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REPORT

EXXARO BELFAST COAL MINE

Surface Water Assessment

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APPENDICES

APPENDIX A
Document Limitations

1.0 INTRODUCTION

Golder Associates Africa Pty Ltd (Golder) have compiled a detailed baseline wetland delineation and wetland assessment report, including a wetland impact assessment and management plan associated with the proposed Belfast Coal Mine Project in Mpumalanga Province. The outcome of the report showed the presence of wetlands within a large area of the original proposed mining layout and associated infrastructure arrangement. A wetland offset report was therefore required. The wetland offset report focused on the identification of potential wetland offset areas to compensate for loss and/or mining related impacts on wetlands within the proposed Exxaro Belfast Coal Mine Project footprint area.

Discussions were held with the Department of Water Affairs (DWA) to present and discuss the original proposed mine layout plan, the location of the plant and the wetland offset report. DWA have therefore requested Exxaro to explore alternative locations for the coal washing plant, as the original proposed position was situated within a sensitive hillslope wetland, while the proposed pit layout and discard dump location also include sensitive wetlands and pans.

The Exxaro Belfast Coal Mine Project team have therefore re-investigated and re-designed the proposed open pit footprint layout, the position of the washing plant and associated infrastructure, as well as the design and proposed discard dump footprint area, in order to try and avoid sensitive wetland areas. A water treatment plant will also be constructed and a maximum of 4 ML of water per day will be discharged into the surrounding wetland and aquatic ecosystems. A surface water assessment will be required to determine the potential impacts of the release of treated water to the environment. The potential impacts of the proposed release of 4ML water per day will be evaluated.

2.0 PROJECT OBJECTIVES

The objectives of the study were to:

- Provide a location for the water treatment plant point of discharge into the Klein Komati. The location will be selected to limit the erosion at the discharge point. The required energy dissipation structures must be designed at the conceptual level to limit erosion; and
- The proposed maximum discharge rate of 4 ML/d will be characterised in terms of the flow ranges that can be expected in the river, particularly during the low flow season. The effect of the increased flow on the potential erosion of the receiving water channel will be assessed.
- Determine potential impact on river crossings etc., due to increased baseflow conditions.
- Assess downstream water users, especially with respect to irrigation and crop type being irrigated;
- Determine the Resource Water Quality Objectives (RWQO's);
- Undertake modelling of water quality and quantity to assess the impact of the discharge to the Klein Komati river;
- Determine changes to the baseflow of the river over a typical hydrological cycle as well as dry and wet conditions;
- Produce a water balance schematic for the mine to assess the water treatment requirements.

3.0 LEGISLATION OVERVIEW

In order to limit impacts onto the environment by adjusting the stream flow, the mine is to comply with the National Water Act, and more particularly to the section 704 of the National Water Act related to the mining industry. The various issues to be addressed are presented below.

The National Water Act (NWA), 1998 (Act 36 of 1998) defines the water uses in Section 21 of the Act as the following:

- Taking water from a water resource;
- Storing water;
- Impeding or diverting the flow of water in a watercourse;
- Discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- Disposing of waste in a manner which may detrimentally impact on a water resource; and
- Altering the bed, banks, course or characteristics of a watercourse.

Section 21 (c) and (i) water uses, namely the impeding or diverting the flow of water in a watercourse and the alteration of the bed, banks, course or characteristics of a watercourse is applicable to all the activities/ structures located within the 1:100 year flood line.

4.0 SITE DESCRIPTION

4.1 Location

The project is situated in the province of Mpumalanga, 10 km south east of Belfast on the farms Leeubank, Zoekop and Blyvooruitzicht. The location of the mine is presented in Figure 1. The proposed development area is located in the headwaters of the Komati River catchment.

4.2 Topography

The topography of the project area is sloping gently towards the south. The area is divided in three catchments with three streams running southward, namely the Leeubankspruit, Klein Komati and Driehoek Spruit.

Elevations vary between 1,870 mamsl in the upper reaches of the catchments and 1,740 mamsl in the south of the catchments. The majority of the catchment supports cattle grazing, and crop cultivation activities. The natural vegetation and lands that are being rested are covered by grasslands. There are a few stands of trees in the catchment.

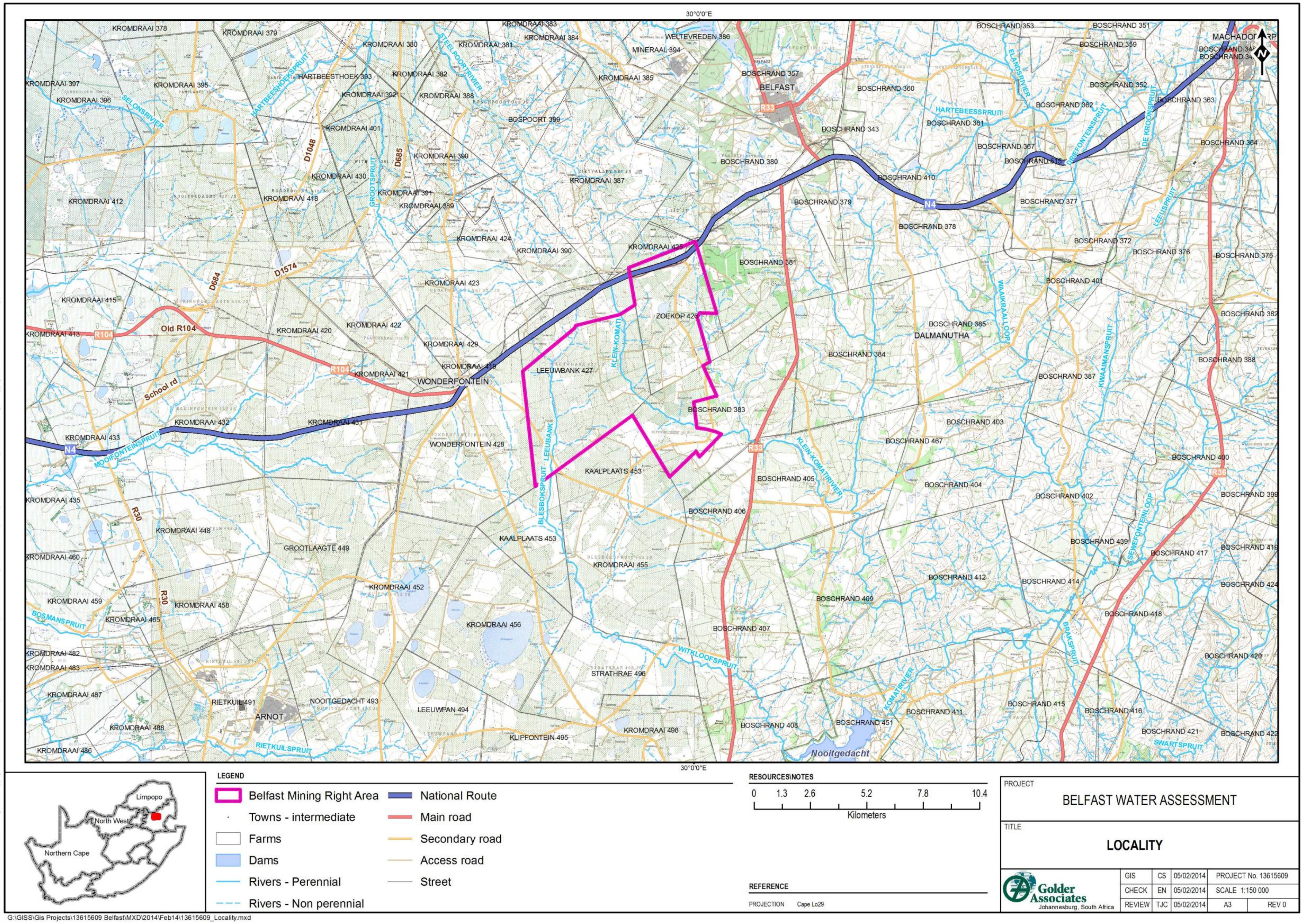

Figure 1: Locality of the proposed mining areas.

4.3 Rainfall

The Rainfall Depths were extracted from the closest weather station obtained from the Design Rainfall Estimation Program (details given in Table 1). The selection of station 0516554_W (Roodepoort) is based on the fact that this is the closest station to the study area, with a reliable record. The rainfall distribution on site is classified as a type 3 design rainfall distribution. The daily rainfall record covered the period of January 1903 to September 2000. A cumulative plot of the daily record shown in Figure 2 was used to check the record for any anomalies. The plot does not highlight any inconsistencies in the record. The Mean Annual Precipitation (MAP) in the vicinity of the mine is about 690mm. About 85% of the yearly rainfall falls in summer (October to March), in the form of showers and thunderstorms, with the maximum precipitation falling in January. The average number of rain days is 55 per year. The 24 hour rainfall depths for the different recurrence interval storms are listed in Table 2.

Table 1: Details for rainfall station 0516554_W (Roodepoort).

Name of rainfall station	Rainfall station number	Distance (km)	Latitude (°)(‘)	Longitude (°)(‘)	Record (Years)	MAP(mm)
Roodepoort	0516554_W	18	25° 44’	29° 49’	97	690

Table 2: 24 Hour Storm Rainfall Depths (mm).

Recurrence Interval (Years)	1 in 2	1 in 5	1 in 10	1 in 20	1 in 50	1 in 100	1 in 200
24 hour Rainfall Depth (mm)	58	77	90	104	123	137	153

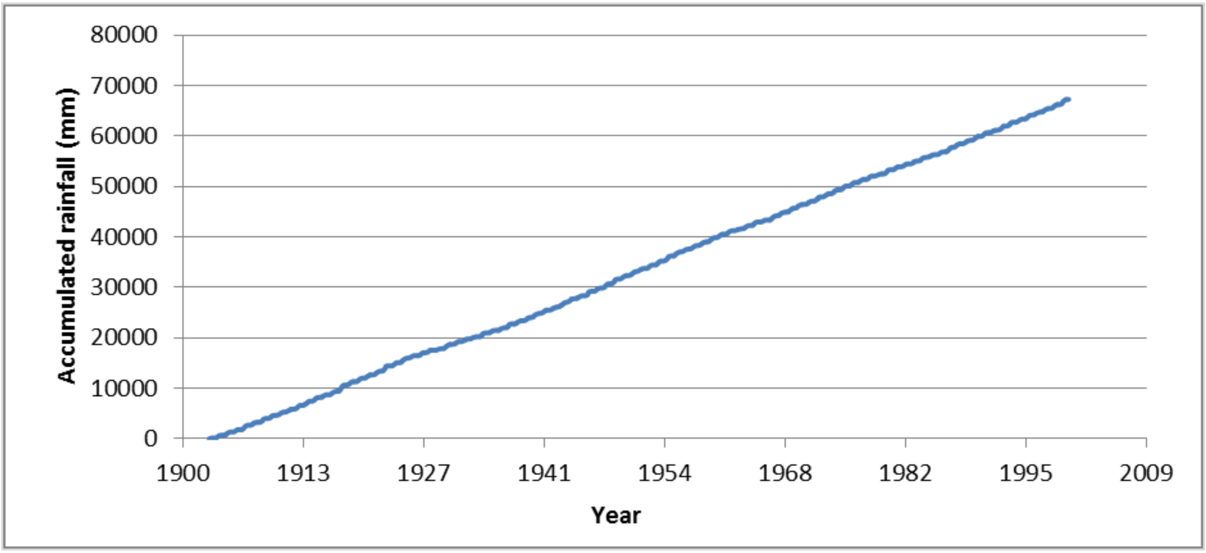

Figure 2: Plot of cumulative rainfall depths measured at the Roodepoort rain gauge

4.4 Evaporation

The mean annual Symons-pan (S-Pan) evaporation in the project area was found to be 1450mm (WR90). Mean monthly evaporation values are presented in Table 6.4.

Table 3: Mean Monthly S-Pan Evaporation values for Belfast area.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average evaporation (mm)	138	138	156	164	140	138	104	91	75	81	102	124	1451

4.5 Regional Hydrology

The Komati River falls within the X1 drainage region as shown in Figure 3, the catchment area was calculated to be 11 200 km^2. The river is surrounded by towns such as Carolina, Eerstehoek, Machadodorp, Waterval Boven, Ekulindeni, Mbojane, Barberton, Emangweni, Sibayeni and Komatipoort. The river crosses the South African border into Swaziland, and back into South Africa, to the north of Swaziland, and eventually flows into Mozambique.

Bulk water management in the upper Komati River is driven mainly by two large dams (Nooitgedacht and Vygeboom), and two diversion weirs (Gemsbokhoek and Vriesland). The system was designed mainly to meet the water requirements for cooling of power stations, located in the adjacent Olifants River Catchment. Landuse is characterised by commercial dryland agriculture, some irrigated agriculture, livestock grazing (mainly cattle), and localised ecotourism developments (fishing, walking, biking and birding).

Currently the major strains facing the Inkomati WMA are the high water demands for Eskom, irrigation, afforestation and industry and rapidly increasing domestic water demands. The water shortages experienced in the area have led to competition for the available water resources among user sectors. A substantial portion of the population in the catchment does not have access to a basic level of services and a number of planned expansions to water uses have been put on hold. Furthermore the major dams in the study area change the flow regime and impact on the water quality. Having water of the right quality is just as important as having enough water.

The Komati River Catchment study detailed in a report by AfriDev Consultants was of particular relevance to this water quality assessment (AfriDev, 2006). Overall the study revealed that the water in the headwaters of the Komati River where the proposed mine is located was generally of good quality with no major water quality problems being experienced. Some water quality impact is experienced in terms of dry land farming and forestry in the Upper Komati River between Nooitgedacht and Vygeboom Dams, however the catchment is in good ecological condition (AfriDev, 2006). The two main dams in the Upper Komati catchment are operated to ensure the maximum yield. The volumes of water abstracted are based on the water available through the inter-basin transfers from the Vaal-Eastern Sub-system. The water is abstracted by Eskom for power generation. Eskom power stations receiving water from the Komati catchment were designed for use of this high quality (low sulphate) water. The continued supply of good quality water to Eskom is of strategic national importance and a key factor for the management of the catchment water resources. Due to the abstraction and rigid operating rules, the low flows of the Komati River between the dams have been impacted upon. This has resulted in an increase of nutrients in this reach of the river due to trout dams and tourism activities (AfriDev, 2006). The low flow reduction coupled with trout dams, agricultural and tourism activities has resulted in increased nutrient concentrations in the river.

Nooitgedacht and Vygeboom Dams supply water to power station and therefore are sensitive to the water quality especially sulphate contents concentrations..

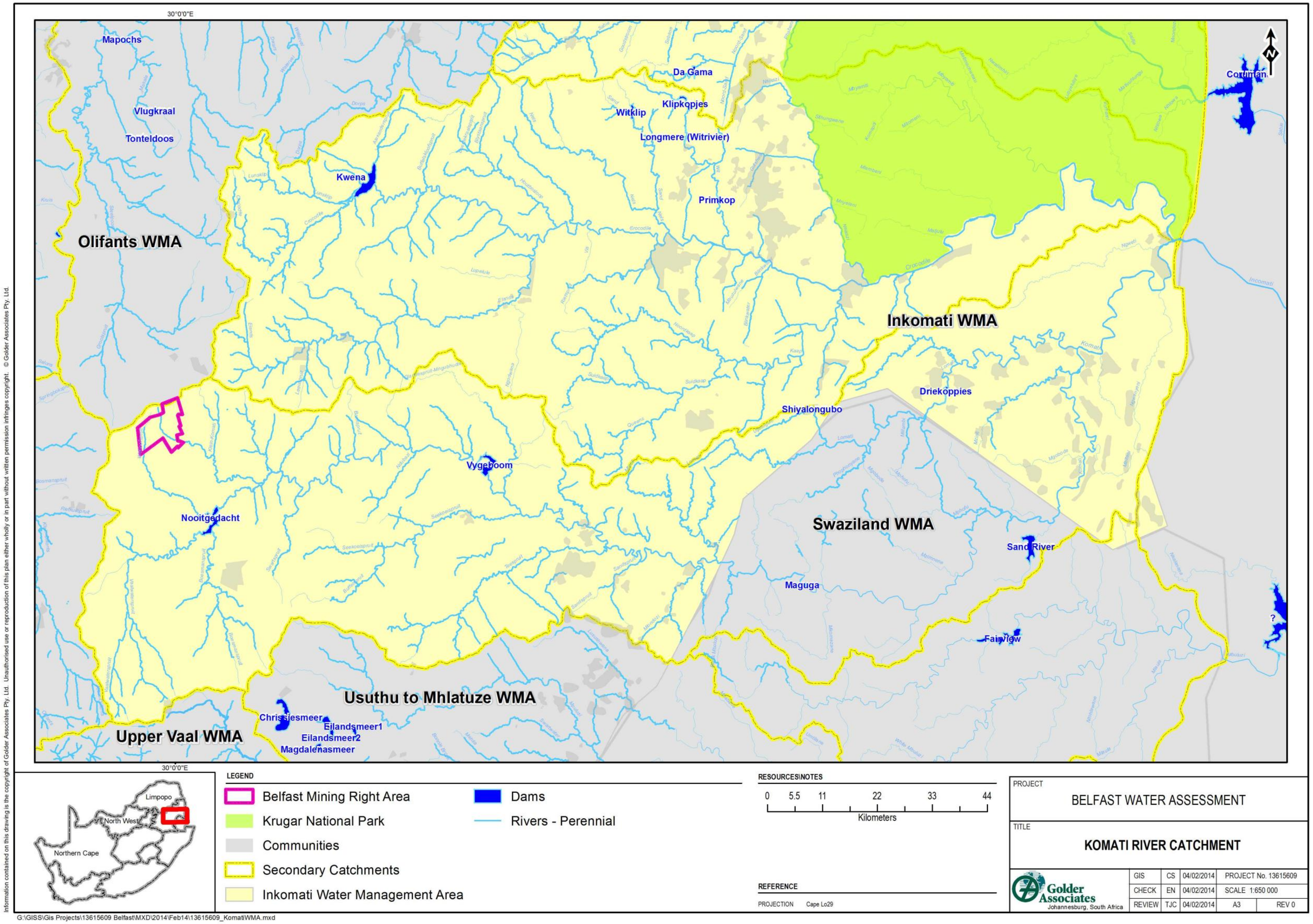

Figure 3: Komati river catchment

4.6 Description of Infrastructure

The proposed mining area will consist of plants, waste rock dump facility and two open cast pits. Mining is planned to start in 2016 with the East Block pit and West Block pit and will run to 2033. For both pits mining will occur uphill towards the north as shown in the mining plan in Figure 4.

The West Block proposed mining area is flanked by the Leeubankspruit on the west running to the south and the Klein Komati running on the west. The East Block proposed mining area is flanked by the Klein Komati on the west and the Driehoek Spruit running on the west. The mine area is therefore drained by three streams. The plant and waste rock dump location are located south of both mining areas on the side of the Klein Komati.

The main mine infrastructure to be built with the proposed storm water control facilities are listed below and is shown on Figure 5.

- Two pits with associated stockpiles and water containment facilities;
- Waste rock dump facility;
- Crushing, screening and washing plant;
- Borehole water supply and reservoirs;
- Haul roads;
- Storm water control measures;
- Various mining offices.

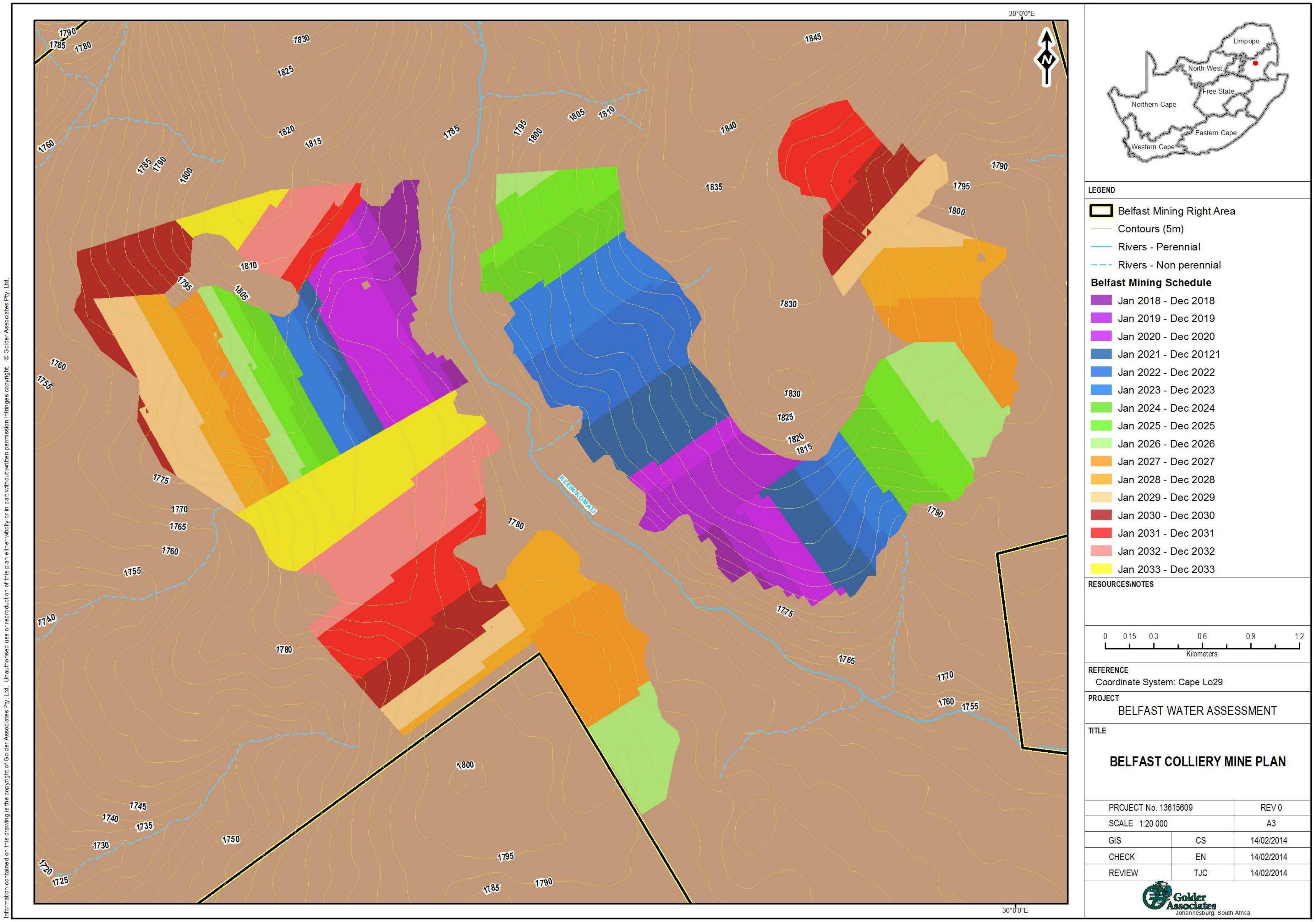

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Figure 4: Belfast Colliery Mine Plan

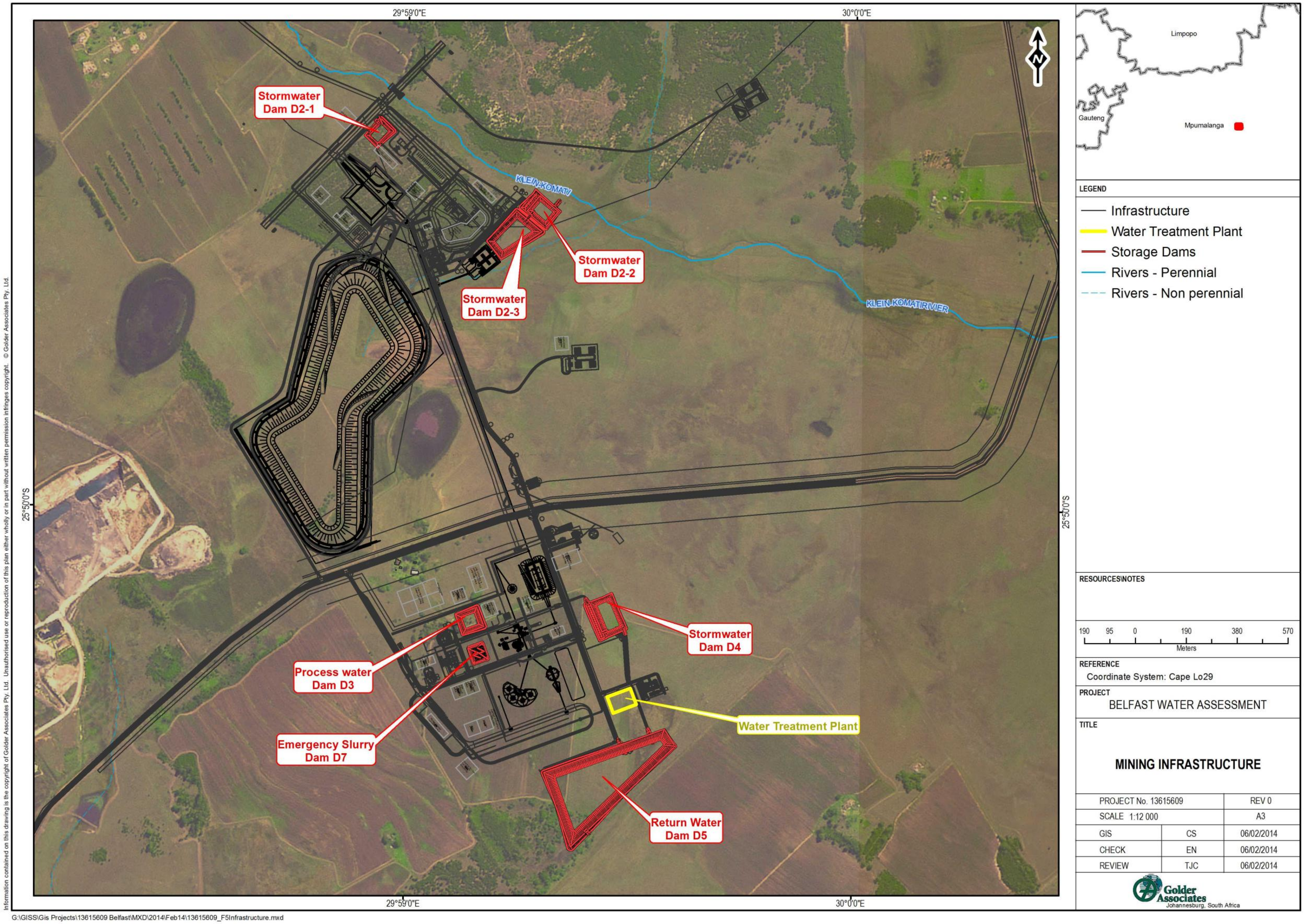

Figure 5: Belfast Colliery proposed infrastructure layout

5.0 SITE HYDROLOGY

5.1 Catchment Characteristics

The three catchments (Leeubank, Klien Komati and Driehoek) are characterised by moderately undulating plains and pans, with grasslands vegetation and no industrial/urban areas. There are various small capacity dams along the course of the rivers. The location of the mining facilities and catchment can be seen on Figure 6.

