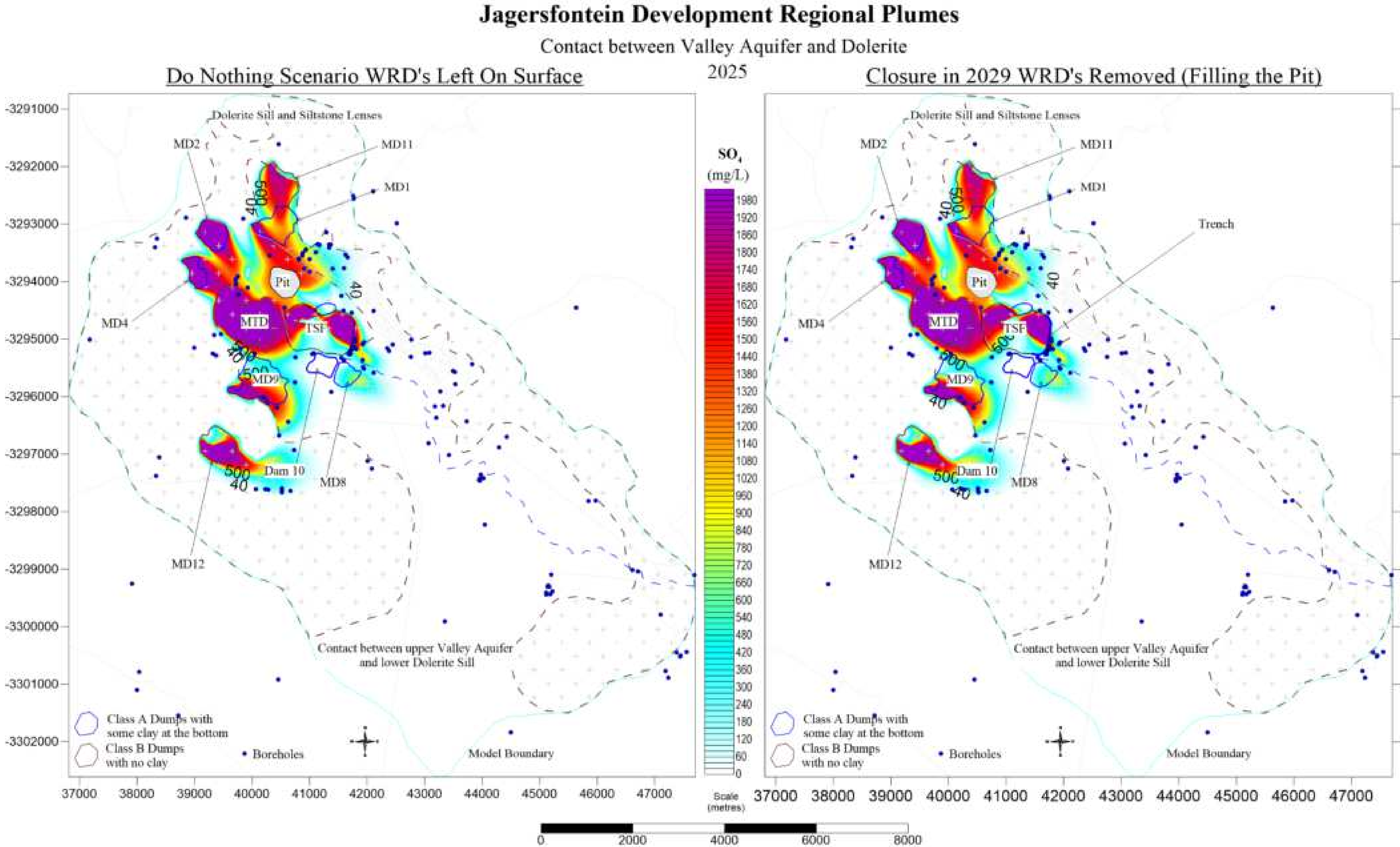


Figure 76. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2025).

Closure

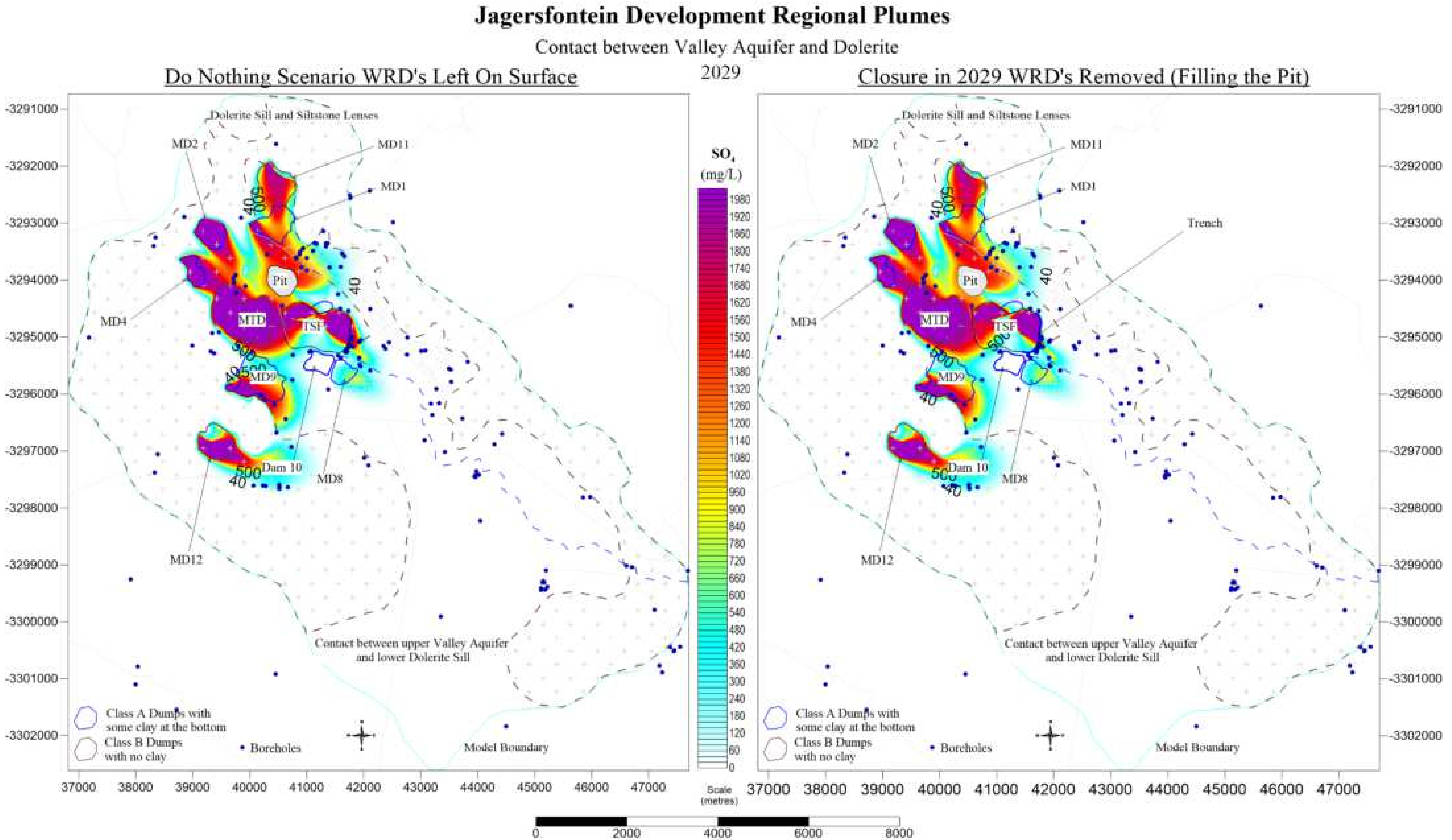


Figure 77. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2029 at end of operations).

Post Closure

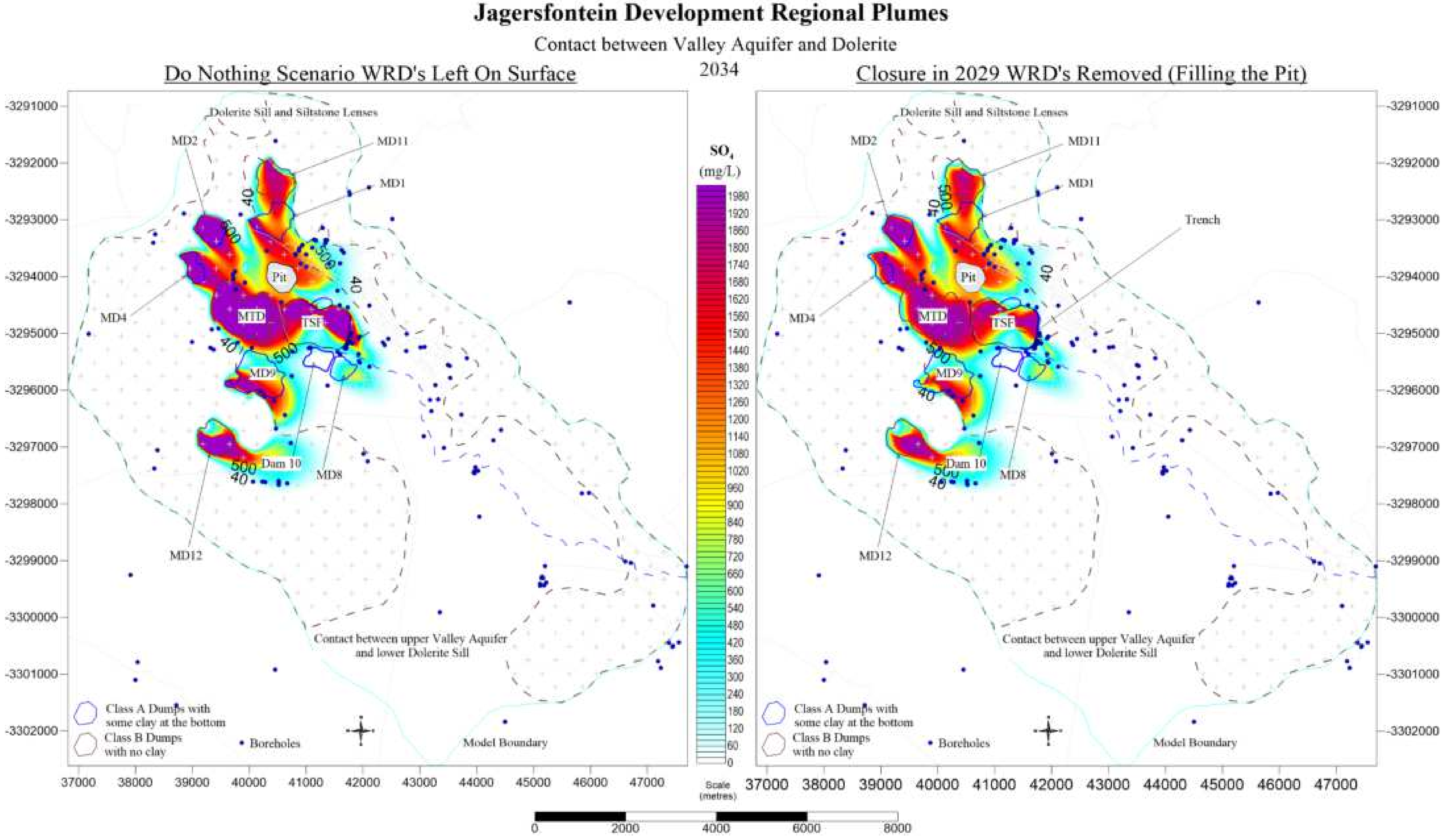


Figure 78. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2034).

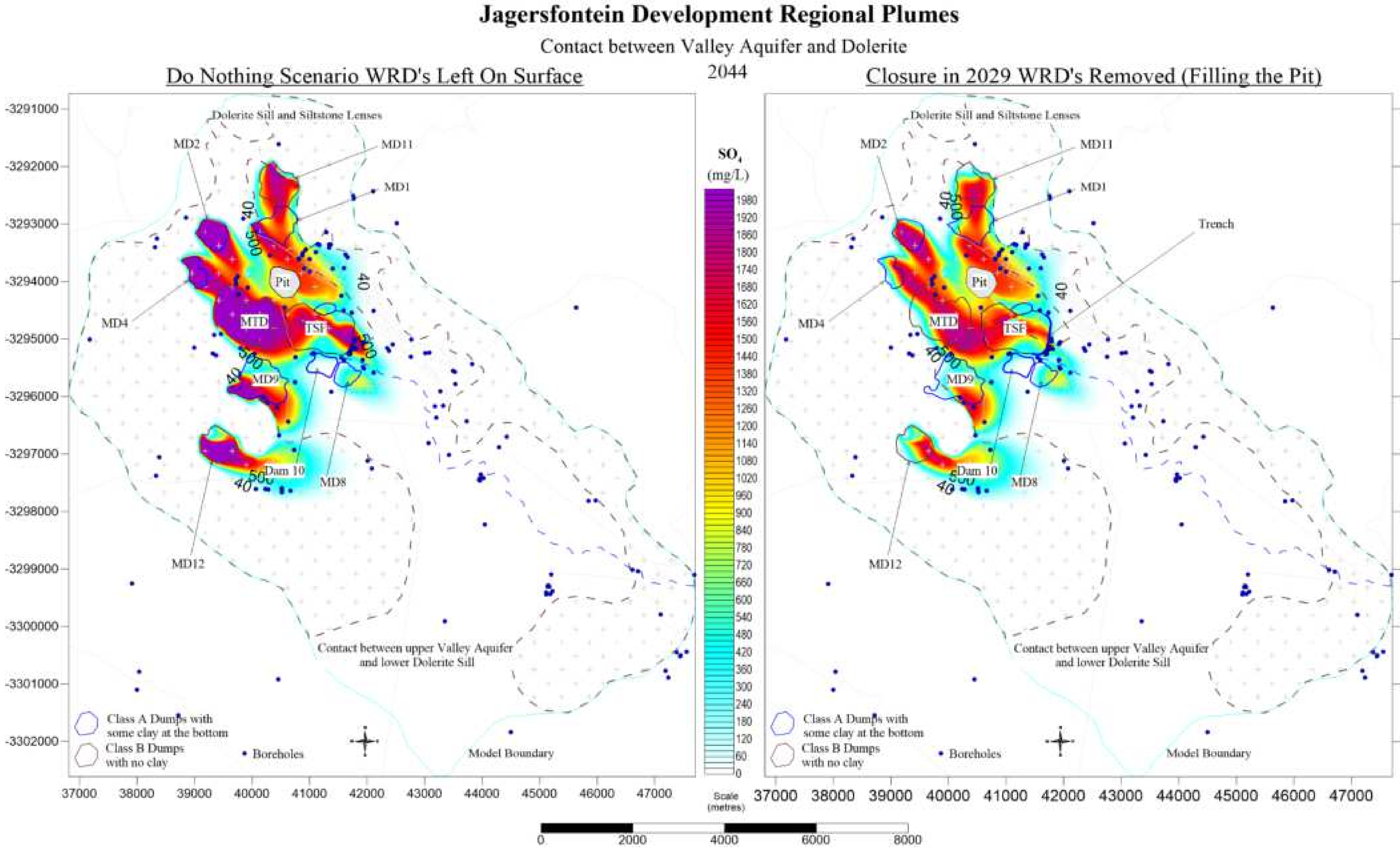


Figure 79. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2044).

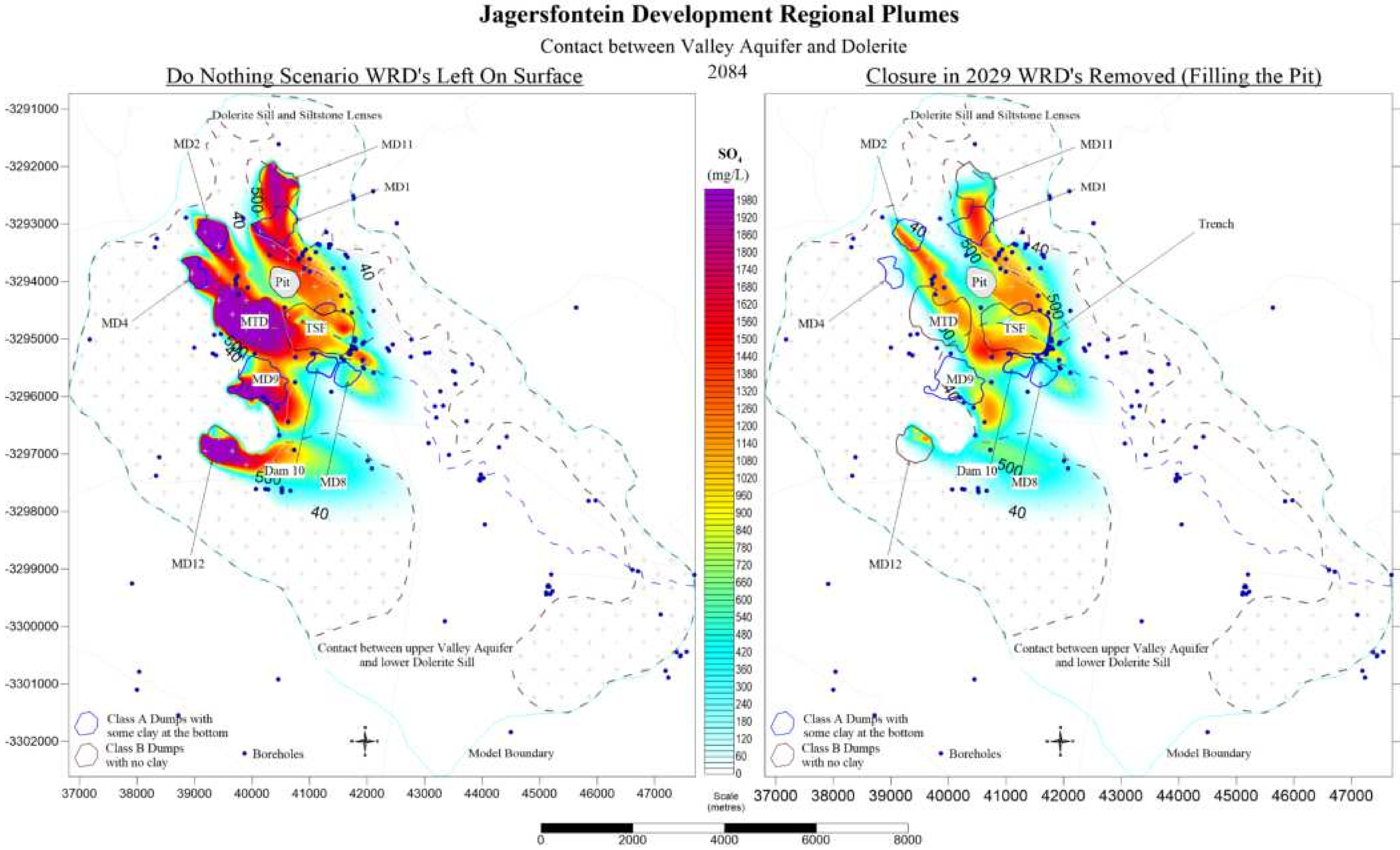


Figure 80. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2084).

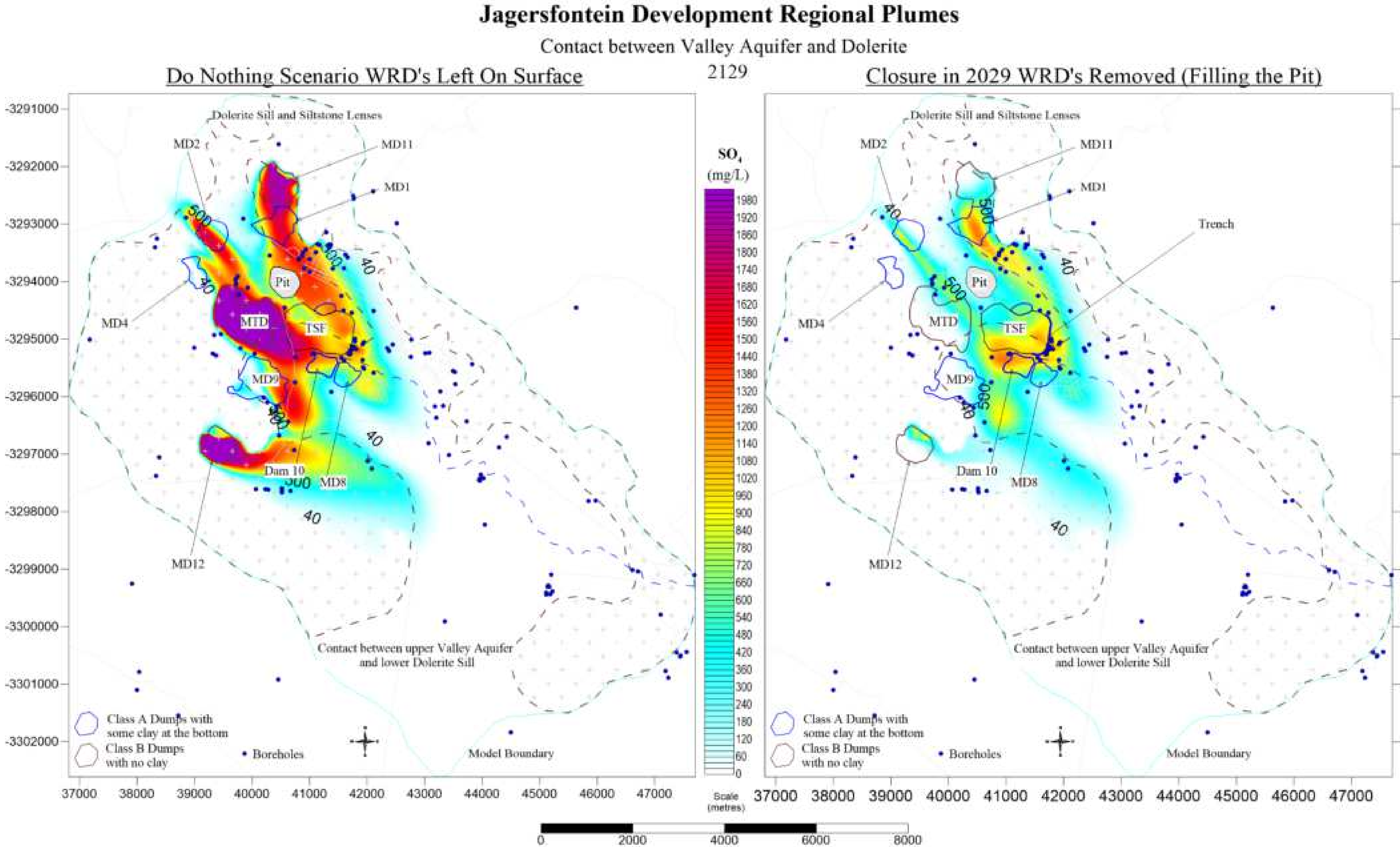


Figure 81. Comparison between the simulated pollution plumes of the different scenarios within the contact between the Valley aquifer and dolerite sill (year 2129).

6.4.2.4 Deep Geology Dolerite and Possible Siltstone Lenses

The simulated pollution plumes within deep geology are displayed in Figure 82 to Figure 88. The prolonged simulated activities since 1940 with the dolerite siltstone lenses seen as homogenous isotropic entity and low porosity show some imprints at a depth 40mbgl of between 5 to 25 mg/l SO_4 from the on-surface sources. There is however no lateral movement (as expected) from the pit in any of the images from 2025 (Figure 83) to 2129 (Figure 88). The main reason for this being that the permeability of the slimes is much lower than that of the host rock and groundwater movement (if any) will thus rather move around the slimes than into or through it. Furthermore, the property of the slimes (smectite clay) with regards to retention also means that the slimes will rather retain moisture than releasing it to the environment.

No pollution is migrating in any of the simulations from the pit to the deep geology.