5.2 Floodline determination

5.2.1 Study approach and methodology

The approach adopted in the study can be summarised as follows:

- The site was visited to assess the site specific hydrological conditions of the three streams, which will influence the flood line determination;
- The river crossings were measured for input into the flood analysis model;
- The catchment areas were determined;
- A flood peak analysis was undertaken to determine the different recurrence interval flood peak for the Leeubankspruit, Klein Komati and Driehoek Spruit;
- The flood peaks and the survey data of the study area were used as inputs to the HEC-RAS backwater program to determine the surface water elevations for the 1: 50 and 1:100 year floods peaks;
- The floodlines were plotted on the available mapping.

5.2.2 Limitations and assumptions

The following limitations and assumptions have been made in this specialist study:

- No flow and rainfall data against which the runoff calculations might be calibrated were available. The runoff volumes were therefore calculated theoretically;
- Since no flow data was available for estimation of the roughness coefficients, the Manning's n coefficients were estimated by comparing the vegetation and nature of the channel surfaces to published data (Barnes, 1967; Chow, 1959; Hicks and Mason, 1991);
- The survey data and infrastructure layout were supplied by Exxaro.

5.2.3 Flood peak Calculation

The following method was used in determining the adopted peak discharges:

5.2.3.1 Rational Method

The Rational Method was applied to the development area sub-catchments. The Rational Method considers the entire drainage area as a single unit and estimates the peak discharge at the most downstream point of that area. The extent of the proposed development area's sub-catchments is shown in Figure 7. The sub-catchment characteristics used in applying the Rational Method are shown in Table 4.

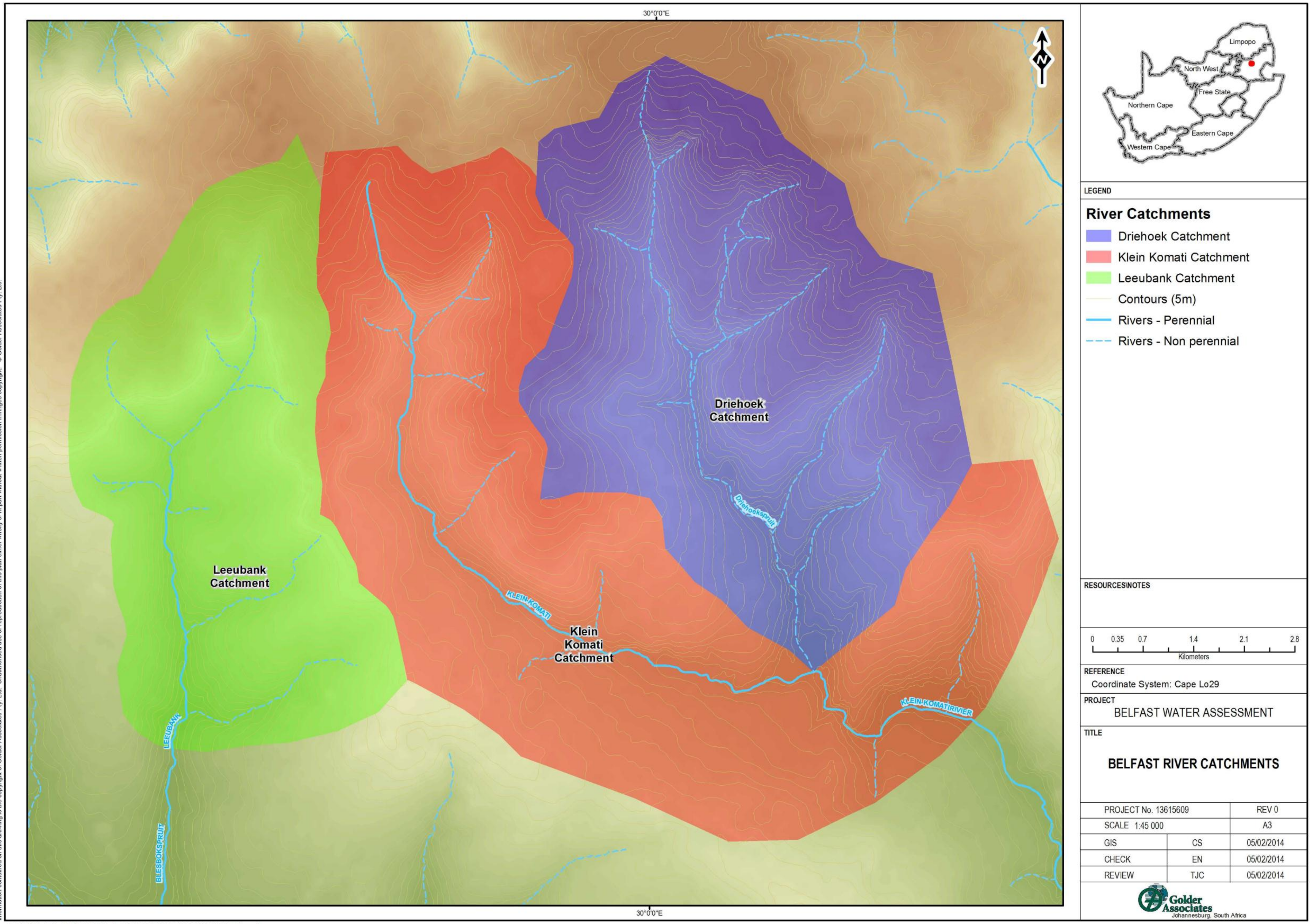

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Figure 6: Natural River Catchments

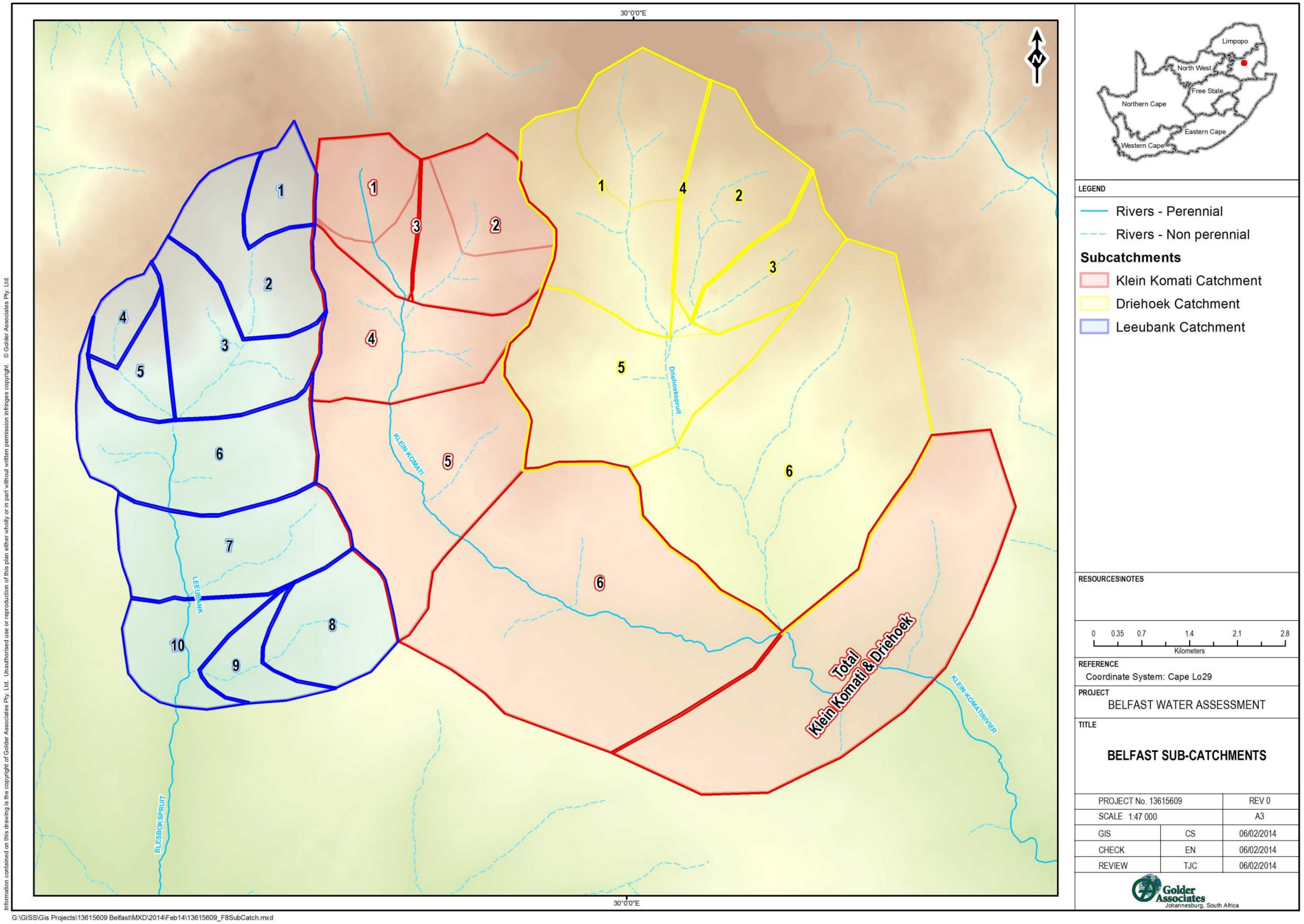

Figure 7: Discretization of study area into sub-catchments for the calculation of the flood peaks

Table 4: Sub-catchment characteristics used in the Rational Method.

Catchment Name	Stream Name	Area	Stream Length	10/85 Elevation (mamsl)		Slope	Time of Concentration
		(km^2)	(m)	10%	85%	(m/m)	(hrs)
L1	Leeubankspruit	0.93	1510	1839	1873	0.030	0.70
L2	Leeubankspruit	4.36	3325	1775	1853	0.031	1.07
L3	Leeubankspruit	0.94	1640	1815	1843	0.023	0.83
L4	Leeubankspruit	2.08	2750	1757	1835	0.038	0.94
L5	Leeubankspruit	7.88	4882	1757	1841	0.023	1.49
L6	Leeubankspruit	14.74	6150	1741	1831	0.020	1.73
L7	Leeubankspruit	2.36	2570	1735	1783	0.025	1.03
L8	Leeubankspruit	0.89	1150	1765	1797	0.037	0.53
L9	Leeubankspruit	18.51	7360	1735	1825	0.016	2.06
L10	Leeubankspruit	24.83	9060	1721	1821	0.015	2.39
KK1	Klein Komati	2.74	1965	1797	1845	0.033	0.42
KK2	Klein Komati	4.15	2260	1789	1830	0.024	0.52
KK3	Klein Komati	6.89	2317	1789	1830	0.024	0.54
KK4	Klein Komati	11.28	3586	1780	1845	0.024	0.74
KK5	Klein Komati	18.21	8016	1772	1840	0.011	1.85
KK6	Klein Komati	31.95	13545	1744	1799	0.005	3.68
D1	Driehoek Spruit	7.40	1846	1785	1822	0.027	0.43
D2	Driehoek Spruit	3.55	1834	1796	1829	0.024	0.44
D3	Driehoek Spruit	2.17	1375	1783	1812	0.028	0.34
D4	Driehoek Spruit	13.28	1846	1785	1846	0.044	0.35
D5	Driehoek Spruit	19.63	4938	1740	1809	0.019	1.05
D6	Driehoek Spruit	33.63	8512	1740	1809	0.011	1.97
Total KK & D	Klein Komati & Driehoek Spruit	65.58	13545	1744	1799	0.005	3.68

The calculated results from the Rational Method are presented in Table 5. Table 5 shows the 1 in 50 and the 1 in 100 year recurrence interval flood peaks for the rivers within the study area.

Table 5: 50 year and 100 year Peak flows calculated using the Rational Method (m^3/s).

Catchment Name	1 in 50 year	1 in 100 year
L1	11	13
L2	41	48
L3	10	12
L4	21	24
L5	56	66
L6	91	107
L7	23	27
L8	13	15
L9	99	116
L10	116	136
KK1	32	38
KK2	60	71
KK3	98	115
KK4	129	152
KK5	106	125
KK6	103	121
D1	85	100
D2	57	67
D3	40	48
D4	235	276
D5	179	210
D6	180	212
Total KK and D	201	235

5.2.3.2 PCSWMM Method

PCSWMM was used as an alternative flood analysis model. PCSWMM is a dynamic rainfall-runoff simulation model used for single event or long-term simulation of runoff quantity. This model was set up for the site and used to calculate the 1 in 50 and 1 in 100 year recurrence interval flood peaks.

The parameters used to model the overland flow are shown in Table 6. Manning's 'n' coefficient used in the model for the impervious areas and pervious areas were 0.013 and 0.035 respectively. The Manning's n for the pervious areas is based on medium to dense bush land cover.

The soils were identified as being in the sandy loam group. The model uses this criterion to incorporate infiltration into the analysis using the Green-Ampt infiltration method. This resulted in a Suction Head of 110 mm, a Hydraulic Conductivity of 22 mm/hr and an Initial Deficit of 0.35 being used in the modelling. The infiltration parameters are listed in Table 6.

Table 6: Catchment parameters used in the PCSWMM modelling of overland flow.

Catchment Name	Stream Name	Area (km^2)	Stream Length (m)	Slope (m/m)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)
L1	Leeubankspruit	0.93	1133	0.030	110	21.8	0.36
L2	Leeubankspruit	4.36	2494	0.031	110	21.8	0.36
L3	Leeubankspruit	0.94	1230	0.023	110	21.8	0.36
L4	Leeubankspruit	2.08	2063	0.038	110	21.8	0.36
L5	Leeubankspruit	7.88	3662	0.023	110	21.8	0.36
L6	Leeubankspruit	14.74	4613	0.020	110	21.8	0.36
L7	Leeubankspruit	2.36	1928	0.025	110	21.8	0.36
L8	Leeubankspruit	0.89	863	0.037	110	21.8	0.36
L9	Leeubankspruit	18.51	5520	0.016	110	21.8	0.36
L10	Leeubankspruit	24.83	6795	0.015	110	21.8	0.36
KK1	Klein Komati	2.74	1474	0.033	110	21.8	0.36
KK2	Klein Komati	4.15	1695	0.024	110	21.8	0.36
KK3	Klein Komati	6.89	1738	0.024	110	21.8	0.36
KK4	Klein Komati	11.28	2690	0.024	110	21.8	0.36
KK5	Klein Komati	18.21	6012	0.011	110	21.8	0.36
KK6	Klein Komati	31.95	10159	0.005	110	21.8	0.36
D1	Driehoek Spruit	7.40	1385	0.027	110	21.8	0.36
D2	Driehoek Spruit	3.55	1376	0.024	110	21.8	0.36
D3	Driehoek Spruit	2.17	1031	0.028	110	21.8	0.36
D4	Driehoek Spruit	13.28	1385	0.044	110	21.8	0.36
D5	Driehoek Spruit	19.63	3704	0.019	110	21.8	0.36
D6	Driehoek Spruit	33.63	6384	0.011	110	21.8	0.36
Total KK and D	Klein Komati & Driehoek Spruit	65.58	10159	0.005	110	21.8	0.36

The calculated results from the PCSWMM analysis are presented in Table 7. Table 7 shows the 1 in 50 and the 1 in 100 year recurrence interval flood peaks for the rivers within the study area.

Table 7: 50 year and 100 year Peak flows calculated using PCSWMM (m^3/s).

Catchment Name	1 in 50 year	1 in 100 year
L1	9	12
L2	38	41
L3	8	11
L4	22	28
L5	52	63
L6	96	110
L7	25	29
L8	12	16
L9	89	111
L10	105	140
KK1	42	52
KK2	52	63
KK3	85	103
KK4	100	124
KK5	97	120
KK6	93	99
D1	111	135
D2	51	63
D3	41	49
D4	237	288
D5	192	236
D6	172	211
Total KK and D	171	202

5.2.3.3 Summary of calculated peak flows

A comparison of the calculated 1 in 50 and 1 in 100 year Rational flood peaks to the flood peaks calculated using the regional maximum flood (RMF) and PCSWMM is presented in Table 8 and Table 9. A conservative approach was taken and therefore the Rational Method flood peaks were used in calculating the water surface elevations.

Table 8: Comparison of the calculated 1 in 50 Year Peak Flows (m^3/s).

Catchment Name	Rational	PCSWMM	RMF
L1	11	9	61
L2	41	38	110
L3	10	8	61
L4	21	22	83
L5	56	52	138
L6	91	96	168
L7	23	25	87
L8	13	12	60
L9	99	89	183
L10	116	105	204
KK1	32	42	147
KK2	60	52	172
KK3	98	85	208
KK4	129	100	251
KK5	106	97	301
KK6	103	93	373
D1	85	111	214
D2	57	51	162
D3	40	41	134
D4	235	237	267
D5	179	192	310
D6	180	172	380
Total KK and D	201	171	490

Table 9: Comparison of the calculated 1 in 100 Year Peak Flows (m³/s).

Catchment Name	Rational	PCSWMM	RMF
L1	13	12	61
L2	48	41	110
L3	12	11	61
L4	24	28	83
L5	66	63	138
L6	107	110	168
L7	27	29	87
L8	15	16	60
L9	116	111	183
L10	136	140	204
KK1	38	52	147
KK2	71	63	172
KK3	115	103	208
KK4	152	124	251
KK5	125	120	301
KK6	121	99	373
D1	100	135	214
D2	67	63	162
D3	48	49	134
D4	276	288	267
D5	210	236	310
D6	212	211	380
Total KK and D	235	202	490

5.2.4 Floodline modelling

Cross-sectional data was obtained from topographical map provided by Exxaro. Locations and numbering of the cross-sections are shown in Figure 8. The site was visited and photographs of the study area were taken. The river crossings and dams within the along the Klein Komati River were identified using aerial imagery as shown in Figure 8. During the site visit the river crossing locations were visited to measure the dimensions. Photographs of the river crossings are shown in Table 10, the properties of the crossings are shown in Table 11.

Two scenarios were modelled. The first being the predevelopment floodlines, this scenario models the catchments as they are naturally. The second scenario that was modelled includes development of the mine infrastructure. This scenario includes the increase in impervious areas as well as the proposed discharge of water from the water treatment plant (4 Ml per day was modelled as a conservative approach).

Table 10: River crossing observations

River Crossing	Upstream View	Downstream View
Road 2: ■ Bridge crossing (R33) ■ Low flows observed ■ Rocky river bed observed ■ Vegetated banks		
Dirt Road 6: ■ Farm road ■ Box Culverts ■ Vegetated channel ■ Low flows observed		
Dam 4: ■ Broad crested weir ■ Weir is damaged. ■ Vegetated channel ■ Low flows observed		

River Crossing	Upstream View	Downstream View
Dirt Road 1: ■ Farm road/ cattle crossing ■ Circular Culverts ■ Vegetated channel ■ Low flows observed		
Dam 3: ■ Embankment dam ■ Low dam wall (less than 0.5m) ■ Rocky channel upstream and downstream of Dam ■ Low flows observed		
Road 7: ■ Farm road crossing ■ Circular Culverts ■ Vegetated channel ■ Debris obstructing upstream inlet of culverts ■ Low flows observed		

River Crossing	Upstream View	Downstream View
Road 8: ■ Farm road crossing ■ Circular Culverts ■ Vegetated channel ■ No defined channel ■ Low flows observed		
Dam 9: ■ Embankment dam ■ Rocky channel ■ Low flows observed		

Table 11: River crossing properties, along the Klein Komati River.

Name	Description	Type	Number of Barrels	Height (m)/ Diameter (m)	Width (m)	Barrel Length (m)	Deck Length (m)	Deck Thickness (m)
Road 2 (R33)	Bridge	Box	1	7.8	19.5	15.0	22.0	1.0
Dirt Road 6	Culvert	Box	5	2	3	5.0	16.0	0.5
Dam 4	Dam	Embankment	-	1.5	10.2	-	-	-
Dirt Road 1	Culvert	Circular	3	0.5	-	4.2	6.0	1.5
Dam 3	Dam	Embankment	-	0.5	10.4	-	-	-
Road 7	Culvert	Circular	5	0.8	-	7.8	5.5	0.9
Road 8	Culvert	Circular	6	0.7	-	5.0	4.7	1.0
Dam 9	Dam	Embankment	-	2.5	70.8	-	-	-

The Manning's n resistance coefficients for the stream channel and the stream banks were estimated by comparing the vegetation and nature of the channel surface with published data (Barnes, 1967; Chow, 1959; Hicks and Mason, 1991). Since no flow data was available for estimation of the roughness coefficients, slightly conservative estimations were adopted. The Manning's n coefficient of 0.04 and 0.035 has been estimated for the river bed and river banks respectively.

5.3 Results

The floodlines were calculated using US Army Corp of Engineers HEC-RAS model. A sensitivity analysis was performed to assess the effect of the Manning's n resistance coefficient. A low sensitivity was found.