Operational Phase

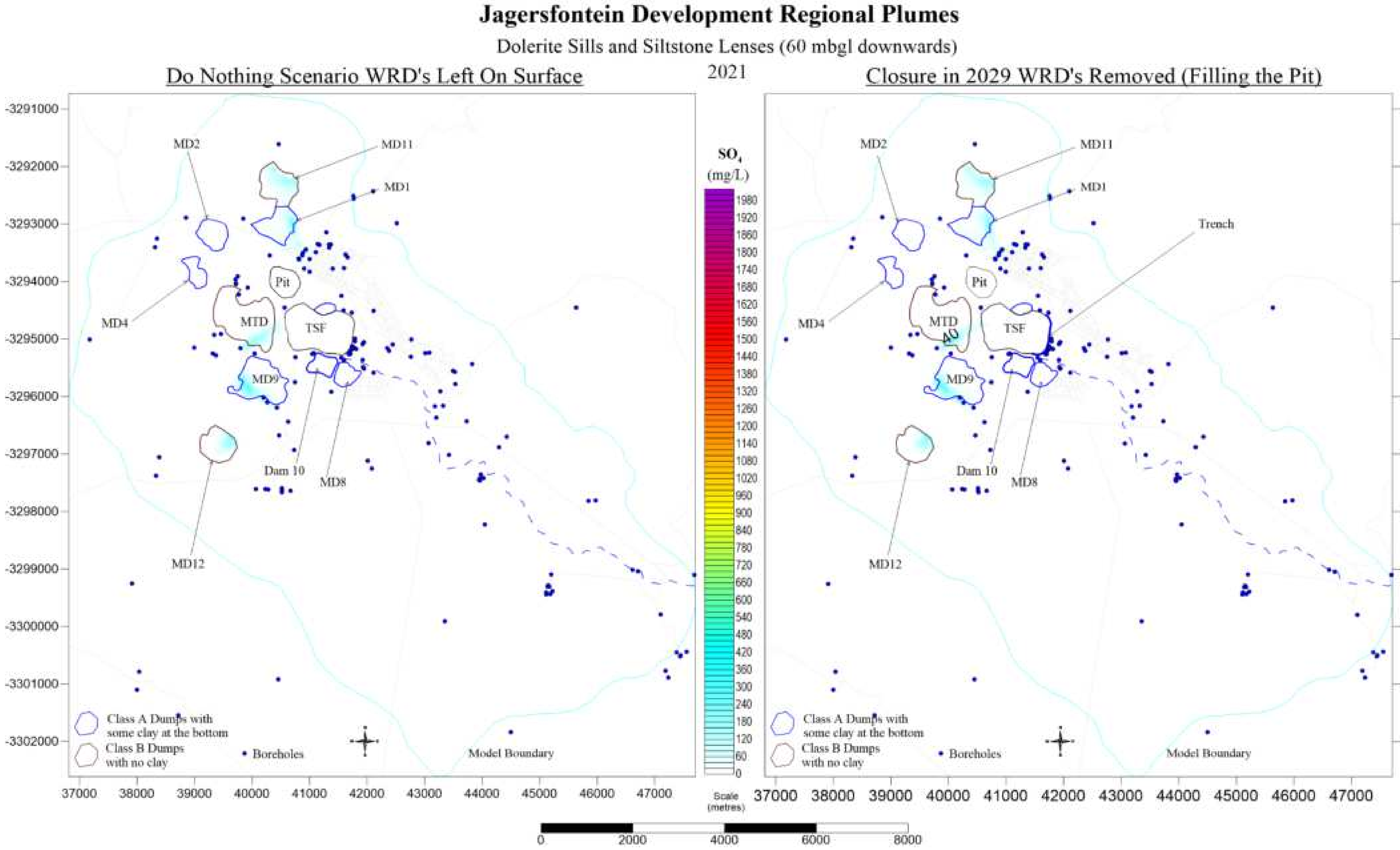


Figure 82. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2021).

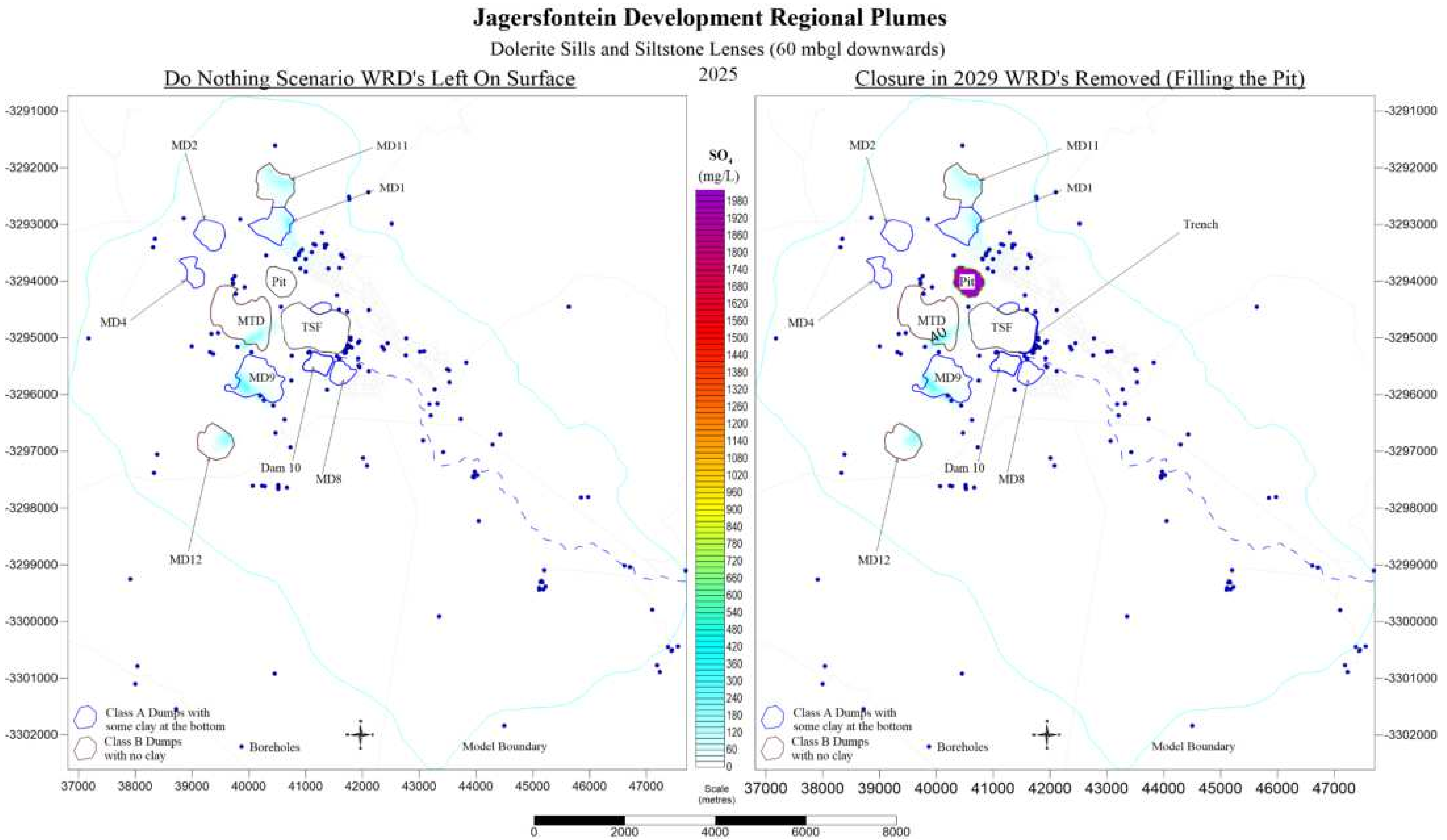


Figure 83. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2025).

Closure

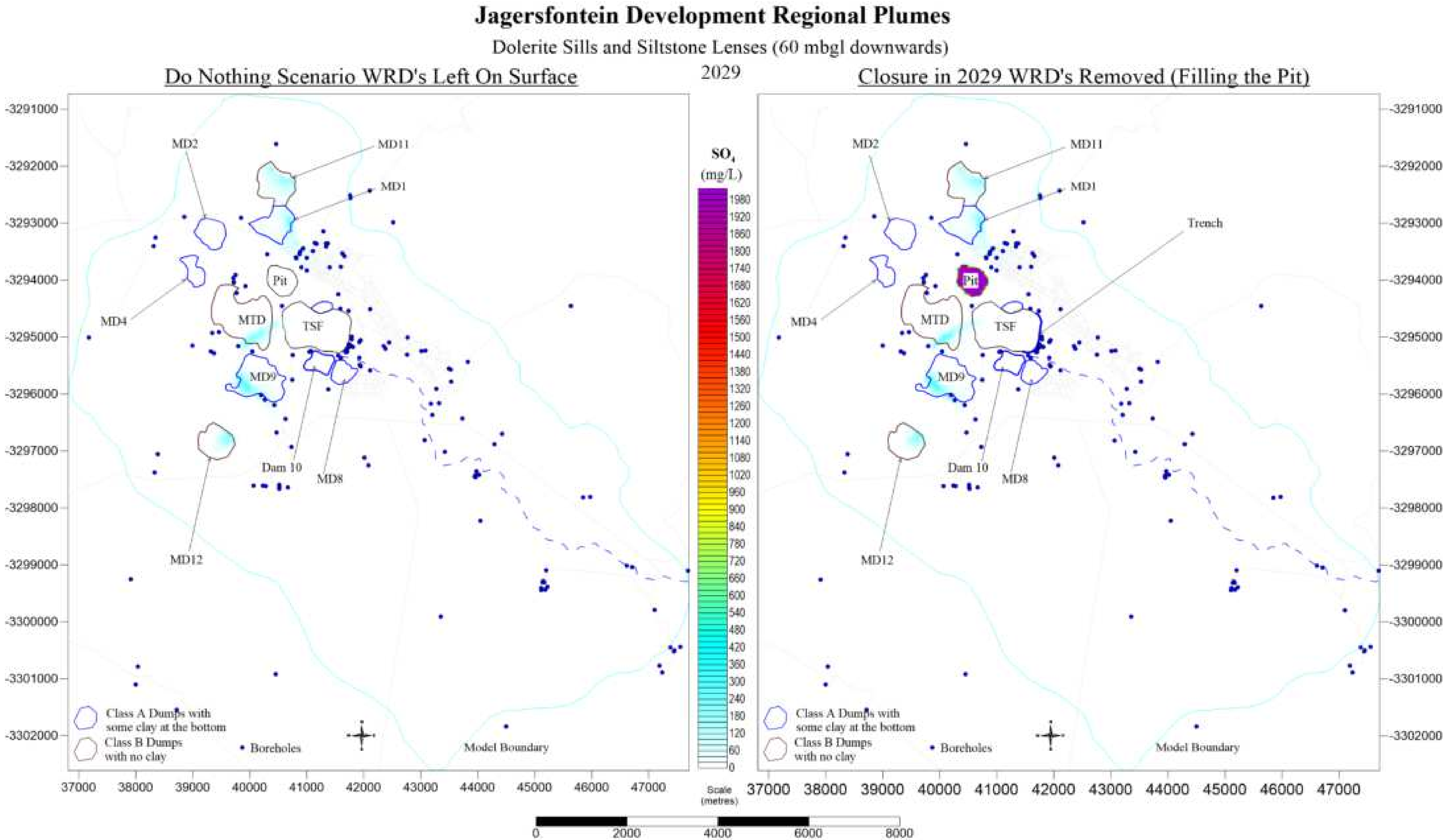


Figure 84. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2029 at end of operations).

Post Closure

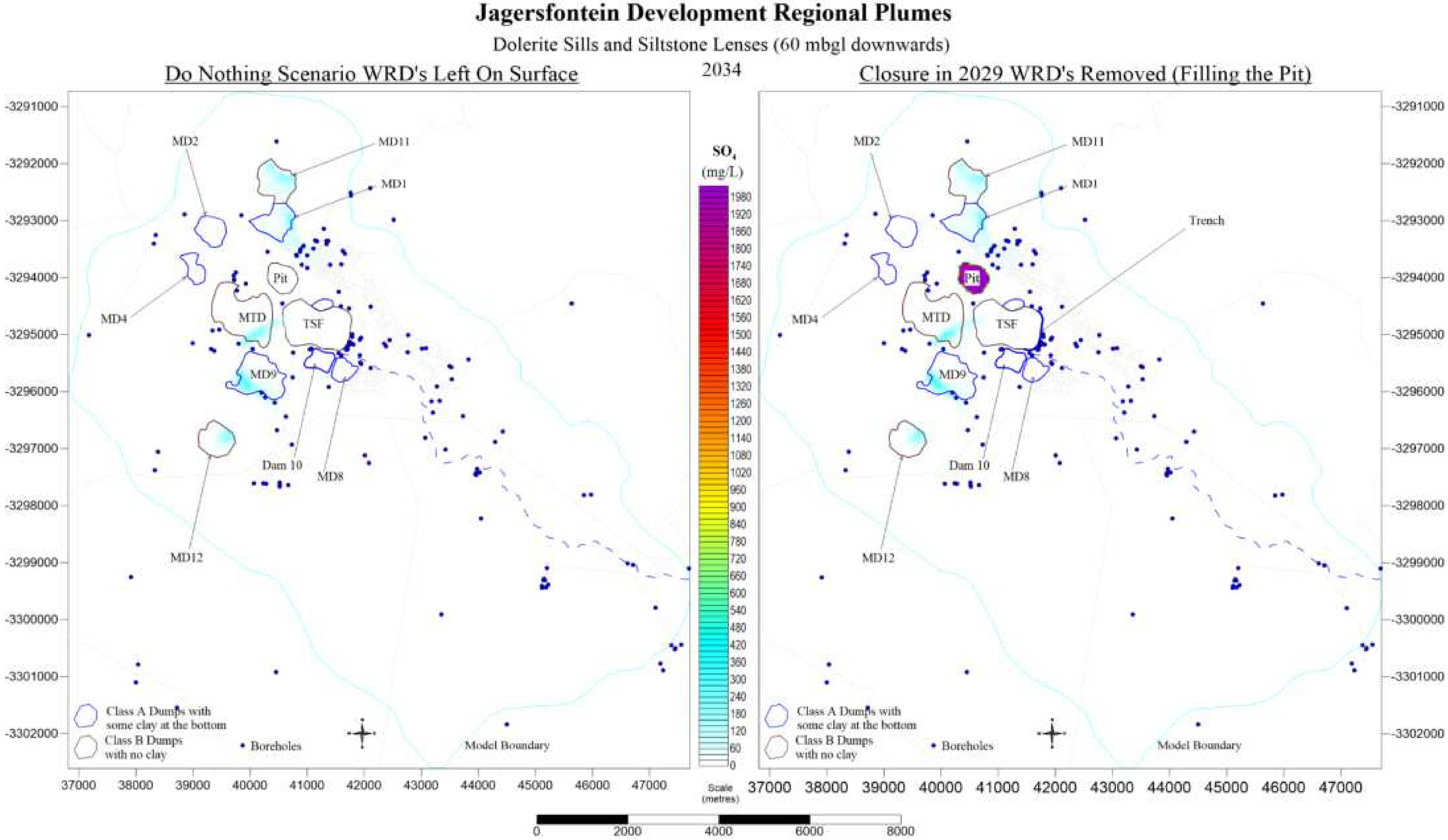


Figure 85. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2034).

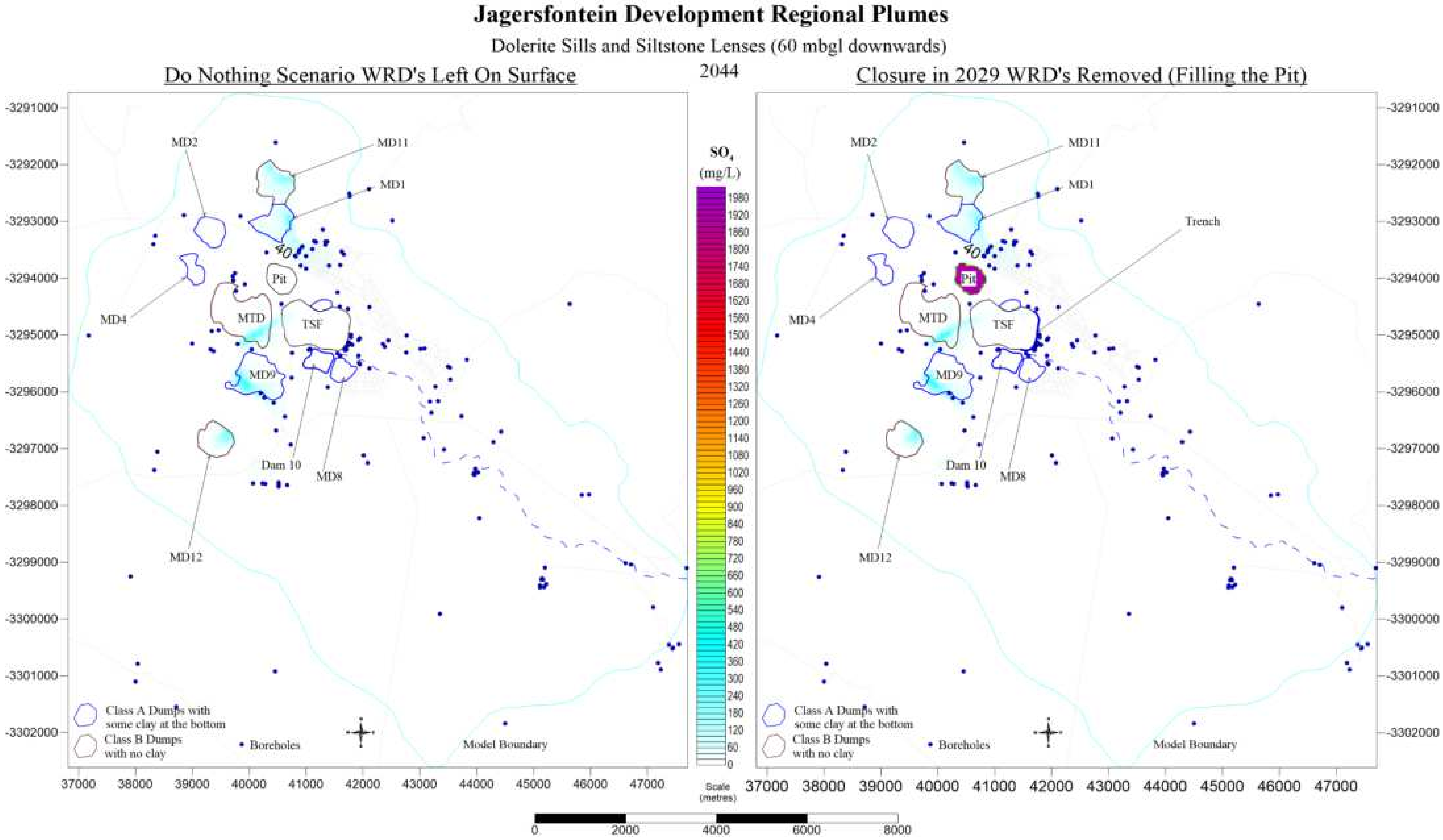


Figure 86. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2044).

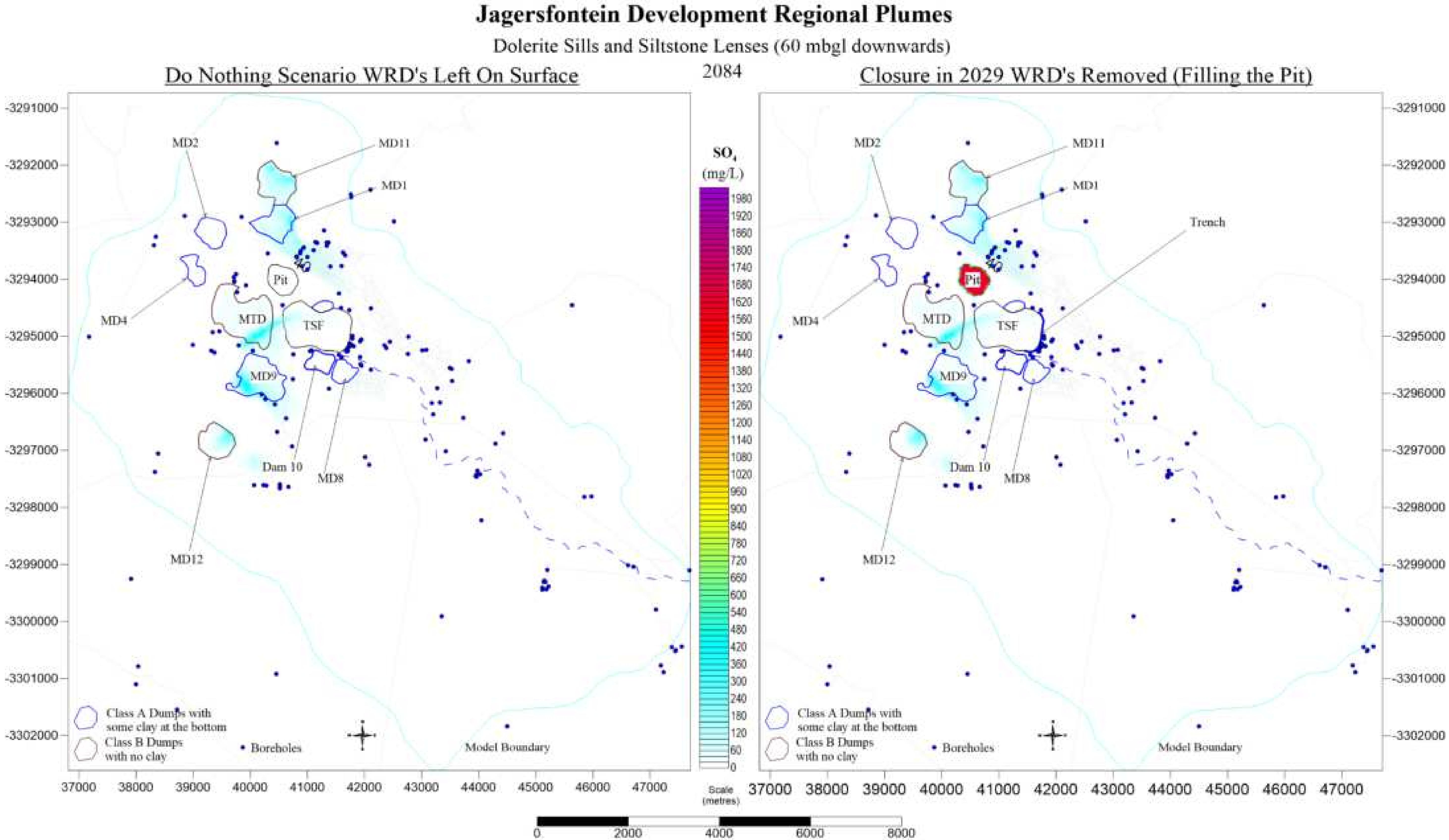


Figure 87. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2084).

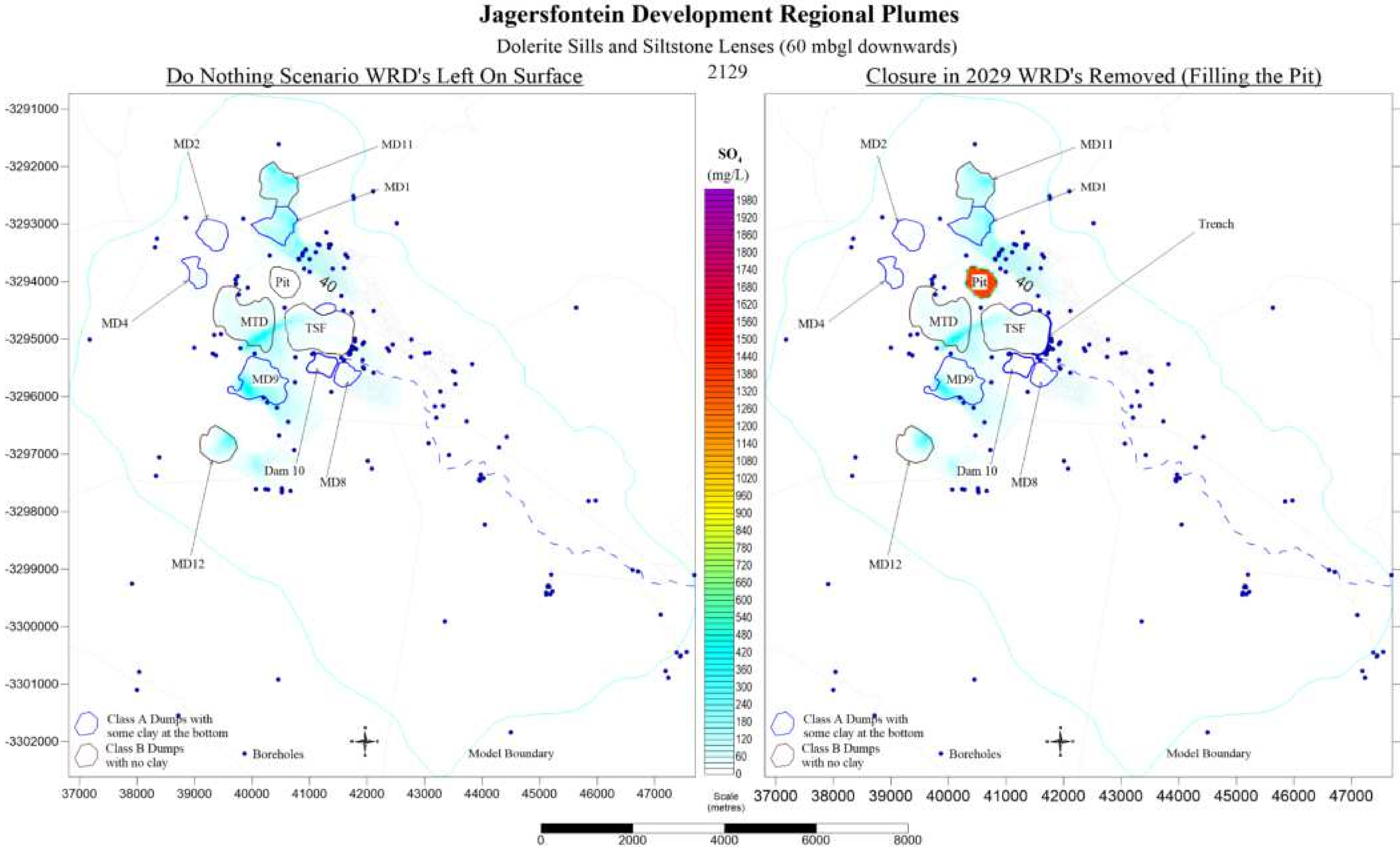


Figure 88. Comparison between the simulated pollution plumes of the different scenarios within the deep geology (year 2129).