The pre-development flood lines for the 1:50-year and 1:100-year flood peaks were determined and plotted in Figure 9. The post-development flood lines for the 1:50-year and 1:100-year flood peaks were determined and plotted in Figure 10

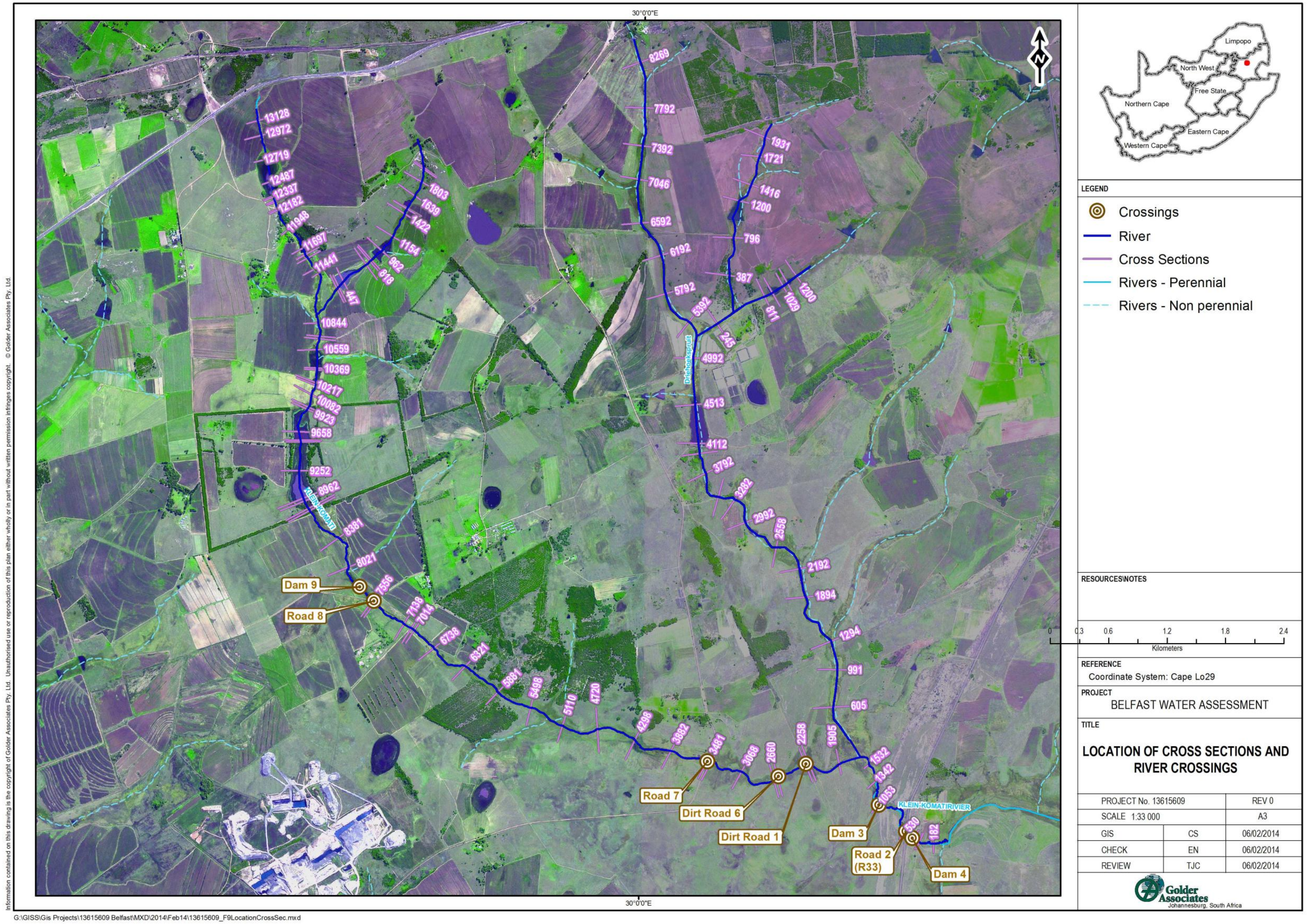

Figure 8: The extent and location of the cross sections and river crossings within the study area

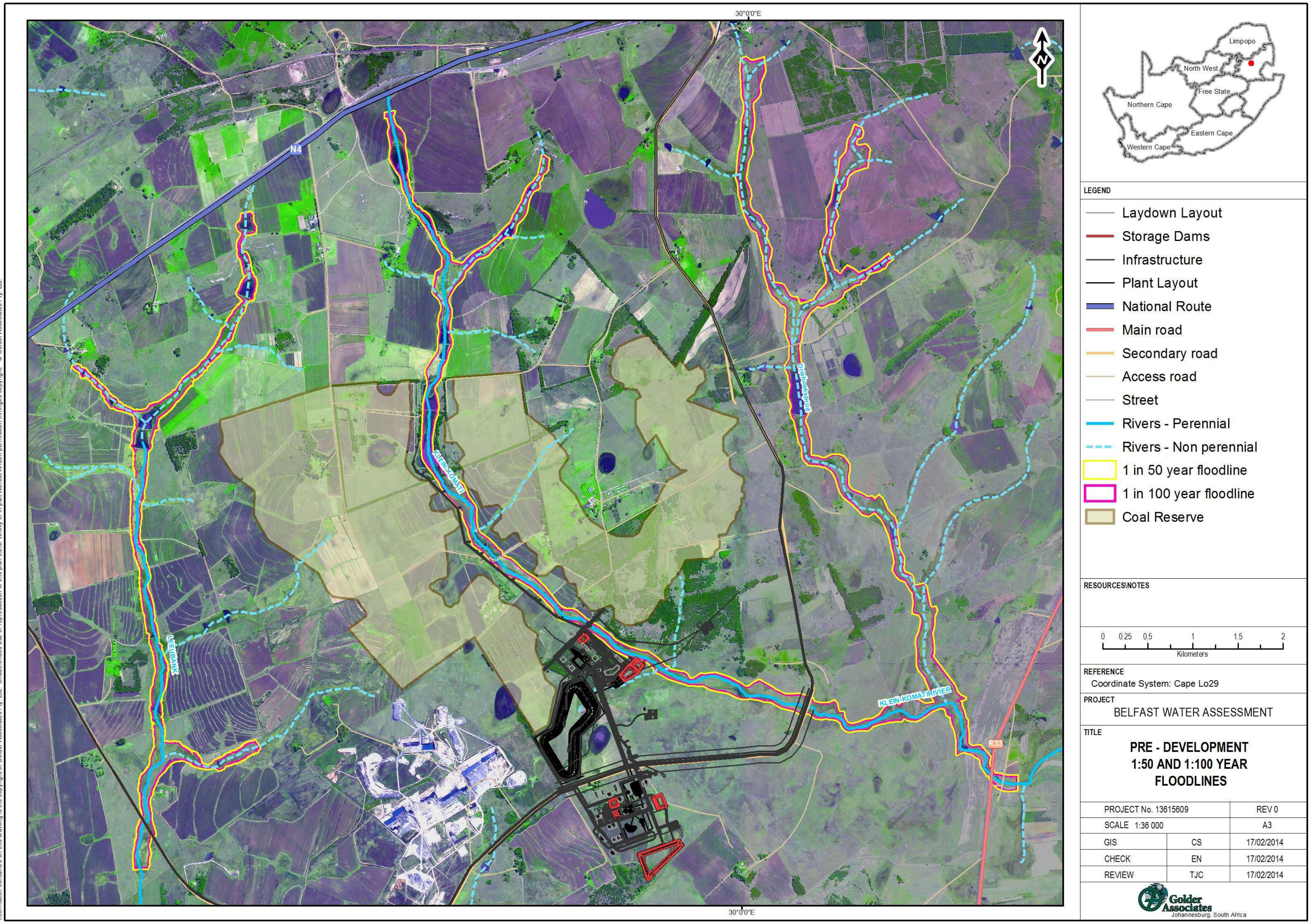

Figure 9: The pre-development 1 in 50 year and 1 in 100 year floodlines

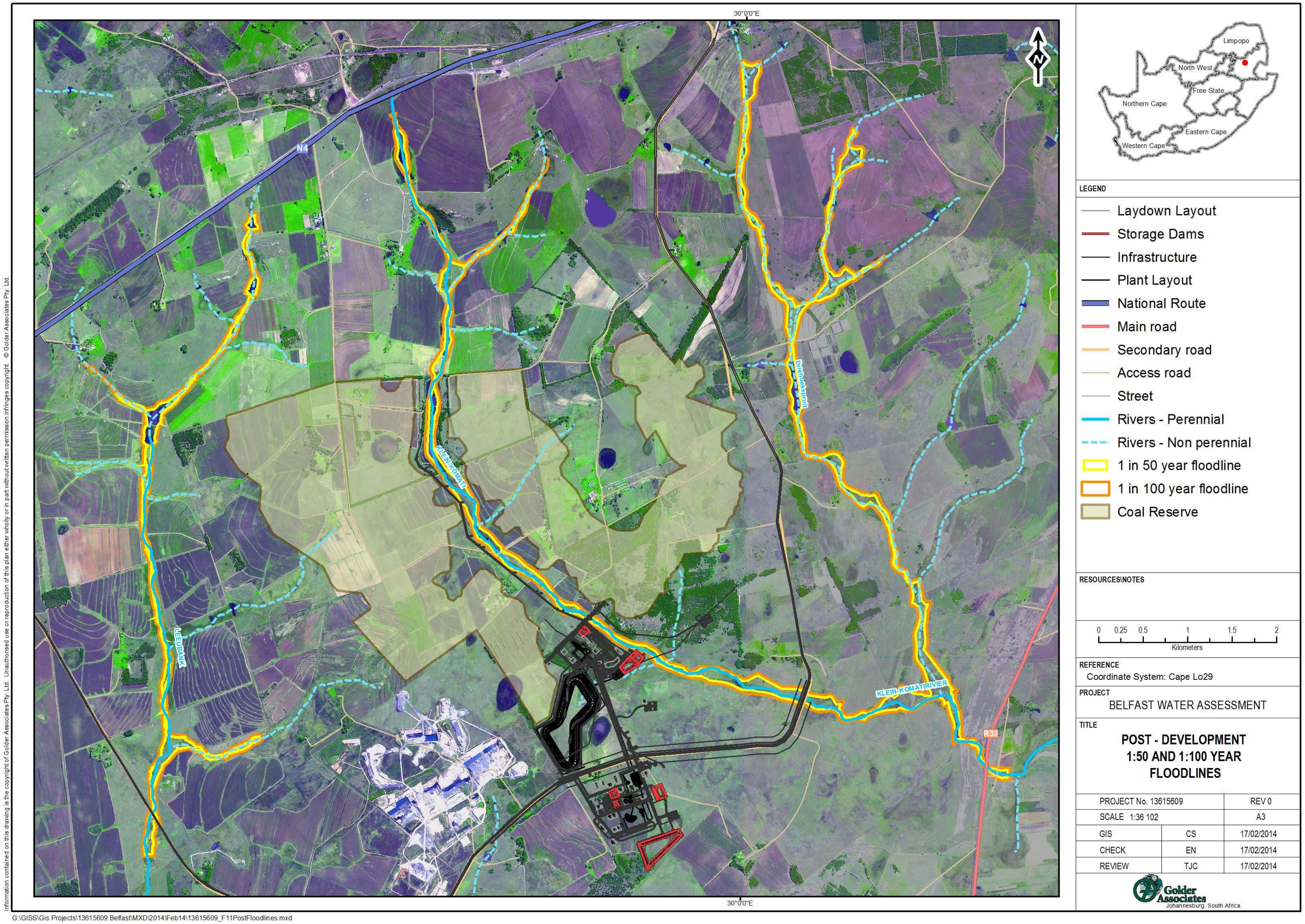

Figure 10: The post-development 1 in 50 year and 1 in 100 year floodlines

6.0 SELECTION OF A LOCATION FOR THE WATER TREATMENT PLANT POINT OF DISCHARGE INTO THE KLEIN KOMATI RIVER

The first criterion for selecting the location of the discharge point was to limit any potential erosion that may occur. Therefore the discharge location should be located where there is concentrated, turbulent and high velocity flows so that the natural channel is less likely to be erosive. Another important criterion is the distance from the water treatment plant, this has financial implications. A pipeline will be required to route the treated water from the treatment plant to be discharged into the Klein Komati River. The further away the discharge point is located from the water treatment plant, the higher the pipeline costs.

The HEC-RAS model was used to calculate the velocities, Froude numbers and shear force of the stream flow along the Klein Komati for both the 1 in 50 year and 1 in 100 year events, the results are shown for a 3.5 km stretch of the river adjacent to the proposed mine infrastructure (Between cross-section 7138 and 3882 as shown in Figure 11). The Froude Number is a dimensionless value that describes different flow regimes of open channel flow; it is a ratio of inertial and gravitational forces. If the Froude number is greater than 1 the flow is described as supercritical (fast, rapid, and erosive flow), if the Froude number is less than 1 the flow is described as (slow and calm flow). Therefore the ideal location for the discharge point would be a reach of the river which is naturally supercritical, as this would reduce the erosion.

Shear Stress is a measure of the force of friction from a fluid acting on a body in the path of that fluid, in the case of open channel flow; it is the force of moving water against the bed of the channel. These shear forces acting on the bed of a channel generate shear stress, which initiates erosion of the channel bed. Therefore an area within the river with high shear stress would indicate a position which would be suited to discharging flows as the stream has adapted to these conditions.

The pre-development HEC-RAS results are presented in Table 12. The results show that there are 2 locations (DP1 and DP2 are shown in Figure 11) which fit the criteria. Cross-sections 5881 and 6738 both show high velocities (relative to the upstream and downstream cross-sections) of 2.4m/s and 2.3m/s; however the Froude numbers are 0.92 and 1.02. In terms of the channel shear stress cross-sections 5881 and 6738 have the highest shear stress within the reach at 73.74 N/m^2 and 69.22 N/m^2. Cross-section 5881 (Discharge Point 1) is better suited for the discharge location as the flow is supercritical. The co-ordinates for the proposed discharge location is shown in Table 13.

Table 12: HEC-RAS results for 1 in 50 year and 1 in 100 year events

Cross-section	Channel Distance (m)	1 in 50 yr			1 in 100 yr		
		Velocity in Channel (m/s)	Froude Number	Channel Shear Stress (N/m^2)	Velocity in Channel (m/s)	Froude Number	Channel Shear Stress (N/m^2)
7138	5232.8	1.5	0.57	31.15	1.61	0.59	33.52
7050	5144.69	1.4	0.53	26.94	1.5	0.53	28.87
7014	5108.67	1.4	0.49	25.19	1.48	0.52	27.13
6738	4833.26	2.4	0.92	73.74	2.49	0.98	80.9
6321	4416.13	1.7	0.61	37.77	1.8	0.64	41.05
5881	3975.95	2.3	1.02	69.22	2.43	1.04	75.71
5498	3592.73	1.6	0.6	35.21	1.73	0.56	38.23
5110	3204.99	1.7	0.67	40.53	1.83	1.05	44.94
4720	2814.78	1.7	0.78	44.54	1.8	0.62	47.82
4298	2393.32	1.2	0.53	22.53	1.32	0.87	24.77
3882	1977.33	2.0	0.98	57.70	2.13	0.68	59.93

Table 13: The co-ordinates for the proposed discharge location

Latitude	25˚ 49’ 17.35”
Longitude	29˚ 59’ 6.10”

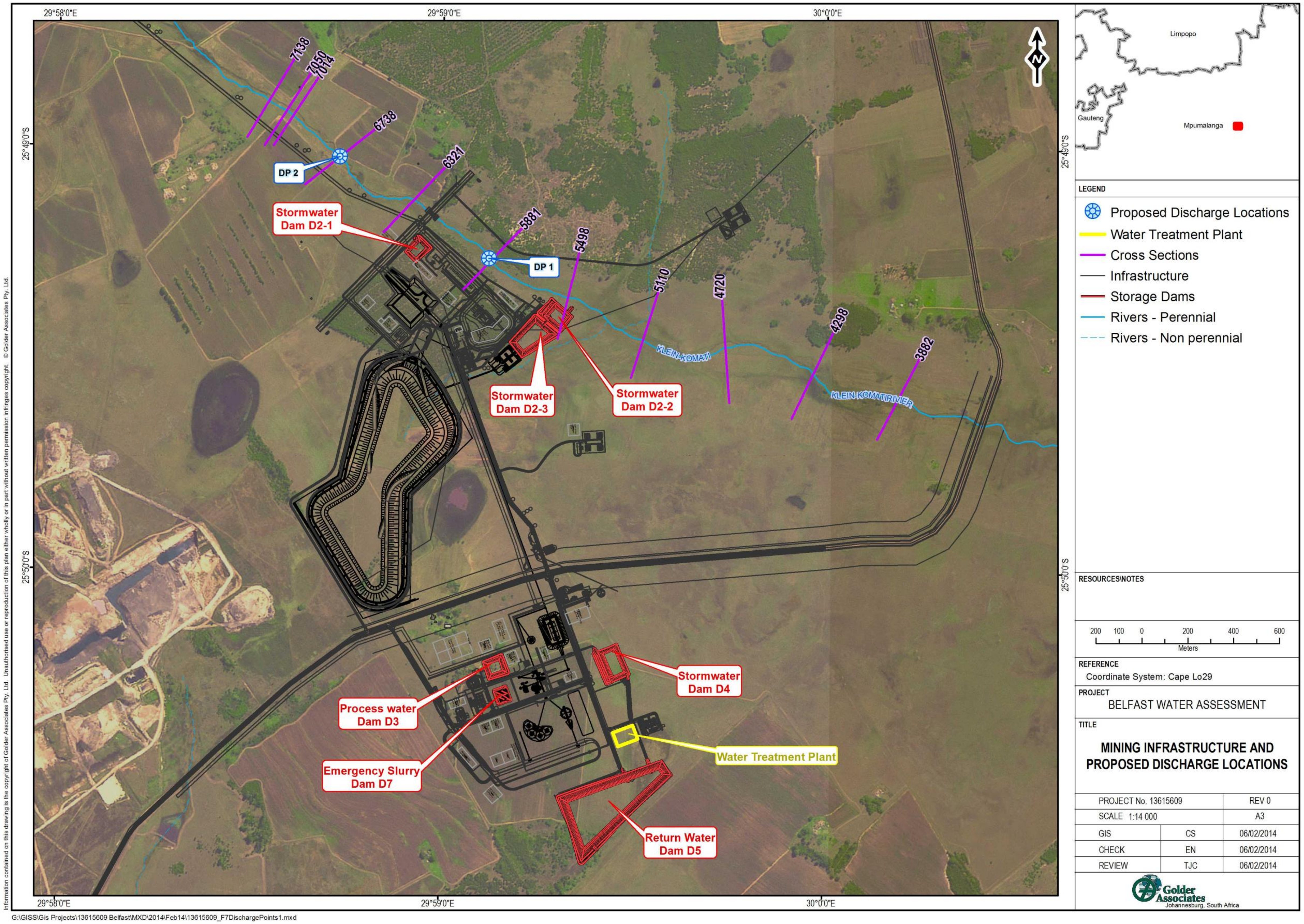

Figure 11: Proposed locations of the water treatment discharge water

6.1 Energy dissipation structure

Energy dissipation structures are used to reduce and control energy from pipe/culvert discharge so as to release the discharge downstream under controlled, stable conditions. The discharge of 4Ml/d (4000m3/d) equates to a discharge of 0.046m^3/s. If a 300mm pipe is assumed the calculated velocity is 0.66 m/s. The velocity is well below the natural velocities in the Klein Komati which are on average around 3m/s. Therefore it is not necessary for a complicated energy dissipation structure. A channel lined with long grass and with rocks at the downstream point of the channel will be sufficient to dissipate the discharge water. However it is important that the channel not be perpendicular to the river. An angled (45˚) discharge channel will allow for less impact on the stream. A plan view of the proposed discharge channel is shown in Figure 12. A cross-sectional view of the upstream and downstream of the discharge channel is shown in Figure 13.

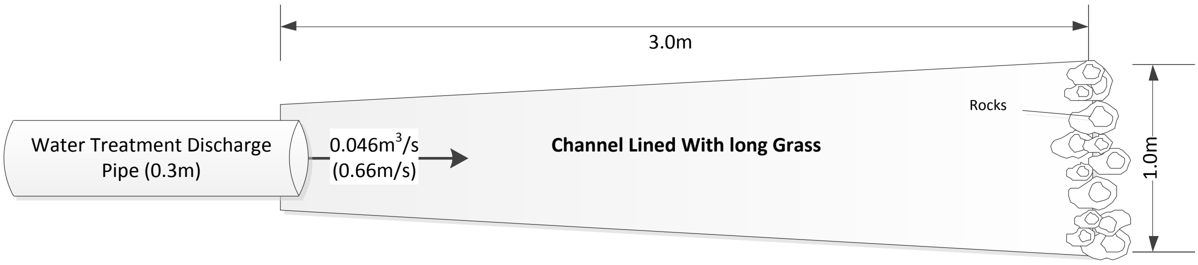

Figure 12: A plan view of the proposed discharge channel

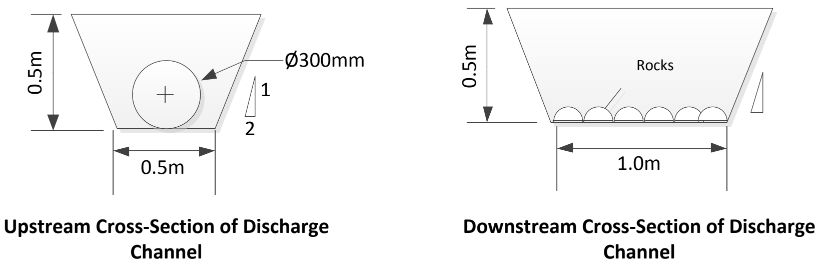

Figure 13: Cross-sectional view of the upstream and downstream of the discharge channel

7.0 SURFACE WATER IMPACT ASSESSMENT

7.1 Assessment of Potential Impacts

In order to assess the impacts of the proposed development on surface water, the following components were included:

- Determine potential impact of the increased flow on the potential erosion of the receiving water channel;
- Determine potential impact on river crossings, due to increased baseflow conditions.

7.1.1 Potential impact of the increased flow on the potential erosion of the receiving water channel

HECRAS was used to determine the potential impacts of the increased flow on the potential erosion of the receiving water channel (Klein Komati). A 10.6km stretch (Cross-section 7138 to 182) of the Klein Komati was analysed. The calculated shear stress was used to determine the potential erosion of the stream for the pre-development scenario; this was compared to the calculated shear stress for the post-development scenario (with the increased flow of 4Ml/d). The results for the 1 in 150 year and 1 in 100 year recurrence interval events are shown in Table 14 and the results show a maximum change in shear stress of 15%. The results indicate that there will be in increase in erosion, particularly downstream of the proposed discharge point, however the effect of the increased flow dissipates downstream of cross-section 2294.

Table 14: Comparison of the calculated 1 in 50 year pre-development and post-development shear stresses

Cross-section	Pre-development Shear Stress (N/m^2)	Post-development Shear Stress (N/m^2)	% Change in Shear Stress
7138	31.2	31.5	1%
7050	26.9	29.2	8%
7014	25.2	26.3	5%
6738	73.7	73.7	0%
6321	37.8	39.1	4%
5881	69.2	71.6	3%
5498	35.2	38.2	9%
5110	40.5	45.7	13%
4720	44.5	48.9	10%
4298	22.5	24.1	7%
3882	67.7	73.3	8%
3481	10.5	11.9	13%
3433	19.0	19.0	0%
3068	71.3	73.6	3%
2660	26.0	28.0	8%
2613	73.9	76.0	3%
2294	23.3	23.3	0%
2258	22.2	22.2	0%
1905	77.8	77.8	0%
1532	64.9	64.9	0%
1342	33.6	33.6	0%
1053	63.6	63.6	0%
530	32.0	32.0	0%
518	80.3	80.3	0%
430	77.6	77.6	0%
362	64.2	64.2	0%
349	87.6	87.6	0%
182	77.3	77.3	0%

Table 15: Comparison of the calculated 1 in 100 year pre-development and post-development shear stresses

Cross-section	Pre-development Shear Stress (N/m^2)	Post-development Shear Stress (N/m^2)	% Change in Shear Stress
7138	33.5	33.9	1%
7050	28.9	32.0	11%
7014	27.1	29.0	7%
6738	80.9	85.8	6%
6321	41.1	44.1	8%
5881	75.7	81.0	7%
5498	38.2	42.4	11%
5110	44.9	51.7	15%
4720	47.8	53.6	12%
4298	24.8	25.8	4%
3882	72.9	79.0	8%
3481	10.7	12.2	14%
3433	20.7	21.4	3%
3068	76.5	80.3	5%
2660	25.5	28.1	10%
2613	54.8	57.5	5%
2294	24.0	24.0	0%
2258	24.0	24.0	0%
1905	85.0	84.9	0%
1532	71.5	71.4	0%
1342	32.8	32.8	0%
1053	54.7	54.7	0%
530	31.4	31.4	0%
518	91.5	91.5	0%
430	95.6	95.6	0%
362	70.4	70.4	0%
349	94.5	94.5	0%
182	84.6	84.6	0%

7.1.2 Potential impact on river crossings

HECRAS was used to determine the potential impacts of the increased flow on the river crossings downstream of the proposed discharge location. The river crossings and dams within the along the Klein Komati River were identified using aerial imagery as shown in Figure 8. During the site visit the river crossing locations were visited to measure the dimensions. Photographs of the river crossings are shown in Table 10, the properties of the crossings are shown in Table 11. The river crossings were then modelled in HECRAS for the 1 in 50 year and 1 in 100 year recurrence event. The water surface elevation results are shown in Table 16 and Table 17, for the 1 in 50 year and 1 in 100 year recurrence interval events. The results show that there is a maximum change of 0.46m for the 1 in 50 year event and 0.57m for the 100 year event at Dirt Road 6. The remaining river crossings show an average change in water surface elevation of 0.3m.

Table 16: Road crossing water surface elevation results for the 1 in 50 year event.

River Crossing	Pre-Development Upstream Water Surface Elevation (mamsl)	Post-Development Upstream Water Surface Elevation (mamsl)	Change in W.S Elevation (m)
Road 8	1772.27	1772.65	0.38
Road 7	1748.07	1748.42	0.35
Dirt Road 6	1743.02	1743.48	0.46
Dirt Road 1	1740.40	1740.70	0.30
Road 2 (R33)	1733.81	1733.81	0.00

Table 17: Road crossing water surface elevation results for the 1 in 100 year event.

River Crossing	Pre-Development Upstream Water Surface Elevation (mamsl)	Post-Development Upstream Water Surface Elevation (mamsl)	Change in W.S Elevation
Road 8	1772.31	1772.76	0.45
Road 7	1748.12	1748.5	0.38
Dirt Road 6	1743.25	1743.82	0.57
Dirt Road 1	1740.45	1740.79	0.34
Road 2 (R33)	1734.38	1734.38	0.00

The upstream culvert velocity results are shown in Table 18 and Table 19, for the 1 in 50 year and 1 in 100 year recurrence interval events. The results show that there is a maximum upstream velocity change of 15% for the 1 in 50 year event and 12% for the 100 year event at Dirt Road 6. The approach velocities do not show any significant change.

Table 18: Road crossing upstream culvert velocity results for the 1 in 50 year event.

River Crossing	Pre-Development Upstream Culvert Velocity (m/s)	Post-Development Upstream Culvert Velocity (m/s)	% Change in Velocity (m/s)
Road 8	3.87	3.89	1%
Road 7	4.01	4.05	1%
Dirt Road 6	2.97	3.41	15%
Dirt Road 1	3.18	2.96	-7%
Road 2 (R33)	4.34	4.34	0%

Table 19: Road crossing upstream culvert velocity results for the 1 in 100 year event.

River Crossing	Pre-Development Upstream Culvert Velocity (m/s)	Post-Development Upstream Culvert Velocity (m/s)	% Change in Velocity (m/s)
Road 8	3.92	3.92	0%
Road 7	4.09	4.09	0%
Dirt Road 6	3.16	3.55	12%
Dirt Road 1	3.17	3.17	0%
Road 2 (R33)	4.6	4.87	6%

The downstream culvert velocity results are shown in Table 20 and Table 21, for the 1 in 50 year and 1 in 100 year recurrence interval events. The results show that there is a maximum upstream velocity change of 21% for the 1 in 50 year event and 17% for the 100 year event at Dirt Road 6. The downstream velocities do not show any significant change.

Table 20: Road crossing downstream culvert velocity results for the 1 in 50 year event.

River Crossing	Pre-Development Downstream Culvert Velocity (m/s)	Post-Development Downstream Culvert Velocity (m/s)	% Change in Velocity (m/s)
Road 8	3.33	3.78	14%
Road 7	4.01	4.05	1%
Dirt Road 6	4.37	5.28	21%
Dirt Road 1	3.18	2.96	-7%
Road 2 (R33)	4.61	4.61	0%

Table 21: Road crossing downstream culvert velocity results for the 1 in 100 year event.

River Crossing	Pre-Development Downstream Culvert Velocity (m/s)	Post-Development Downstream Culvert Velocity (m/s)	% Change in Velocity (m/s)
Road 8	3.39	3.79	12%
Road 7	4.09	4.01	-2%
Dirt Road 6	4.55	5.33	17%
Dirt Road 1	3.17	2.92	-8%
Road 2 (R33)	4.87	4.87	0%

The results show that the increased baseflow has a minimal impact on the river crossings. The increase velocity and water surface elevation at Dirt Road 6 will not be substantial enough to impact on the river crossings ability to convey the flow.

7.2 Development of Mitigation

A common approach to describing mitigation measures for critical impacts is to specify a range of targets with a predetermined acceptable range and an associated monitoring and evaluation plan. To ensure successful implementation, mitigation measures should be unambiguous statements of actions and requirements that are practical to execute. The following summarize the different approaches that may be used in prescribing and designing mitigation measures:

- Avoidance: e.g. mitigation by not carrying out the proposed action on the specific site, but rather on a more suitable site;
- Minimization: mitigation by scaling down the magnitude of a development, re-orienting the layout of the project or employing technology to limit the undesirable environmental impact;
- Rectification: mitigation through the restoration of environments affected by the action;
- Reduction: mitigation by taking maintenance steps during the course of the action; and
- Compensation: mitigation through the creation, enhancement or acquisition of similar environments to those affected by the action.

Table 22 below shows the identified impacts as well as the recommended mitigation measures. The mitigation measures identified focused on minimization and reduction of the impacts.

Table 22: Recommended Mitigation and Management Measures

Recommended Mitigation and Management Measures		
Objective	**Put in place mitigation measures with the aim to prevent a further reduction in the river hydraulics integrity by minimizing erosion**	**Responsibility**
Impacts:	***Construction Impacts*** ■ Stripping of vegetation may increase erosion from barren areas, thereby preventing increased suspended solids in downstream watercourses. ***Construction, Operational and Decommissioning Impacts*** ■ Channel modification through increased erosion caused by the proposed 4ML/d discharge; ■ Change in surface water quality (pH, suspended solids, oil and grease); ■ Spillage of oils, fuel and chemicals could pollute adjacent water bodies during mining operations.	■ Exxaro Belfast Coal Mine Environmental Manager
Mitigation measure(s):	***Construction and operation*** ■ The use of standard erosion control measures, such as interception drains, contour planting, silt fences, establishment of groundcover species, optimal drainage construction, and silt ponds are applied where appropriate. Where possible earthwork activities should be undertaken during dry periods; ■ Progressive rehabilitation of disturbed land should be carried out to minimize the amount of time that bare soils are exposed to the erosive effects of rain and subsequent runoff; ■ The total footprint area to be developed will be kept to a minimum by demarcating the construction areas and restricting construction to these areas only. ***Construction, Operational and Decommissioning*** ■ Localized energy dissipation structures should be constructed at the discharge locations;	

<table>
<tr><th colspan="3">Recommended Mitigation and Management Measures</th></tr>
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Effective diversion of clean stormwater, by implementation of the proposed stormwater management plan should reduce the impacts of reduced catchment runoff. To minimize the impact on the stream flow integrity on downstream water users;
It is important that rehabilitation and revegetation of the exposed areas be undertaken on a continual basis and should not be left for the decommissioning phase. If erosion has taken place, rehabilitation should be implemented as soon as possible.
Implementation of a system to identify acid generation potential of resources and waste;
Develop a mitigation and management strategy for projects where toxic material is identified ;
Implement the management strategy during the operations;
Investigate and assess the construction of treatment wetlands where appropriate to decontaminate shaft discharges before flowing into the receiving environment; and
Maintain a surface water monitoring procedure.

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<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Performance Criteria and Monitoring/Measurements</td></tr>
<tr><td>Performance criteria</td><td>
Conformance with section 704 of the National Water
</td><td></td></tr>
<tr><td>Monitoring/ Measurement</td><td>

A monitoring plan must be compiled and include the following:

Water quality from the proposed 4ML discharge from the mine into the Klein Komati River should be routinely monitored on a monthly basis;
Continual assessment of the in situ water quality;
The monitoring plan must include both wet and dry seasons during the construction and operational phase of the extensions of the Belfast complex and the pipeline; and
The monitoring plan must aim to identify any improvements or degradations within the system and must be reported seasonally.

</td><td>
Exxaro Belfast Coal Mine Environment al Manager
</td></tr>
</table>

7.3 Environmental Impact Significance Assessment

The impacts of the proposed development were assessed in terms of impact significance and recommended mitigation measures.

The determination of significant impacts relates to the degree of change in the environmental resource measured against some standard or threshold (DEAT, 2002). This requires a definition of the magnitude, prevalence, duration, frequency and likelihood of potential change (DEAT, 2002). The following criteria have been proposed by the Department of Environmental Affairs and Tourism for the description of the magnitude and significance of impacts (DEAT, 2002).

The consequence of impacts can be derived by considering the following criteria:

- Extent or spatial scale of the impact;
- Intensity or severity of the impact;
- Duration of the impact;
- Potential for Mitigation;
- Acceptability;
- Degree of certainty/Probability;
- Status of the impact; and
- Legal Requirements.

Describing the potential impact in terms of the above criteria provides a consistent and systematic basis for the comparison and application of judgments (DEAT, 2002).

The significance of the impact is calculated as:

Significance of Impact = Consequence (magnitude + duration + spatial scale) x Probability

Magnitude relates to how severe the impact is. Duration relates to how long the impact may be prevalent for and the spatial scale relates to the physical area that would be affected by the impact. Having ranked the severity, duration and spatial scale using the criteria outlined in Table 23, the overall consequence of impact can be determined by adding the individual scores assigned in the severity, duration and spatial scale. Overall probability of the impacts must then be determined. Probability refers to how likely it is that the impact may occur.

Table 23: Consequence and probability ranking

Magnitude/Severity	Duration	Spatial Scale	Probability
10 - Very high/don't know	5 - Permanent	5 - International	5 - Definite/don't know
8 - High	4 - Long-term (impact ceases after operational life)	4 - National	4 - Highly probable
6 - Moderate	3 - Medium-term (5-15 years)	3 - Regional	3 - Medium probability
4 - Low	2 - Short-term (0-5 years)	2 - Local	2 - Low probability
2 - Minor	1 - Immediate	1- Site only	1 - Improbable
0 - None	0 - None	0 - None	0 - None

The maximum value, which can be obtained, is 100 significance points (SP). Environmental effects are rated as either of High, Moderate, Low or No Impact significance on the following basis:

- SP > 75 Indicates high environmental significance
- SP 30 – 75 Indicates moderate environmental significance
- SP < 30 Indicates low environmental significance
- SP = 0 Indicates no environmental significance

The descriptors for the ratings are provided in (Table 24)

Table 24: Categories for the rating of impact magnitude and significance

Category	Description
High	Impact must have an influence on the decision process to develop
Moderate	Impact could influence the decision to develop in the area unless it is effectively mitigated.
Low	Impact doesn't have a direct influence on the decision to develop in the area.

Table 25: Rating of the impact magnitude and significance

Impact	Discussion	Rating before Mitigation (RBM) Rating After Mitigation (RAM)	Significance Score					
			Mag	D	SS	P	Total	Significance
Increased erosion within the stream channel	The proposed maximum discharge rate of 4 ML/d into the Klien Komati stream will increase erosion of the stream banks and channel.	RBM	8	5	2	5	**75**	**Moderate**
		RAM	4	2	2	3	**24**	**Low**

8.0 WATER BALANCE

A water balance was developed of the integrated water system using Goldsim simulation software. The mine water balance is dynamic and depends on many factors including rainfall, the mine plan, floor contours, rehabilitation scheduling and standards as well as mine water requirements. Water will have to be managed either for use to meet the mine water requirements or treatment and discharge.

To represent the mine water management system, the following elements have been included in the model:

- Climate element
- A mine pit element
- Dam
- Coal plant
- Catchment

The above elements can be used to build up a mine water system. The operating rule and connectivity govern how the water streams produced from the different elements are linked together. The connectivity and operating rule are programmed into the Goldsim model.

The time step of the model is dependent on the objective of the model. An annual time step can be used to give an indication of the average water volumes that may need to be managed and an overall indication of the mine water balance. Such a long time step does not address the seasonal or daily variations and therefore cannot be used to size storage facilities. In the case of large storage capacities such as those generally associated with mine workings, an annual water balance accounting for the annual variation of rainfall can be used to determine mine filling times and average recharge rates to the workings. A monthly time step accounts for the seasonal variations and can be used to provide indicative sizing of storage facilities such as pollution control dams. The monthly time step can also be used to provide an indication of the capacities of the pumping pipelines infrastructure needed to convey the water between storage elements. A daily time step model allows for a more accurate determination of the pollution control dam sizes and pump/pipeline capacities. A daily time step was used for this model.

The objective of the water balance modelling is to estimate the volumes of water that will be generated by the proposed activities, including effluent water and surface runoff from the dirty areas. This is assessed together with the water demands on the site to determine whether the site will operate with a water surplus or deficit and to determine the storage capacity required to ensure legal compliance in terms of prevention of spills from the site. The water balance modelling is therefore a key input to the overall water management strategy for the site. The model was used to determine the water treatment capacities required from the Return Water Dam.

The approach and algorithms used to model the different elements are described in the following sections.

8.1 Climate

8.1.1 Stochastic daily rainfall generation

Water management on an open cast mine is further complicated by the unpredictable and seasonal character of rainfall. A stochastic daily rainfall generator is a model capable of reproducing key statistical characteristics of historic records at not only a daily level but also monthly levels. The stochastically generated daily rainfall record can be used to assess the performance of the management system for future scenarios. This allows different sequences of daily rainfall to be generated within the model to determine the probability of spill and failure of supply for a particular water management strategy.

A daily time step stochastic rainfall generator has been developed in the model. The parameters of the stochastic model are determined by fitting the model to a measured daily rainfall record considered to be representative of the area. Record from Roodepoort rain gage was used to calibrate the stochastically daily rainfall generator model.

The following statistics were compared to test the fit of the stochastic model to the measured daily rainfall depths:

- The monthly averages shown in Figure 12
- The probability distribution of the measured and stochastic daily rainfall depths as shown in Figure 13
- The average number of rainfall days in each month shown in Figure 14
- Distribution of the number of days of consecutive rain shown in Figure 15
- Comparison of the number of days between rainfall events shown in Figure 16

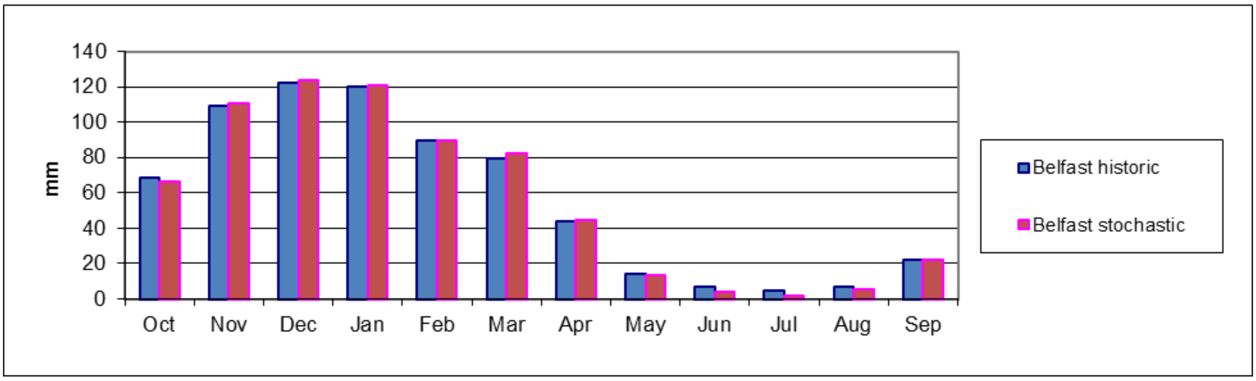

Figure 12: Comparison of stochastic and measured average monthly rainfall depths

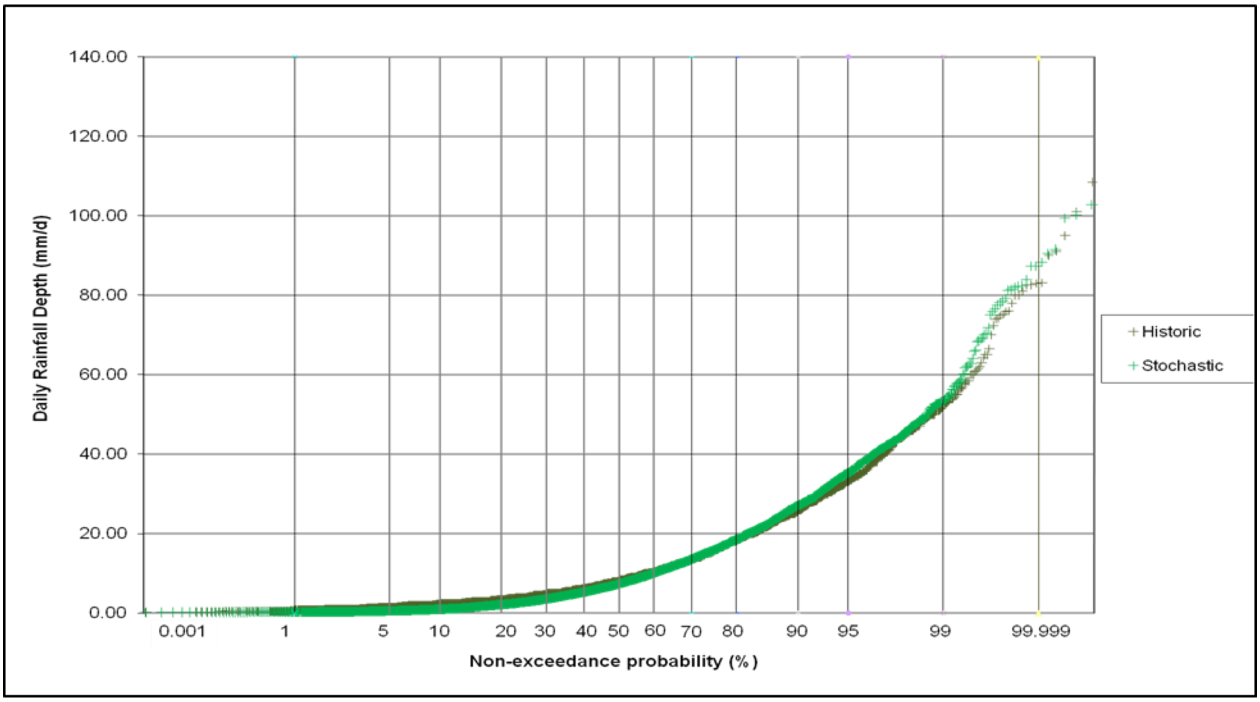

Figure 13: Comparison of stochastic and measured daily rainfall depths

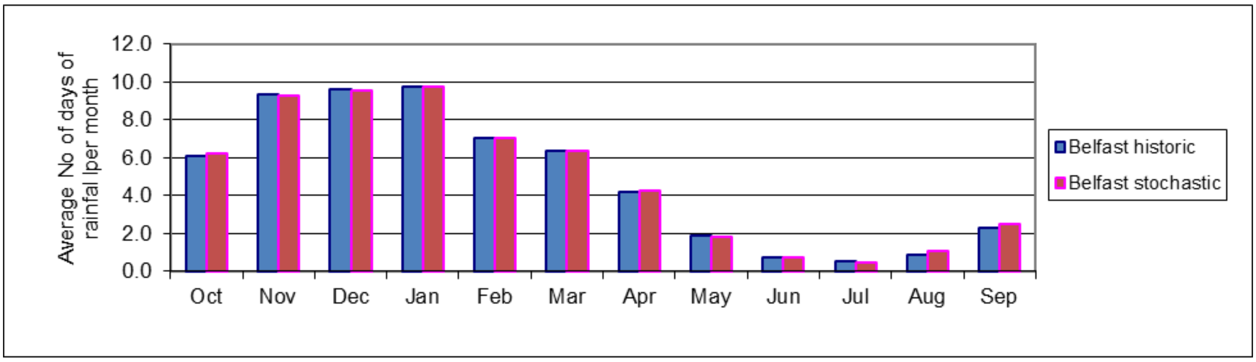

Figure 14: Comparison of the average number of days of rainfall in each month

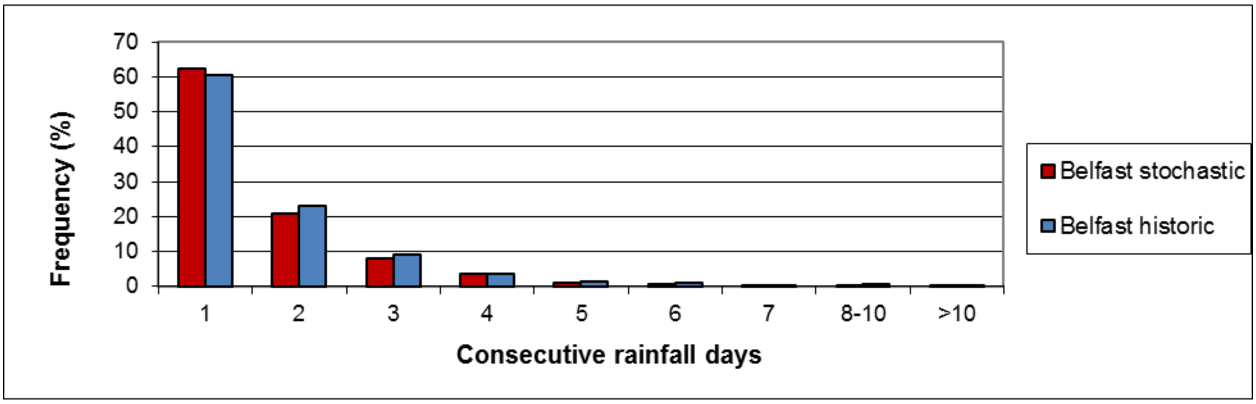

Figure 15: Comparison of distribution of the number of days of consecutive rain

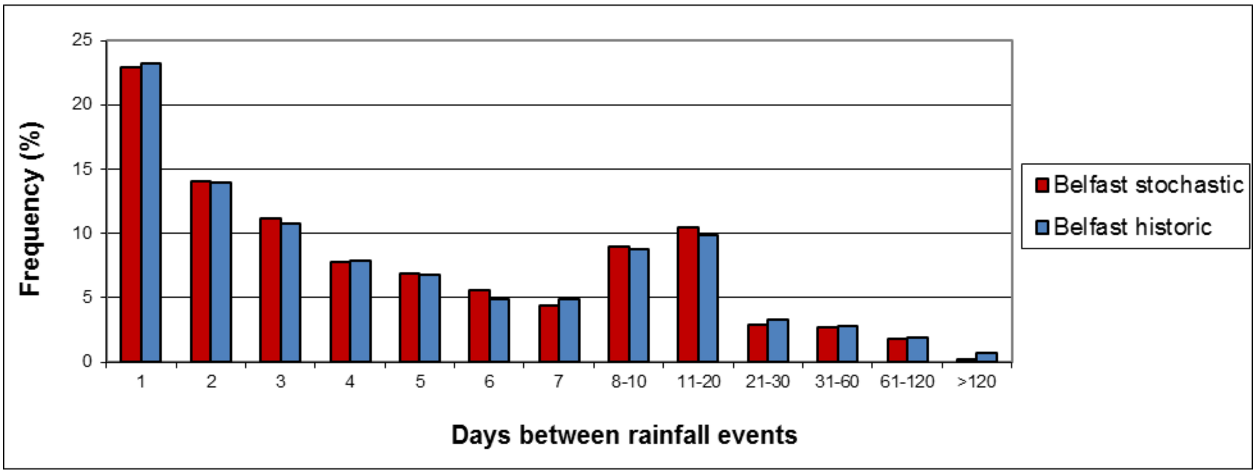

Figure 16: Comparison of days between rainfall events.