6.4.2.5 North-West to South-East Cross-Sectional Views through Pit and TSF

From north-west through the pit and TSF to south-east were exported from Feflow as a visual representation of vertical movement of pollution plumes in Figure 89 to Figure 95. These images indicate that the simulated plume from the pit **does not migrate vertically downwards and that it remains horizontally contained with the host rock** (dolerite and possible siltstone lenses).

Operational Phase

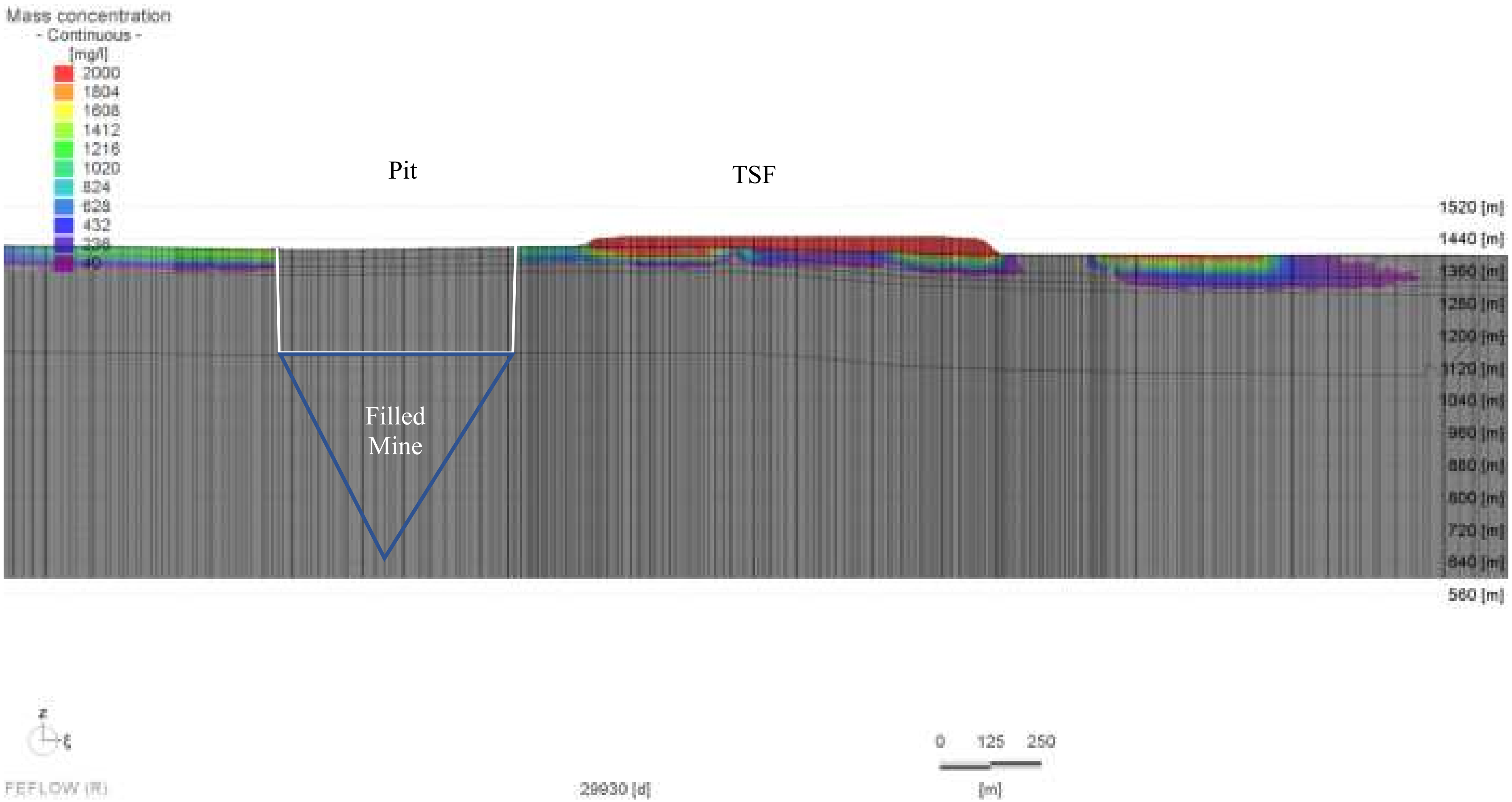


Figure 89. North- west to south-east cross-sectional view through Pit and TSF (year 2021).

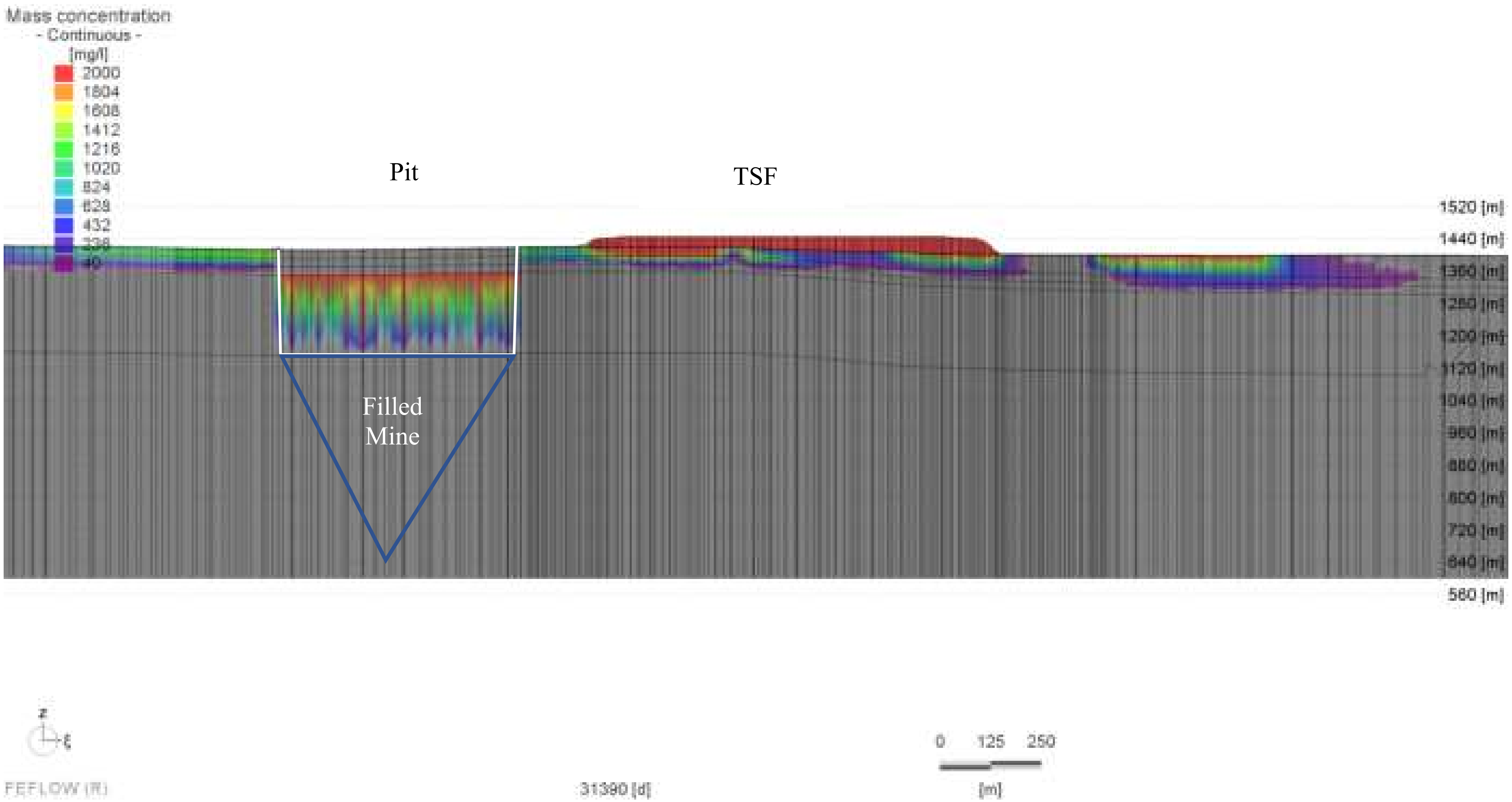


Figure 90. North- west to south-east cross-sectional view through Pit and TSF (year 2025).

Closure

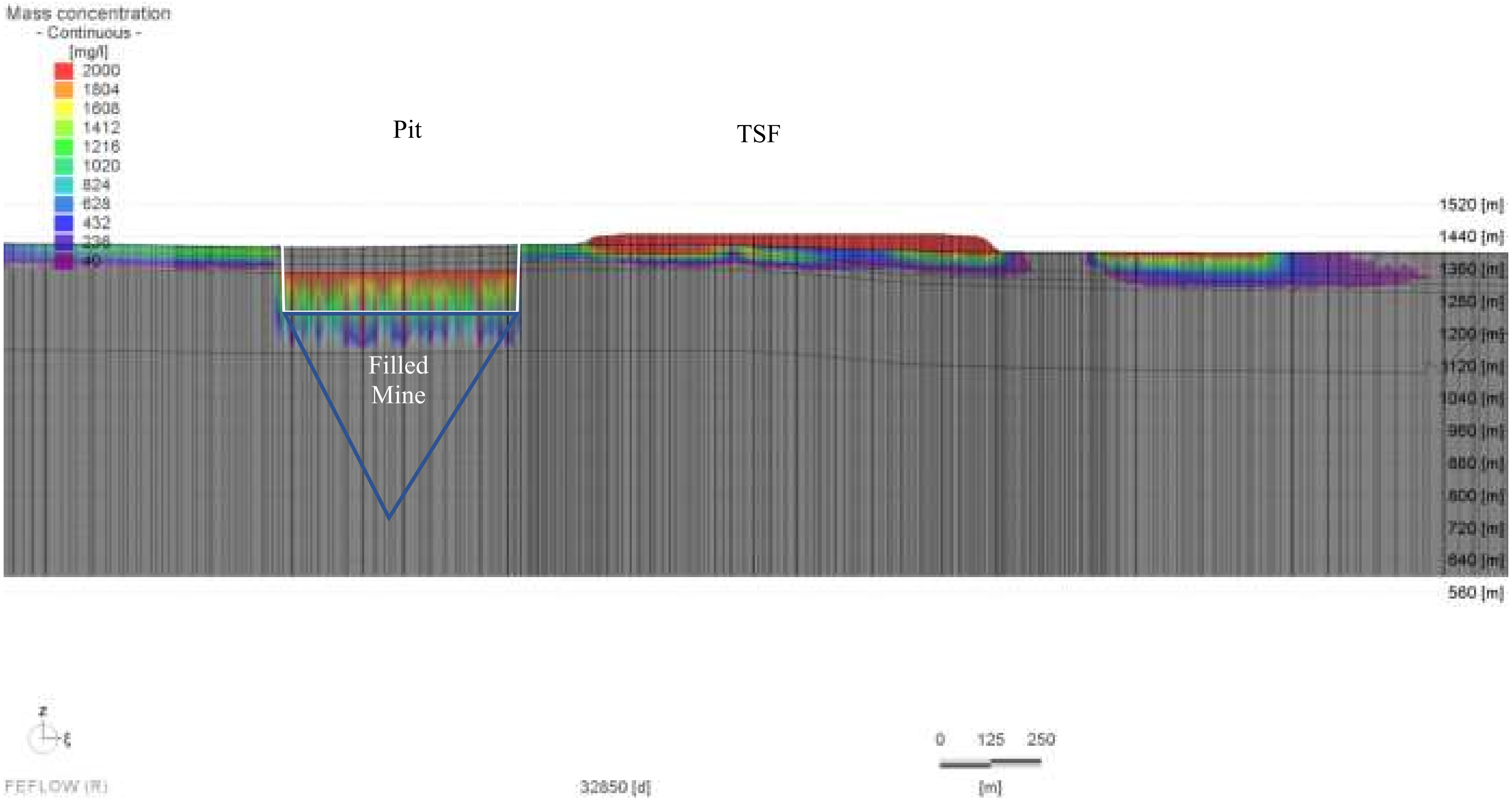


Figure 91. North- west to south-east cross-sectional view through Pit and TSF (year 2029 at end of operations).

Post Closure

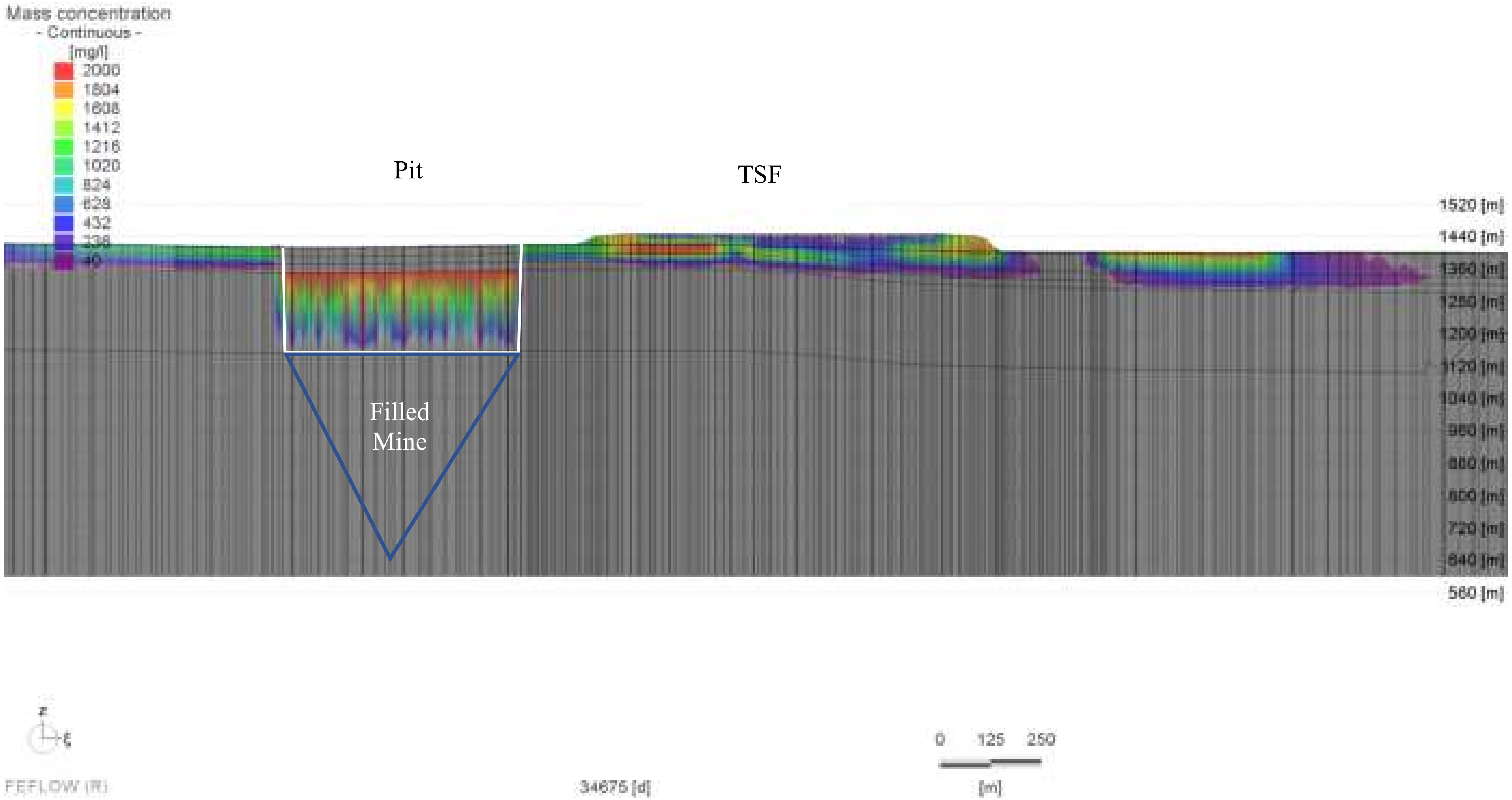


Figure 92. North- west to south-east cross-sectional view through Pit and TSF (year 2034).

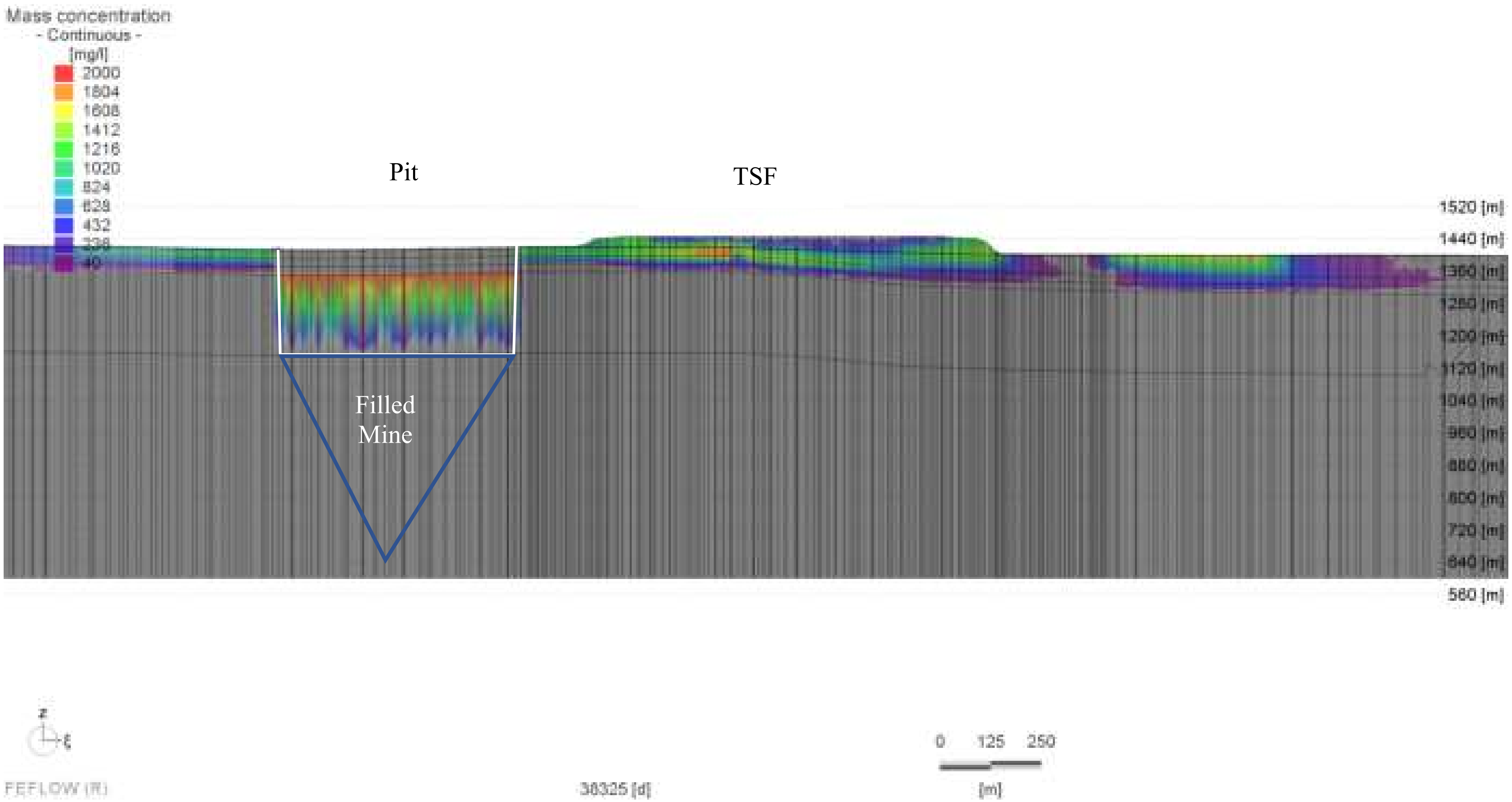


Figure 93. North-west to south-east cross-sectional view through Pit and TSF (year 2044).

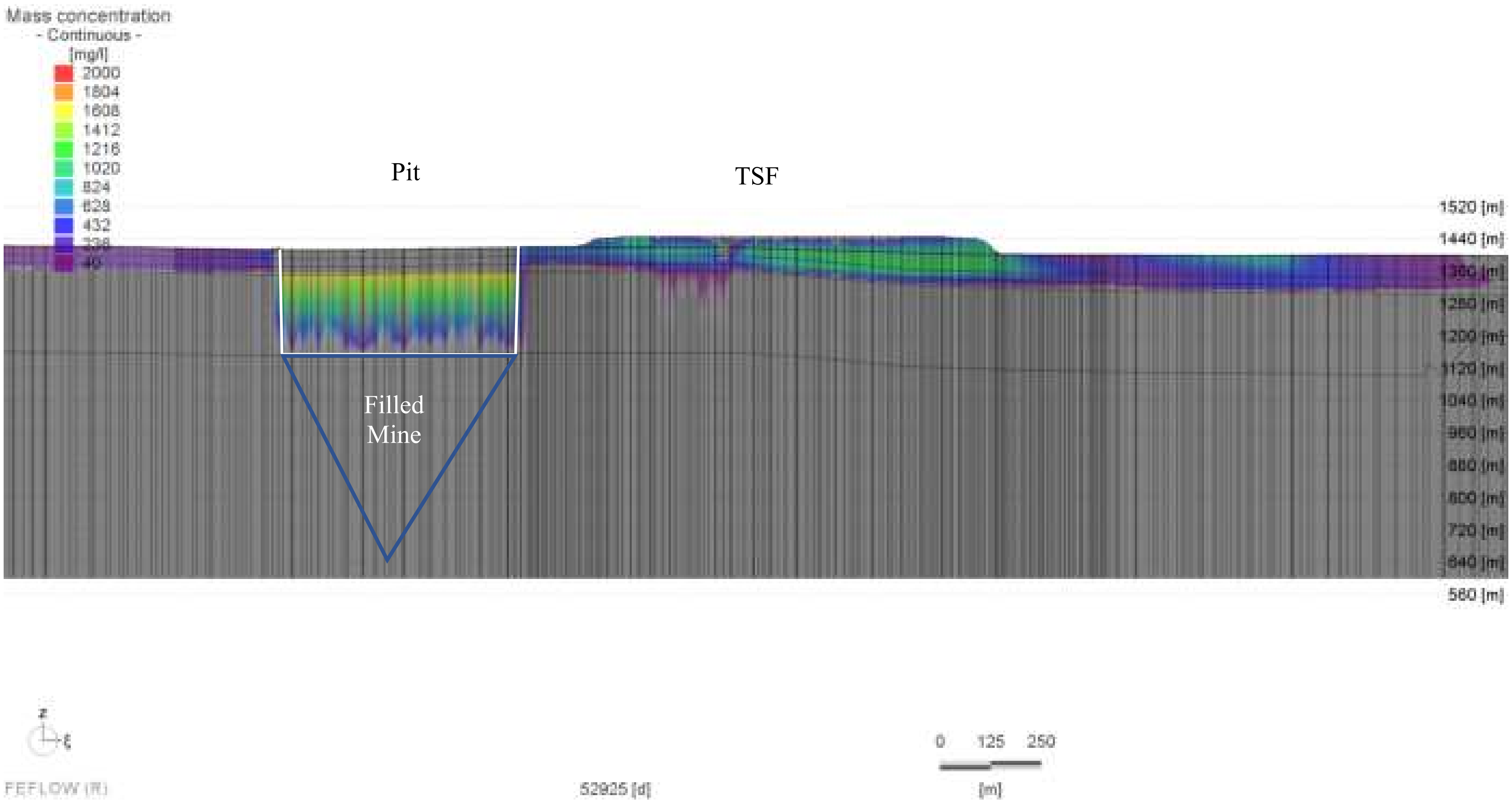


Figure 94. North-west to south-east cross-sectional view through Pit and TSF (year 2084)

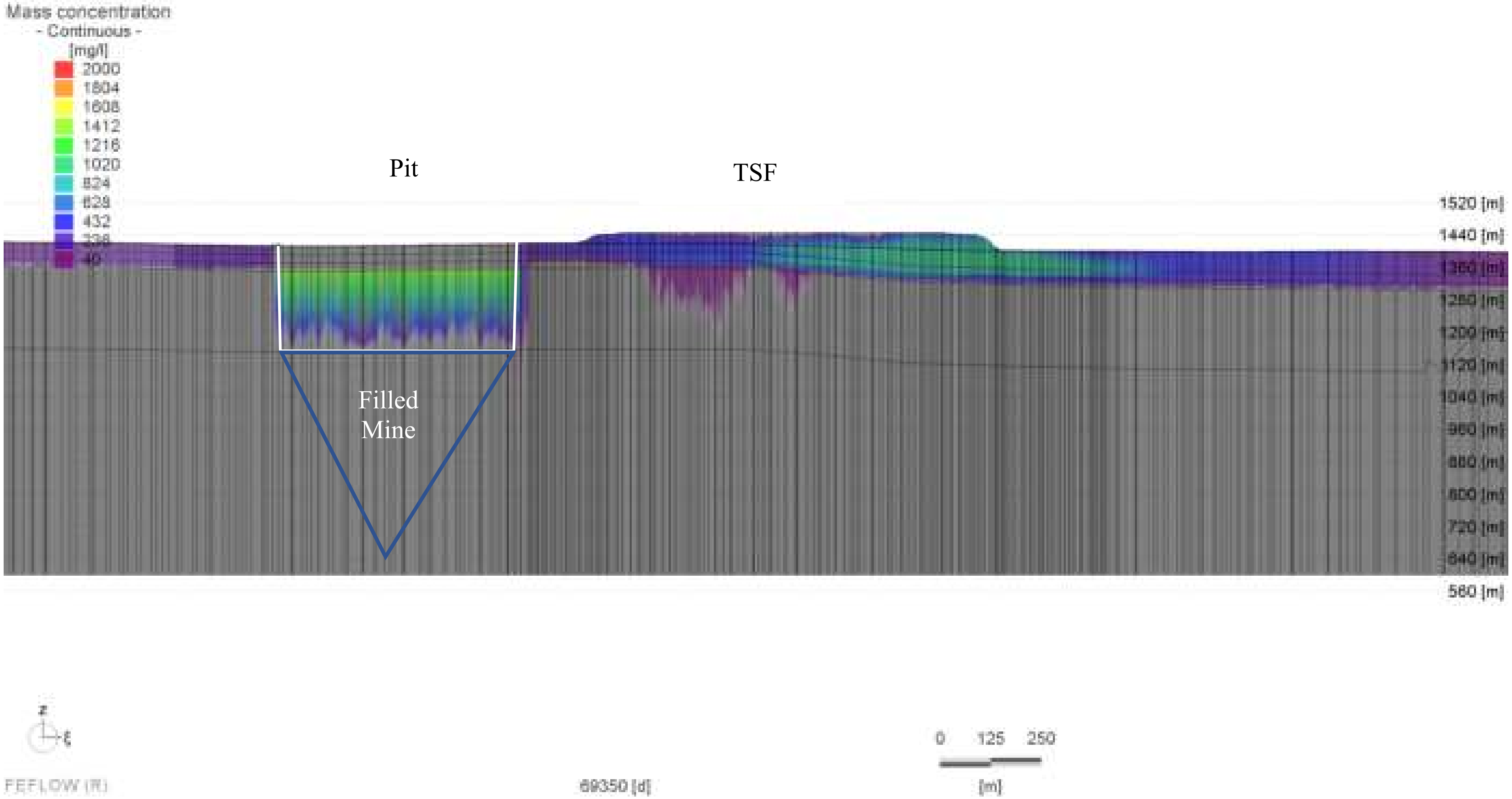


Figure 95. North-west to south-east cross-sectional view through Pit and TSF (year 2129).