The stochastic model was run to generate 1000 sequences of 365 days each. The plots show that the stochastic model fits the measured data reasonably well.

The distribution of the daily rainfall depths for each day is shown in Figure 17. The plots show that the stochastic model is generating a range of daily depths and the seasonality is well captured. The annual rainfall totals simulated ranged from 460 mm in a dry year to 930 mm in the wet year.

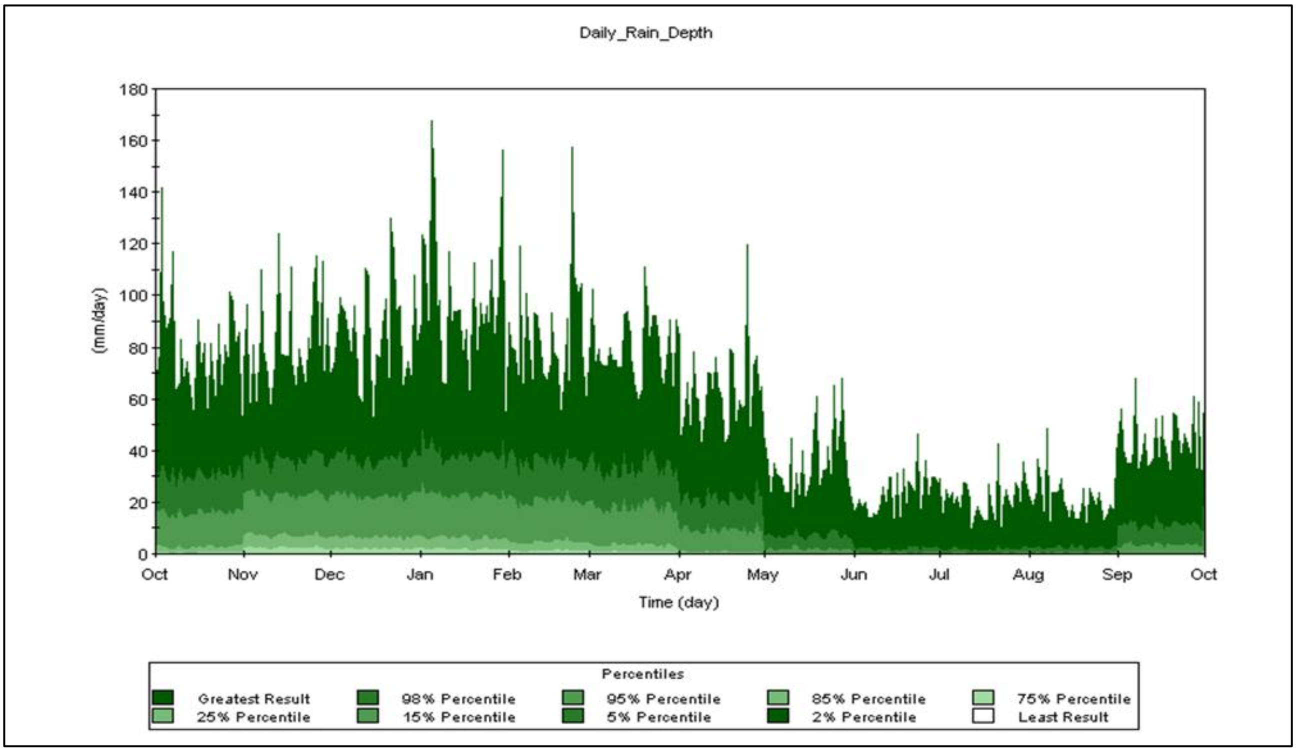

Figure 17: Plot of percentiles of stochastic daily rainfall depths for the 1000 sequences

8.2 Assumptions and Limitations

The following key assumptions and information have been used:

- Runoff from the external catchment draining towards mine surface infrastructure area will be diverted, minimising the volume of water reporting to the PCDs.
- Reserve flows for the Farm Dam were obtained from a high level yield study. The mean monthly flows were calculated using Spatsim for the net X11D quaternary catchment (590 km^2). The X11D values were then proportioned based on the Farm Dam catchment area (0.10 km^2). The runoff values were then calibrated based on the WR2005 Mean Annual Runoff (MAR) values (Middleton & Bailey, 2005). The calculated mean monthly reserve flows are shown in the Table 26. As mentioned before this was a high level study, therefore the values are conservative. It is recommended that full reserve determination study be carried out so as to accurately predict the reserve flows from the Farm Dam.

Table 26: Calculated Mean Monthly Reserve Flows for the Farm Dam

Month	Mean Monthly flows (m3/s)
January	0.018
February	0.012
March	0.007
April	0.006
May	0.004
June	0.003
July	0.003
August	0.002
September	0.002
October	0.002
November	0.009
December	0.020

- The opencast mining areas used for the modelling are based on the LOM plans provided by the mine.
- Plant water requirements for the Belfast plant commissioning was provided by the mine:
  - First fill amount: (3069m^3 to fill the plant and 2931 m^3 buffer in process water dam);
  - Cold commissioning (2months): 2880m^3 for 60days;
  - Hot commissioning (3months): 58320m^3 for 90days;
  - Steady state: 918m3/daily.
- Pre-stripping starts 3 months before active mining.
- Areas based on average strip width of 130m-180m:
  - Pre-strip: 1 strip;
  - Active workings area: 1 strip;
  - Spoils: 3 strips;
  - Rehabilitated area: remainder of mined area.
- Rehabilitation of entire pit completed 1 year after last active mining.
- Areas interpolated between start and end of year values.
- Recharge of the Rehabilitated area based on 300mm cover.
- All surface runoff from rehabilitated area will be directed away from pit (free drainage).
- Spoils storage:

- Based on volume between plane 5 meters below decant point (to prevent weathered zone seepage) and bottom of coal seam. Only the volume in spoils and rehabilitated areas were considered and not active pit.
- Uses void ratio of 0.25
- No Groundwater inflow data available.

There is a number of water storage facilities located on site. In order to model the volume stored and capacity available of each one of these facilities (taking into account the precipitation and evaporation volumes) the maximum capacities and catchment areas are required. The properties of the storage facilities are shown in Table 27 below:

Table 27: Storage facility capacities

Dam	Description	Catchment (m2)	Capacity (m3)	Freeboard (m)	Dam Volume incl. Freeboard (m3)
D1	Farm Dam	103650	138 200	Not known	Not Known
D2-1	Mine Haul roads	93 300	7 000	0.8	10 620
D2-2	Storm water dam	167 650	19 000	0.8	24 400
D2-3	Discard Dump Storm water	525 114	42 000	0.8	52 900
D3	Process Water Dam	N/A	10 846	0.8	15 100
D4	Plant Storm water Dam	385 775	31 200	0.8	39 600
D5	Return Water Dam	N/A	520 000	0.8	585 050

8.3 Operational philosophy

The overall water reticulation network schematic for Belfast is presented in Figure 18, indicating the connectivity of the network elements. The following activities are included:

- Water is required for dust suppression. Water for dust suppression is abstracted from the Return Water Dam D5 and D2-2.
- Dam D2-2 receives the in-pit storm water, which is then pumped to the Return Water Dam D5.
- Return Water Dam D5 water is the pumped to the Process Water Dam D3 to supply the plant.
- Dewatering of the backfilled spoils will report to the Return Water Dam D5 so as to prevent water from decanting into the Klein Komati, to prevent water from overflowing into the pit as well as to supply water to the plant.
- Mine water will be treated at the Return Water Dam D5 prior to release into the environment. The treatment plant was sized assuming package plant modules of 2000 m^3/d capacity that can be added up as treatment is required.
- 6 boreholes will pump water to Return Water Dam D5 so as to meet the plant water requirements. If the borehole water is insufficient an external water source will need to be identified.
- Farm Dam D-1 was identified as a water source. The water from the Farm Dam will be pumped to Return Water Dam D5 for use in the plant. A high level study on the natural yield of the Farm Dam was carried out. The Farm was modelled to first meet the natural requirements thereafter any excess water will be pumped to Return Water Dam D5.
- Water for potable use is abstracted from boreholes and pumped to the potable reservoir for use.

- Dirty water runoff from the plant workshop, diesel depot and tip and crusher ramp is received by Stormwater Dam D2-2. The water is then pumped to Return Water Dam D5 at a controlled manner for use in the plant.
- Dirty water runoff from the plant area reports to Plant Stormwater Dam D4. Water is pumped to Return Water Dam D5.
- Dirty runoff from the mine haul roads are directed to the Stormwater Dam D2-1. This water is then directed towards Stormwater Dam D2-2 for re-use.
- Stormwater Dam D2-3 accommodates the dirty water inflow from the discard dump. The water is then gravity fed to Stormwater Dam D2-2 in a controlled manner.

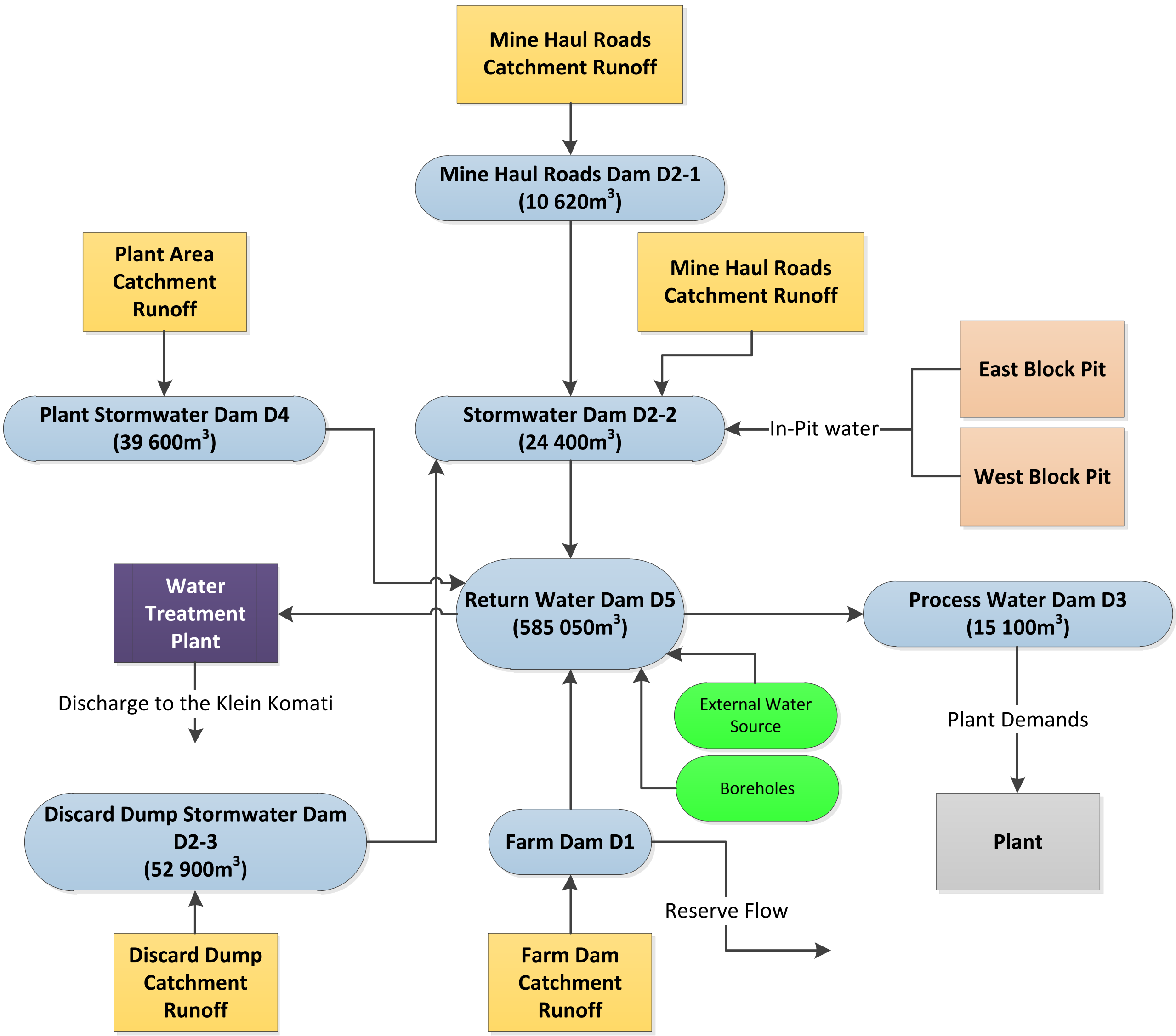

Figure 18: Simplified Water reticulation network schematic for GGV

8.4 Limitations

By their nature, models are theoretical estimates of natural phenomena that are too complex to be derived exactly. It is likely that there will be variations in the actual flows when compared to the predicted flows. This can only be solved by the calibration of modelled data with measured data; this will result in more reliable estimates of the water make and runoff volumes.

8.5 Results

The objective of the water balance modelling is to estimate the volumes of water that will be generated by the proposed activities, including effluent water and surface runoff from the dirty areas. This is assessed together with the water demands on the site to determine whether the site will operate with a water surplus or deficit and to determine the storage capacity required to ensure legal compliance in terms of prevention of spills from the site. The water balance modelling is therefore a key input to the overall water management strategy for the site. The model was used to determine the water treatment capacities required from the Return Water Dam.

8.5.1 Water Treatment Requirements

The model was run to determine when and if water treatment is required for the Return Water Dam. A previous study carried out by Golder concluded that there insufficient capacity for excess water to be stored in the backfill of the pits, therefore the excess water needed to be stored in Return Water Dam D5.

The Return Water Dam is a vital component of the mine water system as shown in the Figure 19 below. The Dam supplies water to the Process Water Dam, this is critical as the plant water demand must be met from the water available in the Return Water Dam. The Return Water Dam obtains water from the pits via Stormwater Dam D2-2, the Farm Dam D1 as well as an option of sourcing water from boreholes or external sources. The first scenario that was run in Goldsim only considered the rainfall, pit return water as water sources to the Return Water Dam. This was done to determine if the Return Water Dam has sufficient capacity to meet the on-site water requirements. Given the unpredictability of rainfall, the system needed to be assessed under varying rainfall conditions, thus using rainfall sequences generated from the stochastic rainfall generator. The model was run using Monte Carlo simulation. The model is run multiple times (realizations) and simulates the water system for various rainfall sequences and stores the results for each realization.

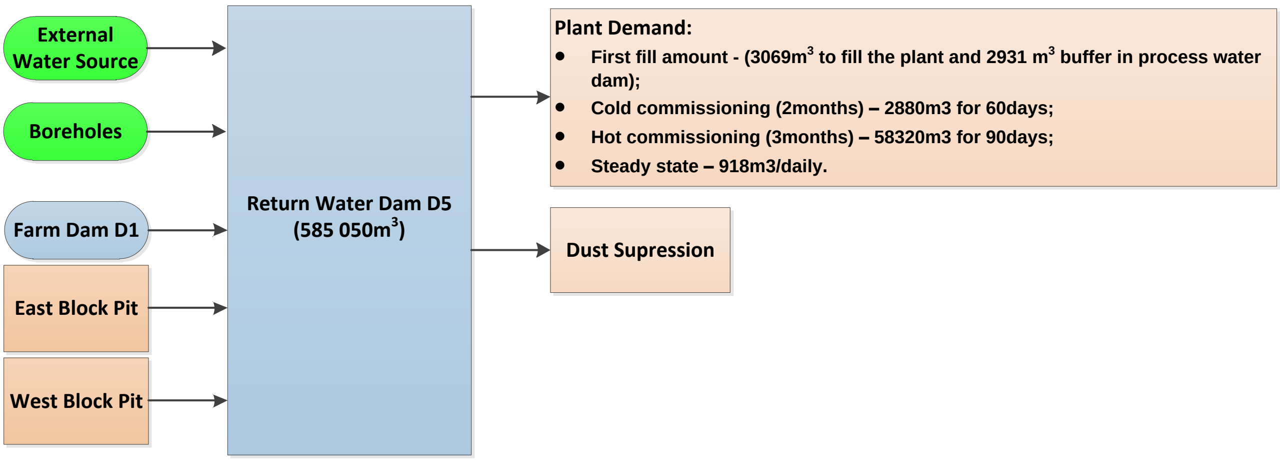

Figure 19: Sources of water and demand centres of the Return Water Dam

The stochastic results from the analysis of the daily volumes in the Return Water Dam are shown in Figure 20. The results are shown as percentiles over the life of mine; the percentiles indicate how the system behaves during high and low rainfall periods, with the mean indicating the most likely occurrence. Figure 21 shows the stochastic results in more detail. The figures show that there is a possibility of a shortage of water during the first year of mining.

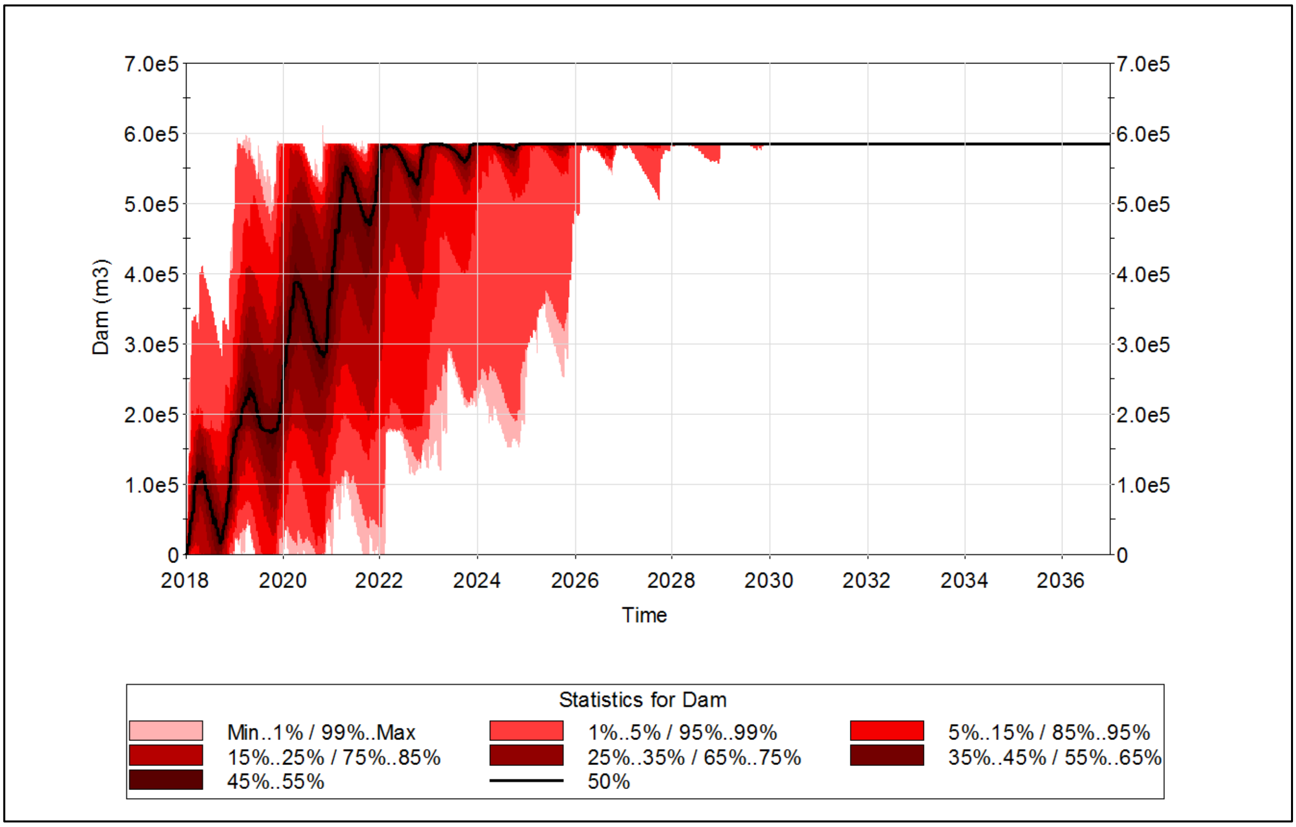

Figure 20: Stochastic Return Water Dam D5 daily volumes (m^3)

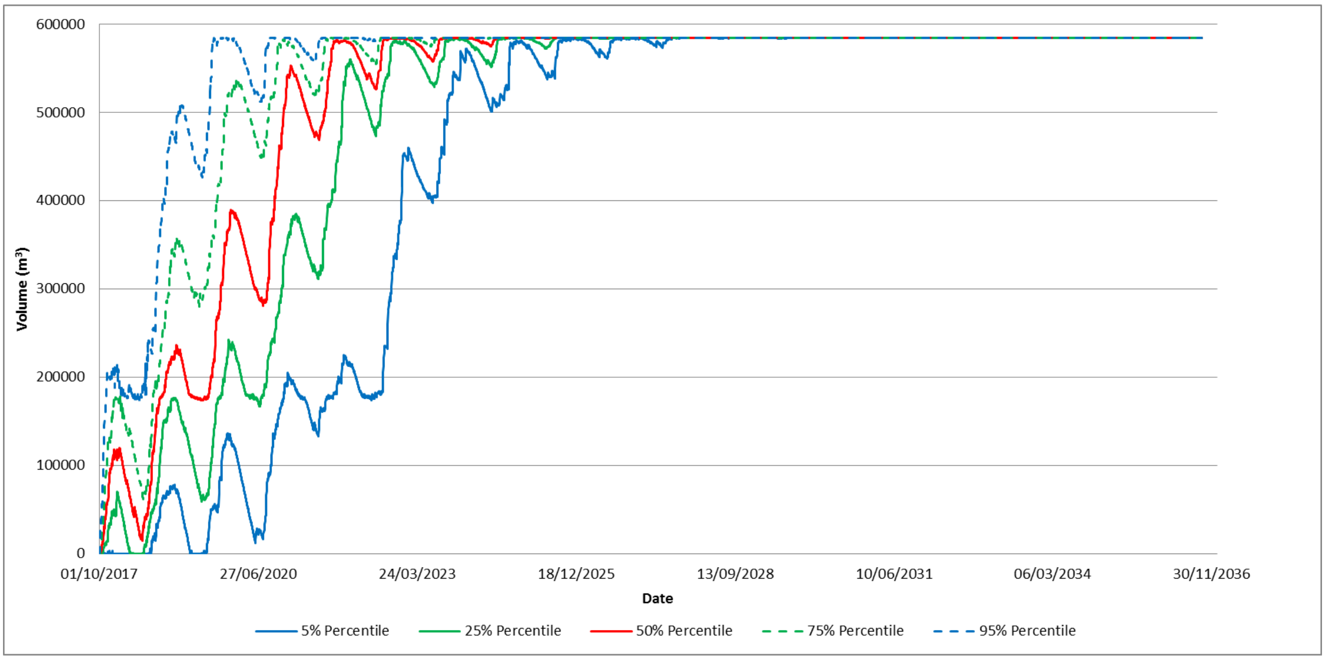

Figure 21: The 5%, 25%, 50%, 75% and 95% percentile daily volumes (m^3)

The second scenario that was run included the Farm Dam, boreholes and the external water source to address the shortage of water shown in the previous scenarios results. This scenario allows for the dam to fill more rapidly allowing for the Return Water Dam demands to be met within the first year. The results show that the Dam will take approximately 2 years to fill up; however there will be enough water to meet demands during the first year. The stochastic results from the analysis of the daily volumes in the Return Water Dam for the second scenario are shown in Figure 22. The results show that the Dam will spill as the maximum freeboard capacity has been achieved (585 050 m^3). Therefore treatment will be required.

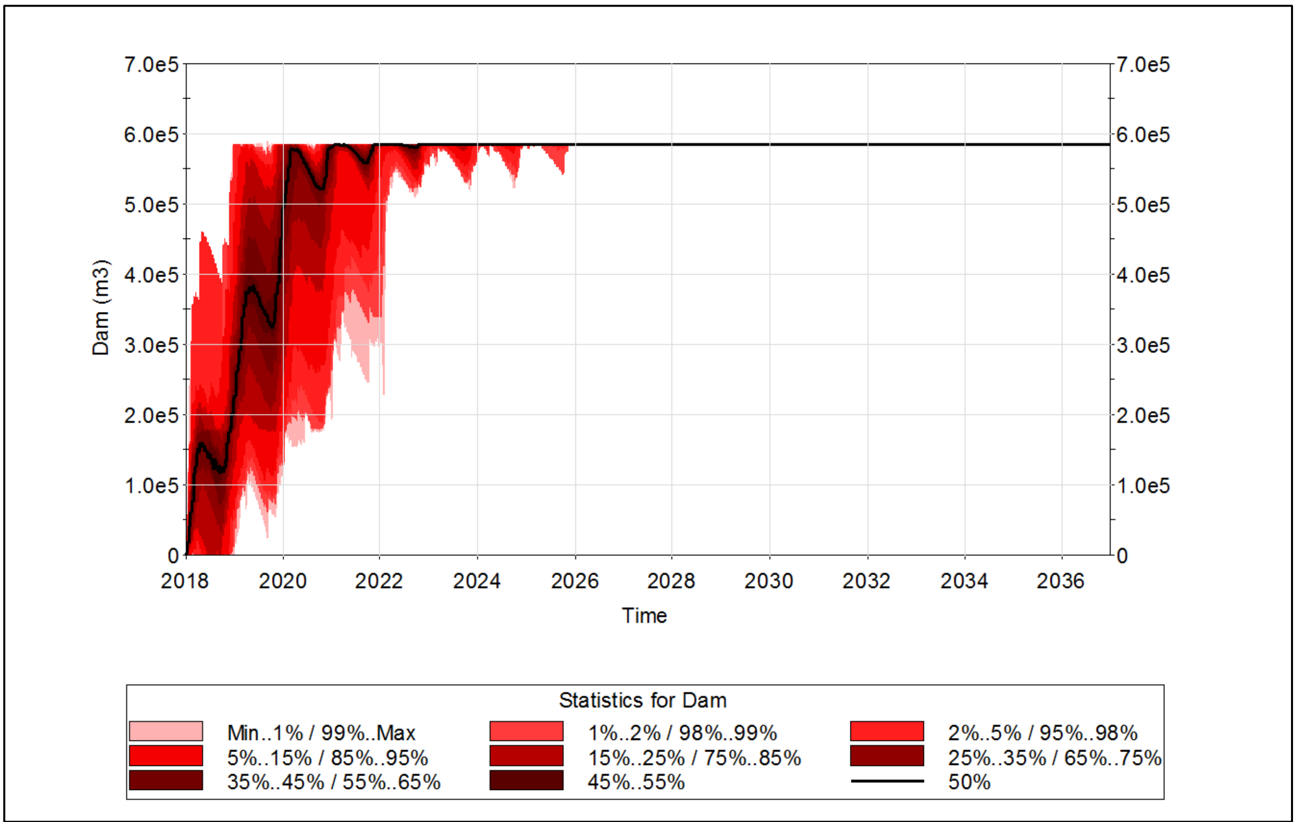

Figure 22: Stochastic Return Water Dam D5 daily volumes (m^3) for the second scenario

Sizing of the treatment plant was carried out by adding an additional module to the model. The water treatment module will activate when the Dam is at risk of spilling (90% of the Dam capacity was assumed as the trigger).The water treatment module was based on the assumption that the minimum water treatment capacity will be 2000m^3/day (Packaging Plant); this allowed for the flexibility to increase the treatment plant capacity when required. The model was then run to determine the required treatment plant capacity as well as the date when the first treatment plant will be required to be implemented.

The proposed date of implementation of the first 2000m^3/day water treatment plant module is shown in the Table 28 below, based on the mine starting in 01/10/2017. The maximum treatment plant capacity was calculated to be 4000m^3/day. The stochastic results were used to determine the date of implementation; the actual date will occur between the 50th and the 98th percentile results.

Table 28: Date of implementation of the water treatment plant

Percentile Results	Implementation of first 2000m3/d	Implementation of second 2000m3/d
98th Percentile (extreme scenario)	19/09/2018	26/06/2019
50th Percentile (most likely)	23/10/2020	12/04/2021

Another important consideration is that of the operational volume of the Return Water Dam so as to maintain its ability to meet the demands, treat excess water as well as having a large enough buffer to contain large rainfall events feeding into the water network. This is important to study this volume as it effects both compliance with Regulation 704 (of the National Water Act), in terms of spillages to the environment as well as the treatment plant capacity. The treatment plant capacity must be kept at a minimum to limit its influence on the CAPEX (Capital expenditure). The results show the operational volume (which is able to meet all the requirements) as 20% of the Dam capacity (117 010 m^3) as shown in Figure 23. The treatment capacity was maintained at a maximum of 4000m^3/d.

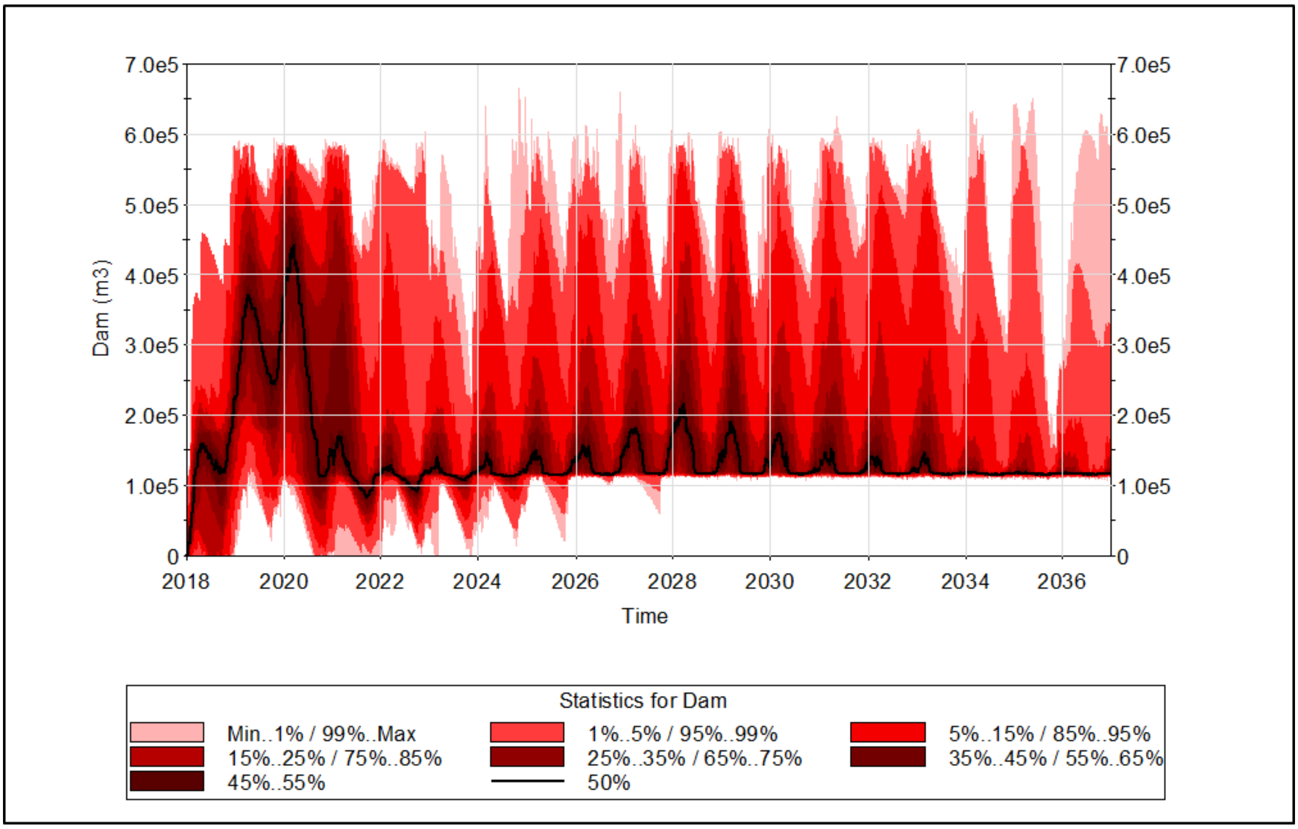

Figure 23: The operational Return Water Dam volume, after water treatment has commenced.

It is proposed that the mine carry out this study on an annual basis. This will allow for better results as there will be monitored data once the mining commences for calibration of the model i.e. measured daily rainfall and dam volumes. If done annually it will allow for a more accurate prediction of the required date of implementation of the water treatment plant. This should allow for enough lead time to start the detailed design and construction.

8.5.2 Water Balance Results

Multiple scenarios are required to fully understand how the system behaves. The first aspect to consider is the duration that the model is run. The mine system is changing with time and therefore it is essential to see how the system behaves at different times within the LOM. Therefore the water balance results are shown for the first 5 years, 10 years and finally for the full LOM. The maximum results are shown as well.

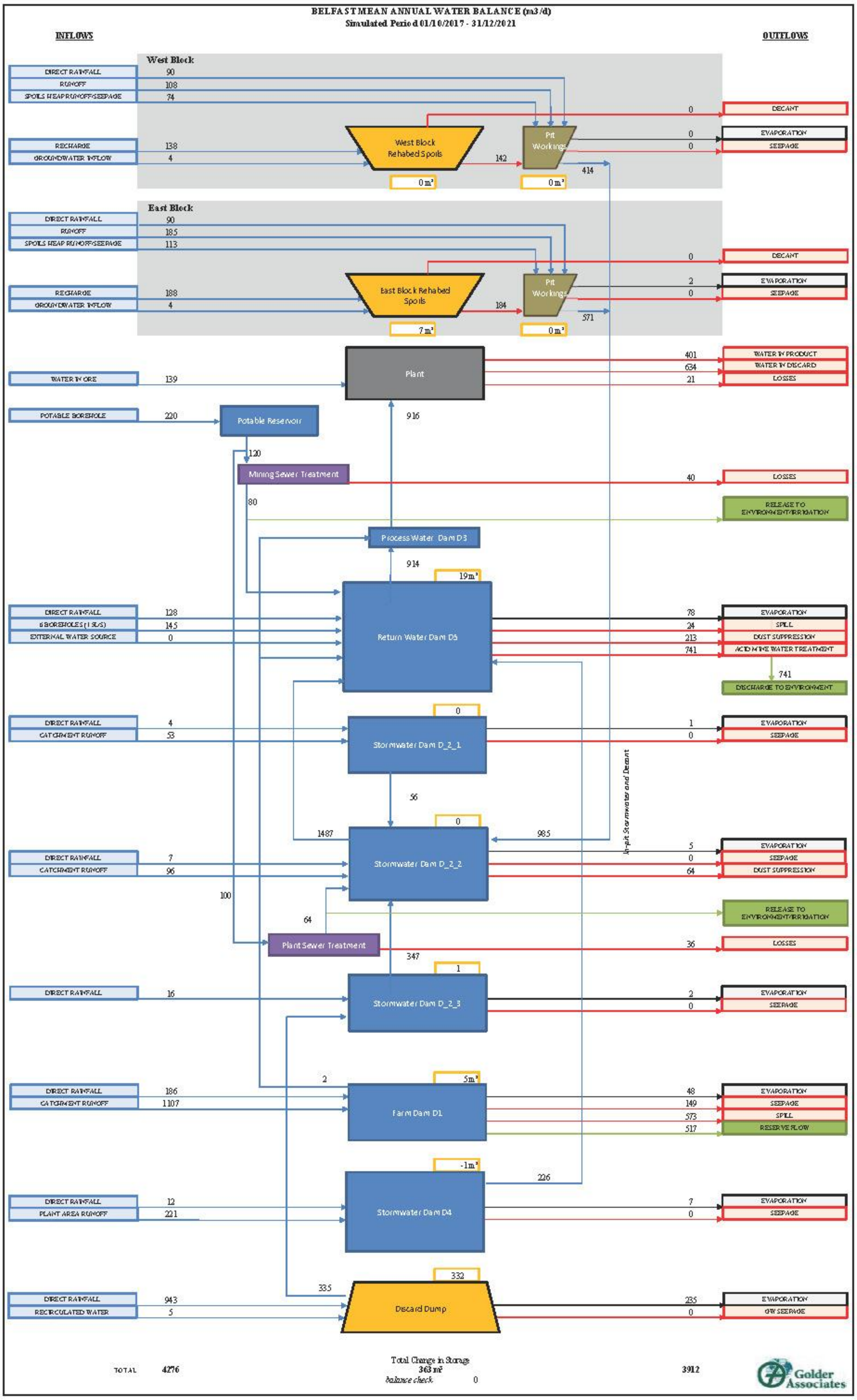

Figure 24: The water balance schematic for the first 5 years

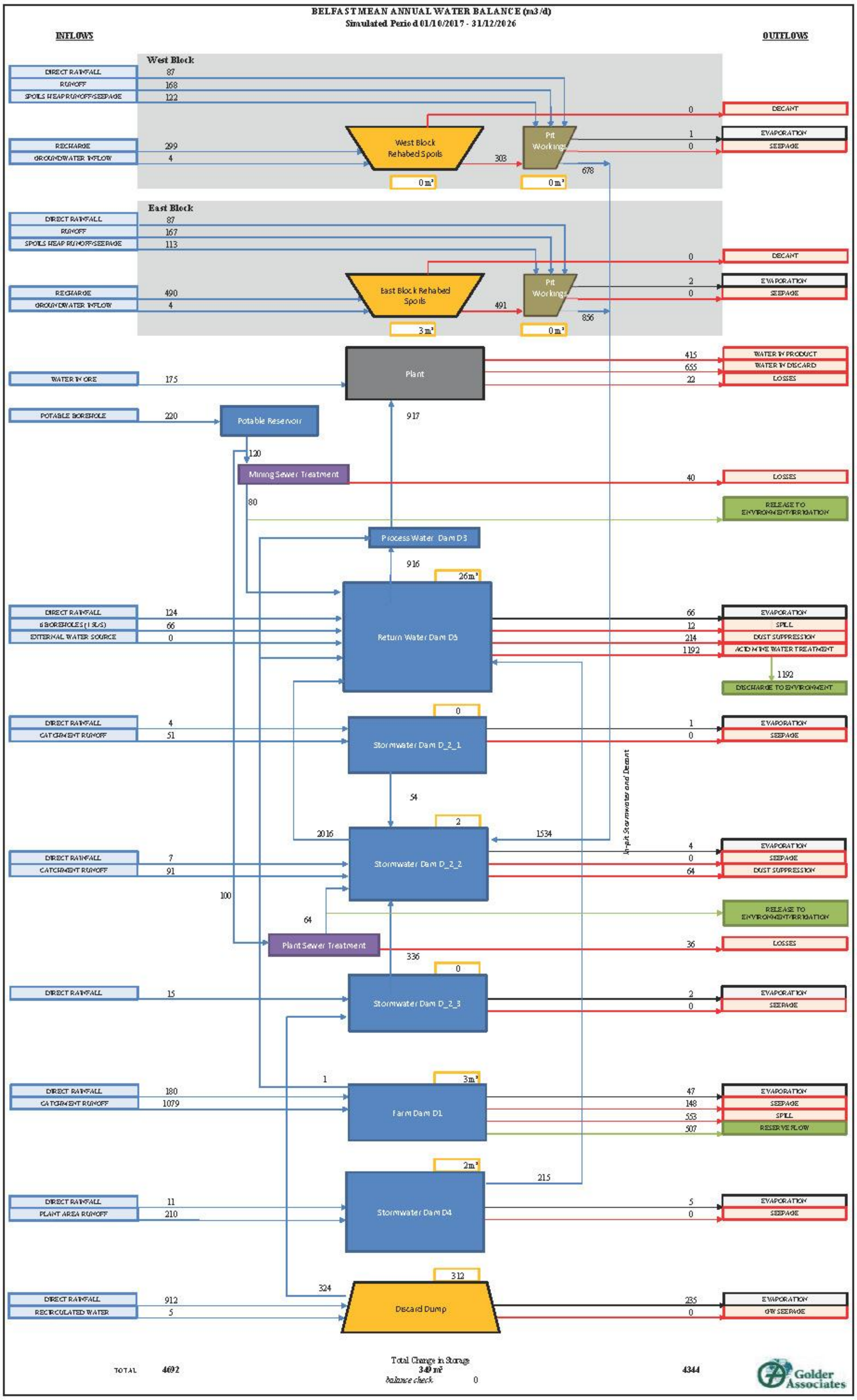

Figure 25: The water balance schematic for the first 10 years

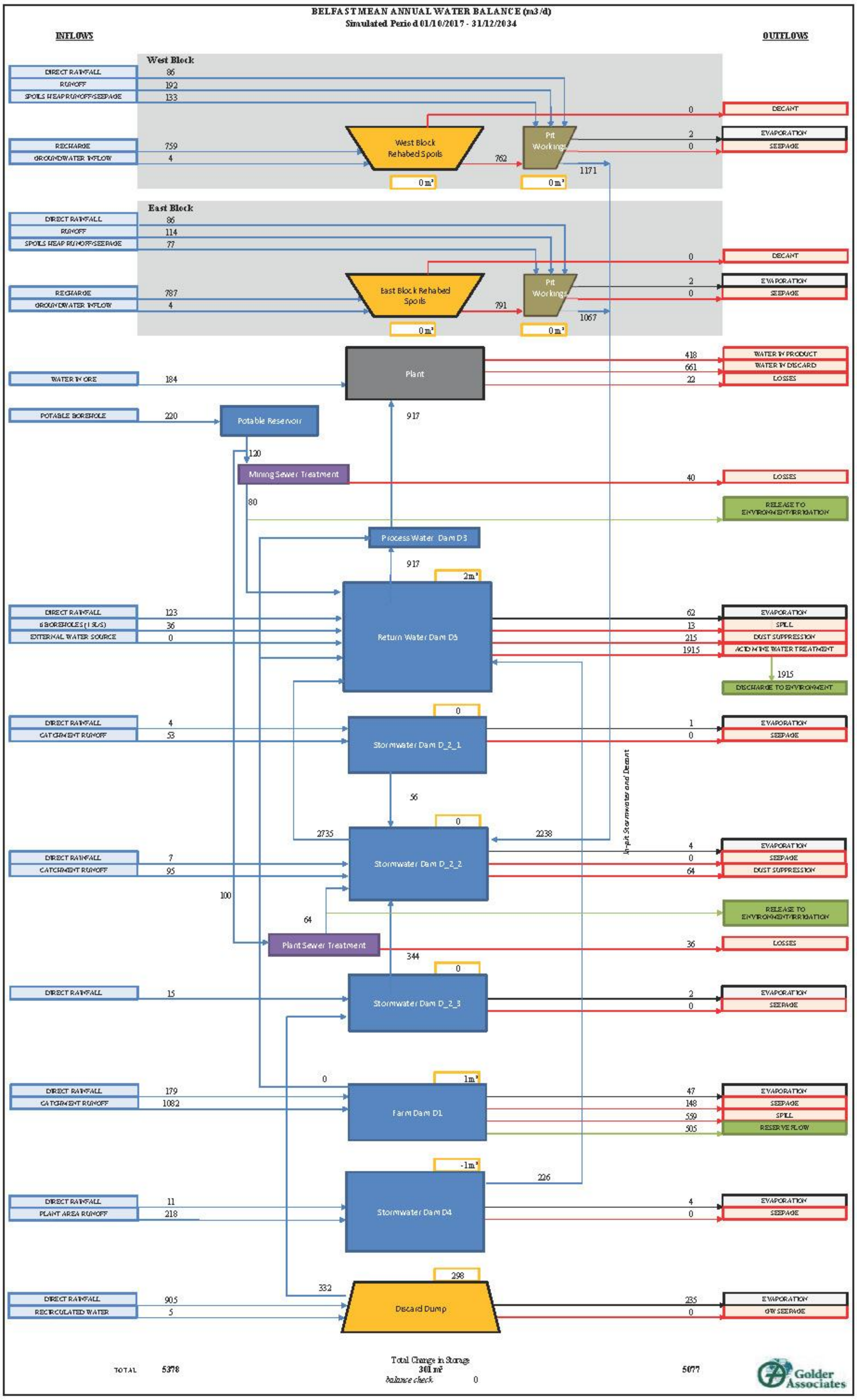

Figure 26: The water balance schematic for the full life of the mine

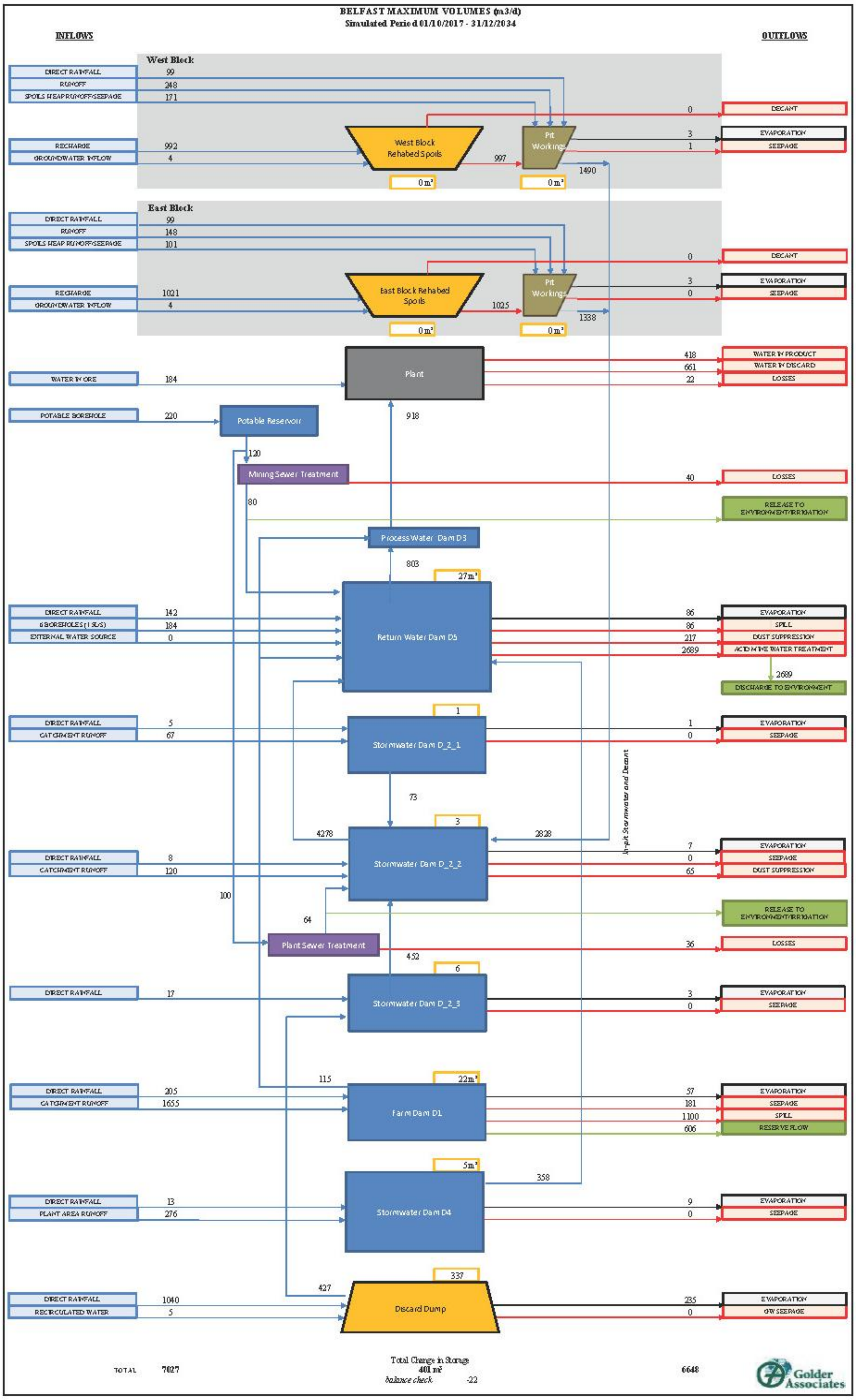

Figure 27: The maximum volumes over the full life of the mine.