6.4.3 Evaluation of the Groundwater Monitoring Network

Apart from groundwater level and quality monitoring from the Shaft, there is currently no groundwater monitoring network in place to monitor possible pollution emanating from the pit if backfilling is to proceed. The future monitoring network can be evaluated by assessing the simulated pollution plume migration from the pit. However, the simulated plume remains within the host rock and as such can the possible movement not be related to optimal positioning of boreholes to be utilized in a monitoring network. Another method to employ is to superimpose the plume together with the Bayes interpolated groundwater flow directions on an aerial photo and derive possible locations from this as can be seen in Figure 96. Monitoring areas are indicated in this figure to form part of a monitoring program to be discussed in in Chapter 7.

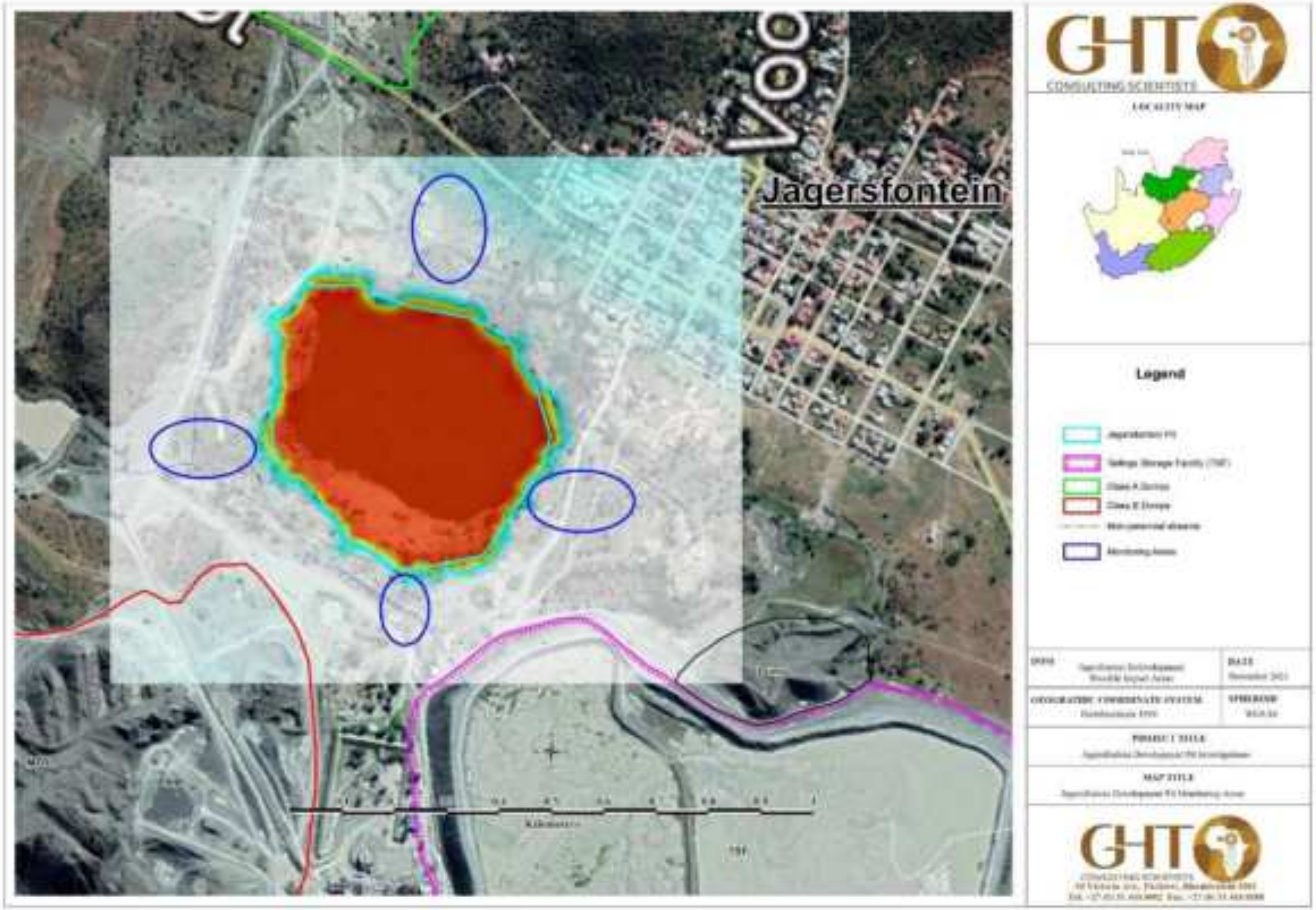


Figure 96. Superimposed pollution plume and groundwater flow direction on an aerial photo.

6.5 Conclusions

6.5.1 Groundwater Elevations

Interpolations of simulated water levels negates the effect of the "inactive elements" and wrongly represents the pit as a drain with water flowing towards the centre of the pit. Simulations also indicate that groundwater levels in the pit will not recover to regional ambient groundwater levels.

6.5.2 Pollution Plume Migrations

6.5.2.1 Superficial Soils

Simulation results of pollution plumes within the superficial soils indicate the following:

- With the pit area marked as inactive, possible pollution emanating from the WRD's to the north of the pit migrates past the pit. In reality though, no flow is taking place or migrating past the pit as already explained. The superficial soils (approximately 4 metres thick) above the dolerite sills are simulated as weathered material receiving recharge and as such will propagate pollution in the model due to the homogenous isotropic modelling assumptions.
- **No pollution is migrating in any of the simulations from the pit to the superficial soils.**

6.5.2.2 Valley Aquifer

The simulations of the regional pollution plumes within the minor Valley aquifer can be summarized as follows:

- Simulations of both scenarios of the 2129 pollution plumes indicate the edge of the 40 mg/L SO4 WUL limit to be mostly within 2km downgradient from the pollution sources. However, there is a significant difference in the concentrations and footprint when the sources are not removed.
- Decreasing pollution plumes both in extent and concentrations can be seen from as early as 2034 in the scenario where the on-surface WRD's were removed by 2029. Improvements are becoming more apparent from 2044 in this scenario as opposed to the do-nothing scenario.
- The prolonged impacts from the class B dumps left on-surface can be seen in the simulated plumes of 2084 and 2129. Earlier removal would be a major improvement as the Valley aquifer is the main exploitable aquifer in the region feeding the contact between this aquifer and the dolerite sill beneath.
- **No pollution is migrating in any of the simulations from the pit to the Valley aquifer.**
- **There is no interconnection between the Valley Aquifer and the pit.**

6.5.2.3 Contact between Valley Aquifer and Dolerite Sill

The simulated pollution plumes within the contact between the Valley aquifer and the lower dolerite sill can be summarized as follows:

- The diminishing pollution plume trends in the contact between the Valley aquifer and the dolerite sill are very similar to those of the Valley aquifer itself due to the already explanation that Valley aquifer is the source of water to the contact and this zone is. This zone normally has a higher permeability and yield than the sedimentary Valley aquifer and is often targeted by drilling and pump inlet at this level. Removal of the on-surface WRD's will thus cause the readily improvement of this source.

- **No pollution is migrating in any of the simulations from the pit to the contact between Valley aquifer and the dolerite sill.**
- **The contact between the Valley Aquifer and the lower dolerite sill does not extend to or intersect the pit.**

6.5.2.4 Deep Geology

The simulated pollution plumes within deep geology can be summarized as follows:

- The prolonged simulated activities since 1940 with the dolerite siltstone lenses seen as homogenous isotropic entity and low porosity show some imprints at a depth 40mbgl of between 5 to 25 mg/l SO_4 from the on-surface sources. There is however no lateral movement (as expected) from the pit in any of the images from 2025 to 2129.
- **The main reason for this being that the permeability of the slimes is much lower than that of the host rock and groundwater movement (if any) will thus rather move around the slimes than into or through it. Furthermore, the property of the slimes (smectite clay) with regards to retention also means that the slimes will rather retain moisture than releasing it to the environment.**
- **No pollution is migrating in any of the simulations from the pit to the deep geology.**
- These north-west to south-east cross-sections images indicate that the simulated plume from the pit **does not migrate vertically downwards and that it remains horizontally contained with the host rock** (dolerite and possible siltstone lenses). **Once again, because the permeability of the slimes is much lower than that of the host rock.**

6.6 Recommendations

6.6.1 Groundwater Elevations

Monitoring of the groundwater elevations in the region of the pit must be implemented according to the monitoring plan (Chapter 7). The following is recommended in general:

- Groundwater levels of the shaft and Pit monitoring network (to be installed) must be measured monthly and properly evaluated against rainfall data and abstraction volumes utilising evaluation techniques such as trend analyses and comparing measured values against historical water level depths and evaluations.
- If pollution is detected, pump rates must be adjusted and water levels of the shaft and pit monitoring boreholes (to be installed) must be monitored to establish if an adequate drawdown cone of depletion (in unconfined conditions) or reduced pressures (in confined conditions) is maintained.

6.6.2 Pollution Plume Migrations

The following recommendation are made with regards to the simulated pollution plume migrations:

- Groundwater samples must be collected (form the monitoring network boreholes to be proposed in the monitoring plan chapter 7) on a quarterly basis for analyses and properly evaluated against historical concentrations utilising the different evaluation techniques and trend analyses.

- Should pollution be detected (in the boreholes of the monitoring network to be proposed in the monitoring plan chapter 7), remedial actions should be taken as will be discussed in chapter 9.
- In the event of pollution detection, pollution migration direction and rates must be determined which in turn will determine if additional boreholes may have to be drilled.

6.6.3 Monitoring Network

The only recommendations made with regards to the Pit monitoring network are the following:

- A groundwater monitoring network for pollution detection in the shallow and deep aquifers must be installed with boreholes in the regions indicated in Figure 96.

7 TSF, OLD DUMPS AND PIT IMPACT ASSESSMENT, RISK ASSESSMENT AND GROUNDWATER MANAGEMENT PLAN

7.1 Introduction

A groundwater management plan provides a link between the impacts predicted and mitigation measures recommended and the implementation activities to ensure that on site activities are managed and mitigated so that unnecessary or preventable environmental impacts do not result.

The groundwater management plan is a dynamic document which must be updated on an on-going basis as the project develops.

7.1.1 Purpose of a Groundwater Management Plan

The objective of the groundwater management plan is to provide consistent information and guidance for implementing the management and monitoring measures established in the permitting process and help achieve environmental policy goals. This groundwater management plan provides specific environmental guidance for the operation and maintenance phase of the Jagersfontein Development and is intended to manage and mitigate operations and maintenance activities for that unnecessary of preventable environmental impacts do not result.

The purpose of the groundwater management plan is to help ensure continuous improvement for environmental performance, reducing negative impacts and enhancing positive effects during the construction and operation of the facility. An effective groundwater management plan is concerned with both the immediate outcome as well as the long-term impacts of the project

The groundwater management plan has the following objectives:

To outline mitigation measures, and environmental specifications which are required to be implemented for the operation/maintenance phase of the power station in order to minimise the extend of environmental impacts, and to manage environmental impacts associated with the project.

- To identify measures that could optimise beneficial impacts.
- To ensure that the operation and maintenance activities associated with the power station do not result in undue of reasonably avoidable adverse environmental impacts, and ensure that any potential environmental benefits are enhanced.
- To ensure that all environmental management conditions and requirements as stipulated in the environmental authorisation are implemented throughout the project life-cycle.
- To ensure that all relevant legislation (including national. Provincial and local) is complied with during the operation and maintenance of the power station.
- To identify entities who will be responsible for the implementation of the measures and outline functions and responsibilities.
- To propose mechanisms for monitoring compliance, and prevent long-term or permanent environmental degradation.
- To facilitate appropriate and proactive response to unforeseen events for changes in project implementation that was not considered in the EIA process.

This document is a Technical Report that investigates the water management system in the vicinity of the Jagersfontein Tailings Dam, Old dumps (inferred from detailed TSF investigations) and the Pit.

The groundwater management plan has been developed as a set of environmental specifications (i.e. principles of environmental management for the operation and maintenance of the Jagersfontein Tailings Dam, Old dumps and PIT), which are appropriately contextualised to provide clear guidance in terms of the on-site implementation of these specifications.

7.2 Management phases

As part of a groundwater management plan management phases are used, namely the Construction Phase, the Operational Phase and the Decommissioning phase. However, in the case of Jagersfontein Development, the construction phases of the TSF and dumps (historically) have been completed, thus only the Operational Phase and the Decommissioning phase will be discussed in detail to determine the impact of the TSF and dumps on the groundwater of the area. The filling of the Pit will entail construction and operational phases.

The following documentation was utilised for the management options described below:

- Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Development Residue Deposits.
- Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Developments.
- Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

7.2.1 Operational Phase

The operational phases are likely to change both the quantity (possible gradual rise in water levels) and quality of local groundwater (possible quality deterioration in the immediate vicinity of the TSF and removal processes at the dumps). A comparison will be made between leaving the dumps on-surface (do-nothing scenario) as opposed to removal.

The local groundwater flow direction may also be modified due to the local rise in the water table – especially if the site chosen is one which straddles a water divide (quaternary catchment boundary).

The operational phase of the Pit involves disposal of course and fine tailings through conveyors.

7.2.2 Decommissioning Phase

Decommissioning of the Tailings Dam will mean that slimes will no longer be disposed to the facility, and also that a degree of re-vegetation and re-sloping may be achieved. Whilst it will be practically impossible to prevent the percolation of some leachate into local groundwater in the long term, mitigation measures can reduce this. Decommissioning of the old TSF's or WRD's (by removal) may also have short term impacts due to disturbances of the pollution sources that may be reflected by short term spikes in groundwater contamination. The overall long-term benefit to groundwater improvement cannot be over emphasized.

No decommissioning of the Pit after filling will be possible due to the fill depth remaining well below the rim.

7.3 Groundwater Environmental Risk Assessment

A risk assessment was done for the Pit and TSF and extended to the old TSF's and WRD's. The purpose of the risk assessment was to determine the potential impact of different activities at the source of operations on the environmental, especially the groundwater and the aquifer in the region and downstream of the TSF, old dumps and Pit during the Construction, Operational and Decommissioning Phases of the projects.

The scoring matrix and the description of the significance ranking of the environmental risk assessment used to determine the groundwater impacts of the activities can be studied in Table 7 and Table 8.

The Activity at the Tailings Dam was identified; the potential environmental impact and the environmental significance prior to mitigation for the Operational and Decommissioning Phase were determined by making use of the following categories:

- Severity / Magnitude (M)
- Reversibility (R)
- Duration (D)
- Spatial Extent (S) and
- Probability (P).

Table 7. Scoring matrix of the environmental risk assessment.

Score According to Impact Assessment Matrix	Significance Definitions	Colour Scale Ratings	
		Negative Ratings	Positive Ratings
Less than 30 significance points indicate **Low Significance**	An impact of low significance is one where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value.	**Low**	**Low**
Between 30 and 60 significance points indicate **Moderate Significance**	An impact of low significance is one where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value.	**Moderate**	**Moderate**
More than 60 significance points indicate **High Significance**	An impact of high significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An impact with high significance will completely modify the baseline conditions. A goal of the EIA process is to get to a position where the Project does not have any high negative residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be high residual impacts after all practicable mitigation options have been exhausted. It is then the function of regulators and stakeholders to weigh such negative factors against the positive factors, such as employment, in coming to a decision on the Project.	**High**	**High**

Table 8. Description of the significance ranking of the environmental risk assessment.

Severity / Magnitude (M)	Reversibility (R)	Duration (D)	Spatial Extent (S)	Probability (P)
5 – Very high – The impact causes the characteristics of the receiving environment/ social receptor to be altered by a factor of 80 – 100 %	**5 – Irreversible** – <u>Environmental</u> - where natural functions or ecological processes are altered to the extent that it will permanently cease. <u>Social</u> - Those affected will not be able to adapt to changes and continue to maintain- pre impact livelihoods.	**5 – Permanent** - Impacts that cause a permanent change in the affected receptor or resource (e.g. removal or destruction of ecological habitat) that endures substantially beyond the Project lifetime.	**5 – International** - Impacts that affect internationally important resources such as areas protected by international conventions, international waters etc.	**5 – Definite** - The impact will occur.
4 – High – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 60 – 80 %		**4 – Long term** - impacts that will continue for the life of the Project, but ceases when the Project stops operating.	**4 – National** - Impacts that affect nationally important environmental resources or affect an area that is nationally important/ or have macro-economic consequences.	**4 – High probability** – 80% likelihood that the impact will occur
3 – Moderate – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 40 – 60 %	**3 – Recoverable** <u>Environmental</u> - where the affected environment is altered but natural functions and ecological processes may continue or recover with human input. <u>Social</u> - Able to adapt with some difficulty and maintain pre-impact livelihoods but only with a degree of support or intervention.	**3 – Medium term** - Impacts are predicted to be of medium duration (5 – 15 years)	**3 – Regional** - Impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystem.	**3 – Medium probability** – 60% likelihood that the impact will occur
2 – Low – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 20 – 40 %		**2 – Short term** - Impacts are predicted to be of short duration (0 – 5 years)	**2 – Local** - Impacts that affect an area in a radius of 2 km around the site.	**2 – Low probability** - 40% likelihood that the impact will occur
1 – Minor – The impact causes very little change to the characteristics of the receiving environment/ social receptor and the alteration is less than 20 %	**1 – Reversible** <u>Environmental</u> - The impact affects the environment in such a way that natural functions and ecological processes are able to regenerate naturally. <u>Social</u> - People/ communities are able to adapt with relative ease and maintain pre-impact livelihoods.	**1 – Temporary** - Impacts are predicted to be intermittent/ occasional over a short period.	**1 – Site only** - Impacts that are limited to the site boundaries.	**1 – Improbable** - 20% likelihood that the impact will occur

7.4 The Tailings Storage Facility (TSF)

The results together with the recommended mitigation measures suggested to improve the identified risks as well as the risk assessment significance after mitigation are implemented for each of identified activities can also be viewed Table 9 to Table 10.

7.4.1 Operational Phase Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Operational phase risk and groundwater management plan for Jagersfontein Development Tailings Dam can be perused in Table 9. The Operational phase groundwater management is segmented into the different potential groundwater impacts taking place on the and around the Tailings facility as well as their associated objectives and recommended mitigation / management options, monitoring actions according to WUL license conditions, annual and closure cost.

The Operational phase groundwater management plan includes management impacts from the following:

- Tailings Storage Facility.
- Storm Water.

7.4.1.1 Impacts:

- Deterioration of groundwater quality due to leachate from Tailings Dam. Leachate from Tailings Dam may cause groundwater contamination (however limited by the newly installed trench as stated earlier).
- Rise in local groundwater table.
- Minor changes in local groundwater flow directions due to possible rise in local water table.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– <u>Objective:</u>

- Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented, where problems are encountered.

– <u>Mitigation Measure and Management Plan</u> <u>to be Implemented:</u>

- Implement processes that reduce water usage because water contained in the slimes may impact on groundwater quality (increase salt loading to aquifer), the groundwater level and may change the local groundwater flow by means of seepage to underlying receiving aquifer.
- Ground- and surface water monitoring must continue to operate as is. Additional boreholes that have been drilled will be incorporated into the monitoring management system.

– <u>Annual Cost:</u> Maintenance and running cost of facility and groundwater monitoring programme.

– <u>Closure Cost:</u> General rehabilitation cost allowed for at closure.

7.4.1.2 Impact: Storm water (runoff water)

Overflow of Pollution control dams and return water canals (cut of trenches) during heavy rainstorms.

– Objective:

- Effective management of storm water and containment of potentially polluted surface that may impact on groundwater quality by means of overflow or seepage to underlying receiving aquifer (increase salt loading to aquifer).

Mitigation Measure and Management Plan to be Implemented:

- Monitor pollution control dams and return water canals (Cut of trenches) for signs of water overflow and remove any potential hindrances.
- Pollution control dams should be kept at freeboard to prevent overflows.
- Ground- and surface water monitoring should also continue to operate as is.
- The current data management system needs to be updated monthly/quarterly to prevent loss of data.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.4.1.3 Operational Phase Conclusions

7.4.1.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 9) can be summarized as follows:

- Groundwater quality Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate", the Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Groundwater level Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Groundwater flow directions Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.

The post-mitigation assessment of impacts upon local groundwater users (see Table 9) can be summarized as follows:

- Groundwater quality Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate", the Reversibility classified as "Recoverable". "Medium term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Groundwater level Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Recoverable". "Temporary term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater flow directions Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Reversable". "Temporary term" Duration with a "Local" Spatial Extent. The Probability is "Improbable.

7.4.1.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 9) can be summarized as follows:

- Groundwater quality Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "High", the Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Reversible". "Temporary term" Duration with a "Local" Spatial Extent. The Probability is "Improbable.
- Groundwater flow directions Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Reversible". "Temporary term" Duration with a "Local" Spatial Extent. The Probability is "Improbable.

The post-mitigation assessment of impacts upon private groundwater users (see Table 9) can be summarized as follows:

- Local groundwater quality Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate", the Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Local groundwater level Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Reversible". "Short term" Duration with a "Local" Spatial Extent. The Probability is "Low.
- Local groundwater flow directions Impact Significance – "**Low**" due to Severity/Magnitude classified as "Minor". Reversibility classified as "Reversible". "Temporary term" Duration with a "Local" Spatial Extent. The Probability is "Improbable.

7.4.1.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "High". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium".

Post mitigation impact assessment:

- Storm Water Impact Significance – "**Low**" due to Severity/Magnitude classified as "Low". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Low".

Table 9. Environmental risk assessment for groundwater impacts during the Operational phase of the FTSF in the region of the FTFS.

JAGERSFONTEIN TAILINGS FACILITY - GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR OPERATIONAL PHASE IMPACTS

No.	Activity	Area	Type	POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Operational Phase Impacts																			
1.)	**Tailings Facility.**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from Tailings Facility. Leachate from Tailings Facility may cause groundwater contamination.	3	3	4	2	3	36	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Implement processes that reduce water usage because water contained in the slimes may impact on groundwater quality (increase salt loading to aquifer), the groundwater level and may change the local groundwater flow by means of seepage to underlying receiving aquifer. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring borehole be drilled downstream of the Tailings Facility to act as an early detection monitoring system.	3	3	3	2	3	33	"Moderate
			Water levels	Minor rise in local groundwater table at TSF, and local depletion at abstraction boreholes.	3	3	2	2	3	30	"Moderate		1	1	1	1	2	8	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table and towards boreholes where abstraction is taking place.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from Tailings Facility. Leachate from Tailings Facility may cause groundwater contamination.	4	3	4	2	4	52	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Implement processes that reduce water usage because water contained in the slimes may impact on groundwater quality (increase salt loading to aquifer), the groundwater level and may change the local groundwater flow by means of seepage to underlying receiving aquifer. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring borehole be drilled downstream of the Tailings Facility to act as an early detection monitoring system.	3	3	3	2	3	33	"Moderate
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	2	8	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Overflow of Pollution control dams and return water canals (Cut of trenches) during heavy rainstorms.	4	3	4	1	3	36	"Moderate	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Monitor pollution control dams and return water canals (Cut of trenches) for signs of water overflow and remove any potential hindrances. Pollution control dams should be kept at freeboard to prevent overflows. Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	2	3	4	1	2	20	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.
* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.
* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.4.2 Decommissioning and Post Closure Phases Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Decommissioning phase risk and groundwater management plan for Jagersfontein Development's Tailings Dam can be perused in Table 10. The Decommissioning phase groundwater management is segmented into the different potential groundwater impacts taking place on the and around the TSF facility as well as their associated objectives and recommended mitigation / management options, monitoring actions according to WUL license conditions, annual and closure cost.