9.0 WATER QUALITY IMPACTS OF PROPOSED WASTEWATER TREATMENT PLANT DISCHARGE

In order to assess the future impact of the proposed discharge on surface water resources with the region of Belfast Coal Mine, the most suitable perennial stream, Klein Komati, was identified as the likely receiving stream. The Driehoek Spruit., a non-perennial stream, confluences with Klein Komati approximately 3.6 km downstream of the discharge point.

9.1 Evaluation of Resource Water Quality Objectives

In-stream Water Quality Objectives are required for the river against which to compare the measure instream water qualities. No water quality objectives are available for these rivers, however, ecological water requirements and reserve has previously been conducted (DWA, 2006). The results from the ecological specifications and water user requirements derived in this study were used in the evaluation of the Resource Water Quality Objectives (RWQO) to use. The South African Water Quality Guidelines (DWAF, 1996) for the recognised water users were used as a basis.

A 2011 study conducted by the DWA, entitled “Planning Level Review of Water Quality in South Africa”, has developed national RWQOs (Table 29) which are applicable anywhere in the country. These were compared to the RWQOs values previously developed in the 2009 Golder report), developed using the Targert Water Quality Guidelines (TWQG).

Table 29: National Generic Resource Water Quality Objectives (DWA, 2011)

Variable	Units	Bound	Ideal	Sensitive user	Acceptable	Sensitive user	Tolerable	Sensitive user
Alkalinity ($CaCO_3$)	mg/l	Upper	**20**	AAq	**97.5**	AAq	**175**	AAq
Ammonia (NH_3-N)	mg/l	Upper	**0.015**	Ecological	**0.044**	Ecological	**0.073**	Ecological
Calcium (Ca)	mg/l	Upper	**10**	Dom	**80**	BHN	**80**	BHN
Chloride (Cl)	mg/l	Upper	**40**	In2	**120**	In2	**175**	In2
EC	mS/m	Upper	**30**	In2	**50**	In2	**85**	Ecological
Fluoride (F)	mg/l	Upper	**0.7**	Dom	**1**	Dom	**1.5**	Dom
Magnesium (Mg)	mg/l	Upper	**70**	Dom	**100**	Dom	**100**	Dom
NO_3 (NO_3-N)	mg/l	Upper	**6**	AIr	**10**	AIr	**20**	AIr
pH	units	Upper	**≤ 8**	In2	**<8.4**	In2		
		Lower	**≥6.5**	AIr AAq In2	**>8.0**	AIr AAq In2		
Potassium (K)	mg/l	Upper	**25**	Dom	**50**	Dom	**100**	Dom
PO_4-P	mg/l	Upper	**0.005**	Ecological	**0.015**	Ecological	**0.025**	Ecological
SAR	mmol/l	Upper	**2**	AIr	**8**	AIr	**15**	AIr
Sodium (Na)	mg/l	Upper	**70**	AIr	**92.5**	AIr	**115**	AIr
SO_4	mg/l	Upper	**80**	In2	**165**	In2	**250**	In2
TDS	mg/l	Upper	**200**	In2	**350**	In2	**800**	In2
Si	mg/l	Upper	**10**	In2	**25**	In2	**40**	In2

BHN-Basic Human Need; *Dom*-Domestic Use; *AIr*-Agriculture Irrigation; *AAq*-Agriculture-Aquaculture; *In2*-Industrial-Category 2.
Highlighted rows indicate parameters incorporated into the final RWQO selected.

Table 30: Quality guidelines used to assess water quality status in the 2009 Golder study

Water Quality Variable	Most Stringent user	Water Quality Guideline Concentration (TWQR)
Chloride	Industrial: Category 1	20 mg/l
Ammonia as N	Aquatic ecosystem	≤0.007 mg/l N
Electrical conductivity	Industrial: Category 1	15 mS/m
Nitrate as N	Domestic: Class 0	6 mg/l N
pH	Domestic: Class 0	6 – 9 pH units
Phosphorus as P (inorganic)	Aquatic ecosystem	<0.005 mg/l
Sodium	Irrigation	≤70 mg/l
Sulphate	Industrial: Category 1	30 mg/l
Magnesium	Domestic: Class 0	30 mg/l
Alkalinity	Industrial: Category 1	50 mg $CaCO_3$/l
Total Dissolved Solids	Industrial: Category 1	100 mg/l
Potassium	Domestic	25 mg/l
Manganese	Industrial: Category 1	0.05 mg/l
Iron	Domestic/Industrial Cat1	0.1 mg/l
Aluminium	Domestic	0.15
Silicone	Industrial: Category 1	5 mg/l

Highlighted rows indicate additional parameters which have been included based on the user category in this study

For the purposes of this study, these RWQO's have been developed at a low to medium confidence. The derivation of water quality guidelines was based on the following protocol:

- Identify the recognised water users present.
- List the water quality requirements for each user in terms of the water quality variables of concern to the particular user.
- Analyse the different requirements with respect to each water quality variable and identify the most sensitive user.

The most sensitive user requirement then determines the water quality guideline value for a specific variable of concern.

9.2 Identification of water users

Downstream water user identification was conducted as part of a 2009 Golder surface water assessment. These included:

- Domestic use (Class 1);
- Industrial use (Class 1);
- Power generation;
- Irrigation; and
- Livestock watering.

These users were used in evaluating the set National RWQOs and the selected RWQO in the 2009 Golder study. A set of guidelines (shown below) was thus developed for the Klein Komati for the purposes of this study.

9.3 Selected RWQOs

In the selection of final RWQO to be used, the most stringent values were selected for the water quality variables between the National and the previously developed guidelines. Table 31 details the final selection of RWQOs for the Klein Komati River.

Table 31: Final selected water quality guidelines for the Klein Komati River in catchment X11D

Water Quality Variable	Units	Water Quality Guideline Concentration (TWQR)	Most Stringent user
Physico-chemical parameters			
pH	Units	6 – 9	Domestic
Electrical conductivity	mS/m	15	Industrial: Category 1
Total Dissolved Solids	mg/l	100	Industrial: Category 1
Alkalinity	mg CaCO3/l	50	Industrial: Category 1
Major Anions			
Chloride	mg/l	20	Industrial: Category 1
Nitrate as N	mg/l N	6	Domestic
Sulphate	mg/l	30	Industrial: Category 1
Fluoride (F)	mg/l	0.7	Domestic
Major cations			
Magnesium	mg/l	30	Domestic
Potassium	mg/l	25	Domestic
Sodium	mg/l	70	Irrigation
Manganese	mg/l	0.05	Industrial: Category 1
Calcium (Ca)	mg/l	10	Domestic
Potassium (K)	mg/l	25	Domestic
Organics and Nutrients			
Chemical Oxygen Demand	Mg/l	10	Industrial: Category 1
Ammonia as N	mg/l N	0.007	Aquatic ecosystem
Phosphorus as P (inorganic)	mg/l	0.005	Aquatic ecosystem
Silicone	mg/l	5	Industrial: Category 1
SAR	mmol/l	2	Irrigation
Metals			
Dissolved Iron (Fe)	Mg/l	0.1	Aquatic ecosystem
Aluminium	Mg/l	015	Aquatic ecosystem

9.4 Water quality data analysis: Status Quo

Surface water quality monitoring is currently being conducted by Clean Stream. The most recent data obtained from the client. Samples were taken by Clean Stream for the three streams over the period September 2008 to September 2011. The location of the samples is shown in Figure 28 and description is given in Table 32.

It is to be noted that only four (4) locations measure stream water quality whereas the seven (7) others measure dam water quality. The 4 water quality locations are relevant for this impact assessment and they occur in the receiving stream, Klein Komati. The data encompasses approximately 36 samples per monitoring point, which is sufficient to make statistically relevant inferences.

Table 32: Sample location description

Sample No	Description	River	Latitude	Longitude
Bwq 01	Dam In North-Eastern Corner	Driehoek Spruit	25º 45’ 35” S	29º 59’ 53” E
Bwq 02	Dam In Eastern Corner	Driehoek Spruit	25º 47’ 56” S	30º 00’ 20” E
Bwq 03	Stream Draining Towards The South-East	Klein Komati	25º 50’ 04” S	30º 01’ 37” E
Bwq 04	Stream Draining Towards South	Klein Komati	25º 49’ 41” S	30º 00’ 23” E
Bwq 05	Central Stream Draining Towards Bwq 04	Klein Komati	25º 48’ 48” S	29º 58’ 21” E
Bwq 06	Dam In Northern Corner	Klein Komati	25º 46’ 33” S	29º 57’ 43” E
Bwq 07	Dam In North-Western Corner	Leeubankspruit	25º 46’ 51” S	29º 56’ 40” E
Bwq 08	Dam In Western Corner	Leeubankspruit	25º 48’ 02” S	29º 56’ 02” E
Bwq 09	Stream Draining Towards The South-West	Leeubankspruit	25º 50’ 24” S	29º 56’ 01” E
Bwq 10	Dam To The Northwest of Belfast Nbc		25º 46’ 10” S	29º 56’ 01” E

The only complete raw dataset supplied by the client was water quality results for the 2010/2011 hydrological year. The 2008/2009 and 2009/2010 years did not have raw data for all parameters currently being measured. Hence, the raw data for the selected parameters of concern were used in the overall water quality analyses detailed below. This was deemed sufficient for the assessment of the impacts.

In order to obtain the current status, the 2010/2011 average water quality results (all parameters included) were assessed for compliance with the RWQO shown in Table 33. These results depict the pre-development of the overall project and will, together with the overall statistics, form the basis of the surface water quality impact assessment.

The proposed discharge point 1 is located approximately 1.6 km downstream of BWQ05, and 2.5 km before BWQ04 (Figure 28).

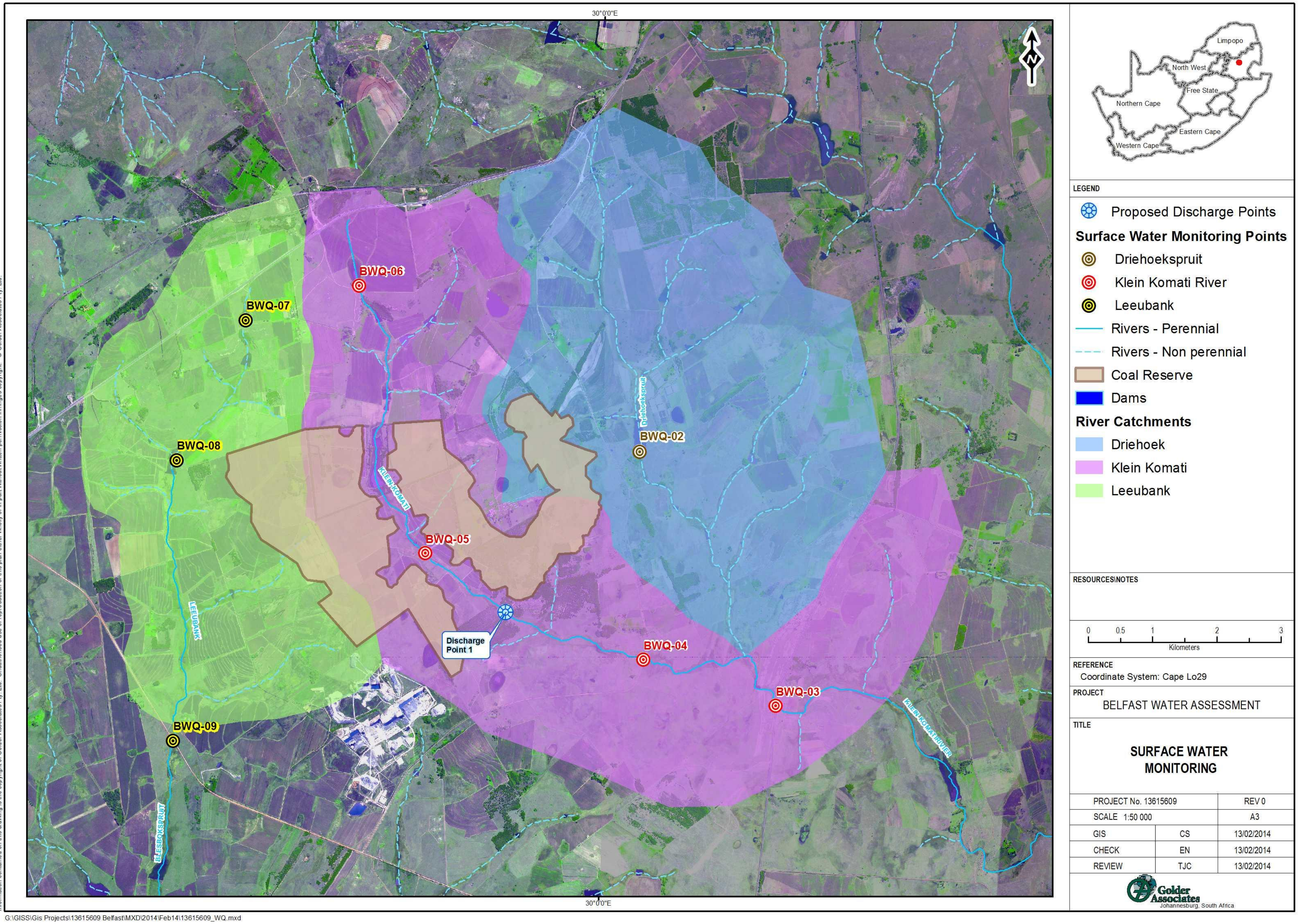

Figure 28: Belfast Coal Mine surface water monitoring points

Table 33: Average water quality results for the Belfast Mine surface water monitoring during 2010/2011 hydrological cycle

Water Quality Variable	Unit	RWQO	Monitoring Point									
			BWQ01	BWQ02	BWQ03	BWQ04	BWQ05	BWQ06	BWQ07	BWQ08	BWQ09	BWQ10
pH*	Unit	6 to 9	6.91	7.23	7.46	7.06	6.73	7.63	7.20	7.21	7.78	7.87
Electrical conductivity	(mS/m)	15	11	8	13	12	14	31	35	18	16	34
Total Dissolved Solids*	(mg/l)	100	53	40	50	54	62	140	147	86	71	165
T hardness	(mg/l)		23.4	17.6	29	26.6	31.8	103	84.1	38.8	46.5	130
Calcium	(mg/l)	10	4	3	5	4	5	16	15	7	8	27
Magnesium	(mg/l)	30	3	2	4	4	5	15	11	5	6	16
Sodium	(mg/l)	70	8	6	7	9	10	14	21	15	10	16
Potassium	(mg/l)	25	3	2	2	2	3	5	4	4	2	2
M Alkalinity	(mg/l)	50	16	16	30	23	25	72	48	24	46	124
Chloride	(mg/l)	20	12	9	8	17	22	44	56	30	13	16
Sulphate	(mg/l)	30	11	6	6	3	2	1	8	10	4	13
Nitrate as N	(mg/l)	6	0.12	0.14	0.11	0.12	0.18	0.36	1.05	0.33	0.29	0.6
Fluoride	(mg/l)	0.7	0.10	-0.02	0.12	0.00	0.07	0.25	0.75	0.32	0.03	0.15
Aluminium*	(mg/l)	0.15	0.15	0.06	0.13	0.37	0.14	0.07	0.13	0.05	0.12	0.21
Iron*	(mg/l)	0.1	*1.06	*1.60	*1.21	0.81	0.99	0.45	*2.77	0.60	0.63	0.28
Manganese	(mg/l)	0.05	0.03	0.05	*1.056	0.10	0.14	0.19	*0.471	0.10	0.04	0.16
Ammonium as N	(mg/l)	-	0.05	0.10	0.11	0.07	0.06	0.21	0.40	0.17	0.12	0.05
Phosphate as P	(mg/l)	-	0.01	0.003	0	0.001	0.01	0.01	0.004	0.01	0.004	0.01
Chemical Oxygen Demand*	(mg/l)	10	49.8	39.1	349	72.7	74.9	328	2542	252	38	48.8
Suspended Solids*	(mg/l)	100	254	1.69	744	35	66.5	696	8578	848	35.8	104
SAR	(ratio)	2	0.8	0.7	0.6	0.8	0.8	0.6	1.0	1.0	0.6	0.6

* Water quality variables with sufficient raw data over the three (3) hydrological years. These were selected for the quantification of impacts.

The water quality results show most non-compliance of the water quality in the Leeubankspruit as compared to the Klein Komati, when comparing them to the RWQO. In the stream of interest, the Klein Komati, the water quality is generally good with moderate flow conditions (quantified below).

Due to the sparse raw data available, only the water quality parameters which were selected for the quantification of impacts were pH, total dissolved solids (TDS), suspended solids (SS), aluminium (Al), iron (Fe) and chemical oxygen demand (COD). Inspection of the average water quality showed that the selection of these parameters was justified as these exhibited an overall exceedance of their respective RWQO levels for at most sites throughout the year.

For the three year period prior to development, the overall spatial water quality variability along the Klein Komati is depicted in Figure 29 to Figure 31. The box plots were generated using a statistical software package (Statistica™ version 9).

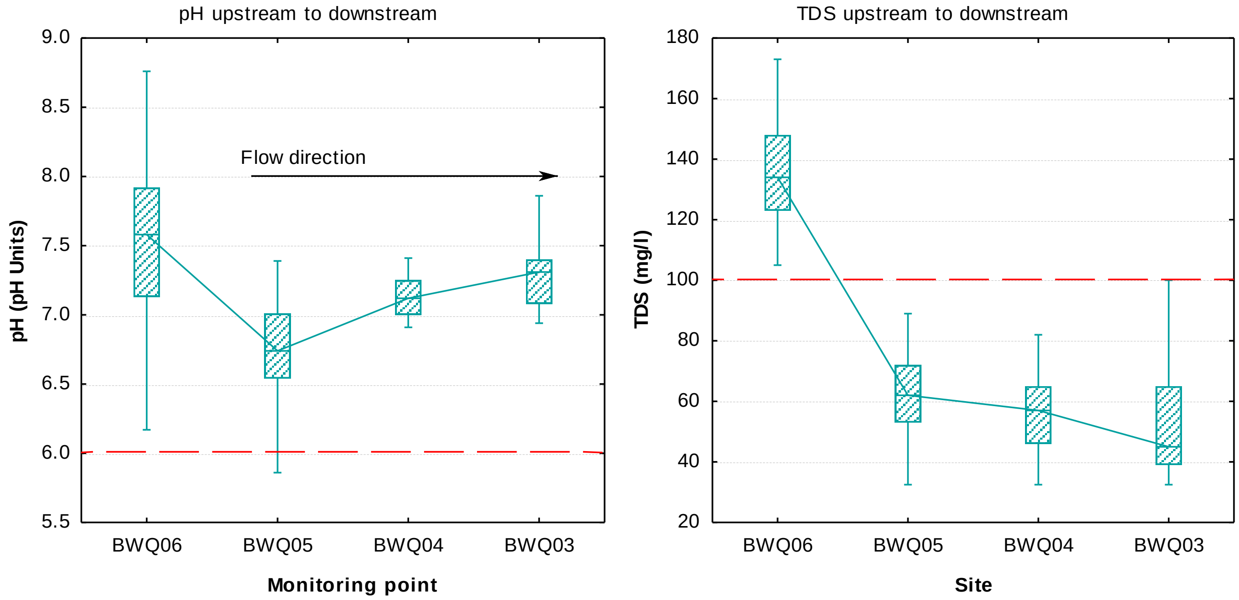

Figure 29: Spatial box plots of pH and TDS showing variability along the Klein Komati (2008 – 2011)

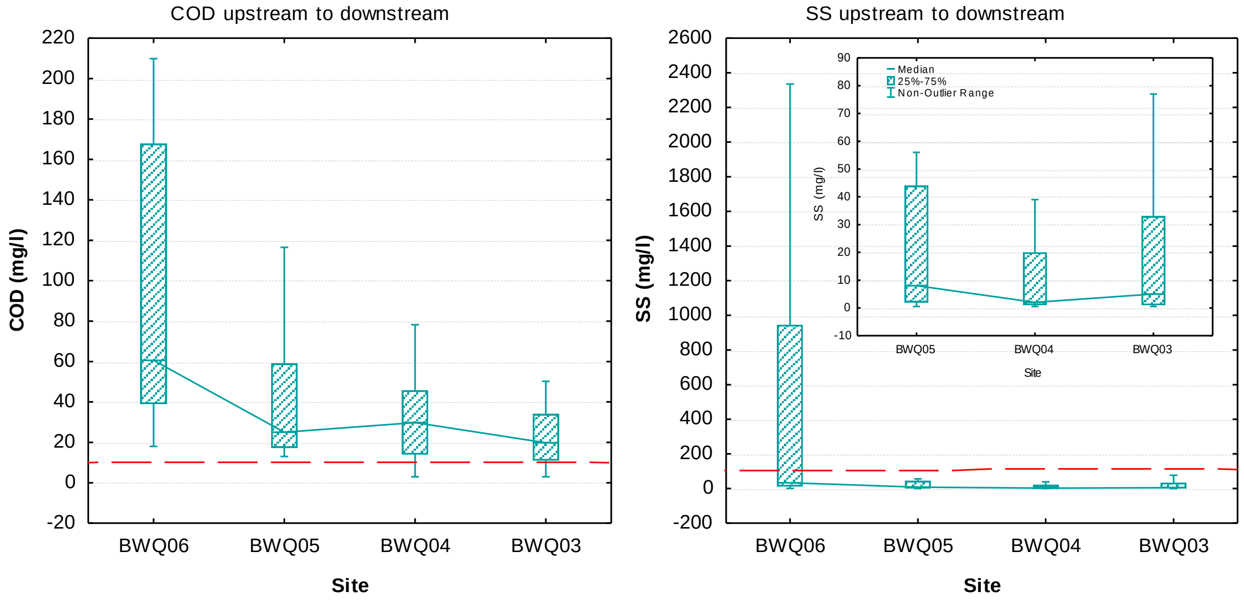

Figure 30: Spatial box plots of COD and SS showing variability along the Klein Komati (2008 – 2011)

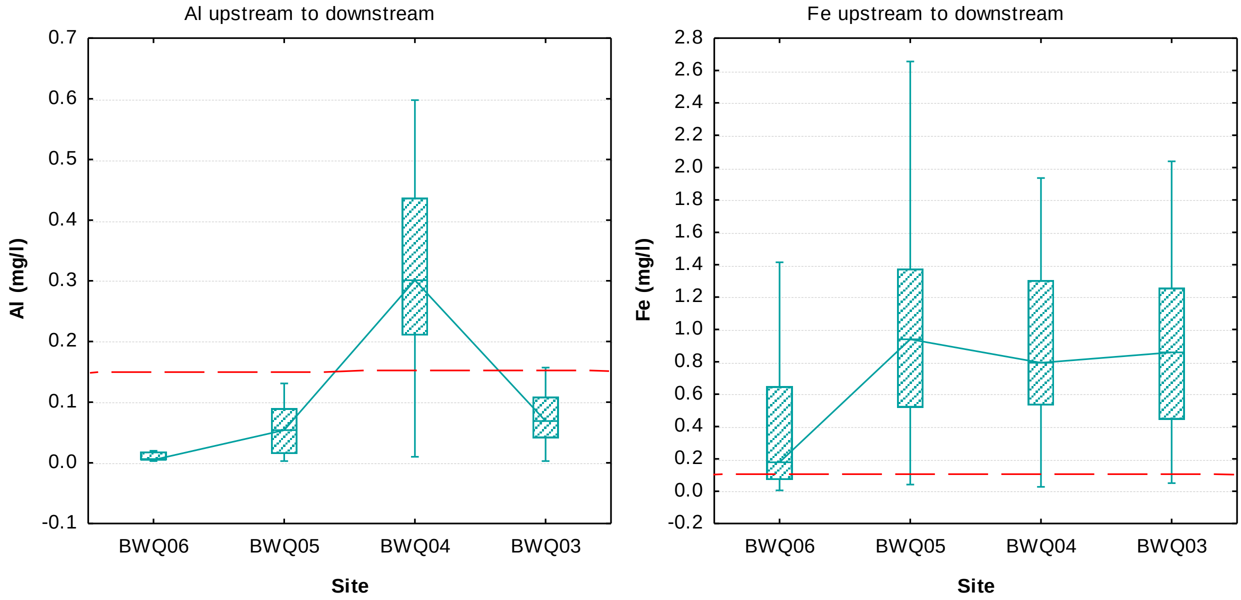

Figure 31: Spatial box plots of aluminium and iron showing variability along the Klein Komati (2008 – 2011)

As mentioned, the monitoring point BWQ06 is actually a dam in the northern corner of the Klein Komati catchment. This dam is associated with upstream neighbouring farm fields, which might explain the high levels of TDS and SS under normal pH conditions (Figure 29 and Figure 30) due to surface run-off. However, the farm and the dam are located outside the mineral rights area of Belfast Coal Mine. COD, as a measure of biodegradable and non-biodegradable organic content, is also prevalent at relatively high levels (40 to 170 mg/l, as high as 210 mg/l) BWQ06 and thus points to the agricultural fields as a source of organic pollution.

An improvement in organic pollution (COD: median of 25 mg/l) arises at BWQ05, together with a total virtual improvement in TDS (median of 62 mg/l) and SS (median of 8 mg/l). This improvement might be due to the presence of approximately five (5) downstream small farm dams and the filtering effect of vegetation between the BWQ06 and BWQ05.

However, this site (BWQ05) also marks the midway point of the mining coal reserves (Figure 28) where mining related pollution such as increasing dissolved metals and possible decreases in pH are likely to occur. This is evidenced by the overall decrease in pH that can occur as levels as low as 5.8 (non-outlier range). This decrease in pH in mining environments often gives rise to increasing dissolved metal such as Al and Fe as shown in Figure 31. The high variability of Fe, and sometimes Al, downstream along the sampling points may also be due to local mineralisation of local soils.

It is worth noting that all parameters, except Fe, eventually recover to below the selected RWQO at BWQ03.

9.5 Water quality impact assessment

The impact assessment was based on the evaluation of all four (4) proposed wastewater discharge scenarios namely:

- 2 Ml/day discharge of treated wastewater into Klein Komati;
- 4 Ml/day discharge of treated wastewater into Klein Komati;
- 6 Ml/day discharge of treated wastewater into Klein Komati
- 8 Ml/day discharge of treated wastewater into Klein Komati

The parameters assessed have been used to quantify the relative impact of the above volumes of discharge in the quality of the Klein Komati River.

In the absence of projected quality of the final treated effluent, it was assumed that the quality of the treated wastewater will be identical that of the selected RWQOs. The base flow of the Klein Komati was estimated using the recent WR2005 Mean Annual Runoff (MAR) values (Middleton & Bailey, 2005) and the relative proportion of the Klein Komati catchment area (see flood line determination) to the net catchment area of quaternary catchment X11D (table).

Table 34: Stream base flow calculation data

Aspect	Value	Unit
Klein Komati net area	31.95	km^2
X11D net area	590	km^2
X11D base flow contr.	40.7	MCM
Klein Komati baseflow	0.07	m^3/s

The resulting base flow was used together with the discharge scenario (Table 35) to determine the effect of the discharge on the water quality parameter.

Table 35: Stream mixing volumes and % change in Klein Komati base flow

Scenario	Discharge Vol.	Combined with base flow	% Change in base flow
Scen1 – 2Ml/d	0.023	0.093	33%
Scen2 - 4Ml/d	0.046	0.116	66%
Scen3 – 6Ml/d	0.069	0.139	99%
Scen4 – 8Ml/d	0.093	0.162	132%

Two assumptions for COD were compared, one where biodegradation exists and one without biodegradation. For biodegradation, a rate constant $k = 0.1\ d^{-1}$ was used. An average cross sectional area of 10 m^2 was used. The advantage of adding biodegradation is that COD decreases exponentially and a spatial reduction can also be computed (i.e. what is COD likely to be 6 km downstream of the discharge point (BWQ03) given a specific scenario). The COD analysis is shown in Figure 32

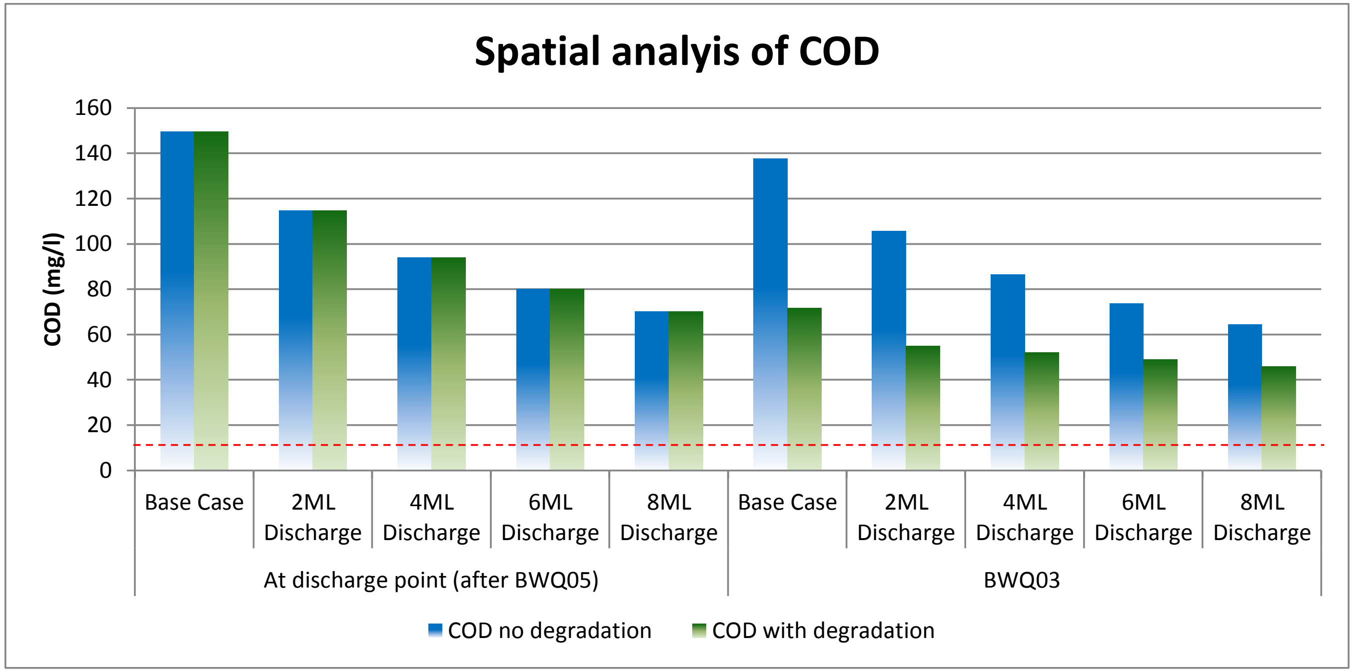

Figure 32: Spatial analysis (from discharge point to BWQ03) of COD with and without biodegradation.

Table 36: Water quality discharge impact assessment on the Klein Komati for various scenarios

Monitoring point	RWQO	Assumed Treated Water Quality	At discharge point (after BWQ05)						BWQ04				
			Base Case[a]	2ML	4ML	6ML	8ML	Normalised Improvement (%)	Base Case	2ML	4ML	6ML	8ML
pH (pH Units)	6 - 9	7.5	***7.39***	Maintain in range					***7.82***	Maintain in range			
COD (mg/l)	10	10	***150***	115	94	80	70	41%	***200***	154	126	107	94
SS (mg/l)	100	100	***425***	344	295	263	240	33%	***299***	242	208	185	169

Monitoring point	RWQO	Assumed Treated Water Quality	At discharge point (after BWQ05)						BWQ04				
			Base Case[a]	2ML	4ML	6ML	8ML	Normalised Improvement (%)	Base Case	2ML	4ML	6ML	8ML
Al (mg/l)	0.15	0.15	***0.32***	0.28	0.25	0.24	0.22	23%	***1.62***	1.40	1.27	1.19	1.13
TDS (mg/l)	100	100	***116***	112	110	108	107	6%	***118***	114	112	110	109
Fe (mg/l)	0.1	0.1	***2.66***	2.02	1.64	1.38	1.20	42%	***3.83***	3	2	2	2
COD (mg/l) assuming degradation		10	***150***	115	94	80	70	41%	**-**	-	-	-	-

Shade cells indicate likely non-compliance. Used 95th percentile values for the base case

a – The base case quality at BWQ05 is the current water quality

Monitoring point	RWQO	Assumed Treated Water Quality	BWQ03				
			Base Case	2ML	4ML	6ML	8ML
pH (pH Units)	6 - 9	7.5	***8.26***	Maintain in range			
COD (mg/l)	10	10	***137.6***	106	86	74	64
SS (mg/l)	100	100	***645***	522	448	399	364
Al (mg/l)	0.15	0.15	***0.558***	0.48	0.44	0.41	0.39
TDS (mg/l)	100	100	***100***	97	95	93	92
Fe (mg/l)	0.1	0.1	***5.176***	4	3	3	2
COD (mg/l) assuming degradation		10	***72***	55	52	49	46

Shade cells indicate likely non-compliance. Used 95th percentile values for the base case

In the analyses above, base case indicates the prevailing water quality conditions prior to any development.

The normalised improvement per parameter was the assumed to have propagated throughout the stream, except for where COD is subject to degradation. Thus the same percentage improvement is seen at BWQ04 and BWQ03. This shows a 30% average overall improvement in water quality.

Looking at the COD graph, similar profiles are generated for the remaining parameters, as depicted below with the same improvement percentage spatially towards BWQ03.

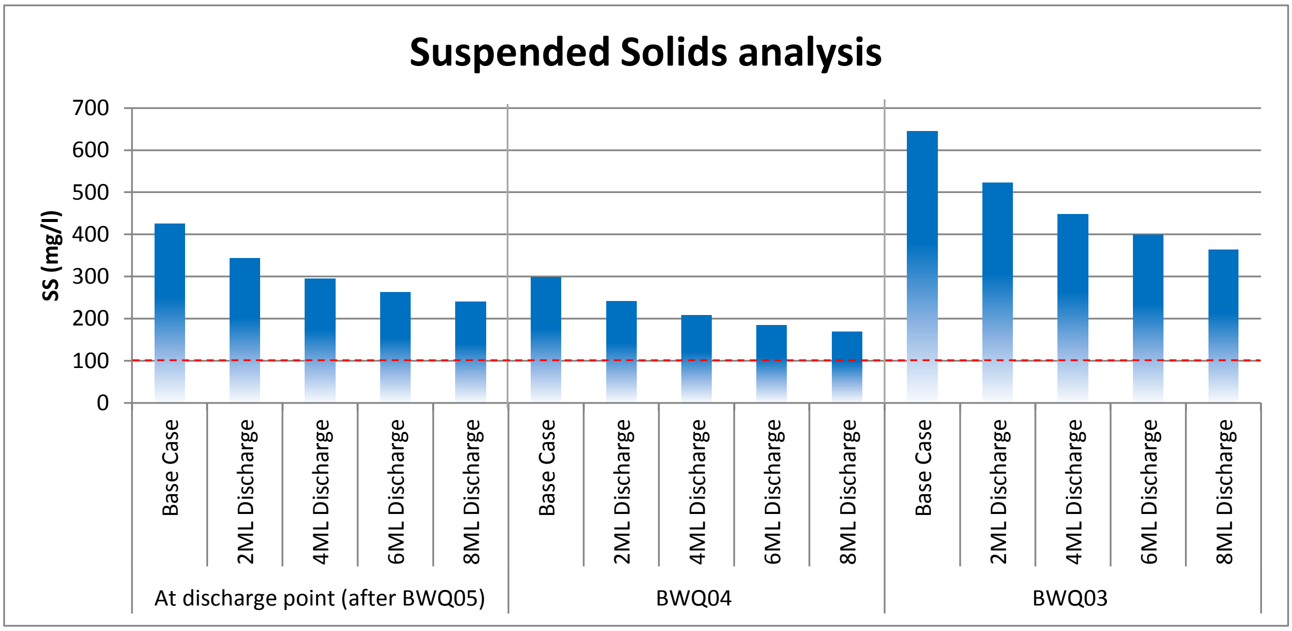

Figure 33: Spatial analysis (from discharge point to BWQ03) of suspended solids

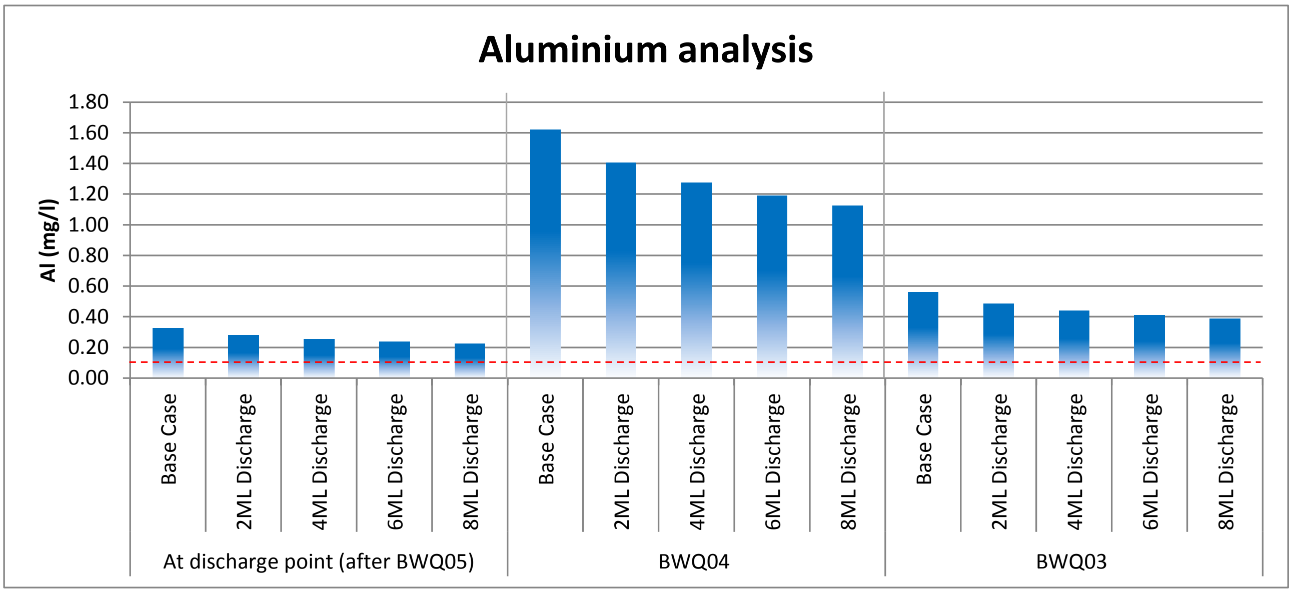

Figure 34: Spatial analysis (from discharge point to BWQ03) of Aluminium

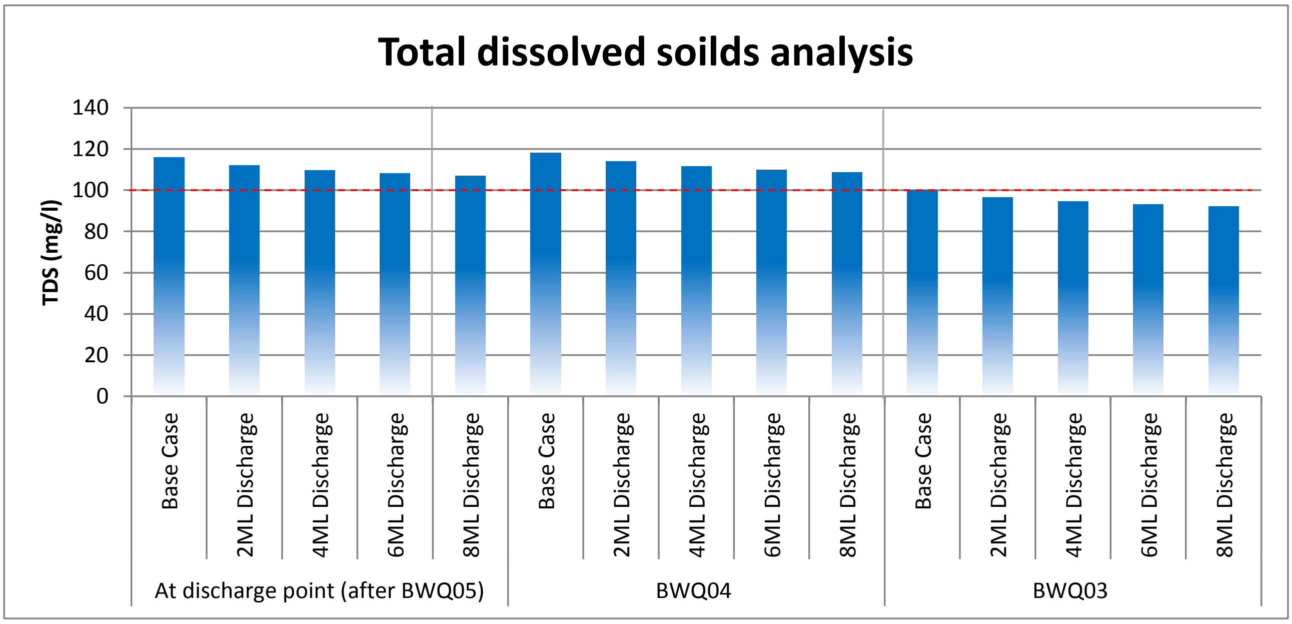

Figure 35: Spatial analysis (from discharge point to BWQ03) of total dissolved solids

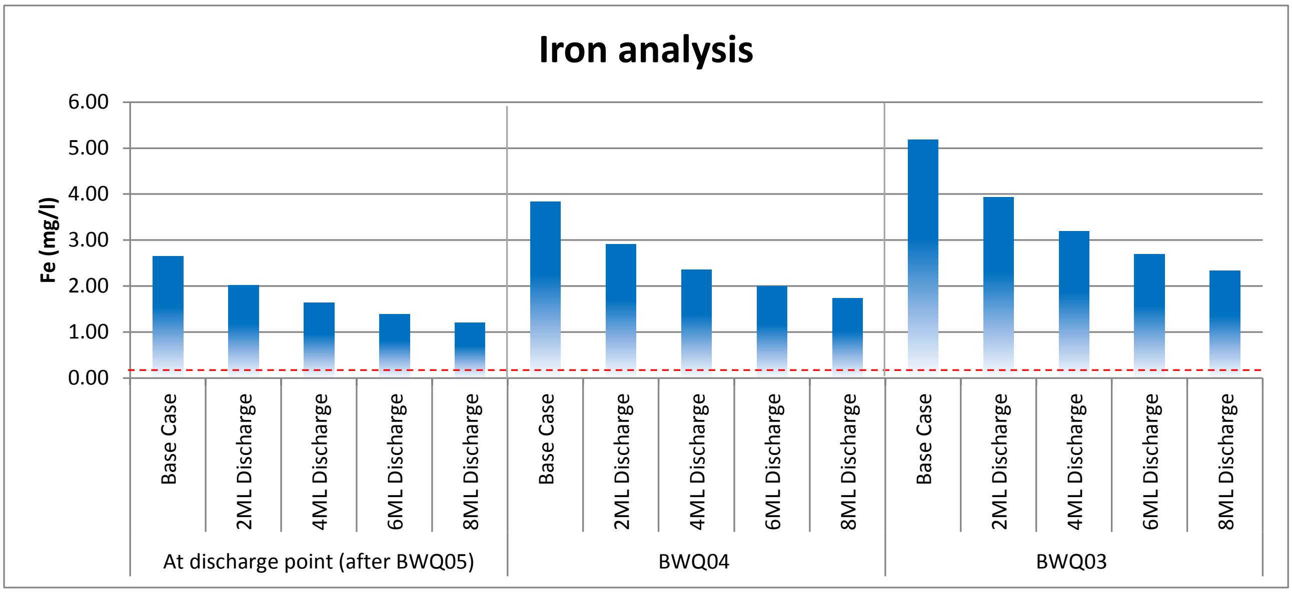

Figure 36: Spatial analysis (from discharge point to BWQ03) of iron.

In general, there seems to be an increase in aluminium and iron between BWQ05 and BWQ05. However, all discharge scenarios will seek to improve this trend. This will improve mainly due to overall dilution the water as the base flow increases. The drastic increase in aluminium, although it may be due to natural mineralisation, needs to be investigated because in occurs downstream of the discharge point upstream of BWQ04 and exhibits an 8-fold increase in aluminium. The presence of local springs in the vicinity of the project may also elucidate this phenomenon.

The smallest improvement, as expected is seen with TDS, primarily because the base case 95th percentile only exceeds the RWQO by a small margin. For all discharge scenarios, TDS recovers and reaches compliance levels at BWQ03.

The pH conditions preferably need to be kept within the RWQO range and ideally at around 7.5 to prevent an increase in dissolved metals.

Using the assumptions stated above for COD degradation, COD will only reach compliance levels at after approximately 20 km downstream for the first scenario (2 Ml).

10.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were made:

- A location was selected for the water treatment plant point of discharge into the Klein Komati. The location was selected based on the hydraulic properties. The shear stress, velocity and Froude numbers were used to select the point. Discharge point DP1 was selected. An energy dissipation device was conceptually designed to limit any localised erosion issues.
- The effect of the increased flow on the potential erosion of the receiving water channel was assessed. It was concluded that there will be a maximum change in erosion potential of the stream of 15% at certain locations on the stream.
- The potential impact on river crossings was investigated and it was determined that there was a minimal effect on the velocity (both upstream and downstream of the river crossings) and water level of the river crossings.
- The Resource Water Quality Objectives (RWQO's) were determined based on the downstream water users and are presented in the water quality section of the report.
- The impacts were identified and rated, with erosion being the most critical. The rating showed that with the correct mitigation in place, the risk of the impact can be reduced from moderate to low.
- Water balance schematics were produced for the first 5 years, 10 years and finally for the full LOM. The water balance model was also used to determine the mine water treatment requirements form the Return Water Dam. The model showed that there is a shortage of water in the first 2 years. However the addition of the 6 Boreholes and the external water source to the Farm Dam as sources of water, addressed the water shortage.
- The maximum mine water treatment capacity was calculated to be 4000m^3/d. With the most likely scenario indication that the first treatment module will be required February 2021. It is recommended that the mine carry out this study on an annual basis. This will allow for more accurate results as there will be monitored data once the mining commences for calibration of the model i.e. measured daily rainfall and dam volumes. If done annually it will allow for a more accurate prediction of the required date of implementation of the water treatment plant modules. This should allow for enough lead time to start the detailed design and construction.
- Reserve flows for the Farm Dam were obtained from a high level yield determination study. It is recommended that full reserve determination study be carried out so as to accurately predict the reserve flows from the Farm Dam. The values used in the model were conservative estimates.
- There will be approximately a 33, 66, 99 and 132% increase in base flow on the Klein Komati for the 2, 4, 6, and 8 Ml discharge scenarios from the proposed point of discharge;
- The parameters of concern are the dissolved metals (Al and Fe), and SS;

- COD is likely to decrease exponentially downstream, assuming no additional load is introduced, reaching compliance levels at 20 km;
- The will be an overall improvement in water quality along the Klein Komati, however, dissolved oxygen should be added to the monitoring programme.

11.0 REFERENCES

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APPENDIX A

Document Limitations

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