The Decommissioning phase groundwater management plan includes the following:

- Tailings Storage Facility.
- Storm Water.
- Final Operational Impacts and Site Clean-up

7.4.2.1 Impacts: TSF.

- Deterioration of groundwater quality due to leachate from Tailings Dam. Leachate from Tailings Dam may cause groundwater contamination.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is.
- The current data management system needs to be updated monthly/quarterly to prevent loss of data.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.4.2.2 Impact: Storm water (runoff water)

Overflow of Pollution control dams and return water canals (Cut of trenches) during heavy rainstorms.

– Objective:

- Effective management of storm water and containment of potentially polluted surface that may impact on groundwater quality by means of overflow or seepage to underlying receiving aquifer (increase salt loading to aquifer).

Mitigation Measure and Management Plan to be Implemented:

- Monitor pollution control dams and return water canals (Cut of trenches) for signs of water overflow and remove any potential hindrances.
- Pollution control dams should be kept at freeboard to prevent overflows.
- Ground- and surface water monitoring should also continue to operate as is.

- The current data management system needs to be updated monthly/quarterly to prevent loss of data.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.4.2.3 Impact: Final Clean-up Operations

- Slimes spillages due to possible leaking pipes: Run-of and rainfall will cause seepage to the underlying aquifer, which may cause groundwater contamination (increase salt loading to aquifer).

– Objective:

- To avoid the potential for soil, as well as ground and surface water pollution, through the leaching of contaminants from spilled materials. Early detection of any potential ground- or surface water pollution resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented where problems are encountered.

Mitigation Measure and Management Plan to be Implemented:

- Routinely inspections should be done along the roads to detect any spillages as well as after storm water events to inspect possible overflows from the trenches that may convey tailings or slimes material down-gradient
- Accumulated or slimes spilled in the event of leaking pipes must be cleaned up and sent to the TSF to minimise groundwater and surface water contamination.
- Groundwater monitoring is to be undertaken as per Jagersfontein Development WUL conditions.

– Mitigation actions, Management Plan, time frame and associated costs include the following:

– Annual Cost: Maintenance and running cost of groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.4.2.4 Decommissioning Post Closure Phase Conclusions

7.4.2.4.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 10) can be summarized as follows:

- Groundwater quality Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate", the Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Groundwater level Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.
- Groundwater flow directions Impact Significance – "**Moderate**" due to Severity/Magnitude classified as "Moderate". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Medium.

The post-mitigation assessment of impacts upon local groundwater users (see Table 10) can be summarized as follows:

- Groundwater quality Impact Significance – “**Moderate**” due to Severity/Magnitude classified as “Moderate”, the Reversibility classified as “Recoverable”. “Medium term” Duration with a “Local” Spatial Extent. The Probability is “Medium.
- Groundwater level Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Recoverable”. “Temporary term” Duration with a “Local” Spatial Extent. The Probability is “Low”.
- Groundwater flow directions Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Reversable”. “Temporary term” Duration with a “Local” Spatial Extent. The Probability is “Improbable.

7.4.2.4.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 10) can be summarized as follows:

- Groundwater quality Impact Significance – “**Moderate**” due to Severity/Magnitude classified as “Moderate”, the Reversibility classified as “Recoverable”. “Long term” Duration with a “Local” Spatial Extent. The Probability is “High”.
- Groundwater level Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Reversible”. “Temporary term” Duration with a “Local” Spatial Extent. The Probability is “Improbable.
- Groundwater flow directions Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Reversible”. “Temporary term” Duration with a “Local” Spatial Extent. The Probability is “Improbable.

The post-mitigation assessment of impacts upon private groundwater users (see Table 10) can be summarized as follows:

- Local groundwater quality Impact Significance – “**Moderate**” due to Severity/Magnitude classified as “Moderate”, the Reversibility classified as “Recoverable”. “Long term” Duration with a “Local” Spatial Extent. The Probability is “Medium.
- Local groundwater level Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Reversible”. “Short term” Duration with a “Local” Spatial Extent. The Probability is “Low.
- Local groundwater flow directions Impact Significance – “**Low**” due to Severity/Magnitude classified as “Minor”. Reversibility classified as “Reversible”. “Temporary term” Duration with a “Local” Spatial Extent. The Probability is “Improbable.

7.4.2.4.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – “**Moderate**” due to Severity/Magnitude classified as “High”. Reversibility classified as “Recoverable”. “Long term” Duration with a “Local” Spatial Extent. The Probability is “Medium”.

Post mitigation impact assessment:

- Storm Water Impact Significance – "**Low**" due to Severity/Magnitude classified as "Low". Reversibility classified as "Recoverable". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Low".

Table 10. Environmental risk assessment for groundwater impacts during the decommissioning and post closure phases of the FTSF in the region of the FTSF.

JAGERSFONTEIN TAILINGS FACILITY - GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR DECOMMISIONING AND POST CLOSURE PHASE IMPACTS

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	**Tailings Facility.**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from Tailings Facility. Leachate from Tailings Facility may cause groundwater contamination.	3	3	4	2	3	36	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Implement processes that reduce water usage because water contained in the slimes may impact on groundwater quality (increase salt loading to aquifer), the groundwater level and may change the local groundwater flow by means of seepage to underlying receiving aquifer. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately.	3	3	3	2	3	33	"Moderate
			Water levels	Minor rise in local groundwater table at TSF, and local depletion at abstraction boreholes.	3	3	2	2	3	30	"Moderate		1	1	1	1	2	8	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table and towards boreholes where abstraction is taking place.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from Tailings Facility. Leachate from Tailings Facility cause groundwater contamination downstream of the Tailings Facility. Chemistry of groundwater sites are an indication of the impact on the groundwater.	3	3	4	2	3	36	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Implement processes that reduce water usage because water contained in the slimes may impact on groundwater quality (increase salt loading to aquifer), the groundwater level and may change the local groundwater flow by means of seepage to underlying receiving aquifer. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately.	3	3	3	2	3	33	"Moderate
			Water levels	None	1	1	1	1	1	4	"Low"		1	1	1	1	2	8	"Low"
				None	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Overflow of Pollution control dams and return water canals (Cut of trenches) during heavy rainstorms.	4	3	4	1	3	36	"Moderate	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Monitor pollution control dams and return water canals (Cut of trenches) for signs of water overflow and remove any potential hindrances. Pollution control dams should be kept at freeboard to prevent overflows. Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	2	3	4	1	2	20	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.
* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.
* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.4.3 Recommendations

The recommended management options suggested for the Operational and Decommissioning phases should be used to ensure proper groundwater management in the vicinity of the Tailings Dam at Jagersfontein Development.

Should any serious incident associated with the operations (Operational and Decommissioning phases) occur which is likely to have detrimental effects on the receiving ground- and surface water the Department of Water Affairs and Sanitation (DWS), as well as the Department of Environmental Affairs (DEA) must immediately be informed. A record of these incidents must be kept. All incidents must be reported as per the requirements of S30 of the National Environmental Management Act, No. 107 OF 1998; where "Incident" means an unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed.

A protocol for response during emergencies must be developed and maintained.

7.5 Old Dumps

Information obtained during the aquifer vulnerability study of the TSF was used (extrapolated) to the dumps to identify possible risk and mitigation actions.

7.5.1 Do-Nothing (leave on surface) Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The risk and groundwater management plan of the Do-Nothing option can be seen in Table 11.

7.5.1.1 Impacts upon groundwater qualities and elevations:

- Deterioration of groundwater quality due to leachate from the dumps. Leachate from the dumps may cause downstream groundwater contamination.
- Rise in local groundwater table due to infiltration through the dumps.
- Minor changes in local groundwater flow directions due to possible rise in local water table.

7.5.1.2 Impact: Storm water (runoff water)

Surface runoff will continue to cause downstream surface water and groundwater contamination.

Mitigation Measure and Management Plan to be Implemented:

- Immediate closure will have no mitigation actions.

7.5.1.3 Do-Nothing Conclusions

7.5.1.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (Table 11) can be summarized as follows:

- Groundwater quality Impact Significance – "High" due to Severity/Magnitude classified as "High", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Recoverable". "Short term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment (no mitigation as it is left on surface) of impacts upon local groundwater users (Table 11) can be summarized as follows:

- Groundwater quality Impact Significance – "High" due to Severity/Magnitude classified as "High", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Recoverable". "Short term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.1.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 11) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate" due to Severity/Magnitude classified as "High", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 11) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate" due to Severity/Magnitude classified as "High", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.1.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Moderate” due to Severity/Magnitude classified as "High", the Reversibility classified as "Recoverable". "Long term" Duration with a "Site only" Spatial Extent. The Probability is "Medium".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Moderate” due to Severity/Magnitude classified as "High", the Reversibility classified as "Recoverable". "Long term" Duration with a "Site only" Spatial Extent. The Probability is "Medium".

Table 11. Environmental risk assessment for groundwater impacts in the regions of the dumps (do-nothing scenario leaving dumps on-surface)

JAGERSFONTEIN WRD's - GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR IMMEDIATE CLOSURE PHASE IMPACTS (DO-NOTHING LEAVE ON-SURFACE)

No.	Activity	Area	Type	POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Operational Phase Impacts																			
1.)	WRD's	Local Groundwater	Quality	Deterioration of groundwater quality due to leachate from dumps. Leachate from dumps may cause groundwater contamination.	4	5	5	2	4	64	"High"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. This monitoring process will stop immediatlely. *Management plan:* None	4	5	5	2	4	64	"High"
			Water levels	Minor rise in local groundwater table at dumps	2	3	2	2	2	18	"Low"		2	3	2	2	2	18	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	Quality	Deterioration of groundwater quality due to leachate from dumps . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	4	5	5	2	4	64	"Moderate"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. This monitoring process will stop immediatlely. *Management plan:* None	4	5	5	2	4	64	"Moderate"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Surface run-oof from dumps during heavy rainstorms.	4	3	4	1	3	36	"Moderate"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* None	4	3	4	1	3	36	"Moderate"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)

* Reversibility (R)

* Duration (D)

* Spatial Extent (S)

7.5.2 Operational Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Operational phase risk and groundwater management plan for the dumps can be studied in Table 12.

The Operational phase groundwater management plan includes the following:

- Operational impacts during dumps removal.
- Storm Water.

7.5.2.1 Impacts: Groundwater.

- Deterioration of groundwater quality due to disturbance of material and infiltration during storm events. Leachate from dumps may cause groundwater contamination.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is.
- The current data management system needs to be updated monthly/quarterly to prevent loss of data.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.5.2.2 Impact: Storm water (runoff water)

Surface runoff during rainstorms.

– Objective:

- Effective management of storm water and containment of potentially polluted surface that may impact on groundwater quality by means of overflow or seepage to underlying receiving aquifer (increase salt loading to aquifer).

Mitigation Measure and Management Plan to be Implemented:

- Prevent ponding of water in pools by removal of material and proper sloping to allow runoff to dissipate.
- Ground- and surface water monitoring should also continue to operate as is.
- The current data management system needs to be updated monthly/quarterly to prevent loss of data.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.5.2.3 Operational Phase Conclusions

7.5.2.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 12) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate due to Severity/Magnitude classified as "High", the Reversibility classified as "Reversible". "Temporary" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Moderate", the Reversibility classified as "Reversible". "Short term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 12) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.2.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 12) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate due to Severity/Magnitude classified as "High", the Reversibility classified as "Reversible". "Temporary" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Reversible". "Short term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 12) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.2.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Moderate due to Severity/Magnitude classified as "High", the Reversibility classified as "Recoverable". "Long term" Duration with a "Site only" Spatial Extent. The Probability is "Medium".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Recoverable". "Long term" Duration with a "Site only" Spatial Extent. The Probability is "Low".

Table 12. Environmental risk assessment for groundwater impacts in the regions of the dumps during the decommissioning of the dumps (dump removal).

JAGERSFONTEIN TAILINGS FACILITY - GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR DECOMMISIONING PHASE (REMOVAL OF DUMPS) IMPACTS

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	**WRD's**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from dumps. Leachate from dumps may cause groundwater contamination.	4	1	1	2	4	32	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Removal of the dumps will be benificial in the long term. The removal process is a short-term process. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. Hydrocensus data needs to be evaluated to monitor the long term benificial effect. Old tailings material to be removed as far as possible to encourage re-vegateation.	1	1	1	1	1	4	"Low"
			Water levels	Minor rise in local groundwater table at dumps	3	1	2	2	2	16	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from dumps . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	4	1	1	2	4	32	"Moderate	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Removal of the dumps will be benificial in the long term. The removal process is a short-term process. Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. Hydrocensus data needs to be evaluated to monitor the long term benificial effect. Old tailings material to be removed as far as possible to encourage re-vegateation.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	2	1	2	2	2	14	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Surface run-oof from dumps during heavy rainstorms.	4	3	4	1	3	36	"Moderate	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Removal of on-surface residue as far as possible. Monitoring of downstream surface- and groundwater to be contiued until closure to verify groundwater quality improvement.	2	3	4	1	2	20	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)

* Reversibility (R)

* Duration (D)

* Spatial Extent (S)

* Probability (P)

7.5.3 Post-Closure (removed dumps) Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The post closure impacts can be perused in Table 13.

7.5.3.1 Impacts: Cleared vegetation

- Re-vegetation may be a slow process due to the historical prolonged timespan of the dumps on surface.

7.5.3.2 Impact: Storm water (runoff water)

Excessive erosion may occur due to loss of vegetation

– Objective:

- Preventing of erosion by proper clearing of old material and proper sloping.

Mitigation Measure and Management Plan to be Implemented:

- Inspect surfaces for proper sloping to manage surface runoff.

7.5.3.3 Post Closure Phase Conclusions

7.5.3.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 13) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 13) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.3.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 13) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 13) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.5.3.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 13. Post-closure environmental risk assessment for groundwater impacts in the regions of the dumps (dump removed).

JAGERSFONTEIN WASTE ROCK DUMP - GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR POST CLOSURE PHASE IMPACTS

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	**WRD's**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from dumps. Leachate from dumps may cause groundwater contamination.	1	1	1	1	1	4	"Low"	*Objective:* Recovery of system to pre-mining state. *Management plan:* Natural attenuation and re-vegatation will occur over time.	1	1	1	1	1	4	"Low"
			Water levels	Minor rise in local groundwater table at dumps	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from dumps . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* Recovery of system to pre-mining state. *Management plan:* Natural attenuation and re-vegatation will occur over time.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Surface run-oof from dumps during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Natural attenuation and re-vegatation will occur over time.	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.
* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.
* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.6 The Pit – Shallow Aquifer

7.6.1 Do-Nothing (not filling the Pit) Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Do-Nothing risk and groundwater management plan for not filling the Pit can be seen in Table 14.

7.6.1.1 Impacts:

- No impacts upon shallow groundwater aquifer water levels or qualities.
- Possible breakback.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- None

– Mitigation Measure and Management Plan to be Implemented:

- None

7.6.1.2 Impact: Storm water (runoff water)

Surface runoff to the pit enhances pit breakback.

– Objective:

- Effective management of storm water and diverting away from the pit.

Mitigation Measure and Management Plan to be Implemented:

- Divert storm water around the pit.

– Annual Cost: Maintenance and running cost of surface water diversion.

– Closure Cost: None

7.6.1.3 Do-Nothing Conclusions

7.6.1.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (Table 14) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 14) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.1.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 14) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 14) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.1.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 14. Environmental risk assessment for shallow groundwater impacts in the region of the Pit (do-nothing scenario leaving dumps on-surface and no Pit backfilling)

JAGERSFONTEIN PIT - SHALLOW GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR IMMEDIATE CLOSURE PHASE IMPACTS (DO-NOTHING LEAVE AS IS NO BACKFILLING)

No.	Activity	Area	Type	POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Operational Phase Impacts																			
1.)	**PIT**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from material already in the pit (same material as dumps). Leachate from matatial may cause groundwater contamination.	1	1	1	1	1	4	"Low"	*Objective:* None *Management plan:* None	1	1	1	1	1	4	"Low"
			Water levels	Minor rise in local groundwater table at dumps	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate material in the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* None *Management plan:* None	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Surface run-oof from dumps during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* None *Management plan:* None	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.6.2 Pit Operational Phase Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Operational phase risk and shallow aquifer groundwater management plan for filling the pit can be perused in Table 15.

The operational phase shallow aquifer groundwater management plan includes management impacts from the following:

- Filling the Pit.
- Storm Water.
- Operational Impacts.

7.6.2.1 Impacts upon shallow aquifer groundwater:

- Impacts upon shallow aquifer groundwater flow directions and qualities.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented, where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is with the proposed new boreholes to be incorporated in the monitoring programme.
- Remediation actions (abstraction, treatment, and re-use) to be implemented upon detection.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme. Possibly extending groundwater monitoring network, drilling etc.

– Closure Cost: General rehabilitation cost allowed for at closure and possible groundwater rehabilitations (pump, cleaning and re-use).

7.6.2.2 Impact: Storm water (runoff water)

– Objective:

- Preventing surface runoff entering the pit.

Mitigation Measure and Management Plan to be Implemented:

- Diverting surface runoff around the pit limiting breakback.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.6.2.3 Operational Phase Conclusions

7.6.2.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 15) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 15) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.2.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 15) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 15) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.2.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 15. Environmental risk assessment for shallow aquifer groundwater impacts in the region of the Pit (operational phase Pit backfilling)

JAGERSFONTEIN PIT - SHALLOW GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR OPERATIONAL PHASE IMPACTS (BACKFILLING)

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION (M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE	OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION (M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	**PIT**	**Local Groundwater**	**Quality**	Deterioration of groundwater quality due to leachate from material added to pit. Leachate from material may cause groundwater contamination.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring boreholes (at least 100 metres deep) be drilled around the pit for early detection monitoring system. Monitoring of upstream and downstream boreholes to be included in monitoring network.	1	1	1	1	1	4	"Low"
			Water levels	Minor rise in local shallow groundwater table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate material in the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring boreholes (at least 100 metres deep) be drilled around the pit for early detection monitoring system. Monitoring of upstream and downstream boreholes to be included in monitoring network.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Storm water (rain) and Surface run-off to the pit during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Prevent all surface run-off from entering the pit (proper ber walls and diversions). Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)

* Reversibility (R)

* Duration (D)

* Spatial Extent (S)

* Probability (P)

7.6.3 Post Closure Phases Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The post-closure phase shallow aquifer groundwater management plan includes management impacts from the following:

- Storm Water.

7.6.3.1 Impacts upon shallow aquifer groundwater:

- Impacts upon shallow aquifer groundwater flow directions and qualities.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented, where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is with the proposed new boreholes to be incorporated in the monitoring programme.
- Remediation actions (abstraction, treatment, and re-use) to be implemented upon detection.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme. Possibly extending groundwater monitoring network, drilling etc.

– Closure Cost: General rehabilitation cost allowed for at closure and possible groundwater rehabilitations (pump, cleaning and re-use).

7.6.3.2 Impact: Storm water (runoff water)

– Objective:

- Preventing surface runoff entering the pit.

Mitigation Measure and Management Plan to be Implemented:

- Diverting surface runoff around the pit limiting breakback.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.6.3.3 Decommissioning Post Closure Phase Conclusions

7.6.3.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 16) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 16) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.3.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 16) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 16) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.6.3.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 16. Environmental risk assessment for shallow aquifer groundwater impacts in the region of the Pit (post closure phase Pit backfilling)

JAGERSFONTEIN PIT - SHALLOW GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR POST CLOSURE PHASE IMPACTS (BACKFILLING)

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	PIT	Local Groundwater	Quality	Deterioration of groundwater quality due to leachate from material added to pit. Leachate from material may cause groundwater contamination.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring boreholes (at least 100 metres deep) be drilled around the pit for early detection monitoring system. Monitoring of upstream and downstream boreholes to be included in monitoring network.	1	1	1	1	1	4	"Low"
			Water levels	Minor rise in local shallow groundwater table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	Quality	Deterioration of groundwater quality due to leachate material in the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that additional groundwater monitoring boreholes (at least 100 metres deep) be drilled around the pit for early detection monitoring system. Monitoring of upstream and downstream boreholes to be included in monitoring network.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Storm water (rain) and Surface run-off to the pit during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Prevent all surface run-off from entering the pit (proper ber walls and diversions). Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.
* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.
* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)

7.7 The Pit – Deep Aquifer

7.7.1 Do-Nothing (not filling the Pit) Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The Do-Nothing risk and deep aquifer groundwater management plan for not filling the Pit can be seen in Table 17.

7.7.1.1 Impacts:

- No impacts upon deep aquifer groundwater water levels or qualities.
- Possible breakback.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- None

– Mitigation Measure and Management Plan to be Implemented:

- None

7.7.1.2 Impact: Storm water (runoff water)

Surface runoff to the pit enhances pit breakback.

– Objective:

- Effective management of storm water and diverting away from the pit.

Mitigation Measure and Management Plan to be Implemented:

- Divert storm water around the pit.

– Annual Cost: Maintenance and running cost of surface water diversion.

– Closure Cost: None

7.7.1.3 Do Nothing impact assessment - No Backfilling

7.7.1.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (Table 17) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 17) can be summarized as follows:

- Groundwater quality Impact Significance – "Moderate" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Irreversible". "Permanent" Duration with a "Local" Spatial Extent. The Probability is "High".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.1.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 17) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 17) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.1.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 17. Environmental risk assessment for deep groundwater impacts in the region of the Pit (do-nothing scenario leaving dumps on-surface)

JAGERSFONTEIN PIT - DEEP GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR IMMEDIATE CLOSURE PHASE IMPACTS (NO BACKFILLING)

No.	Activity	Area	Type	POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE NO MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Operational Phase Impacts																			
1.)	**PIT**	**Local Groundwater**	**Quality**	Deterioration of deep groundwater quality due to leachate from material added to pit. Leachate from material may cause groundwater contamination.	2	5	5	2	4	56	"Moderate"	*Objective:* None *Management plan:* None	2	5	5	2	4	56	"Moderate"
			Water levels	Minor rise in local deep groundwater table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local deep groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from material added to the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* None *Management plan:* None	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Storm water (rain) and Surface run-off to the pit during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* None *Management plan:* None	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.7.2 Pit Operational Phase Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The operational phase deep aquifer groundwater management plan includes management impacts from the following:

- Filling the Pit.
- Storm Water.
- Operational Impacts.

7.7.2.1 Impacts upon shallow aquifer groundwater:

- Impacts upon deep aquifer groundwater flow directions and qualities.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented, where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is with the proposed new boreholes to be incorporated in the monitoring programme.
- Remediation actions (abstraction, treatment, and re-use) to be implemented upon detection.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme. Possibly extending groundwater monitoring network, drilling etc.

– Closure Cost: General rehabilitation cost allowed for at closure and possible groundwater rehabilitations (pump, cleaning and re-use).

7.7.2.2 Impact: Storm water (runoff water)

– Objective:

- Preventing surface runoff entering the pit.

Mitigation Measure and Management Plan to be Implemented:

- Diverting surface runoff around the pit limiting breakback.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.7.2.3 Operational Phase Conclusions

7.7.2.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 18) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as 0. "Permanent" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 18) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Reversible". "Long term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.2.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 18) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 18) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.2.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 18. Environmental risk assessment for deep aquifer groundwater impacts during the operational phase of the facility in the region of the Pit (backfilling).

JAGERSFONTEIN PIT - DEEP GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR POST CLOSURE PHASE IMPACTS (BACKFILLING)

No.	Activity			POTENTIAL ENVIRONMENTAL IMPACTS	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
					(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE		(M)	(R)	(D)	(S)	(P)	TOTAL	SIGNIFICANCE
Decommissioning Phase Impacts																			
1)	PIT	Local Groundwater	Quality	Deterioration of deep groundwater quality due to leachate from material added to pit. Leachate from material may cause groundwater contamination.	2	2	5	2	2	22	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that three additional groundwater monitoring boreholes (at least 300 metres deep) be drilled around the pit for early detection monitoring system. At leas one deep borehole (300 metres) must be drille upstream for background water quality monitoring. Monitoring of upstream and downstream boreholes to be included in monitoring network. Should groundwater contamination be detected, pump, treat and distribution must be implemented.	2	1	3	2	2	16	"Low"
			Water levels	Minor rise in local deep groundwater table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local deep groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	Quality	Deterioration of groundwater quality due to leachate from material added to the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that three additional groundwater monitoring boreholes (at least 300 metres deep) be drilled around the pit for early detection monitoring system. At leas one deep borehole (300 metres) must be drille upstream for background water quality monitoring. Monitoring of upstream and downstream boreholes to be included in monitoring network. Should groundwater contamination be detected, pump, treat and distribution must be implemented.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Storm water (rain) and Surface run-off to the pit during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Prevent all surface run-off from entering the pit (proper ber walls and diversions). Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.
* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.
* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)
* Reversibility (R)
* Duration (D)
* Spatial Extent (S)
* Probability (P)

7.7.3 Post Closure Phases Impact Assessment and Groundwater Management Plan in terms of Risk, Quality and Quantity

The post-closure deep shallow aquifer groundwater management plan includes management impacts from the following:

- Storm Water.

7.7.3.1 Impacts upon deep aquifer groundwater:

- Impacts upon deep aquifer groundwater flow directions and qualities.

Mitigation actions, Management Plan, time frame and associated costs include the following:

– Objective:

- Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented, where problems are encountered.

– Mitigation Measure and Management Plan to be Implemented:

- Ground- and surface water monitoring must continue to operate as is with the proposed new boreholes to be incorporated in the monitoring programme.
- Remediation actions (abstraction, treatment, and re-use) to be implemented upon detection.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme. Possibly extending groundwater monitoring network, drilling etc.

– Closure Cost: General rehabilitation cost allowed for at closure and possible groundwater rehabilitations (pump, cleaning and re-use).

7.7.3.2 Impact: Storm water (runoff water)

– Objective:

- Preventing surface runoff entering the pit.

Mitigation Measure and Management Plan to be Implemented:

- Diverting surface runoff around the pit limiting breakback.

– Annual Cost: Maintenance and running cost of facility and groundwater monitoring programme.

– Closure Cost: General rehabilitation cost allowed for at closure.

7.7.3.3 Decommissioning Post Closure Phase Conclusions

7.7.3.3.1 Local groundwater users

The pre-mitigation assessment of impacts upon local groundwater users (see Table 19) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as 0. "Permanent" Duration with a "Local" Spatial Extent. The Probability is "Low".

- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon local groundwater users (see Table 19) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Low", the Reversibility classified as "Reversible". "Medium term" Duration with a "Local" Spatial Extent. The Probability is "Low".
- •Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.3.3.2 Private groundwater users

The pre-mitigation assessment of impacts upon private groundwater users (see Table 19) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

The post-mitigation assessment of impacts upon private groundwater users (see Table 19) can be summarized as follows:

- Groundwater quality Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater level Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".
- Groundwater flow directions Impact Significance "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

7.7.3.3.3 Storm Water

Pre mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Post mitigation impact assessment:

- Storm Water Impact Significance – "Low" due to Severity/Magnitude classified as "Minor", the Reversibility classified as "Reversible". "Temporary" Duration with a "Site only" Spatial Extent. The Probability is "Improbable".

Table 19. Environmental risk assessment for deep aquifer groundwater impacts closure phase of the facility in the region of the Pit (backfilling)

JAGERSFONTEIN PIT - DEEP GROUNDWATER IMPACT ASSESSMENT & PROPOSED MITIGATION MEASURES FOR POST CLOSURE PHASE IMPACTS (BACKFILLING)																			
No.	**Activity**			**POTENTIAL ENVIRONMENTAL IMPACTS**	**ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION**							**OBJECTIVES AND RECOMMENDED MANAGEMENT PLAN (BASED ON DWS, BPG)**	**ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION**						
					(M)	**(R)**	**(D)**	**(S)**	**(P)**	**TOTAL**	**SIGNIFICANCE**		**(M)**	**(R)**	**(D)**	**(S)**	**(P)**	**TOTAL**	**SIGNIFICANCE**
Decommissioning Phase Impacts																			
1)	**PIT**	**Local Groundwater**	**Quality**	Deterioration of deep groundwater quality due to leachate from material added to pit. Leachate from material may cause groundwater contamination.	2	2	5	2	2	22	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that three additional groundwater monitoring boreholes (at least 300 metres deep) be drilled around the pit for early detection monitoring system. At leas one deep borehole (300 metres) must be drille upstream for background water quality monitoring. Monitoring of upstream and downstream boreholes to be included in monitoring network. Should groundwater contamination be detected, pump, treat and distribution must be implemented.	2	1	3	2	2	16	"Low"
			Water levels	Minor rise in local deep groundwater table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Minor changes in local deep groundwater flow directions due to possible rise in local water table.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
		Private Groundwater Users	**Quality**	Deterioration of groundwater quality due to leachate from material added to the pit . Leachate from dumps may cause groundwater contamination downstream of the dumps. Chemistry of groundwater sites are an indication of the impact on the groundwater.	1	1	1	1	1	4	"Low"	*Objective:* Early detection of any potential ground- or surface water pollution, groundwater level rise or change in the groundwater flow direction resultant from undertaking the respective activities on site, such that appropriate remedial/corrective actions can be implemented; where problems are encountered. *Management plan:* Ground- and surface water monitoring must continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data. Any deviation in the groundwater quality, groundwater level or a change in the local groundwater flow direction should be reported imediately. It is recommended that three additional groundwater monitoring boreholes (at least 300 metres deep) be drilled around the pit for early detection monitoring system. At leas one deep borehole (300 metres) must be drille upstream for background water quality monitoring. Monitoring of upstream and downstream boreholes to be included in monitoring network. Should groundwater contamination be detected, pump, treat and distribution must be implemented.	1	1	1	1	1	4	"Low"
			Water levels	Change in groundwater table at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
				Change in groundwater flow directions at private groundwater users - NONE.	1	1	1	1	1	4	"Low"		1	1	1	1	1	4	"Low"
2.)	**Storm water**			Storm water (rain) and Surface run-off to the pit during heavy rainstorms.	1	1	1	1	1	4	"Low"	*Objectives:* Effective management of storm water and containment of potentially polluted surface water at all times. *Management plan:* Prevent all surface run-off from entering the pit (proper ber walls and diversions). Ground- and surface water monitoring should also continue to operate as is. The current data management system needs to be updated monthly/quarterly to prevent loss of data.	1	1	1	1	1	4	"Low"

* Series A - Activity Guidelines - A2, Best Practices Guideline: Water Management of Mine Residue Deposits.

* Series A - Activity Guidelines - A5, Best Practices Guideline: Water Management for Surface Mines.

* Series H - Hierarchy Guidelines - H2, Best Practices Guideline: Pollution Prevention and Minimisation of Impacts.

* Severity / Magnitude (M)

* Reversibility (R)

* Duration (D)

* Spatial Extent (S)

* Probability (P)

8 PIT MONITORING PLAN

Although the Pit would form part of an integrated monitoring plan, a monitoring plan is presented separately to highlight the proposed monitoring network. When approved, this plan must be merged with the general surface- and groundwater monitoring plan previously submitted to DWS.

8.1 Reasons for Monitoring

In general, surface runoff and seepages from pollution sources to surface- and groundwater receptors may contribute to both downstream surface- and groundwater users. Groundwater is the only source of water for households and stock watering in many rural areas, in some places whole villages or towns receive all their water supply form groundwater. Groundwater is different from surface water in that if it is polluted it is often difficult or impossible to clean and pollution problems may persist for many hundreds of years.

Many remediation attempts in various parts of the world have been extremely costly. At present, in many countries the approach is to prevent pollution from occurring rather than, allowing limited degradation and trying to maintain the water quality at a given standard, or trying to clean up the groundwater after pollution has occurred. This approach is referred to as groundwater protection.

Even though it is evident that there are no water bearing faults or intrusions intersecting the pit and that there is no interconnectivity between the pit and surrounding aquifer systems, it remains of utmost importance to monitor any possible impacts on the surrounding geology or aquifers including groundwater levels and groundwater qualities upon pit back filling.

Groundwater monitoring should therefore identify so-called Key Performance Indicators (KPI's) to properly define the goals to be achieved with monitoring as well as rate or evaluate successful monitoring. These KPI's will be discussed in section 8.11.1.

8.2 Surface and Groundwater Monitoring

Monitoring forms and integral part of surface and groundwater protection and is essential whenever the water forms an important resource or where there are human activities that may generate substances that are harmful to surface and groundwater. Water monitoring at Jagersfontein Development (Pty) Ltd is undertaken by the appointed contractor (currently Turn180 Environmental Consultants). The monitoring program and relevance of each of the monitoring points must be reviewed annually by a professional environmental practitioner in conjunction with Jagersfontein Development (Pty) Ltd.'s environmental personnel.

The purpose of the water monitoring programme is to monitor surface- and groundwater to proactively identify and implement the actions needed to manage the water related risks of the activities and operations throughout Jagersfontein Development (Pty) Ltd.'s life cycle.

The objectives of water monitoring are thus to:

- o Ensure that the Jagersfontein Development (Pty) Ltd is complying with relevant legislation and/or authority requirements.

- Assess (quantify and qualify) potential impacts that Jagersfontein Development (Pty) Ltd may be having on the surrounding environment, and particularly upon groundwater and downstream users of water. These impacts may be groundwater depletion due to dewatering or contaminant impacts upon surface- and groundwater receptors.
- Assess potential liabilities that Jagersfontein Development (Pty) Ltd may face as a result of contamination that may be derived from the operations.
- Provide information on developing pollution plumes to allow Jagersfontein Development (Pty) Ltd to take timely preventative action designed to minimise closure liabilities.
- Proactively identify and implement the actions needed to manage the water related risks of the operation throughout t Jagersfontein Development (Pty) Ltd.'s life cycle.

8.2.1 Surface Water and Storm Water Management

The Pit water balance with regards to precipitation is negative due to the substantial difference between precipitation and evaporation as indicated in Table 20 and Table 21. This diminishes the chance of oversaturation of the disposed material and therefore reduce the risk of groundwater pollution. The negative water balance together with no groundwater inflow from the surrounding geology means that the groundwater level in the pit will not recover to regional ambient groundwater levels. It is however of utmost importance to prevent surface run-off entering the pit and take the appropriate measures with the installation of proper berm walls retaining natural surface flow along the stream to the east and south of the pit as indicated in Figure 97.

Table 20: Precipitation and Evaporation

Annual Precipitation and Evaporation		
Precipitation (mm/a)	Evaporation (mm/a)	Netto Precipitation (mm/a)
427.70	1500.00	-1072.30

Table 21: Precipitation and Evaporation Water Volumes

Pit Water Balance (Precipitation minus Evaporation)			
Area (hectares)	Precipitation (m^3/a)	Evaporation (m^3/a)	Netto Precipitation (m^3/a)
21.72	92 896.44	325 800.00	-232 903.56

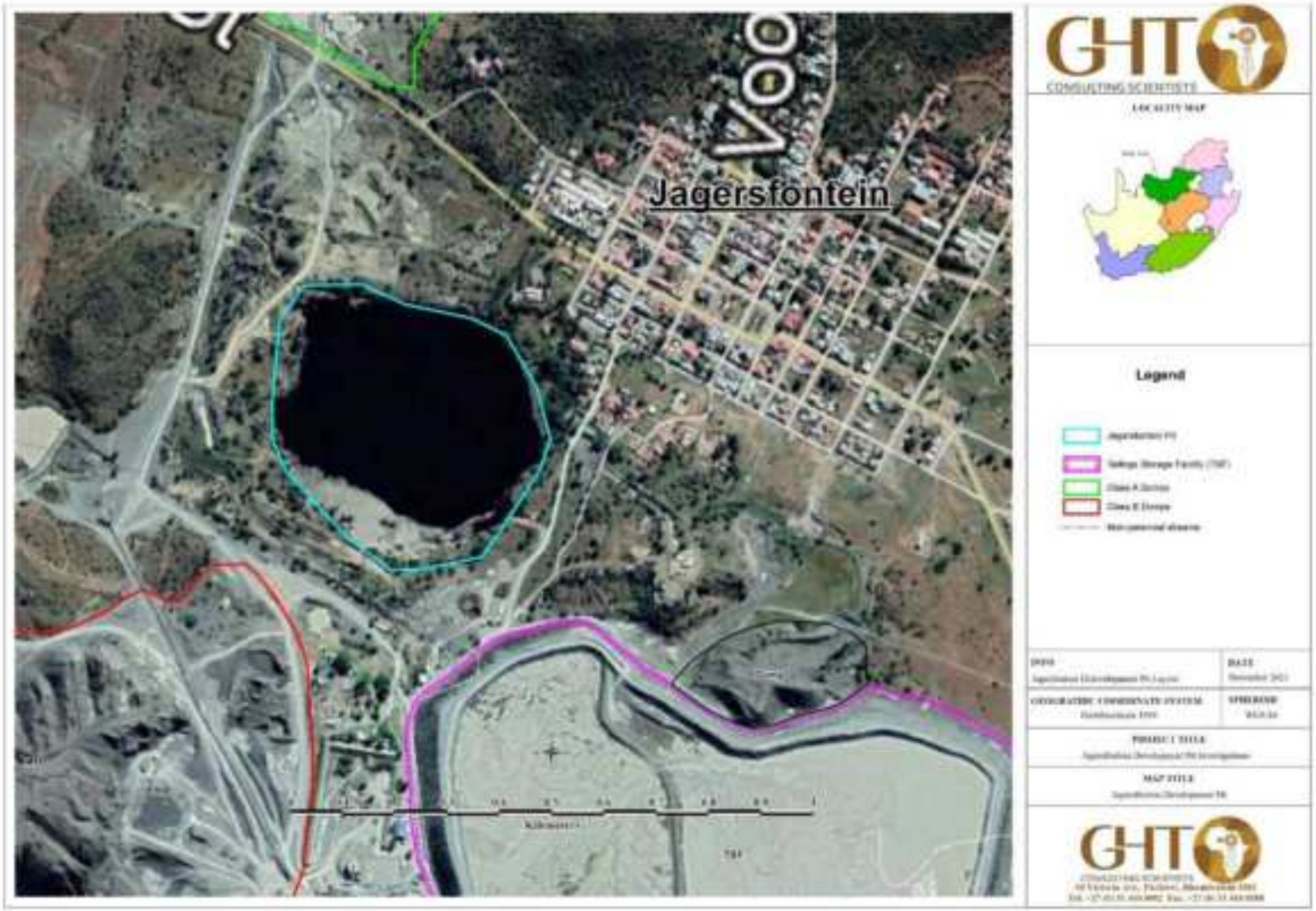


Figure 97. Pit Layout indicating natural streams.

8.2.2 What Should be Monitored

No surface water impacts are expected from the Pit due to the fill level to 60mbgl.

With regards to groundwater monitoring and the possible different aquifer (s) system, the groundwater monitoring system must make for provisions of the following:

- Monitoring of groundwater levels within the deep and possible shallow aquifer (s).
- Monitoring of groundwater qualities within the deep and possible shallow aquifer (s).
- Due to the depth of the pit, ultimate fill level and a shallow and deep aquifer system (s), monitoring of both systems needs to be performed by installation of deep and shallow boreholes as an early detection system and possibly to be used in mitigation strategies.

8.2.3 Positioning Monitoring Sites

Contaminants spread away from a contaminant source in a contaminant plume that moves downgradient away from the source becoming wider and more dilute with distance from the source. The actual shape of the plume and concentration gradients are dependent on the local hydrogeology. In fractured aquifers the movement and spread may be very different from what would be predicted using normal hydrodynamic equations and modelling, which assume, that the aquifer is a porous medium. In fractured aquifers, movement usually follows a preferred pathway (the fracture) it is thus much faster and less spread out than what is found in a porous medium.

The aim of installing a monitoring borehole is to intercept any contamination that may enter the groundwater as soon as possible. This means that for the monitoring borehole(s) to be properly places, the site's geology must be understood so that the potential plume's shape, direction and rate of movement can be predicted. The knowledge gain from field excursions, and pit images which indicate the pit not to be connected to the surrounding aquifer(s) systems (except the possible the deep aquifer) is the determining factor regarding the required depth and construction of monitoring boreholes.

To position the boreholes downgradient of the potential contaminant site may need a certain amount of prior knowledge about the site. For example, the water levels should be known, so that the water table gradient and groundwater flow direction can be determined. This information is not available (except for the shaft) and would be determined with the installation of the monitoring network.

The geophysical techniques normally employed to help to delineate areas where groundwater movement might preferentially occur or to show the extent of the pollution plume has been applied extensively over the region with limited prospect of being employed locally around the pit due to several impeding man-made features around the pit.

Any other method that may help in understanding the geology and possible structural control of subsurface water movement should also be used. For example, in some places, dikes or major structures such as faults may form preferential pathways for water movement, or they may form barriers preventing migration. No faults or dykes have been previously identified to by either aerial magnetic or aerial photo interpretations.

The best method is therefore to target the proposed areas (see Figure 96) with the aid of simulated groundwater flow directions by drilling the required boreholes recording the detailed geology.

8.3 Identification Groundwater Monitoring Sites

The positions of monitoring boreholes have been determined in accordance with the results from the numerical pollution plume model in Figure 96 and indicated in Figure 98. These are:

- PitBH1-S and PitBH1-D – Shallow and deep boreholes north of pit (to be drilled upon approval)
- PitBH2-S and PitBH2-D – Shallow and deep boreholes east of pit (to be drilled upon approval)
- PitBH3-S and PitBH3-D – Shallow and deep boreholes west of pit (to be drilled upon approval)
- Pit BH4-S and PitBH4-D – Optional Shallow and deep boreholes south of pit between pit and Shaft (to be drilled upon approval)
- H110 – Shallow aquifer background hydrocensus borehole north-west of pit
- Pit BH5-D – Deep upgradient monitoring borehole north-west of the pit
- Shaft – South of pit to be monitored according to the WUL parameter list and groundwater level recording.

8.4 Borehole Construction

The following is advised with regards to the borehole construction:

- The monitoring boreholes must be installed in deep and shallow pairs to monitor the different aquifer systems.
- With the current pit bottom at approximately 260 mbgl, the deep borehole must extend to at least this depth, but it is strongly advised to 300 mbgl.
- With the fill level to 60 mbgl, the shallow borehole within the pair must be 100 metres deep (at most).
- The drilling of each of the deep (up to 300 m) boreholes within a pair must be performed first. The information obtained during drilling of the deep borehole will determine the deep borehole finishing (casing depth and perforation). This information must then be used to determine the borehole construction of the shallow borehole (up to 100m) in the pair.
- The casings of the boreholes must extrude at least 300mm above ground and protected by installation of a bee-proof sealable caps, marker posts and cement plinths.
- Geological logs must be recorded together with encountered water strikes (as possible future sampling depths). Sampling must be conducted with depth specific bailers. No pumping or purging is currently advised.
- It is not envisioned that these monitoring boreholes will facilitate any pollution remediated with the shaft considered as the best remediation abstraction point. However, due to the borehole construction costs, these boreholes must be constructed in such a fashion as to facilitate abstraction for mitigation purposes (should abstraction from the shaft become a problem) as drilling additional boreholes for this purpose will be more costly in the end.
- To be utilized as possible abstraction mitigation boreholes, only the deep boreholes need to be constructed with an adequate diameter to facilitates pumps that can operate efficiently at the required depths.

- Drilling and construction of the deep (300 metres) boreholes should be as follows:
    - Telescopic drilling is advised with the upper part of the borehole from surface into 6 metres solid bedrock at 305 mm (12 inches) and the rest of the borehole at 254 mm (10 inches).
    - Solid PVC casings 254 mm (10 inches) in diameter must be installed from 300 mm above surface (preventing surface influences) to 6 metres into solid bedrock.
    - Alternating perforated and solid PVC casings 205 mm (8 inches) must be installed from 6 metres into solid bedrock to the bottom of the borehole capped at the bottom. Care must be taken to align perforated parts of the casing with encountered water strikes.
- Drilling and construction of the shallow (up to 100 metres) boreholes should be as follows:
    - Telescopic drilling is advised with the upper part of the borehole from surface into 6 metres solid bedrock at 205 mm (8 inches) and the rest of the borehole at 152 mm (6 inches).
    - Solid casings 152 mm (6 inches) in diameter must be installed from 300 mm above surface (preventing surface influences) to 6 metres into solid bedrock.
    - Depending on the information recorder during the drilling of the deep borehole (solid or loose material at different depths up to 100 mbgl), alternating perforated and solid PVC casings 140 mm (5.5 inches) must be installed from the initial 6 metres drilled into the upper solid bedrock of 6 metres to at least 6 metres below that deepest part of loose material or areas of instability. Care must be taken to align perforated parts of the casing with encountered water strikes.
- If any water strikes are encountered during drilling, depth, field pH and EC values must be immediately recorded.
- A level logger and attachable mechanism for a pully system must be installed at the deep boreholes to facilitate future sampling (only if or once water is detected in a borehole).
- It is also advised to conduct extensive aquifer test (pumping etc.) to determine aquifer parameters, not only for numerical modelling purposes, but for correct pump selection and pumping regimes (should this be necessary).

The proposed construction of the boreholes is displayed in below Table 22 and Table 23.

Table 22: Proposed construction of deep boreholes.

BOREHOLE INFORMATION & CONSTRUCTION DETAILS

BASIC GEOSITE INFORMATION

PROJECT	Pit Monitoring Network	BH NUMBER	PitBH1-D	DWS NUMBER	
CLIENT	Jagersfontein Development	PROVINCE	Free State		
TOWN	Jagersfontein	SOUTH COORDINATE	-29.761041	SYSTEM	GPS WGS84
VILLAGE		EAST COORDINATE	25.419952	SYSTEM	GPS WGS84
CONTRACTOR		ELEVATION (mamsl)		SYSTEM	
LOGGED BY		FINAL DEPTH (m)	300	CASING HEIGHT (mm)	300
DATE STARTED	COMPLETED	FINAL BLOW YIELD (l/s)		l/hr	
BH PURPOSE	Deep Aquifer Monitoring	BOREHOLE SITED BY			

BOREHOLE DIAMETER					CASING DETAILS					
Diameter	From Top (m)	To Bottom (m)	Method	Fluid	Diameter (mm)	Thickness (mm)	Material	From Top (m)	To Bottom (m)	Description S / P
305 mm	0	18	Percussion		254	5	PVC	-0.3	18	Solid
254 mm	18	300	Percussion		205	5	PVC	18	300	Alternating Perforated
216 mm										
172 mm										
165 mm										

WATER STRIKES & AQUIFER				FILTER / GRAVEL / SEAL PACK				
	Depth (m)	Air lift yield (l/hr)	Description / Aquifer type	From Top (m)	To Bottom (m)	TYPE	UNIT	QTY
1st								
2nd								
3rd								
4th								
Final								

GEOLOGICAL & HYDROLGEOLOGICAL DETAILS

Drawing not to scale

From (m)	To Bottom (m)	Lithology / Description
0	4	Superficail Residual Graverls
4	18	Dolerite shale contact
18	300	Dolretite Hard Fresh

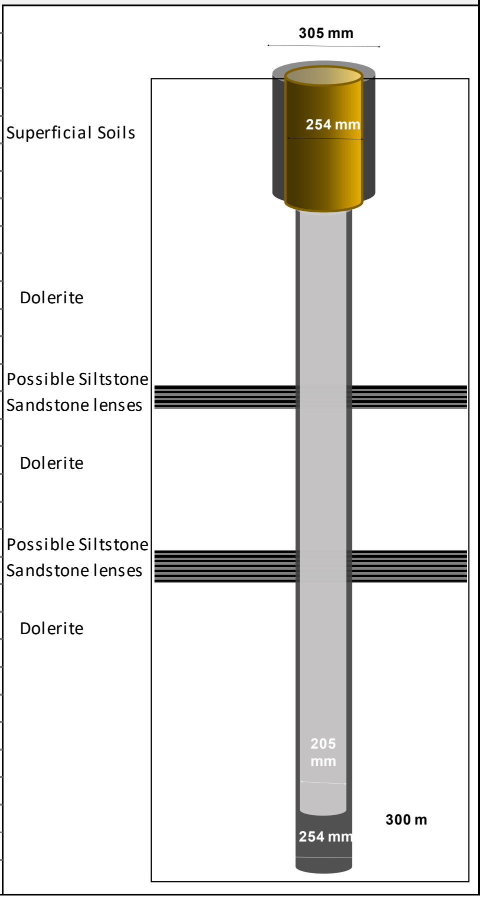


Table 23: Proposed construction of shallow boreholes.

BOREHOLE INFORMATION & CONSTRUCTION DETAILS

BASIC GEOSITE INFORMATION

PROJECT	Pit Monitoring Network	**BH NUMBER**	PitBH1-S	**DWS NUMBER**			
CLIENT	Jagersfontein Development		**PROVINCE**	Free State			
TOWN	Jagersfontein		**SOUTH COORDINATE**	-29.760974	**SYSTEM**	GPS WGS84	
VILLAGE			**EAST COORDINATE**	25.419993	**SYSTEM**	GPS WGS84	
CONTRACTOR			**ELEVATION (mamsl)**		**SYSTEM**		
LOGGED BY			**FINAL DEPTH (m)**	100	**CASING HEIGHT (mm)**	300	
DATE STARTED		**COMPLETED**		**FINAL BLOW YIELD (l/s)**		**l/hr**	
BH PURPOSE	Shallow Aquifer Monitoring		**BOREHOLE SITED BY**				

BOREHOLE DIAMETER

Diameter	From Top (m)	To Bottom (m)	Method	Fluid
305 mm	0	18	Percussion	
254 mm	18	100	Percussion	
216 mm				
172 mm				
165 mm				

CASING DETAILS

Diameter (mm)	Thickness (mm)	Material	From Top (m)	To Bottom (m)	Description S / P
254	5	PVC	-0.3	18	Solid
205	5	PVC	18	100	Alternating Perforated

WATER STRIKES & AQUIFER

	Depth (m)	Air lift yield (l/hr)	Description / Aquifer type
1st			
2nd			
3rd			
4th			
Final			

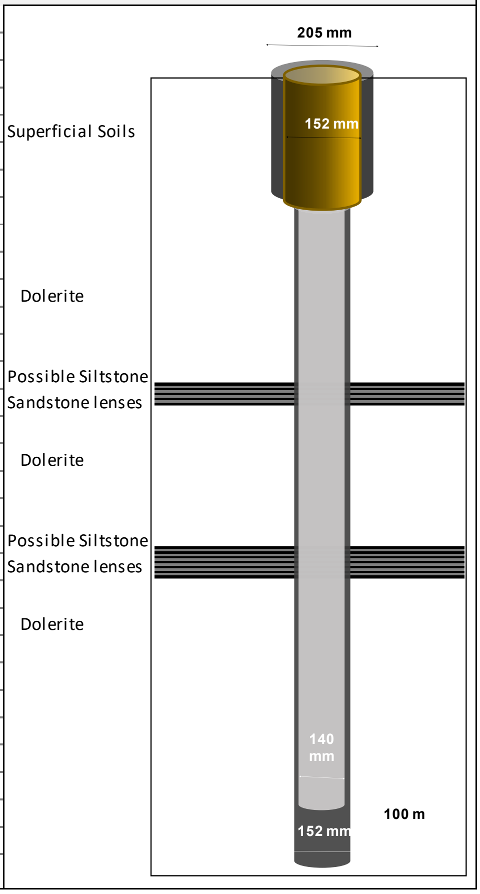
FILTER / GRAVEL / SEAL PACK

From Top (m)	To Bottom (m)	TYPE	UNIT	QTY

GEOLOGICAL & HYDROLGEOLOGICAL DETAILS

From (m)	To Bottom (m)	Lithology / Description
0	4	Superficail Residual Graverls
4	18	Dolerite shale contact
18	100	Dolretite Hard Fresh

Drawing not to scale



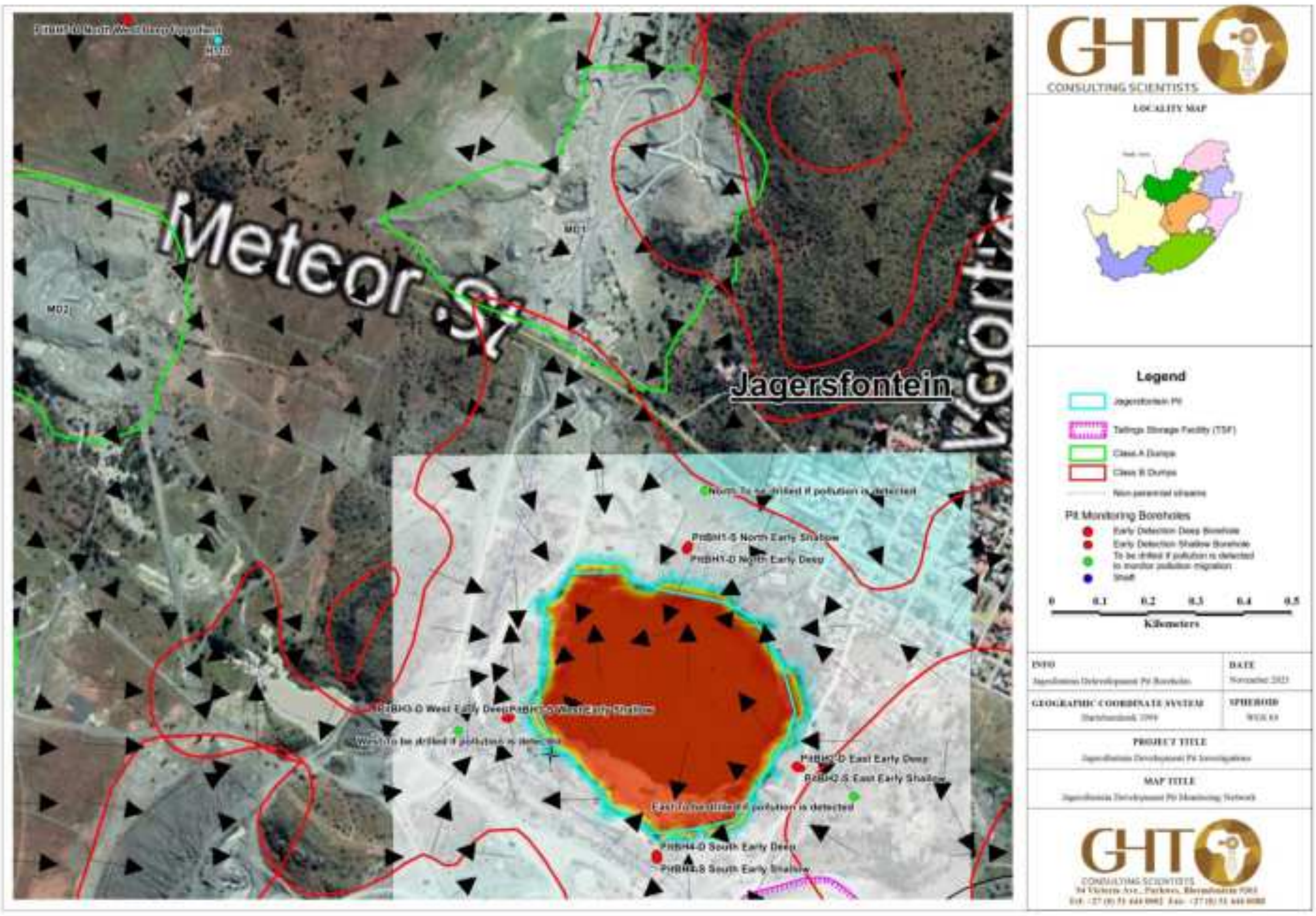


Figure 98. Jagersfontein Development (Pty) Ltd Proposed Pit Monitoring Network.

Table 24: Groundwater Monitoring Sites

PIT GROUNDWATER MONITORING SITES									
Nr OnMap	**Analyses Parameters**	**Longitude (°E)**	**Latitude (°S)**	**Site Description**	**Purpose**	**Monitoring**	**Sample Depth (mbch)**	**Casin Height (m)**	**Hole Depth (m)**
PitBH1-D	N, G	25.41995	-29.76104	Deep monitoring borehole approximately 80 metres north of the pit	Pit Monitoring Deep Aquifer	Early detection pollution to the deep aquifer - North	To be determined	At least 300mm	300
PitBH1-S	N, G	25.41999	-29.76097	Shallow monitoring borehole approximately 80 metres north of the pit	Pit Monitoring Shallow Aquifer	Early detection pollution to the shallow aquifer - North	To be determined	At least 300mm	100
PitBH2-D	N, G	25.42233	-29.76512	Deep monitoring borehole approximately 50 metres east of the pit	Pit Monitoring Deep Aquifer	Early detection pollution to the deep aquifer - East	To be determined	At least 300mm	300
PitBH2-S	N, G	25.42242	-29.76514	Shallow monitoring borehole approximately 50 metres east of the pit	Pit Monitoring Shallow Aquifer	Early detection pollution to the shallow aquifer - East	To be determined	At least 300mm	100
PitBH3-D	N, G	25.41613	-29.76419	Deep monitoring borehole approximately 70 metres west of the pit	Pit Monitoring Deep Aquifer	Early detection pollution to the deep aquifer - West	To be determined	At least 300mm	300
PitBH3-S	N, G	25.41604	-29.76421	Shallow monitoring borehole approximately 70 metres west of the pit	Pit Monitoring Shallow Aquifer	Early detection pollution to the shallow aquifer - West	To be determined	At least 300mm	100
PitBH4-D	N, G	25.41930	-29.76677	Optional deep monitoring borehole approximately 50 metres south of the pit	Pit Monitoring Deep Aquifer	Early detection pollution to the deep aquifer - South	To be determined	At least 300mm	300
PitBH4-S	N, G	25.41931	-29.76684	Optional shallow monitoring borehole approximately 50 metres south of the pit	Pit Monitoring Shallow Aquifer	Early detection pollution to the shallow aquifer - South	To be determined	At least 300mm	100
H110	N, G	25.40982	-29.75151	Background shallow borehole	Pit Background Monitoring Shallow Aquifer	Upgradient shallow aquifer groundwater reference	To be determined	0.23	42
PitBH5-D	N,G	25.40785	-29.75113	Deep upgdarient monitoring borehole	Pit Monitoring Background Deep Aquifer	Background deep aquifer groundwater reference monitoring borehole	To be determined	At least 300mm	300
Shaft	N, G	25.41943	-29.76785	Main Shaft at JD 160 metres south of the pit	Deep Aquifer GW Monitoring and GW Supply to Plant	Abstraction and qualities from shaft and pollution detection - South. Remediation if required.	Pump Level	At least 300mm	450
North To be drilled if pollution is detected	N, G	25.42035	-29.75994	Additional borehole (if pollution is detected) 140 metres north of boreole PitBH1 pair	Pollution Spread Determination	Pollution migration - North	To be determined	At least 300mm	100
East To be drilled if pollution is detected	N, G	25.42357	-29.76568	Additional borehole (if pollution is detected) 120 metres east of boreole PitBH2 pair	Pollution Plume Determination	Pollution migration - East	To be determined	At least 300mm	100
West To be drilled if pollution is detected	N, G	25.41502	-29.76445	Additional borehole (if pollution is detected) 100 metres west of boreole PitBH3 pair	Pollution Plume Determination	Pollution migration - West	To be determined	At least 300mm	100

8.5 Site Assessment – Quarterly Monitoring

The Pit must be included as part of the quarterly water monitoring (surface and groundwater) done at Jagersfontein Development (Pty) Ltd. All information obtained during the site assessment must be recorded into field tables containing the site number, coordinates, site description and sample depth as well as columns to record field parameters.

The following first - hand observations must be made in the field during the site assessment and recorded in the site assessment tables:

- Date and time of sampling event.
- The current static water level of the borehole.
- Photo number for the borehole if any defects are observed.
- Field pH and EC measurements for each borehole.
- Sample taken in the field (Y/N);
- Current State Description; and
- Proposed mitigation.

The Site Assessment Tables for all the Surface- and Groundwater monitoring sites are as follows:

Table 25: Groundwater Monitoring Assessment Table

PIT GROUNDWATER MONITORING SITES												
Nr OnMap	**Analyses Parameters**	**Longitude (°E)**	**Latitude (°S)**	**Site Description**	**Sample Depth (mbch)**	**Date**	**Time**	**Water Level Dam Level Stream Flow**	**Photo**	**Sampled (Yes/No)**	**Current State**	**Comments/Proposed Mitigation**
PitBH1-D	N, G	25.41995	-29.76104	Deep monitoring borehole approximately 80 metres north of the pit								
PitBH1-S	N, G	25.41999	-29.76097	Shallow monitoring borehole approximately 80 metres north of the pit								
PitBH2-D	N, G	25.42233	-29.76512	Deep monitoring borehole approximately 50 metres east of the pit								
PitBH2-S	N, G	25.42242	-29.76514	Shallow monitoring borehole approximately 50 metres east of the pit								
PitBH3-D	N, G	25.41613	-29.76419	Deep monitoring borehole approximately 70 metres west of the pit								
PitBH3-S	N, G	25.41604	-29.76421	Shallow monitoring borehole approximately 70 metres west of the pit								
PitBH4-D	N, G	25.41930	-29.76677	Optional deep monitoring borehole approximately 50 metres south of the pit								
PitBH4-S	N, G	25.41931	-29.76684	Optional shallow monitoring borehole approximately 50 metres south of the pit								
H110	N, G	25.40982	-29.75151	Background shallow borehole								
PitBH5-D	N,G	25.40785	-29.75113	Deep upgdarient monitoring borehole north-west of H110								
Shaft	N, G	25.41943	-29.76785	Main Shaft at JD 160 metres south of the pit	Pump Level							
North to be drilled if pollution is detected	N, G	25.42035	-29.75994	Additional borehole (if pollution is detected) 140 metres north of boreole PitBH1 pair								
East to be drilled if pollution is detected	N, G	25.42357	-29.76568	Additional borehole (if pollution is detected) 120 metres east of boreole PitBH2 pair								
West to be drilled if pollution is detected	N, G	25.41502	-29.76445	Additional borehole (if pollution is detected) 100 metres west of boreole PitBH3 pair								

8.6 Types of Groundwater Monitoring

- Groundwater level monitoring (collection of groundwater depth measurements over time),
- Sample depth determination and monitoring,
- Water quality monitoring (collection of groundwater quality data over time) and
- Borehole depth monitoring (when required), and
- Abstraction volume monitoring.

8.6.1 Water Level Monitoring and Abstraction

8.6.1.1 Groundwater Levels

This is the collection of groundwater depth measurements and abstractions over time. The information could be used to study:

- Water level drawdown and groundwater use.
- Recharge relationships with rainfall. (Both of these may be studied from one well), and
- Shape of the water table and groundwater flow directions. (A minimum of three boreholes are necessary for this type of study).

Groundwater levels must be recorded on a quarterly basis within an accuracy of 0.1 m, using an electrical contact tape, float mechanism or pressure transducer, in order to detect any change or trends.

8.6.2 Groundwater Quality Monitoring

Monitoring of the groundwater quality is currently done on a quarterly basis at Jagersfontein Development (Pty) Ltd (currently by Turn 180 Environmental). The Pit monitoring must be conducted quarterly with general surface- and groundwater monitoring.

Reports on the groundwater quality generated by the environmental consultant are presented to Jagersfontein Development (Pty) Ltd personnel for evaluation so that any deterioration in the groundwater quality can be detected early and that the required mitigation or remedial actions can be taken.

Table 26: Groundwater (quality objectives specified by WUL APPENDIX IV, Table 6)

Groundwater Quality (WUL APPENDIX IV, Table 6)	
Water Quality Variables	**Limits**
pH	6-9.5
EC (mS/m)	78
Chloride (mg/l)	33
Fluoride (mg/l)	0.5
Sodium (mg/l)	40.8
Sulphate (mg/l)	40.5
Total Alkalinity as CaCO3 (mg/l)	93.5
Calcium (Ca) (mg/l)	51.6
Magnesium (Mg) (mg/l)	39.4
Nitrate	6.1

Although the WUL Groundwater Quality Objectives (see Table 26) does not specify any additional parameters to analyse for, these parameters are not adequate to evaluate the reliability of an analyses. The most common way to evaluate the reliability of an analysis is to perform an Ion Balance Calculation. For any water analysis, the total cation and anion concentrations should balance. The difference between these concentrations is referred to as the Ion Balance Error. A negative value indicates that anions predominate in the analysis, whereas a positive value shows that cations are more abundant. For the analysis to be considered reliable, the ion balance error should not be greater than 5% of the total ion concentration. A value greater than this figure indicates that some major constituents have not been analysed for or that there is an analytical error. Some additional parameters to those in Table 26 are required to achieve analyses reliability.

To blindly analyse for all parameters would simply induce unnecessary costs. The information of the preceding tables (Table 26 and Table 27) have been combined into the following groups of required analyses parameters, namely:

- All samples - Normal Inorganic Parameters (**N**).
- All groundwater sample analyses (**G**), additional to normal inorganic parameters.

These parameter groups are presented tin the following tables (Table 27 Table 28):

Table 27: All samples - Normal Inorganic Parameters (N)

All Samples Parameters (N)
pH
EC
Na
Ca
K
Cl
F
Fe
Mg
SO_4

*Table 28: Groundwater Parameters (**G**), additional to normal inorganic parameters*

All Groundwater Parameters (G) additional to (N)
As
NO_3
TDS
Total Alkilinity CaCO3

When evaluating WUL requirements, historical data from previous studies such as leach test (Ochieng et al. 2016 & 2020) and monitoring data, the different surface- and groundwater sites are marked according to the necessary parameters to be analysed for in order to meet the WUL requirements. The different analyses required to be performed are indicated next to the site number in the field tables, Table 25.

All groundwater samples taken for analyses should be submitted to accredited laboratories.

8.7 Hydro-Census

A hydro-census should be done at least once every two years within a maximum of 5 Km Radius around Jagersfontein Development (Pty) Ltd. The hydro-census should not be limited to historical inspected sites and any newly discovered sites must be added to the existing information. The latest map available of a hydro-census completed in 2017 (Van Niekerk et al. 2017) was included in Figure 50. Some of these sites are overlapping with existing monitoring points. Additional hydro-census sites have also been identified and inspected by Turn 180 Environmental during normal monitoring events and in-house by Jagersfontein Development (Mr Johan Swanepoel 2021). The complete list of known hydro-census sites must be updated when the hydro-census report is updated in the future.

8.8 Monitoring Frequency

The surface water monitoring programme consists of routine monitoring.

Because many parameters in the natural environment vary seasonally, it is important to synchronise monitoring with seasonal influences. Sampling should be done at the same times each year to eliminate seasonal influences, for example, monitoring results from the summer can be compared for several years.

This is also important for comparison with other data such as rainfall and recharge characteristics which may influence the chemistry of the groundwater. Other information that should be obtained to compare with the groundwater data could include:

- Rainfall, evaporation, temperature, surface water flow rates, surface water quality data, groundwater use in the area, disposal types and volumes.
- Water level monitoring and water quality monitoring should be conducted on a quarterly basis (2 wet and 2 dry seasons) for the purpose of the surface water monitoring programme.
- Abstraction volumes must be recorded monthly calculating the total abstraction during the calendar year.

8.9 Monitoring Data Processing

The results of all groundwater levels and chemical that have been performed since 2013 on surface and groundwater samples from Jagersfontein Development (Pty) Ltd entered into an Excel database. GIS Maps of the area was also created.

8.10 Groundwater Numerical Modelling

In order to develop a Comprehensive Groundwater Model (CGM), field data is commonly entered into a predictive model to allow simulations to be developed for given field conditions, the outcomes of this simulations used as a guide during the decision-making process. The reliability of these models and consequent understanding of site hydrological behaviour is, however, influenced by the quality and quantity of data available for consideration. Thus, in an ideal case, data should be available for all variations in site conditions, be they geological, chemical, hydrological, or physical. In reality though, it is either not possible, or cost-effective, to account for all possible variations, particularly where there has been a significant disruption to the natural environment from human activities on a large scale. In this instance, a cost-benefit approach will be taken to the investigation by complimenting existing data with previously undetermined site parameters. The existing model in this report must be updated with the data recorded during drilling of the monitoring network (prior to disposal).

The groundwater flow and transport model must be recalibrated every two years to confirm the predicted rate of contaminant migration. The following must be incorporated during the upgrading and recalibration of the model biannually:

- Update and re-calibrate the previous numerical model by incorporating newly generated data (groundwater levels and chemistry).
- Evaluate the confidence of prediction from the previous numerical pollution plume model by means of comparison between the flow and mass transport calibration graphs of the old and the updated numerical models.

- Assess the current, and potential future impacts, of the operations on site water quality using modelling and risk assessment methodologies.
- Assess the influence of recharge and discharging of pollution facilities on the migration of pollutants away from the pollution sources.
- Assess potential impacts of pollution source derived pollution on adjacent surface and groundwater bodies, and
- Incorporate results into a final report.

8.11 Reporting

Detailed monitoring investigations and reports must be conducted on a quarterly basis by an independent professional specialist. These investigations must include but not be limited to the points as stipulated in this monitoring plan. These reports must include at least the following:

- Detailed site assessment and findings.
- Mitigation actions taken depending on recommendations.
- Detailed trending of groundwater levels.
- Detailed trending of the main chemical constituents.
- Evaluation and comparison of chemical concentrations against WUL limits, and
- Recording and evaluation of abstraction volumes against WUL limits, and
- Evaluation of KPI's.

Additional studies must be undertaken based on the monitoring results when deemed necessary.

A detailed surface and groundwater monitoring report which must include all the above mentioned must be submitted to DWS on a quarterly basis.

Should any spillages of contaminants occur from surface water pollution sources or seepage and leachate detected in the groundwater regime, Jagersfontein Development (Pty) Ltd must immediately notify the Chief Director, DWS, Free State Region. Jagersfontein Development (Pty) Ltd must then identify the source of contamination, implement measures for the prevention of this contamination in the short and long term and implement these measures in cooperation with the Chief Director. Should this result in the amendments of the monitoring programme, this document must be updated accordingly and approved by DWS.

8.11.1 Key Performance Indicators (KPI's)

The monitoring report must contain a summary to indicate if the monitoring objectives are met. The key performance indicators can be defined for the pollution sources, monitoring system, surface- and groundwater levels and qualities in terms of the following:

- Current State (describing the current condition of the site, i.e., monitoring site or pollution source).
- Groundwater levels (such as dewatering or artificial recharge or water mound different to that being caused by seasonal variations).
- Groundwater qualities, and
- Abstraction volumes.
- This programme does not imply a fixed format for this summary, but the following table is a suggestion/example of the items to include:

Table 29: Suggested KPI's evaluation table.

KEY PERFORMANCE INDICATOR (KPI) DESCRIPTION	REPORT SECTION	CURRENT STATE OF KPI	KPI SATUS / VERDICT	RECOMMENDATION
Current state of Jagersfontein Pit Monitoring network				
Dewatering Influences Caused by Jagersfontein				
Artificial Recharge Caused by Jagersfontein				
Groundwater Pollution Sources				
Sample Analyses Parameters According to WUL and Monitoring Programme				
Groundwater Quality Objectives (WUL)				
Groundwater Abstraction Volumes (WUL)				

8.12 Recommendation

The following recommendations can be made with regards to this monitoring programme (which also entails the WUL):

- Surface water run-off must be prevented from entering the pit by taking appropriate measures with the installation of proper berm walls retaining natural surface flow along the stream to the east and south of the pit.
- The provided field tables or KPI's tables are not fixed in format and must be updated with additional columns as needed.
- The relevant authorities (DWS) must be informed should any additional pollutants different from those specified by the WUL be detected. The WUL must then be amended in consultation with DWS. This monitoring programme must then be updated accordingly.
- An update of the Hydrocensus report is advised at least once in two years to verify possible impacts upon the surrounding town and farms. A complete list of known hydro-census sites must be compiled (with maps) and updated when the hydro-census report is updated in the future.
- The numerical groundwater model must be updated and re-calibrated at least once every two years incorporating the latest chemistry and abstraction rates, and
- Any amendments to this programme must be liaised with DWS and approved before implemented.
- Groundwater levels of the shaft and Pit monitoring network (to be installed) must be measured on a monthly basis and properly evaluated against rainfall data and abstraction volumes utilising evaluation techniques such as trend analyses and comparing measured values against historical water level depths and evaluations.
- If pollution is detected, pump rates must be adjusted water levels of the shaft and pit monitoring boreholes (to be installed) must be monitored to establish if an adequate drawdown cone of depletion (in unconfined conditions) or reduced pressures (in confined conditions) is maintained.
- It is important to prevent surface run-off entering the pit and take the appropriate measures with the installation of proper berm walls retaining natural surface flow along the stream to the east and south of the pit.
- With the current pit bottom at approximately 260 mbgl, the deep borehole must extend to at least this depth, but it is strongly advised to 300 mbgl. The drilling of each of the deep (up to 300 m) boreholes within a pair must be performed first. The information obtained during drilling of the deep borehole will determine the deep borehole finishing (casing depth and perforation). This information must then be used to determine the borehole construction of the shallow borehole (up to 100m) in the pair. Surface influences upon

the shallow borehole must be prevented by installation of solid casings at least the first 12 metres with perforation of the casings of the shallow boreholes from 12 meters to at least 6 metres into solid bedrock. The casing of the deep borehole must be solid from surface to at least 6 metres into solid bedrock. The casings of the boreholes must extrude at least 300mm above ground and protected by installation of a bee-proof sealable caps, marker posts and cement plinths.

- Even though it is not envisioned that these monitoring boreholes will facilitate any pollution remediated with the shaft considered as the best remediation abstraction point it is advised to construct the deep boreholes to accommodate abstraction and thereby saving considerable cost in the future.
- Geological logs must be recorded together with encountered water strikes (as possible future sampling depths).
- A level logger and attachable mechanism for a pully system must be installed at the deep boreholes to facilitate future sampling (only if water is detected in a borehole) using depth specific bailers. No pumping or purging is currently advised.
- It is also advised to conduct extensive aquifer test (pumping etc.) to determine aquifer parameters, not only for numerical modelling purposes, but for correct pump selection and pumping regimes (should this be necessary).

9 PIT GROUNDWATER REMEDIATIONS AND CONSIDERATIONS IN DESIGNING REMEDIAL ACTION

9.1 General

The highest priority in groundwater science is the protection of groundwater resources thus it is most essential to develop an appropriate site-specific groundwater remediation plan for the Jagersfontein Pit.

9.2 Background information

In the event of groundwater contamination emanating from the pit due to disposal of tailing into the pit, proper remediation methods must be in place. The available options available to evaluate will be discussed below.

9.3 Methods Available for Remedial Action

The containment and or control of contaminated groundwater can generally be accomplished using one or a combination of several available techniques. The alternatives available for remedial action can be broken down into three broad categories:

1. Aquifer rehabilitation
   - Withdrawal, treatment, reinjection (or recharge), and
   - In-situ treatment (not applicable to the Pit circumstances), such as:
     - Chemical neutralization, and
     - Biological neutralization.
2. Withdrawal, treatment and use.
3. Physical containment measures, including:
   - Slurry trench cut-off walls (applicable to surface or shallow sub-surface remediation).
   - Grout curtains (applicable to surface or shallow sub-surface remediation and available porosity).
   - Sheet piling (applicable to surface or shallow sub-surface remediation).
   - Hydrodynamic control; and
   - Cement canals or dirty water perimeter trenches (applicable to surface or shallow sub-surface remediation).

Aquifer rehabilitation methods include all techniques designed to renovate or restore contaminated groundwater to its former uncontaminated state.

The available/applicable remediation techniques will be discussed briefly and their applicability to the site will be considered.

9.3.1 Withdrawal, treatment, and reinjection (pump and treating)

Withdrawal, treatment, and reinjection (pump and treating) is perhaps the most widely practiced of the methods available for controlling contaminated groundwater. This method can be considered if any of the deep monitoring boreholes intersect the deep aquifer and permeabilities permit re-injection. With the limited available water at Jagersfontein, treated water can be better utilized by supply to the town.

9.3.2 Hydrodynamic control

Hydrodynamic control is accomplished through the use of a line of pumping wells up gradient from the plume of contaminated groundwater and a line of recharge injection wells downgradient from the plume. The result is the creation of a groundwater divide around the plume- the flow of groundwater between the pumping and injection wells is essentially stopped or even reversed in relation to the original direction of groundwater flow. The plume is thus held in check while contaminated groundwater is diverted around the plume. Design of hydrodynamic control systems requires an extensive hydrogeological investigation so that an understanding of the effect of the injection wells on the drawdown and radius of influence of the pumping wells is developed. In most cases, the pumping/injection well system is designed so that the radii of influence do not overlap. This type of system also requires careful monitoring to determine any changes in the extent of the plume that may occur as pumping/injection continue. Monitoring is especially critical in detecting potential system failures which could lead to contamination of water outside the system. Hydrodynamic control systems, or "active" groundwater containment systems, are generally less costly to construct than physical barriers or passive containment systems, however, operation and maintenance costs of hydrodynamic control systems are commonly very high, and monitoring of the systems may also provide to be expensive. Environmental impact at the surface is negligible. This method can also only be considered if enough upgradient groundwater is available and if any of the deep monitoring boreholes intersect the deep aquifer with permeabilities high enough to permit re-injection.

9.3.3 Withdrawal, treatment and use

Withdrawal, treatment and use implies exactly that-pumping of the water from normal production wells or shaft, treatment at the surface to remove contamination, and use of the water for whatever purpose.

This would be the most viable option if pollution is detected as the water purification plant at Jagersfontein Development (although moth-bolled) is regularly serviced and can be brought into operation if required. This method would however generate brine to be disposed of in a proper manner.

9.4 Conclusions

Due to the underlying deep geological strata, and based on all the remediation techniques discussed above, withdrawal, treatment and use is the best available option to apply in the event of pollution being detected in the proposed monitoring boreholes. The shaft remains the best viable option for abstraction, with the deep monitoring boreholes as secondary options.

9.5 Recommendations

The following recommendations can be made with regards to the proposed remedial actions:

- If pollution is detected, the pollution plume migration and rate must be determined.
- The water purification plant must be kept in working condition and in ready preparedness for future use.

- Should pollution be detected in the monitoring boreholes and sufficient dewatering cannot be achieve through the shaft alone, abstraction from the deep monitoring borehole must take place.
- This plant will generate brine water to be disposed of. The properties of the slimes were already shown to form an impermeable barrier system and therefore the brine can be disposed of on the TSF on a slimes region.
- Adequate measures must be taken to prevent overflows onto the side walls. The brine production rate must be taken into account when designating an area on the TSF with enough freeboard to accommodate the 1:100 flood event and allow for natural evaporation and precipitation of salts.
- The qualities of the purified recovered water must be adequately monitored (especially that of arsenic) ensuring proper evaluation of final qualities (possible mixing may be required with other sources (as described by Bijengsi, 2012 with water from the Kalkfontein dam) to be safely made available to the community according to the relevant needs (drinking water or agricultural).

10 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be drawn from the preceding chapters.

10.1 Geography, Climate and Drainage

Jagersfontein / Itumeleng are located in the south-western part of the Free State Province within the borders of the town of Jagersfontein on Portions 15, 16 and a portion of the Remainder of the Farm Jagersfontein 14 IS. The historic mine lies within drainage area C, rainfall zone C5B and Quaternary sub catchment C51H. The mean annual precipitation (MAP) for the Jagersfontein / Itumeleng area is 427.7 mm and lies within the evaporation zone 19A, with a mean annual evaporation of 1500 - 1600mm. Surface drainage of the catchment area is generally from north-west at 1439 mamsl to the south-east at 1349 mamsl. Surface drainage in proximity to the TSF follows the same north-west (1416 mamsl) to the south-east (1390 mamsl) drainage pattern towards the non-perennial stream at the south-eastern corner of the TSF. The mean annual surface run-off is between 20 – 50 mm.

10.2 Geophysics

Several historic and new magnetic surveys have been conducted south, east and north of the TSF. None of these were able to identify any anomalies associated with lineaments/intrusions such as dykes that may act as preferential pathways. An ERT survey in conjunction with magnetic work revealed the possibility of different resistivities indicating a possible contact zone between different rock types east of the TSF, as well as a possible difference in weathering of the outcropping dolerite sill north of the TSF. These zones were targeted for percussion drilling. A contact zone between sedimentary rock and a dolerite sill was confirmed east of the TSF. This may act a preferential pathway promoting pollution migrations from the TSF and as such can be used for pollution plume interception. N**o fault zones or lineaments intersecting the pit were detected in any of the other geophysical studies.**

10.3 Geology

The main geology is dominated by the Karoo Supergroup consisting of Adelaide Subgroup sediments of the Beaufort Group. These sediments are comprised of sandstones, mudstone and siltstone; the sediments are intruded by dolerite sills.

Several field excursions were conducted by a professional structure geologist (Prof. W Colliston), mapping the different geological formations and incorporation the drilling logs of old and newly drilled boreholes. The detailed geological report that followed from this indicates the rocks mainly comprise of jointed fine-grained sandstones and siltstones which are underlain and overlain by thick dolerite sills. The prominently jointed outcrops of the upper dolerite sill form the hilltops surrounding the old mine and town. A lower dolerite sill merges with the upper sill in the northern part. The TSF overlies the contact between the upper dolerite sill in the north and the fine-grained sandstone (Valley aquifer) to the south. This fine grained-sandstone dips between 1 and 2 degrees to the east and south-east over a distance of 2.6km where it is once again bordered by the dolerite outcrops and hills.

10.4 Aquifer Delineation

It was deduced form the geological study that the two aquifers identified are very fine-grained lithofeldspathic sandstones with interbedded siltstone and minor mudrock separated by a regionally persistent lower thick dolerite sill in excess of 20 metres in thickness. The upper fine-grained lithofeldspathic sandstones form an unconfined aquifer termed the Valley Aquifer. **The pit is not intersected by these aquifers.**

10.5 Aquifer Classification

The main aquifer identified is a fine-grained unconfined sandstone Valley Aquifer within the extensive valley between the regional dolerite sill that defines the surrounding hills at Jagersfontein. A contact zone exists between this upper Valley aquifer and lower secondary dolerite sill defined as an aquitard although weathering in shallower parts of the Valley aquifer may result in higher permeabilities acting as a preferential flow path with slightly higher conductivities but low sustainability as it is fed by the Valley Aquifer matrix from above. Secondary confined siltstone aquifer lenses are separated from the Valley aquifer by a regionally thick (>20m) dolerite sill and does not significantly contribute to yielding potential. Some overlying siltstone lenses occur to the north-west of the TSF, Pit and the surrounding jointed dolerite hills where recharge to the Valley aquifer occur through the weathered upper part of the merged dolerite sills with siltstone lenses.

The combination of aquifers (Lower Dolerite Sill/ Siltstones and Valley Aquifer) in the region of the TSF and Pit can therefore be classified as **minor** due to low permeabilities and low sustainable yields.

10.6 Aquifer Vulnerability

Conclusions

The vulnerability of the unsaturated zone in the vicinity of TSF is classified as Extreme. The unsaturated zone has an extreme vulnerability due to the short distance to the aquifer, the thin permeable unsaturated zone, and a very high seepage velocity flowing from the topsoil to the water table.

Recommendations

The evident vulnerability of the unsaturated and shallow part of the Valley aquifer stresses the importance of minimizing negative impacts upon these resources. Future monitoring of the groundwater qualities and shallow aquifer as proposed in the Pit monitoring plan (chapter 7) must be implemented to detect pollution which in turn would require effected mitigation actions.

10.7 Numerical modelling - Long Term impact predictions

10.7.1 Groundwater Elevations

Conclusions

If any dewatering is caused by the pit, dewatering can only be considered within the immediate proximity to the pit and primarily the dewatering of the local siltstone lenses that are not interconnected with any aquifer systems. Once again, the reason for this being that there is no water seeping into the pit via the pit faces and there is no dewatering of boreholes caused by dewatering of the pit via abstraction from the shaft (which is linked to the pit). Although the shaft is connected to the pit, the pit does not serve as the primary source of recharge to the shaft. In fact, the pit act merely as a sump when receiving rain- or storm water contributing to the overall availability to be abstracted from the shaft. The water level in the pit steadily declines after these storm events to a stage where the sustainable abstraction rate of the shaft is reached. Simulations also indicate that groundwater levels in the pit will not recover to regional ambient groundwater levels.

Recommendations

The following recommendations are made with regards to the groundwater elevations:

- Groundwater levels of the shaft and Pit monitoring network (to be installed) must be measured monthly and properly evaluated against rainfall data and abstraction volumes utilising evaluation techniques such as trend analyses and comparing measured values against historical water level depths and evaluations.
- If pollution is detected, pump rates must be adjusted and water levels of the shaft and pit monitoring boreholes (to be installed) must be monitored to establish if an adequate drawdown cone of depletion (in unconfined conditions) or reduced pressures (in confined conditions) is maintained.

10.7.2 Pollution Plume Migrations

Conclusions

Simulation results of pollution plumes within the superficial soils indicate the following:

- According to the reports from SRK 2016 and 2021, the tests performed on the slimes indicate conductivities as low as 4.8x10-8 m/d whereas the course tailings used to construct the walls may be as high as 0.86 m/d. The wall material however becomes compacted with time lowering these values substantially. The actual values may even be lower than these values derived from particle size analyses and evaluation (which is conducted by drying of the material and performing sieve analyses). Some layering would occur during disposal and the vertical conductivity would be an order smaller than the horizontal (similarly to what is normally assumed for general groundwater flow). The lowering of these values may be further compounded as there is some expansion in the saturated slimes (smectite) as well as compaction that would occur (both at the bottom of the TSF and definitely in the pit).
- With the pit area marked as inactive, possible pollution emanating from the WRD's to the north of the pit migrates past the pit. In reality though, no flow is taking place or migrating past the pit as already explained. The superficial soils (approximately 4 metres thick) above the dolerite sills are simulated as weathered material receiving recharge and as such will propagate pollution in the model due to the homogenous isotropic modelling assumptions.
- **No pollution is migrating in any of the simulations from the pit to the superficial soils.**

The simulations of the regional pollution plumes within the minor Valley aquifer can be summarized as follows:

- Simulations of both scenarios of the 2129 pollution plumes indicate the edge of the 40 mg/L SO4 WUL limit to be mostly within 2km downgradient from the pollution sources.

However, there is a significant difference in the concentrations and footprint when the sources are not removed.

- Decreasing pollution plumes both in extent and concentrations can be seen from as early as 2034 in the scenario where the on-surface WRD's were removed by 2029. Improvements are becoming more apparent from 2044 in this scenario as opposed to the do-nothing scenario.
- The prolonged impacts from the class B dumps left on-surface can be seen in the simulated plumes of 2084 and 2129. Earlier removal would be a major improvement as the Valley aquifer is the main exploitable aquifer in the region feeding the contact between this aquifer and the dolerite sill beneath.
- **No pollution is migrating in any of the simulations from the pit to the Valley aquifer.**
- **There is no interconnection between the Valley Aquifer and the pit.**

The simulated pollution plumes within the contact between the Valley aquifer and the lower dolerite sill can be summarized as follows:

- The diminishing pollution plume trends in the contact between the Valley aquifer and the dolerite sill are very similar to those of the Valley aquifer itself due to the already explanation that Valley aquifer is the source of water to the contact and this zone is. This zone normally has a higher permeability and yield than the sedimentary Valley aquifer and is often targeted by drilling and pump inlet at this level. Removal of the on-surface WRD's will thus cause the readily improvement of this source.
- **No pollution is migrating in any of the simulations from the pit to the contact between Valley aquifer and the dolerite sill.**
- **The contact between the Valley Aquifer and the lower dolerite sill does not extend to or intersect the pit.**

The simulated pollution plumes within deep geology can be summarized as follows:

- The prolonged simulated activities since 1940 with the dolerite siltstone lenses seen as homogenous isotropic entity and low porosity show some imprints at a depth 40mbgl of between 5 to 25 mg/l SO_4 from the on-surface sources. There is however no lateral movement (as expected) from the pit in any of the images from 2025 to 2129.
- **The main reason for this being that the permeability of the slimes is much lower than that of the host rock and groundwater movement (if any) will thus rather move around the slimes than into or through it. Furthermore, the property of the slimes (smectite clay) with regards to retention also means that the slimes will rather retain moisture than releasing it to the environment.**
- **No pollution is migrating in any of the simulations from the pit to the deep geology.**
- These north-west to south-east cross-sections images indicate that the simulated plume from the pit **does not migrate vertically downwards and that it remains horizontally contained with the host rock** (dolerite and possible siltstone lenses). **Once again, because the permeability of the slimes is much lower than that of the host rock.**

Recommendations

The following recommendation are made with regards to the simulated pollution plume migrations:

- Groundwater samples must be collected (form the monitoring network boreholes to be proposed in the monitoring plan chapter 7) on a quarterly basis for analyses and properly evaluated against historical concentrations utilising the different evaluation techniques and trend analyses.

- Should pollution be detected (in the boreholes of the monitoring network to be proposed in the monitoring plan chapter 7), remedial actions should be taken as will be discussed in chapter 9.
- In the event of pollution detection, pollution migration direction and rates must be determined which in turn will determine if additional boreholes may have to be drilled.

10.8 TSF, Old Dumps and Pit Impact Assessment, Risk Assessment and Groundwater Management Plan

The following summarizes the conclusions from the impact assessment.

10.8.1 TSF

The TSF post-closure and post-mitigation assessment of impacts upon local groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Moderate**”.
- Groundwater level Impact Significance – “**Low**”.
- Groundwater flow directions Impact Significance – “**Low**”.

The TSF post-closure and post-mitigation assessment of impacts upon private groundwater users can be summarized as follows:

- Local groundwater quality Impact Significance – “**Moderate**”.
- Local groundwater level Impact Significance – “**Low**.
- Local groundwater flow directions Impact Significance – “**Low**”.

The TSF post-closure storm water post-mitigation impact assessment can be summarised as follows:

- Storm Water Impact Significance – “**Low**”.

10.8.2 Old Dumps

The Do-nothing versus post-mitigation assessment after dumps removal of impacts upon local groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**High**” vs "**Low**".
- Groundwater level Impact Significance – “**Low**” vs "**Low**.
- Groundwater flow directions Impact Significance “**Low**” vs "**Low**”.

The Do-nothing versus post-mitigation assessment after dumps removal of impacts upon private groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Moderate**” vs "**Low**".
- Groundwater level Impact Significance – "**Low**” vs “**Low**”
- Groundwater flow directions Impact Significance "**Low**".

The Old dumps Do-nothing versus post-closure storm water post-mitigation impact assessment can be summarised as follows:

- Storm Water Impact Significance – “**Moderate**” vs "**Low**".

10.8.3 Pit Shallow Aquifer

The Do-nothing versus post-mitigation assessment of impacts upon local groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Low**” vs "**Low**".
- Groundwater level Impact Significance – “**Low**” vs "**Low**".
- Groundwater flow directions Impact Significance “**Low**” vs "**Low**".

The Do-nothing versus post-mitigation assessment of impacts upon private groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Low**” vs "**Low**".
- Groundwater level Impact Significance – “**Low**” vs "**Low**".
- Groundwater flow directions Impact Significance “**Low**” vs "**Low**".

The Pit shallow aquifer Do-nothing versus post-closure storm water post-mitigation impact assessment can be summarised as follows:

- Storm Water Impact Significance – “**Low**” vs "**Low**".

10.8.4 Pit Deep Aquifer

The Do-nothing versus post-mitigation assessment of impacts upon local groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Moderate**” vs "**Low**".
- •Groundwater level Impact Significance – “**Low**” vs "**Low**".
- Groundwater flow directions Impact Significance – “**Low**” vs "**Low**".

The Do-nothing versus post-mitigation assessment of impacts upon private groundwater users can be summarized as follows:

- Groundwater quality Impact Significance – “**Low**” vs "**Low**".
- Groundwater level Impact Significance – “**Low**” vs "**Low**".
- Groundwater flow directions Impact Significance – “**Low**” vs "**Low**".

The Do-nothing versus post-closure post mitigation storm water impact assessment can be summarised as follows:

- Storm Water Impact Significance – “**Low**” vs "**Low**".

10.9 Pit Monitoring Plan

Conclusions and Recommendations

A monitoring plan was compiled to address pollution detection in the deep and shallow aquifers. The positions of monitoring boreholes have been determined in accordance with the results from the numerical pollution plume model and groundwater flow directions. These are

- PitBH1-S and PitBH1-D – Shallow and deep boreholes north of pit (to be drilled upon approval)
- PitBH2-S and PitBH2-D – Shallow and deep boreholes east of pit (to be drilled upon approval)
- PitBH3-S and PitBH3-D – Shallow and deep boreholes west of pit (to be drilled upon approval)
- Pit BH4-S and PitBH4-D – Optional Shallow and deep boreholes south of pit between pit and Shaft (to be drilled upon approval)
- H110 – Shallow aquifer background hydrocensus borehole north-west of pit
- Pit BH5-D – Deep upgradient monitoring borehole north-west of the pit
- Shaft – South of pit to be monitored according to the WUL parameter list and groundwater level recording.

The depth of the pit (at 260 mbgl) as well as the fill level to 60 mbgl were taken into account in the designing of the monitoring boreholes (depth and construction).

Recommendations

The following recommendations can be made with regards to this monitoring plan (which also entails the WUL):

- The provided field tables or KPI's tables are not fixed in format and must be updated with additional columns as needed.
- The relevant authorities (DWS) must be informed should any additional pollutants different from those specified by the WUL be detected. The WUL must then be amended in consultation with DWS. This monitoring programme must then be updated accordingly.
- An update of the Hydrocensus report is advised at least once in two years to verify possible impacts upon the surrounding town and farms. A complete list of known hydrocensus sites must be compiled (with maps) and updated when the hydro-census report is updated in the future.
- The numerical groundwater model must be updated and re-calibrated at least once every two years incorporating the latest chemistry and abstraction rates, and
- Any amendments to this programme must be liaised with DWS and approved before implemented.
- Groundwater levels of the shaft and Pit monitoring network (to be installed) must be measured on a monthly basis and properly evaluated against rainfall data and abstraction volumes utilising evaluation techniques such as trend analyses and comparing measured values against historical water level depths and evaluations.
- If pollution is detected, pump rates must be adjusted water levels of the shaft and pit monitoring boreholes (to be installed) must be monitored to establish if an adequate

drawdown cone of depletion (in unconfined conditions) or reduced pressures (in confined conditions) is maintained.

- It is important to prevent surface run-off entering the pit and take the appropriate measures with the installation of proper berm walls retaining natural surface flow along the stream to the east and south of the pit.
- With the current pit bottom at approximately 260 mbgl, the deep borehole must extend to at least this depth, but it is strongly advised to 300 mbgl The drilling of each of the deep (up to 300 m) boreholes within a pair must be performed first. The information obtained during drilling of the deep borehole will determine the deep borehole finishing (casing depth and perforation). This information must then be used to determine the borehole construction of the shallow borehole (up to 100m) in the pair. Surface influences upon the shallow borehole must be prevented by installation of solid casings at least the first 12 metres with perforation of the casings of the shallow boreholes from 12 meters to at least 6 metres into solid bedrock. The casing of the deep borehole must be solid from surface to at least 6 metres into solid bedrock. The casings of the boreholes must extrude at least 300mm above ground and protected by installation of a bee-proof sealable caps, marker posts and cement plinths.
- Even though it is not envisioned that these monitoring boreholes will facilitate any pollution remediated with the shaft considered as the best remediation abstraction point it is advised to construct the deep boreholes to accommodate abstraction and thereby saving considerable cost in the future.
- Geological logs must be recorded together with encountered water strikes (as possible future sampling depths).
- A level logger and attachable mechanism for a pully system must be installed at the deep boreholes to facilitate future sampling (only if water is detected in a borehole) using depth specific bailers. No pumping or purging is currently advised.
- It is also advised to conduct extensive aquifer test (pumping etc.) to determine aquifer parameters, not only for numerical modelling purposes, but for correct pump selection and pumping regimes (should this be necessary).

10.10 Pit Remediation

Conclusions

Three different remediation techniques were evaluated, namely:

- Withdrawal, treatment, and re-injection.
- Hydrodynamic control, and
- Withdrawal, treatment, and use.

Due to the underlying deep geological strata, and based on all the remediation techniques discussed, withdrawal, treatment and use is the best available option to apply in the event of pollution being detected in the proposed monitoring boreholes. The shaft remains the best viable option for abstraction, with the deep monitoring boreholes as secondary options.

Recommendations

The following recommendations can be made with regards to the proposed remedial actions:

- If pollution is detected, the pollution plume migration and rate must be determined.

- The water purification plant must be kept in working condition and in ready preparedness for future use.
- Should pollution be detected in the monitoring boreholes and sufficient dewatering cannot be achieve through the shaft alone, abstraction from the deep monitoring borehole must take place.
- This plant will generate brine water to be disposed of. The properties of the slimes were already shown to form an impermeable barrier system and therefore the brine can be disposed of on the TSF on a slimes region.
- Adequate measures must be taken to prevent overflows onto the side walls. The brine production rate must be taken into account when designating an area on the TSF with enough freeboard to accommodate the 1:100 flood event and allow for natural evaporation and precipitation of salts.
- The qualities of the purified recovered water must be adequately monitored (especially that of arsenic) ensuring proper evaluation of final qualities (possible mixing may be required with other sources (as described by Bijengsi, 2012 with water from the Kalkfontein dam) to be safely made available to the community according to the relevant needs (drinking water or agricultural).

11 FINAL REMARKS:

The objections raised by the department in the previously declined authorization from DWS, letter 2 7 /2/2/C851 /2/ 1 dated 19 October 2020 (taken from the letter, page 22) can be responded to as follows:

4.1.2 The reports from the applicant indicate that diamond mine residues will be utilised as aligning material for the base and sides of the mine pit. However, the proposed liner material was found not to be consistent with a Class C lining material which the applicant is expected to implement when backfilling a pit with mine residues.

The findings in this report which include the evaluation of permeability of the slimes with a much lower permeability than that of the pit host rock material, the absence of any interconnectivities of the pit with any of the shallow aquifers as well as numerical modelling indicate a very limited risk to pollution emanating from the backfilled pit.

It can be deduced that filling of the pit with slimes which have a lower permeability than the host rock will act as restoring of the perched conditions of the confined deeper aquifer at the pit bottom and leaving the shaft as the only remaining perched position.

A Class C liner is indicated to have a permeability of between $8.64x10^{-4}$ m/d and $8.64x10^{-5}$ m/d whereas the conductivity of slimes is calculated to be $4.8x10^{-8}$ m/d. This is lower than that of a Class C liner and the host rock with isolated siltstone lenses ($4.8x10^{-6}$ m/d). The actual values may even be lower than these values derived from particle size analyses and evaluation (which is conducted by drying of the material and performing sieve analyses). Some layering would occur during disposal and the vertical conductivity would be an order smaller than the horizontal (similarly to what is normally assumed for general groundwater flow). The lowering of these values may be further compounded as there is some expansion in the saturated slimes (smectite) as well as compaction that would occur (both at the bottom of the TSF and definitely in the pit). The moisture retention of the slimes (which is smectite clay) is further a factor that will retain the moisture rather than releasing it to the surrounding host rock. In fact, possibly acting better than a Class C liner.

4.1.3 The documents submitted to the Department in support of the backfilling activity indicate that the applicant is not concerned about the threats posed by the proposed activity on the surface and groundwater resources.

It is true that the geological formations can differ considerably within a short spatial distance. However, it can be stated with confidence that there is no interconnectivity between the upper shallow aquifers and the pit (including the shaft) due to no ingress from the upper geology or aquifers and no dewatering in the surrounding boreholes and dam despite the prolonged pumping from the shaft. Nevertheless, it must be recognized that pollution is always a threat and that it must be treated as such. For this reason, this report addressed remediation and monitoring techniques to be implemented prior to backfilling.

4.1.4 The reports provided by the applicant in support of a WULA did not assist the Department to comprehend the impacts of the activity to surface and ground water resource. Also the reports don't articulate sufficiently how possible pollution to the ground water resources that could emanate from the backfilling of the pit will be managed.

A rehabilitation strategy is included for the department to peruse, advice on and to be implemented upon approval in the event of pollution detection.

4.1.5 The applicant did not prepare a monitoring plan to monitor the impact of backfilling of the pit.

A monitoring plan is included for the department to peruse, advice on and to be implemented upon approval.

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